Mohammad Javed Ali
Editor

Principles and Practice of Lacrimal Surgery

Second Edition

Springer

Principles and Practice of Lacrimal Surgery

Mohammad Javed Ali
Editor

Principles and Practice of Lacrimal Surgery

Second Edition

Springer

Editor
Mohammad Javed Ali
Govindram Seksaria Insitute of Dacryology,
L.V. Prasad Eye Institute
Hyderabad, India

ISBN 978-981-10-5441-9 ISBN 978-981-10-5442-6 (eBook)
https://doi.org/10.1007/978-981-10-5442-6

Library of Congress Control Number: 2017960816

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Dedicated To

The Lacrimal Drainage System: The Reason for My Existence!

To my Wonderful Family—Dawood Ali and Qaiser Yasmeen, Farhana Baig and Hafsa Javed

To my Amazing Team—Milind N. Naik, Swathi Kaliki and Tarjani V. Dave

To all My Mentors and all My Patients

Foreword to the Second Edition by Peter-John Wormald

In this second edition of Dr Mohammad Javed Ali's book on lacrimal surgery eight additional chapters have been added. These include chapters on "Difficult surgical scenarios in endoscopic DCR", "Optical Coherence tomography" and "Navigation guided stereotactic lacrimal surgeries". These chapters focus on helping surgeons understand how to deal with demanding situations during surgery and try to avoid having complications by describing how best to deal with such difficult scenarios. Over the last 25 years the lacrimal system has received increasing interest both from the oculoplastic and sinus surgeons. Traditionally the lacrimal system has been approached through a medial canthal external incision. In the best hands of trained oculoplastic surgeons this technique has excellent results. The revival in interest in approaches to the lacrimal system has been driven by the development of the endoscope and increasingly better digital camera systems that allow the anatomy to be both magnified and displayed in crisp detail facilitating delicate and precise surgery. This move in lacrimal surgery mirrors the general surgical move from incisions to minimally invasive surgery with the endoscope playing the central role in this surgical evolution. The interest in the endoscopic techniques has increased especially amongst oculoplastic surgeons as the results with this technique are now at least equivocal and in some publications better than the traditional external techniques.

This book provides an extraordinarily comprehensive reference starting with historical perspectives, anatomy and assessment then moving through the many and varied external approaches before moving to an extensive guide on the endoscopic approaches. Finally an overview of Quality of Life in lacrimal disorders is provided. The list of contributors is impressive as is their expertise in the chapters which they provide. Including the new chapters on clinical scenarios are a number of chapters on controversial topics in lacrimal surgery such as the role of Mitomycin C, whether the lacrimal system should be routinely intubated after DCR surgery and in the management of common canaliculus strictures.

This text is wide ranging and extensive and covers established knowledge, new ideas and controversies presented by high quality contributors with insight, experience and as recognised experts in the field. This book would be a worthy addition to the library of any surgeon interested in lacrimal surgery allowing them to delve quickly into chapters for valuable insights as well as having it as a major reference text resource. This book is a most valuable contribution to our literature and the editor and contributing authors are to be congratulated.

Department of Otolaryngology Head and Neck Surgery
University of Adelaide,
Adelaide, Australia

Peter-John Wormald

Foreword to the Second Edition by Jonathan Dutton

Scientific interest in lacrimal disorders and their management dates back almost a century. For most of this time numerous workers have contributed to the accumulation of knowledge that today forms the basis of our understanding of this important anatomic and physiologic apparatus. During the past 75 years nearly 6000 papers have been published on this subject, more than half of these published in the past 15 years alone. Today, an efflorescence of interest in the lacrimal drainage system is accumulating new information at such a frenetic pace and in such diverse medical journals that even dedicated lacrimal surgeons may find it difficult to maintain competency and keep pace with advancing knowledge.

Lacrimal disorders comprise a significant proportion of complaints seen by ophthalmologists and otolaryngologists so that the requirement to evaluate and manage these disorders is becoming more important. The repertoire of diagnostic techniques and surgical procedures needed by the modern lacrimal surgeon is growing exponentially, and includes the evaluation and correction of eyelid malpositions, misdirected eyelashes, conjunctival diseases, tumors, and trauma. Advances in management approaches require proficiency in not only in eyelid, nasal and sinus anatomy, but in the physiologic mechanisms underlying tear drainage. Modern surgical approaches to the lacrimal drainage system include the long-standing external skin incision and newer procedures such as endonasal surgery, endoscopic visualization, laser assisted dissections, transcanalicular surgery, and CT navigation.

This second edition of '*Principles and Practice of Lacrimal Surgery'*, by Mohammad Javed Ali, follows just 2 years after the first edition. Is there a need for a new book so soon? The answer is 'YES'. Since the first edition more than 500 papers have been published contributing new insights into the anatomy, physiology, diagnosis, and surgery of the lacrimal system. This edition is Dr. Ali's latest contribution, in a long history of research, to integrate our current understanding of lacrimal drainage disorders and their management. This book is not just a list of disorders, but a logical, measured, and scientific approach to the etiology, diagnosis, and management of common lacrimal disorders encountered in clinical practice. In 48 chapters the embryology, anatomy, and periocular associations are discussed, as well as nicely illustrated chapters on evaluation and treatment of punctal, canalicular, and nasolacrimal duct disorders, including fibrotic obstruction, inflammations, and tumors. New chapters include 3D endoscopy, optical coherence tomography, advanced endoscopic techniques, electron microscopy of the lacrimal system, and navigation guided stereotactic surgery. Several new chapters discuss debates in lacrimal surgery, such as ostium size, use of mucosal flaps, variations in lacrimal anatomy, value of mitomycin, stent intubation, endonasal vs. external DCR, and the relation of translational basic science like electron microscopy to the lacrimal system. All other chapters are fully updated and a new section in each entitled 'Updates' reviews literature of the last 2 years since the first edition.

It is an honor for me to write this Foreword for Dr. Ali. He has dedicated his career to lacrimal disorders and their management, and has contributed a vast amount of research to this field. This book will provide an important contribution to our understanding of this critical component of general ophthalmic and oculoplastic surgery.

University of North Carolina,
Chapel Hill, NC, USA

Jonathan Dutton

Foreword to the Second Edition by Friedrich Paulsen

Historically the lacrimal drainage system belonged to the field of ophthalmology. Considering their orbital points of origin and functional importance for the ocular surface this makes perfect sense. However, with respect to the localization of their main parts consisting of lower lacrimal sac and nasolacrimal duct they would be better classified with the field of Rhinology. Based on this they mark a borderland between disciplines, not really taken "seriously" by both, ophthalmologists and otorhinolaryngologists. Moreover, their complex anatomical structure and difficult surgical accessibility accounts for their comparatively weak representation in scientific research. Scientists in the fields of ophthalmology or otorhinolaryngology who specialize in the investigation of nasolacrimal system may have always been smiled at, as they are commonly considered an exotic part of the scientific community! Unfortunately, nasolacrimal duct research is therefore only poorly supported by third-party funds, which for the clinician is hard to understand since diseases of the lacrimal system are common. However, there have always been a few basic science researchers interested in the nasolacrimal ducts in the past 25 years (including myself).

In the year 2014, Mohammad Javed Ali published the first edition of his comprehensive textbook "Principles and Practice of Lacrimal Surgery". In this remarkable work He had collected the entire scientific and clinical knowledge about the nasolacrimal ducts from history to the present. He had covered areas of basic research, diagnostics and treatment, including conservative and interventional. His standing as a globally leading lacrimal surgeon is reflected on the emphasis and the vast extent of surgical coverage in this text.

Mohammad Javed Ali is one among the exceptionally rare doctors to treat the nasolacrimal ducts as an entity of its own by exclusively treating lacrimal disorders. In addition he is a gifted basic science researcher. This clinician-scientist combination has allowed him to come up with a holistic approach to understanding the nasolacrimal system as a whole. Thus, he became an internationally recognized Dacryologist at a very young age and founded the first independent Institute of Dacryology in his hometown Hyderabad: the Govindram Seksaria Institute, at the L. V. Prasad Eye Institute. This Institute caters exclusively to clinical disorders and basic sciences related to lacrimal disorders.

Based on the increase of his tremendous expertise in ophthalmology and Rhinology, Javed Ali now comes up with the second edition of his outstanding textbook “Principles and Practice of Lacrimal Surgery”.This new version does not simply represent a continuation of the first edition, but must be seen as an even more comprehensive work reflecting all the advances and innovations of this rapidly evolving field. Without question for all who are interested in the lacrimal drainage system, this is a “must have” and I am convinced that Javed Ali will have even greater success with this second edition.

Friedrich Alexander University of Nuremberg-Erlangen, Erlangen, Germany

Friedrich Paulsen

Foreword to First Edition

Over the last 25 years the lacrimal system has received increasing interest both from the oculoplastic and sinus surgeons. Traditionally the lacrimal system has been approached through a medial canthal external incision. In the best hands of trained oculoplastic surgeons this technique has excellent results. The revival in interest in approaches to the lacrimal system has been driven by the development of the endoscope and increasingly better digital camera systems that allow the anatomy to be both magnified and displayed in crisp detail facilitating delicate and precise surgery. This move in lacrimal surgery mirrors the general surgical move from incisions to minimally invasive surgery with the endoscope playing the central role in this surgical evolvement. The interest in the endoscopic techniques has increased especially amongst oculoplastic surgeons as the results with this technique are now at least equivocal and in some publications better than the traditional external techniques.

This book provides an extraordinarily comprehensive reference starting with historical perspectives, anatomy and assessment then moving through the many and varied external approaches before moving to an extensive guide on the endoscopic approaches. Finally an overview of Quality of Life in lacrimal disorders is provided. The list of contributors is impressive as is their expertise in the chapters which they provide. Worthy additions to the text is a number of chapters on controversial topics in lacrimal surgery such as the role of Mitomycin C, whether the lacrimal system should be routinely intubated after DCR surgery and in the management of common canaliculus strictures.

This text is wide ranging and extensive and covers established knowledge, new ideas and controversies presented by high quality contributors with insight, experience and as recognised experts in the field. This book would be a worthy addition to the library of any surgeon interested in lacrimal surgery allowing them to delve quickly into chapters for valuable insights as well as having it as a major reference text resource. This book is the most valuable contribution to our literature and the editor and contributing authors are to be congratulated.

Department of Otolaryngology Head and Neck Surgery
University of Adelaide,
Adelaide, Australia

Peter-John Wormald

Preface to the Second Edition

"The future belongs to the unreasonable ones, the ones who look forward not backward, who are certain only of uncertainty, and who have the ability and the confidence to think completely differently."
—George Bernard Shaw

I am happy to be writing the preface for the second edition of this successful textbook "Principles and Practice of Lacrimal Surgery". The earlier edition of this book was well received by the scientific community with friends and colleagues across the globe pouring in with their messages of encouragement and suggestions for further improvement. The last two years, since the release of the first edition, has seen enormous amount of literature on lacrimal system. This explosion of information not only encompassed core clinical topics and surgical advancements but also basic sciences and this is an encouraging sign of progress. This explosion of knowledge along with some good clinical progress justifies second edition of this text.

Eight new chapters including basic science and translational topics like 'electron microscopy of the lacrimal system' and 'bacteremia in lacrimal surgeries' have been added. All the chapters have been either re-written or significant newer knowledge has been incorporated. The new knowledge since the time of the first edition has been incorporated into each chapter under a new section termed "Updates" with multiple sub-sections based on the needs. Numerous new figures and tables have been added to aid in the understanding of etiopathogenesis, clinical features and surgical interventions. References have been updated to be more comprehensive and detailed.

I thank all my contributing authors for their excellent updates and contributions. I thank Professors Wormald (Otorhinolaryngology), Dutton (Oculoplastics) and Paulsen (Basic Sciences) for their forewords and encouragement. Lastly, I thank Springer for encouraging me to come up with a second edition in 2 years and for all the help with logistics. I am sure that this comprehensive text would be very useful equally for the ophthalmology residents, sub-specialty fellows, ophthalmic plastic surgeons and the rhinologists.

Hyderabad, India — Mohammad Javed Ali

Prologue

Lacrimal Surgery: Glorious Past, Exciting Present Era and the Audacity of Hope for a Brilliant Future

"Do not fear to be eccentric in opinion, for every opinion now accepted was once eccentric".
—Bertrand Russell (1872-1970)

The Evolution of lacrimal disorders and its management amply exemplifies the above stated quote of the twentieth century British philosopher Bertrand Russell. Lacrimal surgeries has been a subject of discussion in antiquity with the earliest documented reference being a lacrimal sac incision in the 'Code of Hammurabi' in 2250 BC [1]. The past which appears glorious today had once travelled through many rough terrains in ancient times nurtured by the Egyptians (Ebers Papyrus—1500 BC), the Greeks (Hippocrates and Celcus—25 BC) and the Romans (Galen—200 AD) [1, 2]. The Arabians chipped in between with their contributions from Ibn Sina and Al Razi in the medieval times. The Modern Dacryology was given impetus with the hallmark anatomical works of Giovanni Morgagni (1682–1771) and Johann Zinn (1727–1759) and equally by the influential lacrimal treatises by Percival Pott (1714–1788) and Johann Schmidt (1759–1809) [3].

'Men love to wonder and that is the seed of science', said the famous nineteenth century American poet, Ralph Waldo Emerson. Lacrimal surgeries have undergone a sea change in the last two centuries. The original Woolhouse technique (1724) of dacryocystectomy underwent numerous changes in techniques and approaches to the present age but with progressively lesser indications. The external dacyrocystorhinostomy (DCR) had a steeper evolution for obvious reasons from the times when Addeo Toti (1904) first described it to the current day practice with various incisions and lacrimal sac implants [4, 5]. With the introduction of rigid endoscopy and better view, endonasal dacyrocystorhinostomy showed a steep resurgence into the practice (McDonough—1989) [6], more than a century after its original description (Caldwell—1893) [7] failed to gain wider acceptance. Endocanalicular laser DCR, however till the present date have failed to gain widespread acceptance despite numerous modifications since its introduction to Dacryology by Levin and Stormogipson in 1992 [8, 9]. Likewise was the journey of trans-conjunctival DCR (CDCR), which evolved into endoscopic and lesser invasive approaches along with numerous Jones tube modifications [10, 11]. Balloon dacryoplasty has evolved mostly in terms of indications rather than instrumentation or techniques [12, 13].

The present era of lacrimal practice is both exciting and at the same time challenging. The state of art equipments including high definition endoscopic systems, diagnostic and therapeutic dacryoendoscopy and higher resolution yet safer imaging are increasingly contributing towards our understanding of the disorders as well as developing minimally invasive surgical options. Many debates today are centered on the approaches to a DCR, ostium size, mitomycin C and intubation. The recent most meta-analysis have been able to shed much needed light into these areas with clinical implications [14, 15]. The PEDIG studies have helped greatly in the management of congenital nasolacrimal duct obstructions in terms of clinical decision making and outcomes [16, 17]. There is an increasing focus on canalicular and nasolacrimal duct recanalizations under dacryoendoscopic guidance in an effort to avoid a DCR [18].

Although this mode appears promising, skepticism is very well justified at this stage. The present era is also seeing many attempts to standardize the nomenclatures [19], drug dosage [20], introduction of newer terminologies [21] and paradigm shifts in the understanding of lacrimal anatomy [22, 23]. The armamentarium of a lacrimal surgeon today is more well equipped than any other time and this very fact brings in more responsibility on us than any other time, to take this forward in every possible way into the future!

The audacity of hope and optimism points towards a brighter future for the patients of tomorrow with lacrimal disorders. However, despite some of the advances highlighted, we still have a long way to go in our understanding and treatment of lacrimal disorders. This would require work on two different fronts with concurrent amalgamation. The first front should be science related and let the second be related to the surgeon. On the science frontier, the need of hour is to demystify the etiopathogenesis of lacrimal disorders primarily that of primary acquired nasolacrimal duct obstruction or PANDO. It would be inappropriate to continue managing lacrimal disorders mechanically without simultaneous efforts to unravel the elusive etiopathogenesis. The key to this, I believe lies with the basic sciences. Embryonic studies to look for regulatory proteins influencing lacrimal primordium and sub adjacent mesenchyme of surface ectoderm during Carnegie stages of development may hold promising clues to understanding of congenital lacrimal disorders. Cytochemical analysis for inflammatory mediators in tears of patients with PANDO and if the culprits are zeroed in on, the search to pharmacologically block them or their receptors in the lacrimal system may have prophylactic value early on in the disease. Lacrimal immunology work on lacrimal drainage associated lymphoid tissues (LDALT), its derangements [24] and how differently it behaves from the rest of the immune system should be carried forward to its logical conclusions as this may have great bearing on our understanding of lacrimal physiology. Other avenues of potential research in near future include lacrimal system stem cell characterization on similar lines as that of lacrimal gland [25], drug coated stents and electron microscopic inter and intra-cellular changes in lacrimal disorders.

On the second front, the lacrimal surgeon should not only focus on evidence based practice but also constantly endeavor to explore avenues to generate evidence. The research potential needs to be unlocked and academic institutes should strive towards protecting and rearing the endangered species of ‘Clinician-Scientists’ rather than pure clinicians. The need of the hour is also to cross specialize where it matters! The lacrimal drainage system has a long course within the nasal cavity and it is obvious that a good lacrimal work cannot be done without a good anatomical and surgical knowledge of the nose. Although, the resurgence of EENT (eye, ear, nose, and throat) specialists may not be desirable due to explosion in the knowledge and vast nature of each subject, the benefits of limited cross specialization cannot be over emphasized. Cross specialization also opens up the surgeon to at least some ideas of one specialty that when appropriately extrapolated to other may have beneficial results. Basic sciences are the key to the future; hence a very good understanding of fundamentals of lacrimal system up to the molecular level would greatly help the lacrimal surgeon in dealing with the disorders both in the lab and the clinics. There should be efforts on part of the lacrimal surgeon to do focused clinical and research work with an emphasis on translational values. The challenge of the future is to set audacious goals and strive hard to achieve them. ‘We’, as lacrimal surgeons need to remind ourselves frequently of our equally important responsibility to advance medicine and hand it over in a better shape to the next generation and probably beyond them. Are we doing enough on these fronts? If not, let us change that from today!

“There is a single light of science, and to brighten it anywhere is to brighten it everywhere”.

—Isaac Asimov (1920–1992)

References

1. Hirschberg J. The renaissance of ophthalmology in 18th century. In: Hirschberg J, editors. The history of ophthalmology. Amsterdam: Wayenborg Publications; 1984, vol 1. p. 11.
2. Hirschberg J. The renaissance of ophthalmology in 18th century. In: Hirschberg J, editors. The history of ophthalmology. Amsterdam: Wayenborg Publications; 1984, vol 3. p. 250–55.
3. Albert DM. Ophthalmic plastics surgery. In: Albert DM, Edwards DD, editors. The history of ophthalmology. Cambridge: Blackwell Science, 1996, p. 235–54.
4. Ekinci M, Cagatay HH, Oba ME, et al. The long term follow-up results of external dacryocystorhinostomy skin incision scar with 'W' incision. Orbit. 2013;32:349–55.
5. De Castro DK, Santiago YM, Cunningham M, et al. A modified lacrimal sac implant for high risk dacyrocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:367–72.
6. McDonogh M, Meiring JH. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–87.
7. Caldwell GW. Two new operations for the obstruction of the nasal duct with preservation of the canaliculi. Am J Ophthalmol. 1893;10:189.
8. Levin PS, Stormogipson DJ. Endocanalicular laser assisted DCR. An anatomic study. Arch Ophthalmol. 1992;110:1488–490.
9. Henson RD, Cruz HL, Henson RG Jr, et al. Post operative application of mitomycin C in endocanalicular laser DCR. Ophthal Plast Reconstr Surg. 2012;28:192–95.
10. Jones LT. Conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1965;59:773–83.
11. Javed Ali M, Honavar SG, Naik M. Endoscopically guided minimally invasive bypass tube intubation without DCR: evaluation of drainage and objective outcomes assessment. Minim Invasive Ther Allied Technol. 2013;22:104–9.
12. Becker BB, Berry FD. Balloon catheter dilatation in lacrimal surgery. Ophthalmic Surg. 1989;20:193–8.
13. Javed Ali M, Naik MN, Honavar SG. Balloon dacryoplasty: ushering the new and routine era in minimally invasive lacrimal surgeries. Int Ophthalmol. 2013;33:203–10.
14. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
15. Feng YF, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
16. Repka MX, Chandler DL, Holmes JM, et al. Balloon catheter dilatation and nasolacrimal duct intubation for treatment of nasolacrimal duct obstruction in after failed probing. Arch Ophthalmol. 2009;127:633–9.
17. Repka MX, Chandler DL, Bremer DL, et al. Repeat probing for treatment of persistent nasolacrimal duct obstruction. J AAPOS. 2009;13:306–7.
18. Javate RM, Pamintuan FG, Cruz RT Jr. Efficacy of endoscopic lacrimal duct recanalization using microendoscope. Ophthal Plast Reconstr Surg. 2010;26:330–3.
19. Javed Ali M, Mohapatra S, Mulay K, et al. Incomplete punctal canalization: the external and internal punctal membranes. Outcomes of membranotomy and adjunctive procedures. Br J Ophthalmol. 2013;97:92–5.
20. Javed Ali M, Mariappan I, Maddileti S, et al. Mitomycin C in dacyrocystorhinostomy: the search for the right concentration and duration—a fundamental study on human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
21. Javed Ali M, Naik MN. Canalicular wall dysgenesis: the clinical profile of canalicular aplasia and hypoplasia, associated systemic and lacrimal anomalies, and clinical implications. Ophthal Plast Reconstr Surg. 2013;29:464–8.
22. Park J, Takahasi Y, Nakano T, et al. The orientation of the lacrimal fossa to the bony nasolacrimal canal: an anatomical study. Ophthal Plast Reconstr Surg. 2012;28:463–8.

23. Kakizaki H, Ichinose A, Takahashi Y, et al. Anatomical relationship of Horner's muscle origin and posterior lacrimal crest. Ophthal Plast Reconstr Surg. 2012;28:66–8.
24. Javed Ali M, Mulay K, Pujari A, et al. Derangements of lacrimal drainage associated lymphoid tissue (LDALT) in human chronic dacryocystitis. Ocul Immunol Inflamm. 2013;21:417–23.
25. Tiwari S, Javed Ali M, Balla MM, et al. Establishing human lacrimal gland cultures with secretory function. PLoS One. 2012;7:e29458.

Contents

Photographs Used from the Editor's Own Publications in the Text

1. Chapter 3—Fig. 23: Kamal et al., Ophthal Plast Reconstr Surg. 2016;32:170–3.
2. Chapter 3—Figs. 24–28 and Chapter 4—Figs. 6 & 7 and Chapter 12—Fig. 6 and Chapter 42—Figs. 3–9: Ali et al., Ophthal Plast Reconstr Surg. 2015;31:414–7.
3. Chapter 9—Fig. 4: Ali et al., Ophthal Plast Reconstr Surg. 2016;32:477–80.
4. Chapter 12—Fig. 1: Kamal et al., Ophthal Plast Reconstr Surg. 2016;32:170–3.
5. Chapter 30—Figs. 8 & 9: Ali et al., J Laryngol Otol. 2015;129:35–40.
6. Chapter 42—Figs. 10 & 11: Ali et al., Ophthal Plast Reconstr Surg. 2015;31:98–102.
7. Chapter 42—Figs. 12 & 13: Ali et al., Ophthal Plast Reconstr Surg. 2016;32:333–6.
8. Chapter 42—Figs. 14 & 15; Chapter 44—Figs. 3–5: Ali et al., Ophthal Plast Reconstr Surg. 2015;31:103–7.
9. Chapter 42—Fig. 16: Ali et al., Ophthal Plast Reconstr Surg. 2017;33:90–2.
10. Chapter 42—Fig. 17: Ali et al., Ophthal Plast Reconstr Surg. 2016;32:252–6.
11. Chapter 44—Figs. 1 & 2: Ali et al., Ophthal Plast Reconstr Surg. 2013;29:469–74.

Know Your Authors!

Mohammad Javed Ali

Sima Das

Hirohiko Kakizaki

Hesham Saleh

Natasha Choudhury

Swati Singh

Lakshmi Mahesh

Saurabh Kamal

Vinod Gauba

Milind N. Naik

Aditi Pujari

Pelin Kaynak

Kelvin Kam-Lung Chong

Samir Mahapatra

Suryasnata Rath

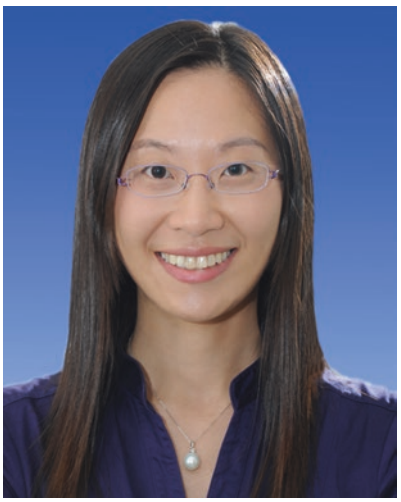
Peter Dolman

Raoul Paolo D. Henson

Noelle S. Matta

David I. Silbert

Emmy Li



Hunter Yuen

Luis Fernando Macias-Valle

Alkis James Psaltis

Peter John Wormald

Ulrich Lachmund

Gangadhara Sundar

Kai Wilhelm

Tarjani Vivek Dave

Khaled Abu Haleeqa

Dan Brettell

Andrea Zarkovic

Edwin C. Figueira

Simon N Madge

Dinesh Selva

Marcus M. Marcet

Yi-fan Feng

Andre Litwin

Adel Al Suhaibani

Raman Malhotra

List of Contributors

Khaled Abu-Haleeqa Department of Ophthalmology, Mafraq Hospital, Abu Dhabi, UAE

Adel Al Suhaibani Department of Ophthalmology, King Abdul Aziz University Hospital, Riyadh, Saudi Arabia

Dan Brettell Department of Ophthalmology, Wye Valley Trust, NHS Hereford, Hereford, UK

Kelvin Kam-Lung Chong Ophthalmic Plastics Surgery, Chinese University of Hong Kong, Hong Kong, Hong Kong SAR, China

Natasha Choudhury Surrey and Sussex NHS Trust, Surrey, UK

Sima Das Ophthalmic Plastics Surgery, Schroff Eye Hospital, Delhi, India

Tarjani Vivek Dave Govindram Seksaria Institute of Dacryology, L. V. Prasad Eye Institute, Hyderabad, India

Peter J. Dolman Ophthalmic Plastics Surgery, University of British Columbia, Vancouver, Canada

Yi-fan Feng Department of Ophthalmology, Zhongshan Hospital and Fudan University, Shanghai, China

Edwin C. Figueira Ophthalmic Plastics Surgery, Royal Adelaide Hospital, Adelaide, Australia

Vinod Gauba Ophthalmic Plastics Surgery, Imperial Healthcare Institute, Dubai, UAE

Raoul Paolo D. Henson Ophthalmic Plastics Surgery, St Luke Medical Center, Manilla, Philippines

Mohammad Javed Ali Govindram Seksaria Institute of Dacryology, L. V. Prasad Eye Institute, Hyderabad, India

Hirohiko Kakizaki Department of Ophthalmology, Aichi Medical University, Aichi, Japan

Saurabh Kamal Ophthalmic Plastics Surgery, EyeHub, Faridabad, New Delhi, India

Pelin Kaynak Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey

Ulrich Lachmund Institute of Neuroradiology, University Hospital of Zurich, Zurich, Switzerland

Emmy Li Department of Ophthalmology, Chinese University of Hong Kong, Hong Kong, Hong Kong SAR, China

Andre Litwin Oculoplastic Surgery, Queen Victoria NHS Trust, London, UK

Luis Fernando Macias-Valle The Queen Elizabeth Hospital, Adelaide, Australia

Simon N. Madge Department of Ophthalmology, Wye Valley Trust, NHS Hereford, Hereford, UK

Samir Mahapatra Govindram Seksaria Institute of Dacryology, L. V. Prasad Eye Institute, Bhubaneshwar, India

Lakshmi Mahesh Department of Ophthalmology, Manipal Hospital, Bangalore, India

Raman Malhotra Oculoplastic Surgery, Cadogan Clinic and Queen Victorial NHS Trust, London, UK

Marcus M. Marcet Department of Ophthalmology, University of Hong Kong, Cyberport, Hong Kong

Noelle S. Matta Family Eye Group, Lancaster, PA, USA

Milind N. Naik Govindram Seksaria Institute of Dacryology, L. V. Prasad Eye Institute, Hyderabad, India

Alkis James Psaltis Department of Otolaryngology, Head Neck Surgery, The Queen Elizabeth Hospital, Adelaide, Australia

Aditi Pujari Ophthalmic Plastics Surgery, Sunayn Oculoplasty Center, Kolhapur, India

Suryasnata Rath Govindram Seksaria Institute of Dacryology, L. V. Prasad Eye Institute, Bhubaneswar, India

Hesham Saleh Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK

Dinesh Selva Ophthalmology and Visual Sciences, University of Adelaide, Adelaide, Australia

David I. Silbert Family Eye Group, Lancaster, PA, USA

Swati Singh Ophthalmic Plastics Surgery, Lala Jagannath Eye Institute, Ambala, India

Gangadhara Sundar Orbit and Oculofacial Surgery, National University of Singapore, Singapore, Singapore

Kai Wilhelm Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

Peter John Wormald Department of Otolaryngology, Head Neck Surgery, University of Adelaide, Adelaide, Australia

Hunter Yuen Department of Ophthalmology, Chinese University of Hong Kong, Hong Kong, Hong Kong SAR, China

Andrea Zarkovic Department of Ophthalmology, Wye Valley Trust, NHS Hereford, Hereford, UK

Lacrimal Disorders and Surgery: Historical Perspectives

1

Mohammad Javed Ali

Introduction

The evolution of lacrimal surgeries and the understanding of lacrimal disorders have been an amazing journey! From times immemorial, lacrimal disorders have continued to intrigue mankind and pose significant challenges. Tough problems have fortunately met tougher wise men at the right time, and this science continued to evolve at a rapid pace. The spectrum of events in this journey can be captured in two wise quotations, one of Sir Isaac Newton (1642–1727) who lauded the culture of each contributor building a higher platform for the subsequent one to fly higher and of Sir Rudolph Virchow (1821–1905) who not long ago expressed his pain at the diminishing number of students who learn from history in subsequent generations:

> *If I have seen further, it is by standing on the shoulders of ye giants.* (Sir Isaac Newton)

> *It is one of the worst aspects of our present development that historical knowledge diminishes with each generation of students.* (Sir Rudolph Virchow)

Ancient Dacryology

The earliest documented reference to any ophthalmic plastics surgery is that of an incision to an infected lacrimal sac in the Code of Hammurabi (2250 BC) (Fig. 1.1). The ancient Egyptians document lacrimal sac infections in the Ebers Papyrus (1500 BC) (Fig. 1.2) and recommended a mixture of antimony, wood powder, myrrh, and dried honey rubbed into the eyes for 4 days! [1]. Hippocrates (460 BC–377 BC) (Fig. 1.3) believed that watery eyes set in an old age and if it turns thicker (discharge), a dried juice of white grapes mixed with copper sulfate is recommended [1].

The Greeks made significant contributions in the early days. Most diseases of the lacrimal system were referred to as "fistules." Celsus (25 BC–50 AD) in his landmark text "Da Medicina" advocated cautery and burning of the lacrimal abscess to cure "fistules" [2]. Claude Galen (129–200 AD), a century after Celsus, advocated the use of hot iron to achieve charring of the "fistules" and hence a cure! He believed that puncta evacuate and secrete into the eye! [2]. However, the most remarkable contribution of Galen (Fig. 1.4) has been his description of the causes of epiphora. He documented as follows [2]:

> *A canal goes from the eyes to the palate and empties there the secretion formed in the eye. Watering may have three causes; either this canal is blocked, or the secretion is excessive or a scar at the nasal canthus. The latter most is incurable.*

Medieval Times and Renaissance

The medieval times as well as the renaissance were unfortunately a bit laid-back as far as the scientific progress related to lacrimal system was concerned. The Arabians chipped in with Rhazes (854–925 AD) evaluating the lacrimal passage further down into the nose and later Avicenna (980–1037 AD) (Fig. 1.5) advocating application of mongo bean pastes for lacrimal fistulas. Andreas Vesalius (1514–1564) described lacrimal drainage anatomy with reasonable details [3, 4], and his pupil, Gabriele Falloppio (1523–1562), documented regurgitation of purulent material from the punctum on compression of the lacrimal sac [4, 5]. Leonardo da Vinci's (1453–1519) and later William Harvey's (1578–1657) embryologic works were notable during these times.

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_1

Modern Dacryology

Major Contributors of Early Days

(a) **George Ernst Stahl (1660–1734)**: Stahl was a German physician (Fig. 1.6), who established nasolacrimal duct obstruction as a cause of dacryocystitis. He also suggested probing using a violin thread!

(b) **Dominique Anel (1679–1730)**: Anel was a French surgeon and among the earliest to device a probe and a syringe (Anel's Probes and Syringes) and became famous in 1713 after he treated the Duchess of Savoy for lacrimal fistulae in a period of 10 days! [6, 7].

(c) **Giovanni Battista Morgagni (1682–1771)**: Morgagni was an Italian anatomist (Fig. 1.7) and among the earliest to give a description of lacrimal drainage system. He concluded that there were no valves in this system and the flow was bidirectional! He published his account in the treatise "Adversaria Anatomica Omnia" in 1718.

(d) **Lorenz Heister (1683–1758)**: Heister was the first to classify lacrimal disorders in 1753. He divided the disorders into four chapters, namely, a tearing eye, a tumefaction of the lacrimal system, an ulcer of the lacrimal system, and lacrimal fistulae. The treatise published in 1753 was named "Chirurgische Wahrnehmungen" [8].

(e) **John Louis Petit (1664–1741)**: Petit explained the flow of tears in the lacrimal system and devised a grooved probe for exploration [9].

(f) **Sir William Bowman (1816–1892)**: Sir Bowman was an English anatomist and surgeon (Fig. 1.8), and his contributions to lacrimal surgery are many. He described Bowman's probes in 1851, punctoplasty in 1853, and canaliculotomy in 1857 [10].

(g) **Joseph Hasner (1819–1892)**: Hasner was an Austrian ophthalmologist who contributed immensely toward lacrimal physiology and mechanics of the flow of tears and devised surgical procedures for the treatment of lacrimal fistules. The distal most valve of the lacrimal drainage pathway is named after him.

Influential Treatise that Paved the Way Early on

1. *Descriptio Anatomica Oculi Humani*: This treatise was published in Gottingen in 1755 by the famous German anatomist Johann Gottfried Zinn (1727–1759) (Fig. 1.9). He was among the earliest to describe complete anatomical course of the lacrimal drainage pathway.
2. *Observations on That Disorder of Corner of the Eye Commonly Called Fistula Lacrimalis*: Published by Percival Pott (1714–1788), an English surgeon (Fig. 1.10) and one of the founders of orthopedics, this work of his was one of the earliest texts on lacrimal disorders.
3. *Chirurgische Wahrnehmungen*: This treatise was published in 1753 by Lorenz Heister (1683–1758) and was the first to classify lacrimal disorders into four separate subdivisions. Some of the surgical instruments and their design he published are legendary (Fig. 1.11).
4. *Organic Lacrimalis Pretiumque Externum Oculi Humanos Description Anatomica*: This treatise was published in 1797 in Leipzig by Johann Christian Rosenmuller (1771–1820) (Fig. 1.12). In comparison to Zinn's work, this was very specific treatise only on lacrimal system with advance anatomical details.
5. *Comprehensive Text on Lacrimal Disorders*: Johann Adam Schmidt (1759–1809) was the first to bring out an influential treatise on lacrimal system in German and was published on copper plates!

History of Dacryocystectomy (DCT)

The earliest ways of dealing with lacrimal sac infections have been to burn or char it down with the help of molten lead or iron [1, 2], which is practically destroying the lacrimal sac. The first refined way of surgical dacryocystectomy can be traced back to John Thomas Woolhouse in 1724 [11]. Johannes Platner (1694–1747) practiced Woolhouse's technique and described DCT with trephination of the lacrimal sac and cautery [11]. Most of these surgeries were incomplete and obviously unintentional because of incomplete knowledge of anatomical details. The modern DCT was described by Rudolph Berlin (1833–1897) (Fig. 1.13) in 1868, and he documented [11, 12] as follows:

> *Dacryocystectomy is the principal operation against incurable epiphora. It is the main protection against corneal abscess and purulent infections against cataract.*

Although not much progress has been made in surgical advancement of dacryocystectomy, its indications have become limited but much more refined today [13].

History of Dacryocystorhinostomy (DCR)

Dacryocystorhinostomy is among those surgeries whose fascinating history is paralleled by only a few in medicine. It has tremendously evolved in techniques, instrumentation, and, above all, the approaches! The earliest attempts to create communications can be traced back to John Thomas Woolhouse (1650–1734), who described extirpation of sac, perforation of lacrimal bone, and insertion of drains made of gold, silver, or lead. Antonio Scarpa (1752–1832), an Italian anatomist (Fig. 1.14), designed a lead nail, slit the lacrimal sac, and introduced it in a 50-year-old woman, who died in 4 days following surgery [14], possibly because of tetanus or septicemia! Around the same time, Dupuytren (1777–1835)

designed a gold tubule for similar purpose, but the patient had a palatal perforation and suffocation [14]. Laguier attempted to drain the sac into the maxillary antrum in 1830 [15, 16].

Endonasal DCR was first conceptualized by Caldwell in 1893 [16, 17]. John West in 1914 modified this technique by creating a bony window within the lacrimal and maxillary bone to clear the area of lacrimal sac and nasolacrimal duct into the middle meatus [16, 18]. Rice first introduced the concept of endoscopic endonasal DCR in cadavers in 1988 and showed its feasibility as a good alternative to an external DCR [19]. Mc Donogh and Meiring in 1989 introduced endoscopic endonasal DCR in patients [20], and since then there was no looking back for the endoscopic approach! The techniques have refined, and newer adjunctive technologies have evolved since 1989. Powered and mechanical endoscopic DCR was described by Peter-John Wormald in 2002 [21].

External DCR was described by Italian rhinologist Addeo Toti in 1904 with a 35 mm incision where both the medial wall of the sac and nasal mucosa were excised [22]. Significant change to this procedure happened soon in 1920 when Dupuy-Dutemps and Bourguet introduced the creation of lacrimal sac and nasal mucosal flaps with suturing to create an epithelium-lined fistula [23]. Very few modifications have happened since then, for example, by Viers in 1969 [24] and Iliff in 1971 [25].

Other approaches for a DCR mostly evolved much later [26]. Bruce Massaro in 1990 introduced endoscopic laser-assisted DCR using argon-blue laser in cadavers [27]. Shortly thereafter in 1992, Levin and Stormogipson introduced endocanalicular laser-assisted DCR in cadavers [28], and later Silkiss introduced it in patients in 1992 [29]. Subsequently, various different types of lasers have been used for the bone removal [30, 31]. Endoscopic radiofrequency-assisted DCR as a different technique was introduced by Reynaldo Javate in 1995 [32]. Ultrasonic DCR was first performed by Krasnov in 1971 [33] and reintroduced in 2005 by Sivak-Callcott [34] and has subsequently generated some interest. Nine millimeter balloon DCR was pioneered by David Silbert [35].

Conjunctivodacryocystorhinostomy (CDCR) was introduced by Von Hoffman in 1904 by opening the lacrimal sac and suturing it to conjunctiva without a stent [36]. This procedure was subsequently revisited by Goar [37], Stallard [38], and Bangerter [39]. Lester Jones in 1962 described slitting of the canaliculus to overcome the frustrating problem of proximal lacrimal drainage obstruction [40]. Later on, in collaboration with Gunther Weiss Scientific Glass Blowing Company from Portland, Oregon, he subsequently developed the famous Pyrex Jones Tubes and published his techniques in 1965 with the use of this new stent [41–43]. Subsequently, various stents and their modifications as well as buccal mucosa and vein grafts were used [44].

History of Other Lacrimal Surgeries

Interventional radiological procedures for nasolacrimal duct dilatation were described by Hanafee and Dayton in 1978 using the sialography canulas and fluoroscopic guidance [45]. Dacryoendoscopy was introduced by Junemann in 1975 [46]. Becker and Berry introduced balloon dacryoplasty in 1989 [47], and in the same year, Busse conceptualized microdrill dacryoplasty [48]. Canalicular obstructions beyond proximal canaliculi are usually managed by trephination, and modern canalicular trephines were introduced by Hampson Sisler in 1990 [49].

Ophthalmology with Otolaryngology: Historical Perspectives

Ophthalmology and otolaryngology are used to be practiced together by the "EENT" specialists for most of the nineteenth and twentieth centuries [50–52]. Major institutes where this was practiced include the London Infirmary for Curing Diseases of the Eye and Ear (inaugurated in 1805) which later became the Moorfields Eye Hospital and the Massachusetts Eye and Ear Infirmary (inaugurated in 1824 as the Boston Eye Infirmary) [50]. Two major global societies were formed, namely, "American Ophthalmological and Otological Society (established in 1864)" and "Western Ophthalmological and Otological Society (established in 1896)" [50]. These EENT specialists used to meet and publish together in common journals. With exponential increase in knowledge and evolution of subspecialties within each branch, there was an increase felt need for separation and this led to the formation of separate American societies in 1979 [51]. Nonetheless, it is important to realize that there are many overlapping areas and lacrimal drainage system happens to be on the forefront. A surgeon dealing with lacrimal disorders, whether ophthalmologists or otolaryngologists, needs to understand that this system traverses both the areas and it is essential to gain sound understanding of the anatomy, physiology, and pathologies of both the areas. A healthy collaboration, knowledge transfer, learning from each other's experiences, and teamwork can enhance patient care and help achieve the goal of optimal management of lacrimal disorders.

Conclusion

It is very important to know the depths of history, at least in the area of one's expertise, and this helps greatly in innovating further and advancing medicine. The take-home message can be summarized in the words of Dr. Paul Lichter, the president of the American Academy of Ophthalmology, in its centennial year, who said:

Ophthalmic History must be taught in our residency programs and a must read for all Ophthalmologists as too few of our students revere history and the lessons it can provide.

Note: The photographs used are courtesy of Wikipedia.

References

1. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 1. Amsterdam: Wayenborg Publications; 1984. p. 11.
2. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 3. Amsterdam: Wayenborg Publications; 1984. p. 250–5.
3. Vesalius AWRJC. On the fabrik of the human body: a translation of De Humani Corporis Fabrika Libri Septem. Novato: Norman Publications; 2007.
4. Harish V, Benger RS. Origins of lacrimal surgery, and evolution of dacryocystorhinostomy to the present. Clin Experiment Ophthalmol. 2014;52:284–7.
5. Falloppio G. Observationes Anatomicae. Venice, 1561.
6. Anel D. New method to cure a lacrimal fistule and a report on different arguments, for and against, and in favour of the newly invented method. Torino, 1713.
7. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 3. Amsterdam: Wayenborg Publications; 1984. p. 246–9.
8. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 3. Amsterdam: Wayenborg Publications; 1984. p. 259–60.
9. Petit JL. Memoire sur la fistule lacrimale. Mem Acad R Sci. 1734;135
10. Bowman W. Ann d'Ocul. XXXIX. p. 79–83.
11. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 3. Amsterdam: Wayenborg Publications; 1984. p. 264.
12. Berlin R. Report of the Heidelberg Ophthalmologische Gesell schaft. 1868. p. 355.
13. Ali MJ. Dacryocystectomy: goals, indications, techniques and complications. Ophthal Plast Reconstr Surg. 2014;30:512–6.
14. Hirschberg J. The renaissance of ophthalmology in the 18th century. In: The history of ophthalmology, vol. 3. Amsterdam: Wayenborg Publications; 1984. p. 262.
15. Laguier. Arch Gen de Med. 1830. p. XXIII.
16. Chandler PA. Dacryocystorhinostomy. Trans Am Ophthalmol Soc. 1936;34:240–63.
17. Caldwell GW. Two new operations for the obstruction of nasolacrimal duct with preservation of the canaliculi. Am J Ophthalmol. 1893;10:189.
18. Watkins LM, Janfaza P, Rubin P. Evolution of endonasal dacryocystorhinostomy. Surv Ophthalmol. 2003;48:73–84.
19. Rice DH. Endoscopic intranasal dacryocystorhinostomy. A cadaver study. Am J Rhinol. 1988;2:127.
20. Mc Donogh M, Meiring JH. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–7.
21. Wormald PJ. Powered endonasal DCR. Laryngoscope. 2002;112:69–71.
22. Toti A. La dacriocistorhinostomia. Ann d'Ocul. 1910;CXIiii:417.
23. Dupuy-Dutemps MM, Bourguet ET. Note preliminaire sur un proded de dacryocystorhinostomie. Ann d'Ocul. 1920;157:1445–7.
24. Viers ER. The use of cautery in external dacryocystorhinostomy. Arch Ophthalmol. 1969;82:489–90.
25. Iliff CE. A simplified dacryocystorhinostomy. Arch Ophthalmol. 1971;85:586–91.
26. Ali MJ. Lacrimal surgery: glorious past, exciting present era and the audacity of hope for a brilliant future. Saudi J Ophthalmol. 2014;28:1–2.
27. Massaro BM, Gonnering RS, Harris GJ. Endonasal dacryocystorhinostomy. A new approach to nasolacrimal duct obstruction. Arch Ophthalmol. 1990;108:1172–6.
28. Levin PS, Stormogipson DJ. Endocanalicular laser-assisted dacryocystorhinostomy. An anatomic study. Arch Ophthalmol. 1992;110:1488–90.
29. Silkiss RZ, Axelrod RN, Iwach AG, et al. Transcanalicular THC:YAG dacryocystorhinostomy. Ophthalmic Surg. 1992;23:351–3.
30. Metson R, Woog JJ, Puliafito CA. Endoscopic laser dacryocystorhinostomy. Laryngoscope. 1994;104:269–74.
31. Pearlman SJ, Michalos P, Leib ML, et al. Translacrimal transnasal laser assisted dacryocystorhinostomy. Laryngoscope. 1997;107:1362–5.
32. Javate RM, Campomanes BS, Co ND, et al. The endoscope and the radiofrequency unit in DCR surgery. Ophthal Plast Reconstr Surg. 1995;11:54–8.
33. Krasnov MM. Ultrasonic dacryocystorhinostomy. Am J Ophthalmol. 1971;72:200–1.
34. Sivak-Callcott JA, Linberg JV, et al. Ultrasonic bone removal with Sonopet OMNI: a new instrument for orbital and lacrimal surgery. Arch Ophthalmol. 2005;123:1595–7.
35. Silbert DI. Outcomes of 9mm balloon-assisted endoscopic DCR: retrospective review of 97 cases. Orbit. 2010;29:131–4.
36. Athanasiov PA, Madge S, Kakizaki H, et al. A review of bypass tubes for proximal drainage obstruction. Surv Ophthalmol. 2011;56:252–66.
37. Goar EL. Congenital absence of the lacrimal puncta and canaliculi. Trans Am Ophthalmol Soc. 1931;29:91–9.
38. Stallard HB. An operation for epiphora. Lancet. 1940;2:743–4.
39. Bangerter A. Behandlung bei Tränenröhrchenstenose. Ophthalmologica. 1947;114:195–202.
40. Jones LT. The cure of epiphora due to canalicular disorders, trauma, and surgical failures on the lacrimal passage. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:506–24.
41. Jones LT. Conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1965;59:773–83.
42. Jones LT, Wobig JL. Surgery of the eyelid and lacrimal system. Birmingham, UK: Aesculapius; 1976.
43. Steele EA. Conjunctivodacryocystorhinostomy with Jones tube: a history and update. Curr Opin Ophthalmol. 2016;27:439–42.
44. Paufique L, Durand L. Surgical treatment of eye watering: repair of the canaliculus with a venous graft. Ann Ocul. 1969;202:337–44.
45. Hanafee WN, Dayton GO. Dilatation of the nasolacrimal duct under radiographic control. Radiology. 1978;127:813–5.
46. Junemann G, Shulte D. Moderne Probleme der Erkrankungen der Lider und des Tränenapparates. I ed. Stuttgart: Enke; 1995. p. 243–64.
47. Becker BB, Berry FD. Balloon catheter dilatation in lacrimal surgery. Ophthalmic Surg. 1989;20:193–8.
48. Busse H. Microsurgery in lacrimal disorders. Dev Ophthalmol. 1989;18:50–2.
49. Sisler HA, Allarakhia L. A new ophthalmic microtrephine. Ophthalmic Surg. 1990;21:656–7.
50. Thawley SE. The otolaryngologist-ophthalmologist relationship: an historical perspective. Otolaryngol Clin N Am. 2006;39:845–53.
51. Truhlsen SM. Whatever happened to the EENT specialists? Surv Ophthalmol. 2013;58:92–4.
52. Patel BC, Anderson RL. History of oculoplastic surgery (1896–1996). Ophthalmology. 1996;103:S74–95.

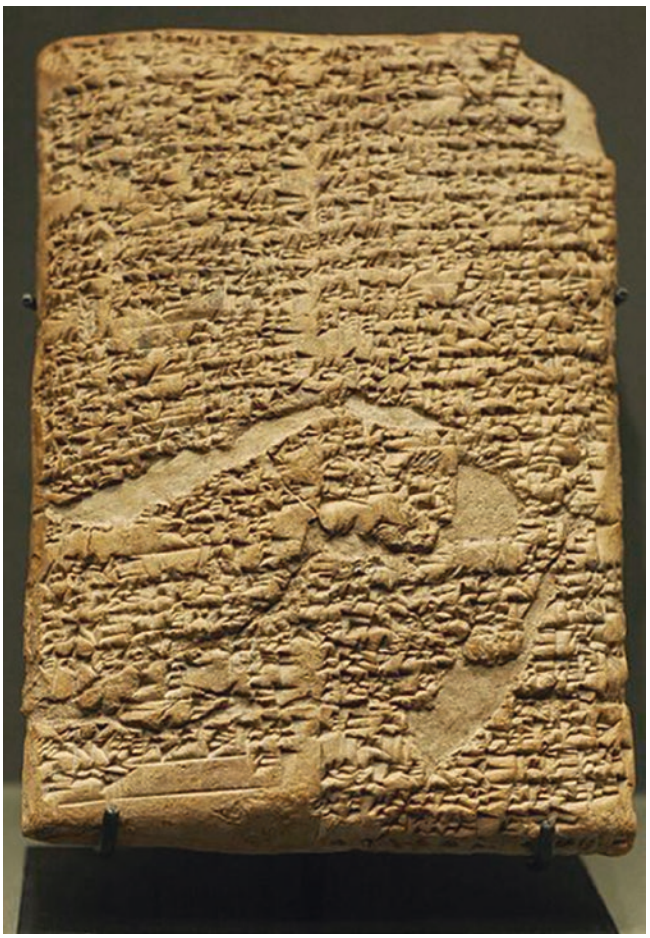


Fig. 1.1 Code of Hammurabi (2250 BC)

Fig. 1.2 Ebers Papyrus (1500 BC)

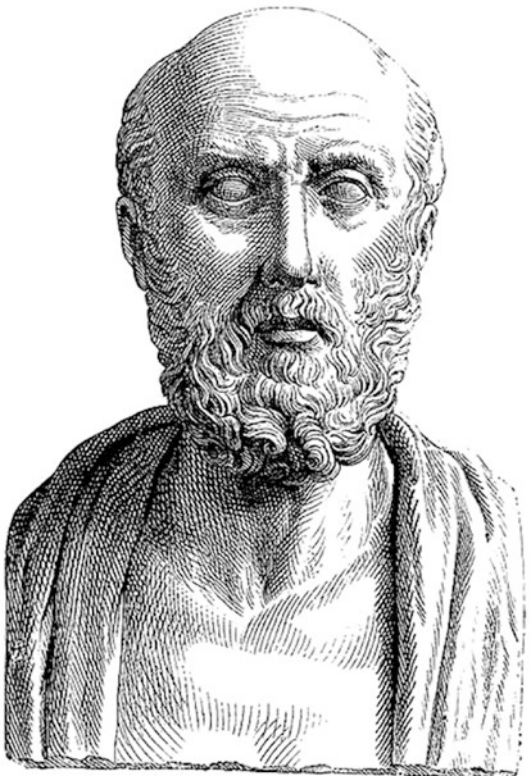


Fig. 1.3 Hippocrates (460–377 BC)

Fig. 1.4 Claude Galen (129–200 AD)

Fig. 1.5 Avicenna (980–1037 AD)

Fig. 1.6 George Ernst Stahl (1660–1734)

Fig. 1.7 Giovanni Battista Morgagni (1682–1771)

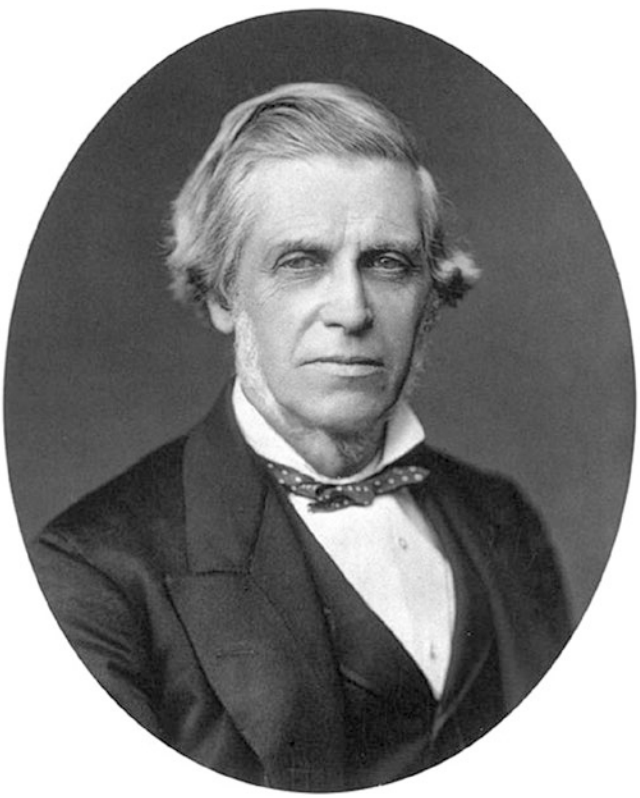


Fig. 1.8 Sir William Bowman (1816–1892)

Fig. 1.9 Johann Gottfried Zinn (1727–1759)

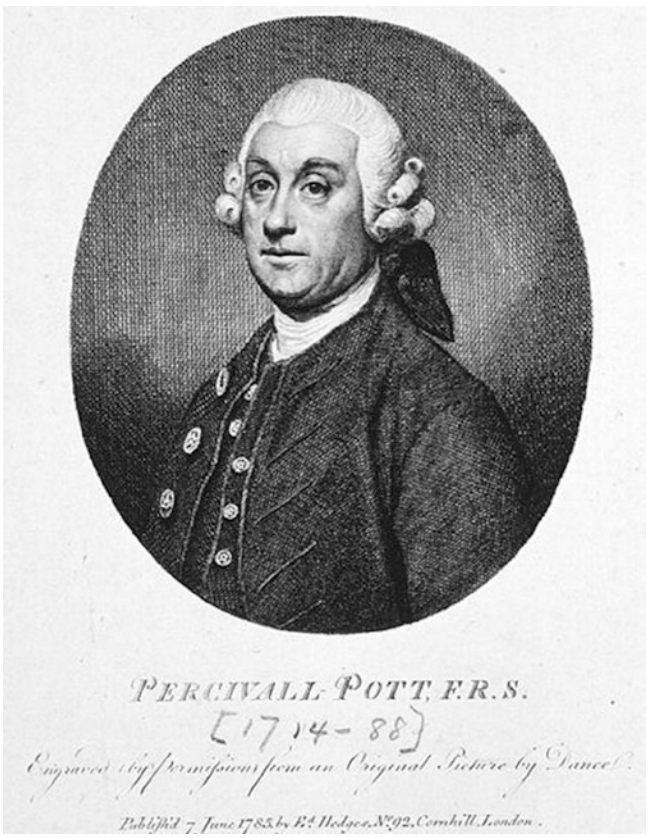


Fig. 1.10 Percival Pott (1714–1788)

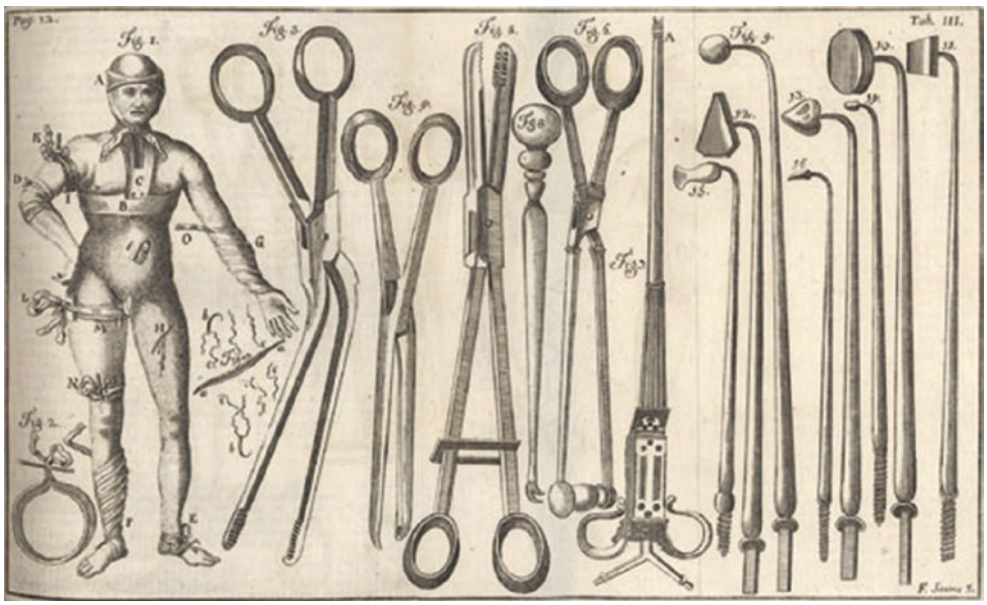


Fig. 1.11 Surgical instruments of Lorenz Heister (1683–1758)

Fig. 1.12 Johann Christian Rosenmuller (1771–1820)

Fig. 1.13 Rudolph Berlin (1833–1897)

Fig. 1.14 Antonio Scarpa (1752–1832)

Embryology of the Lacrimal Drainage System

2

Mohammad Javed Ali and Hirohiko Kakizaki

Introduction

The understanding of lacrimal embryology is very crucial to the understanding of lacrimal anatomy and its subsequent clinical and surgical applications. In addition, numerous congenital anomalies of the lacrimal system and their appropriate management largely depend on a sound knowledge of its evolution. A thorough insight of lacrimal embryology is essential for advancing this science in terms of fundamental reasoning and developing minimally invasive interventions.

The human embryonic period generally covers the first 8 weeks postovulation, after which the embryo is called the "fetus" [1]. The moment when an embryo transforms into a fetus is not clearly determined, though [2] main parts of the human body are formed simultaneously during the embryonic period, and the lacrimal system is roughly completed by the first 10 weeks postovulation [2]. The structure itself does not change largely after that. The lacrimal drainage system can be broadly divided into embryonic and fetal developments for a lucid understanding.

Lacrimal Drainage System Development During Embryogenesis

The lacrimal passages develop along the line of cleft between the maxillary process and the lateral nasal process. From its inception, the maxillary process grows much rapidly in comparison with the lateral nasal process and subsequently overlaps the paraxial region around the eye, leading to the formation of a fold of ectoderm between the processes (Fig. 2.1) [1, 2].

Embryonic development is estimated with the help of Carnegie stages [3]. Carnegie stages have been named after Carnegie Institute of Washington, which began collecting and classifying embryos in the early 1900s. The Carnegie stages divide the human embryonic period to 23 stages [3]. Criteria beyond morphological features include range of age in days, number of somites present, and embryonic crown rump lengths (CRL) [3].

The development of the lacrimal system begins at Carnegie stage 16 (CRL, 11 mm), when an epithelial thickening of the lacrimal groove forms the lacrimal lamina [4]. At Carnegie stage 19 (CRL, 17 mm), the lacrimal lamina separates from the surface ectoderm and forms the lacrimal cord [4]. The lateral extreme of the cord closest to the surface ectoderm bifurcates, thus giving rise to the canaliculi (Fig. 2.2) [4]. At Carnegie stage 20 (CRL, 19–21 mm), the lacrimal cord is arranged lateral to the nasal capsule and finally lateral and inferior to the inferior meatal lamina [4]. At Carnegie stage 22 (CRL, 26 mm), the proximal portion of the lacrimal system is perfectly differentiated, although it does not have a lumen as yet. The surrounding mesenchyme starts condensing [4]. The cells of the lacrimal cord condense at its periphery but are more loosely organized centrally, toward the future lumen [4]. At the end of the embryonic period (Carnegie stage 23; CRL, 27–28 mm), morphology of the lacrimal system is well developed [4]. The lateral portion of the lacrimal system is clearly differentiated into the superior and inferior lacrimal canaliculus proximally and the lacrimal sac distally [4]. The canaliculi are close to the conjunctiva [5]. The medial portion of the lacrimal cord continues caudal and lateral to the inferior meatal lamina although the epithelia have not yet joined [4].

M. Javed Ali, F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology,
L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

H. Kakizaki, M.D., Ph.D.
Department of Ophthalmology, Aichi Medical University,
Aichi, Japan

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_2

Lacrimal System Development During Fetal Period

From the tenth week (CRL, 48–55 mm), various significant changes occur such as canalization of the lacrimal cord and development of the surrounding tissues (Fig. 2.3) [4, 5]. Canalization occurs at the same time throughout the nasolacrimal apparatus [5]. The canalicular epithelium comes in contact with the palpebral conjunctival epithelium, and both epithelia form a continuous epithelial lamina [4]. The caudal extreme of the lacrimal duct and the inferior meatal lamina makes contact, and the latter begins to cavitate [1, 2, 4]. Central cells toward the lumen possibly undergo apoptosis and subsequently degenerate and shed off leaving a clear lumen behind. Muscular fibers of the Horner's muscle are observed to surround the lacrimal canaliculi, and mesenchymal tissue is interposed between the canaliculi and the muscle fibers [1, 2, 4, 5]. During the 12th week of development, reabsorption of the inferior meatal lamina is clearly visible (CRL, 74 mm). After the 13th week of development (CRL, around 85–90 mm), the surrounding tissues of the lacrimal apparatus such as ligament and tendon are clearly formed [4].

Although the canalicular lumina become patent by the fourth month after gestation, the lacrimal puncta do not open onto the eyelid margins until the eyelids separate during the seventh month [1, 2]. However, the lower end of the duct is often separated from the inferior meatus at birth by a membrane constituted by the apposed mucosal linings of the lower ductal end and the nasal fossa. Only in 30% is the lowermost end patent at birth [1, 2]. An obstruction at this site balloons out later into the inferior meatus, and its opening mostly occurs after birth [1, 2].

Clinico-Embryological Correlations

Position of the Puncta

The inferior punctum lies 0.5–1.0 mm more temporally than the superior one, so that they do not superimpose during eyelid closure [1, 2]. This anatomy has embryological explanations and results because of a relative rapid growth of the maxilla compared to that of the frontal bone [1, 2]. The lacrimal caruncle has been shown to be in close relation to the lower eyelid developmentally, and its supero-temporal margin smoothly continues in level with the lower eyelid margin [6] and hence is a reasonable guide to lead to and judge a normal punctal position.

Ectopic Canaliculus and Caruncle

The lacrimal caruncle contains sebaceous glands and hairs and an ectopic canaliculus occasionally opens to the caruncle [7]. The reason for this is the common developmental origin of the lower eyelid and the caruncle (Fig. 2.4) [1, 2, 6].

Punctal Agenesis

The basic etiopathogenesis of punctal agenesis is likely to be failure of canaliculi out-budding from the upper end of the solid lacrimal cord in an embryo of 18–24 mm (Fig. 2.5) [1, 2]. Punctal agenesis has important associated ocular and systemic associations. Lyons et al. [8] found 23% of their cases ($n = 57$) to have ocular abnormalities like lacrimal fistula, blepharitis, distichiasis, eyelid tags, absence of caruncle, and divergent strabismus. Punctal agenesis has well-known association with systemic syndromes like ectodermal dysplasia [1, 9] and Hay-Wells [9] and Levy-Hollister syndromes [10].

Incomplete Punctal Canalization (IPC)

Incomplete punctal canalization is a term that refers to a form of punctal dysgenesis with membranes (Fig. 2.6) [11]. The pathogenesis of punctal membranes is unknown but is believed to either represent failed dehiscence of epithelium overlying the normally formed canaliculi or failure of canalization of the most proximal part of lacrimal apparatus. This dysgenesis is not found to have any systemic association although associated lacrimal system anomalies like canalicular stenosis and congenital nasolacrimal duct obstruction are reported [11].

Canalicular Agenesis

This results from failure of outpouching of epithelial buds from the upper end of lacrimal cord or abrupt halt in migration toward eyelids immediately following outpouching. Canalicular agenesis is associated with punctal agenesis (Fig. 2.5) [12].

Supernumerary Puncta and Canaliculi

These may result from multiple epithelial buds developing from the upper end of lacrimal cord in a 18–24 mm embryo (Figs. 2.7 and 2.8) [12]. Wicherkiewicz estimated the incidence of supernumerary puncta and canaliculi to be

1 in 60,000 [13]. These are known to be associated with lacrimal fistula and lacrimal sac diverticulum. Systemic associations known are Down's syndrome and preauricular sinus [14].

Canalicular Wall Dysgenesis

Canalicular wall dysgenesis and its eight subtypes have been recently described [15] (Fig. 2.9). Its etiopathogenesis is unknown but is believed to represent dysregulation of mesenchymal condensation around the canalicular primordium and its contiguity with the sub-adjacent mesenchyme of the surface ectoderm during Carnegie stage 19 of embryonic development [15].

Congenital Lacrimal Fistula or Lacrimal Anlage Duct

Lacrimal fistula is an accessory or an anlage duct communicating with the skin on one side and the canaliculus, lacrimal sac, or nasolacrimal duct on the other [16] (Figs. 2.10 and 2.11). These result from abnormal embryological development at the optic end of the naso-optic fissure, whereby there are additional out-budding from the embryonic lacrimal epithelial cord or an epithelial core that has not involuted or has not completely separated from the surface ectoderm [16–18]. Histopathological studies have pointed to the common canaliculus as the most potential site of origin of the out-budding [19, 20]. The estimated incidence is reported to be 1:2000 live births [20, 21]. Inheritance patterns known include autosomal dominant, autosomal recessive, and syndromal [16, 22].

Nasolacrimal Duct Variations in Congenital Nasolacrimal Duct Obstruction

1. Nasolacrimal duct does not open into inferior meatus and may end abruptly onto the vault of the meatus or get buried in the lateral wall (Fig. 2.12) [23, 24].
2. Nasolacrimal duct ending blindly into the inferior turbinate.
3. Nasolacrimal duct ending blindly into the medial maxillary sinus wall.
4. Nasolacrimal duct ending in a bony, non-canalized nasolacrimal canal.
5. Absence of nasolacrimal duct [23, 25].

Congenital Dacryocele

The pathogenesis in dacryocele is believed to be persistent non-canalization of the lower end of nasolacrimal duct (NLD) along with a functional obstruction at the valve of Rosenmuller [26]. This is thought to cause sufficient pressure to dilate the entire sac (Fig. 2.13) and in many cases the nasolacrimal duct, leading to an intranasal cyst [27].

Lacrimal Sac Diverticula

Lacrimal diverticula are cystic outpouchings, mostly communicating with the lacrimal sac [28]. An abnormal cellular cord stem from the lacrimal sac region during embryogenesis could contribute to diverticula. They may present as medial orbital mass or dacryocystitis (Figs. 2.14, 2.15, and 2.16) [28, 29]. The infero-lateral wall of the sac is a common area for the diverticula, since resistance to any expansion is least in this region as compared to other walls which have support of the periosteum and orbicularis. Diagnosis is usually by a plain dacryocystography (DCG) or by a CT or MR-DCG, and excision is performed with specific techniques for symptomatic cases (Figs. 2.17 and 2.18) [28, 30].

Congenital Absence of Lacrimal Valves

Lacrimal valves have been described at various levels of the lacrimal sac and are presumed to prevent bidirectional flow of tears [31]. Absence or defective development of the lacrimal valves may result in few uncommon conditions. Absence of the valves in the nasolacrimal duct may result in pneumatoceles of the sac secondary to retrograde passage of air. The absence of valve of Rosenmuller along with Hasner's may result in passage of air from the nose onto the ocular surface [23].

Systemic and Syndromic Associations

Numerous syndromes are known to have associated congenital lacrimal anomalies [16, 25, 32–55]. The most common among them are Down's syndrome and the ectrodactyly-ectodermal dysplasia-clefting or EEC syndrome [32–36]. The prevalence of nasolacrimal anomalies in Down's syndrome has been reported to be as high as 22% [33]. Lacrimal anomalies associated with it include punctal agenesis, canalicular stenosis, canalicular atresia, supernumerary punctum, nasolacrimal duct stenosis, and frank

distal or multilevel nasolacrimal duct obstructions [32–34]. Among these the proximal anomalies are known to predominate as compared to the distal ones. The EEC syndrome has been reported to be associated with punctal agenesis, canalicular atresia, lacrimal fistula, and congenital nasolacrimal duct obstruction with dacryocystitis [35, 36]. Table 2.1 depicts the syndromes and systemic associations of congenital lacrimal anomalies.

Table 2.1 Syndromes and systemic associations with congenital lacrimal anomalies

1	Down's syndrome [32–34]
2	Ectrodactyly-ectodermal dysplasia-clefting (EEC) syndrome [35, 36]
3	Lacrimo-auriculo-dento-digital (LADD) or Levy-Hollister syndrome [40]
4	Treacher Collins syndrome [37, 47]
5	Rubinstein-Taybi syndrome [46, 47]
6	Goldenhar syndrome [47]
7	CHARGE syndrome [16, 54]
8	Blepharophimosis syndrome [56]
9	Hay-Wells syndrome [37]
10	Fraser syndrome [47]
11	HPPD syndrome (hypertelorism, preauricular sinus, punctal pits, deafness) [41]
12	Poland-Möbius syndrome [42]
13	Cornelia de Lange syndrome [39]
14	Johanson-Blizzard syndrome [43]
15	Velocardiofacial (VCFS) syndrome [25]
16	Branchio-oculo-facial (BOF) syndrome [38]
17	Millers syndrome [47]
18	Saethre-Chotzen syndrome [37, 47]
19	ADULT syndrome [44]
20	Amniotic band syndrome [37, 47]
21	Fetal valproate syndrome [49]
22	Pashayan syndrome [50]
23	Rapp-Hodgkin syndrome [52]
24	Robinow's syndrome [53]
25	Waardenburg-Klein syndrome [55]
26	Split-hand/split-foot syndrome [57]
27	Goltz-Gorlin syndrome [58]
28	Limb-mammary syndrome [59]
29	Aplasia of the lacrimal and salivary glands (ALSG) [60]
30	VACTERL associations [16, 45]
31	Mandibulofacial dysostosis [47]
32	Arhinia [51]
33	Uterus didelphys [16, 48]
34	Renal agenesis [16, 48]
35	Preauricular fistulae [16, 41, 61]
36	Naso-orbital meningocele [16]
37	Clefting with holoprosencephaly [47]
38	Craniometaphyseal dysplasia [47]

Inheritance of Congenital Lacrimal Anomalies

Very less is known with regard to inheritance patterns and culprit genes in lacrimal disorders secondary to incomplete penetrance and the large variations of expressions [59]. Grossly the inheritance can be attributed currently to mutations of the fibroblast growth factor 10 (FGF10) and its associated receptors: FGFR2 and FGFR3 (fibroblast growth factor receptors). Lacrimo-auriculo-dento-digital (LADD) syndrome [40] and aplasia of the lacrimal and salivary glands (ALSG) [60] are examples of such inheritance.

Mutations of the tumor protein p63 have also been implicated in lacrimal anomalies. Examples of this pathway involvement are known in ectrodactyly-ectodermal dysplasia-clefting (EEC) syndromes [35, 36], acro-dermato-ungual-lacrimal-tooth (ADULT) syndrome [44], Hay-Wells syndrome [37], and Rapp-Hodgkin syndrome [52].

Mutations of the EYA1 gene that plays a role in normal development of branchial apparatus are known to involve the lacrimal system in an autosomal dominant inheritance [38]. The common syndromes include branchiootic syndrome and branchiootorenal syndromes.

There are isolated reports of congenital lacrimal anomalies secondary to mutations in TWIST gene (Saethre-Chotzen syndrome) [37], UBR1 gene disorders (Johanson-Blizzard syndrome) [43], BPES gene (Blepharophimosis syndrome) [56], and chromosome 14q31 locus abnormalities (HPPD syndrome) [41]. In addition, very few reports of lacrimal anomalies running in families, predominantly involving the proximal lacrimal system, have been reported [22, 61–63]. All these reflect the need for focused research in genetics of the lacrimal disorders to enhance the understanding and translate this increasing knowledge for better patient management.

References

1. Duke-Elder S. Development of ocular adnexa. In: Duke-Elder S, editor. System of ophthalmology, vol. 1. St. Louis: CV Mosby; 1938. p. 364–5.
2. Whitnall SE. The lacrimal apparatus. In: Whitnall SE, editor. The anatomy of the human orbit and accessory organs of vision. Oxford: Oxford University Press; 1921. p. 223–52.
3. O'Rahilly R. Early human development and the chief sources of information on staged human embryos. Eur J Obstet Gynecol Reprod Biol. 1979;9:273–80.
4. De la Cuadra-Blanco C, Peces-Pena MD, Janez-Escalada L, et al. Morphogenesis of the human excretory lacrimal system. J Anat. 2006;209:127–35.
5. Sevel D. Development and congenital abnormalities of the nasolacrimal apparatus. J Pediatr Ophthalmol Strabismus. 1981;18:13–9.
6. Kakizaki H, Valenzuela AA. Lacrimal caruncle: continuation to the lower eyelid retractors. Ophthal Plast Reconstr Surg. 2011;27:198–200.

7. Nirankari MS, Chaddah MR. Supernumerary punctum on the caruncle. Br J Ophthalmol. 1962;46:380–1.
8. Lyons CJ, Rosser PM, Welham RAN. The management of punctal agenesis. Ophthalmology. 1993;100:1851–5.
9. Ahn Yuen SJ, Oley C, Sullivan TJ. Lacrimal outflow dysgenesis. Ophthalmology. 2004;111:1782–90.
10. Katowitz WR, Katowitz JA. Congenital etiologies of lacrimal system obstructions. In The lacrimal system. Cohen AJ, Mercandetti M, Brazzo BG (eds). Springer, Switzerland, 2006, pp 35–42.
11. Ali MJ, Mohapatra S, Mulay K, et al. Incomplete punctal canalization: the external and internal punctal membranes. Outcomes of membranotomy and adjunctive procedures. Br J Ophthalmol. 2013;97:92–5.
12. Kirk RC. Developmental anomalies of the lacrimal passages. A review of the literature and presentation of three unusual cases. Am J Ophthalmol. 1956;42:227–32.
13. Wicherkiewicz. In: Proceeding of XI internat cong med, Rome, 1895;6:49.
14. Satchi K, McNab AA. Double lacrimal puncta: clinical presentation and potential mechanisms of epiphora. Ophthalmology. 2010;117:180–3.
15. Ali MJ, Naik MN. Canalicular wall dysgenesis: the clinical profile of canalicular hypoplasia and aplasia, associated systemic and lacrimal anomalies and clinical implications. Ophthal Plast Reconstr Surg. 2013;29:464–8.
16. Chaung JQ, Sundar G, Javed Ali M. Congenital lacrimal fistula: a major review. Orbit. 2016;35:212–20.
17. Cassady JV. Developmental anatomy of the nasolacrimal duct. AMA Arch Ophthalmol. 1952;47:141–58.
18. Levine J. Congenital fistula of the lacrimal sac. Am J Ophthalmol. 1929;12:745–6.
19. Ali MJ, Mishra DK, Naik MN. Histopathology and immunophenotyping of congenital lacrimal (Anlage) fistula. Ophthal Plast Reconstr Surg. 2016;32:17–9.
20. Welham RAN, Bergin DJ. Congenital lacrimal fistulas. Arch Ophthalmol. 1985;103:545–8.
21. Francois J, Bacskulin J. External congenital fistulae of the lacrimal sac. Ophthalmologica. 1969;159:249–61.
22. Maden A, Yilmaz S, Ture M. Hereditary lacrimal fistula. Orbit. 2008;27:69–72.
23. Buerger DG, Schaefer AJ, Campbell CB, et al. Congenital lacrimal disorders. In: Nesi F, Levine MR, editors. Smith's ophthalmic plastics and reconstructive surgery. St. Louis: Mosby; 1998. p. 649–60.
24. Gupta A, Kamal S, Javed Ali M, et al. Buried probe in complex congenital nasolacrimal duct obstructions: clinical profile and outcomes. Ophthal Plast Reconstr Surg. 2015;31:318–20.
25. Prabhakaran VC, Davis G, Wormald PJ, et al. Congenital absence of nasolacrimal duct in velocardiofacial syndrome. J AAPOS. 2008;12:85–6.
26. Levin AV, Wygnansky-Jaffe T, Forte V, et al. Nasal endoscopy in the treatment of congenital lacrimal sac mucoceles. Int J Pediatr Otolaryngol. 2003;67:255–61.
27. Ali MJ, Psaltis AJ, Brunworth J, et al. Congenital dacryocele with large intra-nasal cyst: efficacy of cruciate marsupialization, adjunctive procedures and outcomes. Ophthal Plast Reconstr Surg. 2014;30:346–51.
28. Kim JH, Chang HR, Woo KI. Multilobular lacrimal sac diverticulum presenting as a lower eyelid mass. Korean J Ophthalmol. 2012;26:297–300.
29. Ackay EK, Cagil N, Yulek F, et al. Congenital lacrimal sac diverticulum as a cause of recurrent orbital cellulitis. Can J Ophthalmol. 2008;44:e29–30.
30. Polito E, Leccisotti A, Menicacci F, et al. Imaging techniques in the diagnosis of lacrimal sac diverticulum. Ophthalmologica. 1995;209:228–32.
31. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of the external and internal surfaces of the lacrimal drainage system. Ophthal Plast Reconstr Surg. 2015;31:414–7.
32. Coats DK, McKreery KM, Plager DA, et al. Nasolacrimal outflow anomalies in Down's syndrome. Ophthalmology. 2003;110:1437–41.
33. Berk AT, Saatci AO, Ercal MD, et al. Ocular findings in 55 patients with Down's syndrome. Ophthalmic Genet. 1996;17:15–9.
34. Al-Faky YH, Mousa A, Alkhiary HT, et al. Management of unilateral versus bilateral lacrimal drainage system dysfunction in Down syndrome. J Pediatr Ophthalmol Strabismus. 2012;49:109–13.
35. Elmann S, Hanson SA, Bunce CN, et al. Ectrodactyly-ectodermal dysplasia clefting (EEC) syndrome. A rare cause of congenital lacrimal anomalies. Ophthal Plast Reconstr Surg. 2015;31:e35–7.
36. Keklikci U, Yavuz I, Tunik S, et al. Ophthalmic manifestations in patients with ectodermal dysplasia syndromes. Adv Clin Exp Med. 2014;23(4):605–10.
37. Yuen SJ, Oley C, Sullivan TJ. Lacrimal outflow dysgenesis. Ophthalmology. 2004;111:1782–90.
38. Demirci H, Shields CL, Shields JA. New ophthalmic manifestations of branchio-oculo-facial syndrome. Am J Ophthalmol. 2005;139:362–4.
39. Avgitidou G, Cursiefen C, Heindl LM. Ophthalmological manifestations of Cornelia de Lange syndrome: case report and review of literature. Ophthalmologe. 2015;112:455–8.
40. Santo RO, Golbert MB, Akaishi PM, et al. Giant dacryocystocele and congenital alacrimia in lacrimo-auriculo-dento-digital syndrome. Ophthal Plast Reconstr Surg. 2013;29:e67–8.
41. Sampath S, Keats BJ, Lacassie Y. HPPD: a newly recognized autosomal dominant disorder involving hypertelorism, pre-auricular sinus, punctal pits and deafness mapping to chromosome 14q31. Am J Med Genet A. 2011;155A:976–85.
42. Aydin A, Ayata A, Sabahyildizi M, et al. Poland-Möbius syndrome associated with lacrimal punctal and canalicular agenesis. J Fr Ophthalmol. 2010;33:119.e1–5.
43. Cheung JC, Thomson H, Buncic JR, et al. Ocular manifestations of the Johanson-Blizzard syndrome. J AAPOS. 2009;13:512–4.
44. Eter N, Zerres K, Propping P, et al. Severe persistent nasolacrimal duct obstruction: a typical finding in ADULT syndrome. Br J Ophthalmol. 2006;90:1206–7.
45. Harrison AR, Dailey RA, Wobig JL. Bilateral congenital lacrimal anlage ducts (lacrimal fistula) in a patient with VACTERL association. Ophthal Plast Reconstr Surg. 2002;18:149–50.
46. Marabotti A, Giannecchini G, Cariello A, et al. Stenosis of the lacrimal system in Rubinstein-Taybi syndrome. Ophthalmologica. 2002;216:272–6.
47. Hicks C, Pitts J, Rose GE. Lacrimal surgery in patients with congenital cranial or facial anomalies. Eye. 1994;8:583–91.
48. Turan-Vural E, Atmaca F, Unlu C, et al. Unilateral lacrimal fistula in a patient with uterus didelphys and renal agenesis. Int Ophthalmol. 2012;32:67–9.
49. Hornby SJ, Welham RA. Congenital nasolacrimal duct obstruction requiring external dacryocystorhinostomies in a child with foetal valproate syndrome. Eye. 2003;17:546–7.
50. Stoll C, Terzic J, Fischbach M. A three generations family with blepharo-naso-facial malformations suggestive of Pashayan syndrome. Genet Couns. 1999;10:337–43.
51. Ali MJ. Bilateral lacrimal mucoceles in a setting of congenital arhinia. Ophthal Plast Reconstr Surg. 2014;30:e167.
52. Rodini EO, Freitas JA, Richieri-Costa A. Rapp-Hodgkin syndrome: report of a Brazilian family. Am J Med Genet. 1990;36:463–6.
53. Aquirre-Vila-Coro A, Mazow ML, Drtil SH, et al. Lacrimal anomalies in Robinow's syndrome: case report. Arch Ophthalmol. 1988;106:454.
54. Bowling BS, Chandna A. Superior lacrimal canalicular atresia and nasolacrimal duct obstruction in the CHARGE association. J Pediatr Ophthalmol Strabismus. 1994;31:336–7.
55. Calmettes L, Deodati F, Bec P, et al. Waardenburg-Klein syndrome with blind lacrimal fistulas. Bull Mem Soc Fr Ophthalmol. 1968;81:144–55.

56. Mukherjee B, Alam MS. Double Jeopardy: Blepharophimosis syndrome with congenital nasolacrimal duct obstruction in twins. Orbit. 2013;32:318–20.
57. Salmon MA, Wakefield MA. The nasolacrimal ducts and split-hand/split foot syndrome. Dev Med Child Neurol. 1977;19:418–9.
58. Sutton VR, Van den Veyver IB. Focal dermal hypoplasia. In: Pagon RA, Adam MP, Ardinger HH, et al., editors. Gene reviews (R). Seattle: University of Washington; 1993.
59. Allen RC. Hereditary disorders affecting the lacrimal system. Curr Opin Ophthalmol. 2014;25:424–31.
60. Ferreira AP, Gomez RS, Castro WH, et al. Congenital absence of lacrimal puncta and salivary glands: report of a Brazilian family and review. Am J Med Genet. 2000;94:32–4.
61. Saltzmann RM, Lissner GS. Familial absence of lacrimal puncta associated with pre-auricular sinus. J Pediatr Ophthalmol Strabismus. 2006;43:233–5.
62. Moro F, Li Volti S, Tomarchio S, et al. Congenital obstruction of the lacrimal passages in five consecutive generations. Ophthalmologica. 1980;181:129–32.
63. Singh S, Ali MJ, Naik MN. Familial incomplete punctal canalization: clinical and fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2016 (Epub).

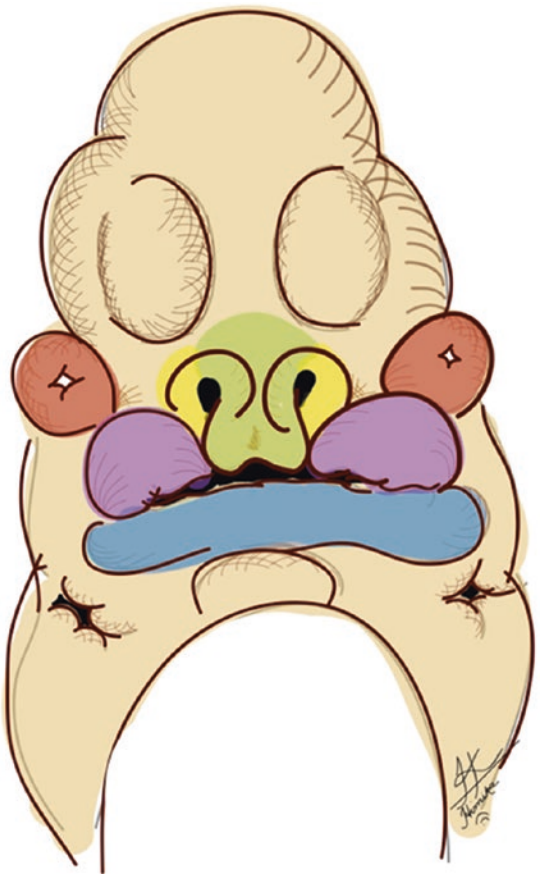


Fig. 2.1 Schematic diagram showing the development of lacrimal system between the maxillary and fronto-nasal process (Photo Courtesy: Dr. Himika Gupta)

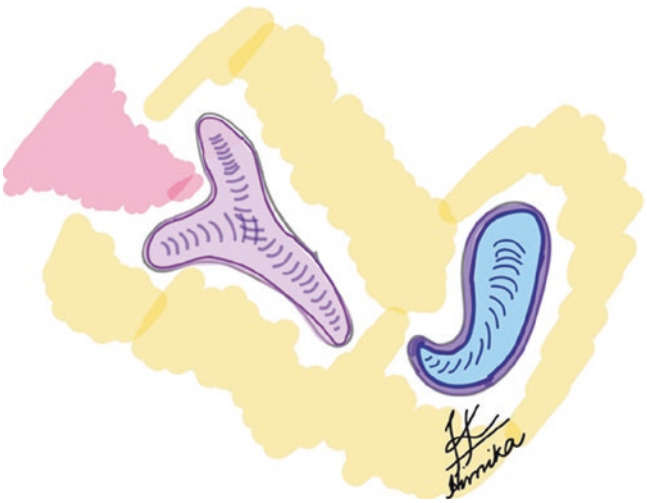


Fig. 2.2 Schematic diagram showing the out-budding of solid canaliculi from the lacrimal cord (Photo Courtesy: Dr. Himika Gupta)

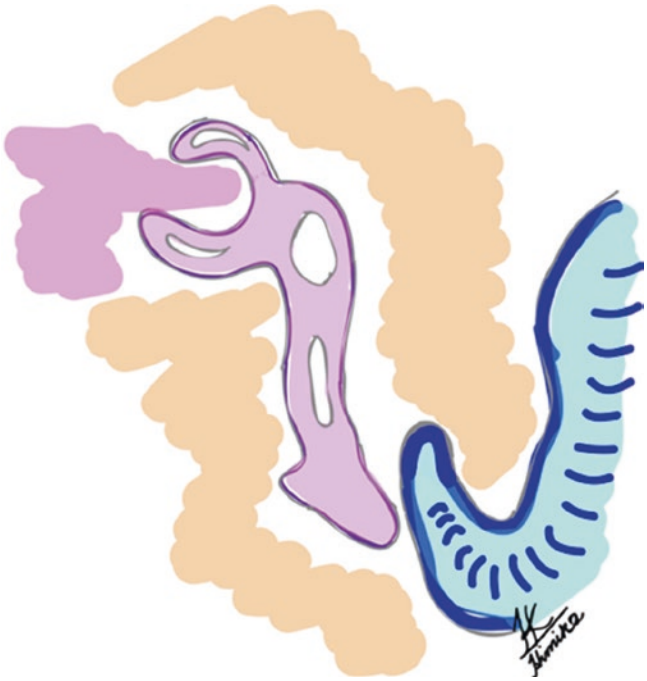


Fig. 2.3 Schematic diagram showing the process of canalization (Photo Courtesy: Dr. Himika Gupta)

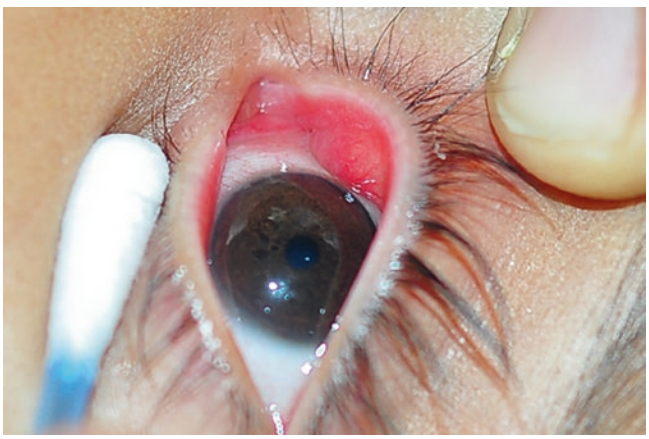


Fig. 2.4 Ectopic canalicular opening near caruncle

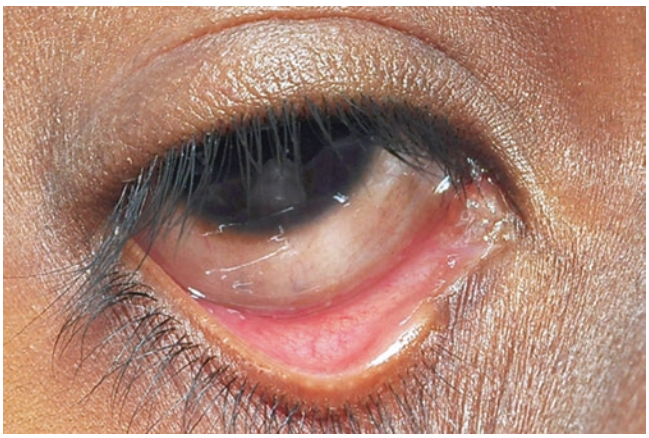


Fig. 2.5 Lower punctal agenesis-associated canalicular agenesis. Note the atrophy of area over the lower canaliculus

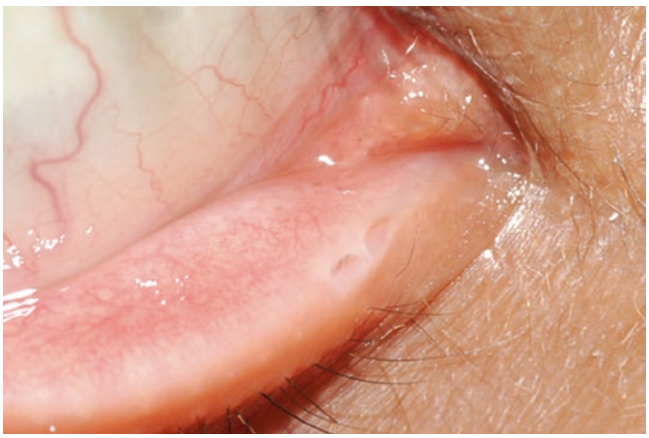


Fig. 2.8 Supernumerary or double puncta in this case

Fig. 2.6 Incomplete punctal canalization of external membrane variety (IPC-EM)

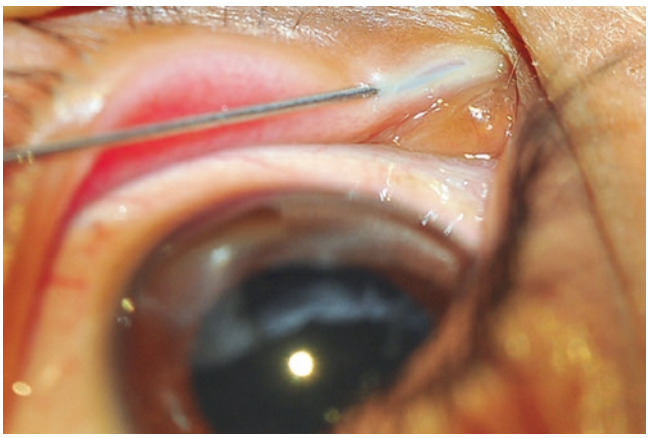


Fig. 2.9 Single canalicular wall dysgenesis (hypoplasia type)

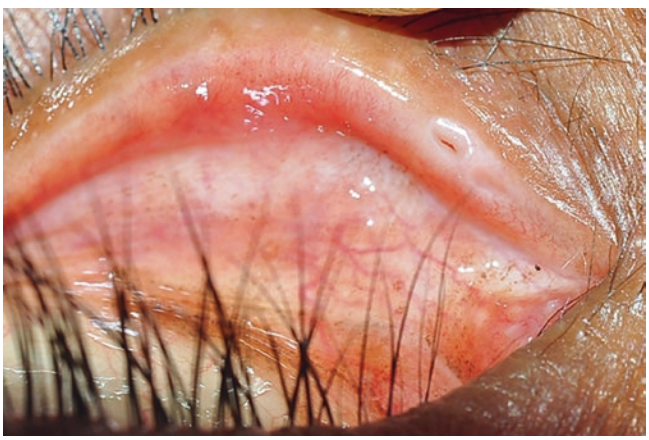


Fig. 2.7 Supernumerary puncta

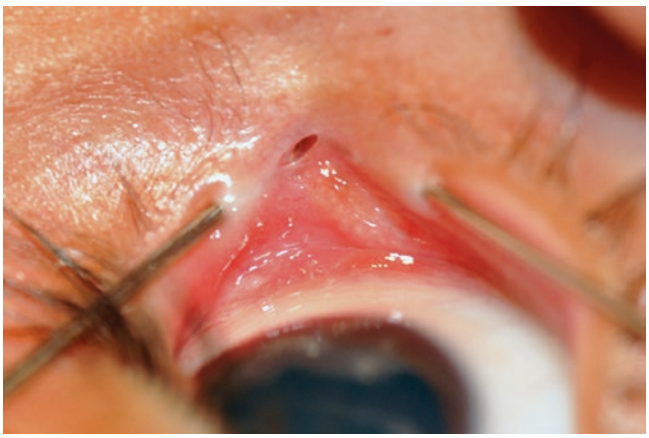


Fig. 2.10 Lacrimal sac fistula

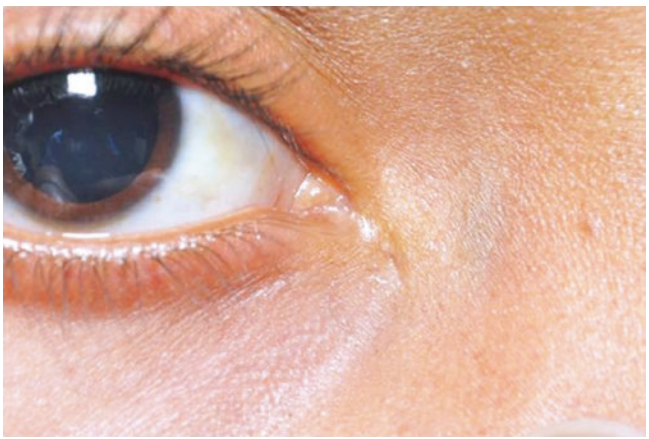


Fig. 2.11 A classical congenital fistula

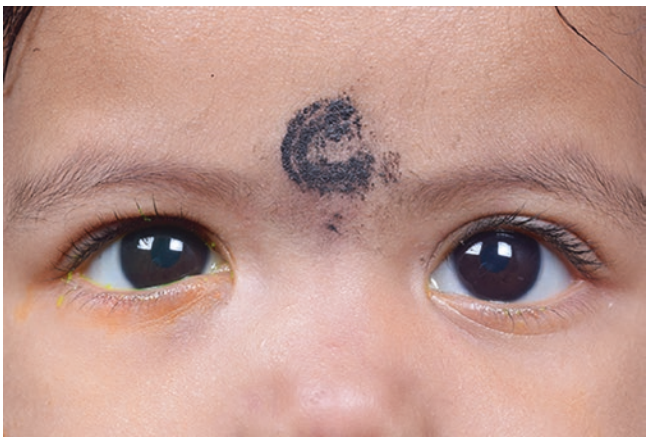


Fig. 2.14 Infant with right inferomedial orbital mass with slight supero-temporal dystopia

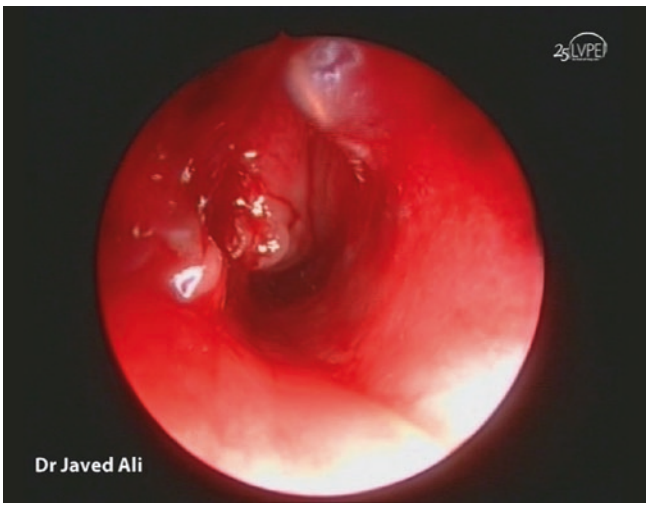


Fig. 2.12 Endoscopic view of a buried probe

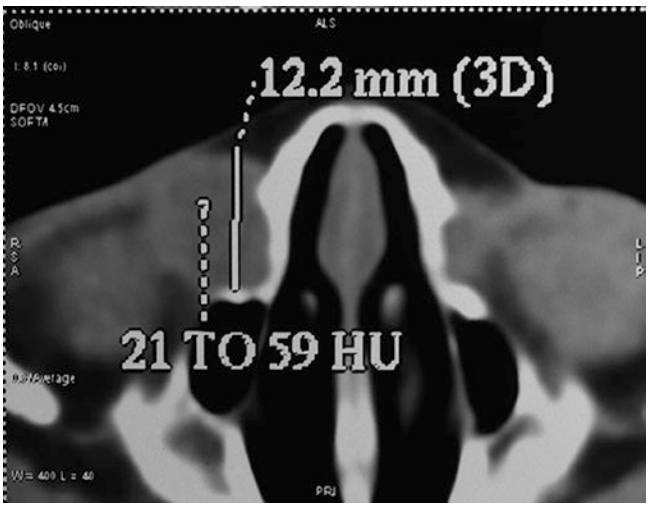


Fig. 2.15 CT scan, axial section of the patient in Fig. 2.14. Note the mass lesion arising from the lacrimal fossa and the huge lacrimal sac

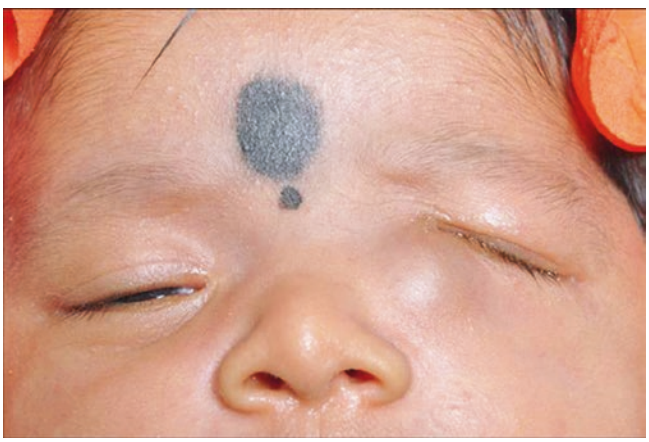


Fig. 2.13 Congenital dacryocele

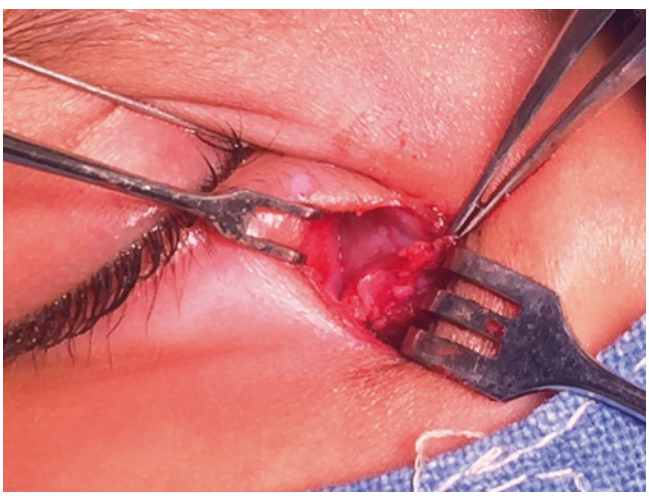


Fig. 2.16 Intraoperative photograph showing the outpouching of the lateral lacrimal sac wall (congenital diverticula) into the orbit

Fig. 2.17 Late presentation of the right congenital lacrimal sac diverticula

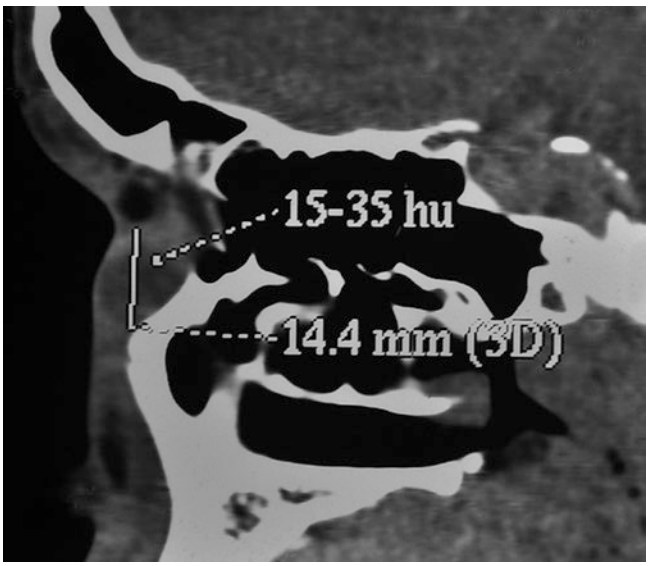


Fig. 2.18 CT Scan, sagittal reconstruction of the patient in Fig. 2.17, showing the lacrimal sac diverticula

Anatomy, Physiology, and Immunology of the Lacrimal System

3

Hirohiko Kakizaki and Mohammad Javed Ali

Introduction

The lacrimal surgery is performed to reconstruct an appropriate lacrimal drainage, and its success depends on how much the anatomy is understood. We describe here the anatomy and physiology of the lacrimal drainage system and also refer to its embryology and immunology.

Anatomy of the Lacrimal Punctum

The lacrimal punctum lies on a small fibrous mound, called the "lacrimal papilla" (Fig. 3.1). Diameter of its opening is 0.2–0.3 mm and directs somewhat posteriorly toward the lacrimal lake [1–6]. The puncta are round or oval in youth but often collapse into fishmouth or slit configuration with age [6]. The inferior punctum lies 0.5–1.0 mm more temporally than the superior one, because the maxillary process in embryonic life grows faster than the lateral nasal process [1, 2]. The inner epithelium is nonkeratinized stratified squamous epithelium [7, 8]. No Meibomian glands exists medial to the papillae, and most medial Meibomian orifices are situated at 0.5–1.0 mm lateral to the puncta [6].

Anatomy of the Lacrimal Canaliculus

The lacrimal canaliculus is divided into the vertical and horizontal portions [1, 2, 6]. Its transitional part occasionally dilates to form an irregular dilated cavity or ampulla (Fig. 3.2) [6]. The length of the vertical portion is 2 mm, that of the horizontal part is 10 mm [6]. However, it is important to realize that these measurements have been originally deciphered from cadaveric studies. The medial most 2 mm of the horizontal portion mostly forms the common duct or canaliculus [5, 9], and more than half of this part runs in the wall of the sac. The punctum and vertical canaliculus are encircled by a similar hard fibrous tissue. This fibrous tissue in the vertical canaliculus contains skeletal muscle fibers, called the muscle of Riolan (Fig. 3.1) [10]. The epithelium of the canaliculus is a nonkeratinized stratified squamous epithelium, similar to the punctum (Fig. 3.3) [10]. As the canalicular wall contains much elastic fibers (Fig. 3.4), its diameter can be changed to enlarge or shrink as needed. Although the diameter of the canaliculus is usually 0.3–0.6 mm [1, 8], it can be expanded to over 1.0 mm. The temporal four-fifths part is directed posteronasally and surrounded by the Horner's muscle, occasionally called the lacrimal part of the orbicularis oculi muscle (Fig. 3.5) [8]. In the nasal one-fifth part, the Horner's muscle directs posteriorly away from the canaliculus (Fig. 3.5) [8]. Although the canaliculus usually directs anteronasally after separation from the Horner's muscle (Fig. 3.5), it occasionally directs posteronasally in cases with proptosis (Fig. 3.6) [8]. The superior canaliculus courses, in general, almost straight to the internal common ostium, but the inferior canaliculus changes the course superiorly before joining the superior canaliculus. The course of the inferior canaliculus independently emptying into the lacrimal sac has not been convincingly proven.

Anatomy of the Common Lacrimal Canaliculus

More than 95% of the upper and lower canaliculi join to become the common canaliculus to reach the common internal ostium [5, 11]. The canaliculi empty into the sinus of Maier (Fig. 3.7), and those independently pouring into the sac are <2% [11]. Sinus of Maier needs further elaboration. The common internal ostium is the part where the common canaliculus enters into the lacrimal sac. However, the common canalicular cavity does not simply connect with the sac

H. Kakizaki, M.D., Ph.D. (✉)
Department of Ophthalmology, Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_3

lumen. A laterally bulged portion of the sac, called the sinus of Maier, is occasionally formed around the common internal ostium and some part of the common canaliculus empty into this portion (Fig. 3.7) [11]. An expanded common canaliculus is can also be called the sinus of Maier (Fig. 3.4) [11].

The common canaliculus has a nonkeratinized stratified squamous epithelium. However, the transitional area with the stratified columnar epithelium of the sac with some goblet cells is occasionally seen in the distal common canaliculus (Fig. 3.3) [8]. To the contrary, the stratified squamous epithelium of the common canaliculus sometimes extends to the sac lumen (Fig. 3.8) [8].

A protuberance (fold) is shown, although in only a half of cases [9], at the junction between the common canaliculus and the sac [12]. This structure is called the valve of Rosenmüller [5, 6]. The common internal ostium largely opens by temporal traction of the Horner's muscle during eye closing, but there is a nasal movement of the ostium as well [13]. Therefore, the part around the common internal ostium needs a structure dealing with this nasal movement, and this may be the real reason for a valvular presence in this region. The sinus of Maier could have also been evolved for the same reason.

Anatomy of the Lacrimal Sac and Its Fossa

The lacrimal sac and the nasolacrimal duct are contiguous structures [14]. The part within the lacrimal sac fossa is called as the "sac," and the part inferior to the superior opening of the nasolacrimal canal is the "nasolacrimal duct." [14] The part of the sac superior to the medial canthal tendon (MCT) is called the fundus, with its vertical length being 3–5 mm [14]. The body of the sac, inferior to the MCT, is about 10 mm in length. The epithelium of the sac is a stratified columnar epithelium (Figs. 3.3, 3.6 and 3.8) [15] and contains goblet cells, cilia, and serous glands [19]. The epithelial surface shows microvilli [16, 17]. Although the sac wall is constituted with a cavernous structure, it is fairly thin and less developed than that of the nasolacrimal duct [18, 19]. The lateral aspect of the sac wall is covered by a fascia, and its posterior portion has a common fascia with the Horner's muscle (Fig. 3.6), which is called the "lacrimal diaphragm" [14].

The lacrimal sac fossa comprises of the anterior frontal process of the maxillary bone and the posterior lacrimal bone [9]. There are ridges anteriorly and posteriorly, which are called the anterior or posterior lacrimal crests, respectively (Fig. 3.9) [5]. The suture between the maxilla and the lacrimal bone is situated in various ways, and some take its site close to the posterior lacrimal crest. A process is formed between the inferior portion of the posterior lacrimal crest and the orbital face of the maxilla, which is called the hamular process (Fig. 3.10) [6]. A groove present nasal to the anterior lacrimal crest is called the sutura notha [5], sutura longitudinalis imperfecta [6], or pseudosuture (Fig. 3.10) [20]. It is not considered as a true suture but a vessel groove formed by a branch of the inferior orbital artery [9].

The superoinferior length of the lacrimal sac fossa is 12–15 mm, anteroposterior 4–9 mm, and the width is 2–3 mm (Figs. 3.9 and 3.10) [9]. The lacrimal sac fossa shows shorter anteroposterior length superiorly [21, 22]. As the lacrimal sac fossa opens temporally, the sac lumen is usually large enough. The long axis of the fossa inclines about 10° posteriorly [23] (Fig. 3.11) and directs about 10° temporally [24] (Fig. 3.12). The angle range of the long axis of the fossa is 0°–20° posteriorly [23] and 1°–30° temporally [24].

Clinical Correlations

1. The orbit is defined as the part posterior to the orbital septum [9]. The lacrimal apparatus is not an orbital tissue as it is located anterior to the orbital septum. However, due to the vicinity with the eyelid as an extra-septal tissue, the lacrimal system is closely related to the eyelid and relies on the eyelid movements for pump functions of the lacrimal drainage. Since the function of the lacrimal apparatus is highly specialized, it is defined as the "lacrimal system" with an independent identity of its own.
2. When an acute dacryocystitis extends around the sac, the inflammation spreads toward the eyelid because of the above anatomical reason. In an advancing stage, it occasionally spreads into the orbital space, since the barriers are not strong enough anymore.
3. The lacrimal bone is too thin with its thickness around 0.1 mm [5]. Therefore, in both external and endonasal dacryocystorhinostomy, an osteotomy is started from the lacrimal bone. In cases of a lacrimo-maxillary suture being situated close to the posterior lacrimal crest, a surgeon occasionally feels difficulty to perform the osteotomy. In an external dacryocystorhinostomy, initial osteotomy sometimes begins at the part around the sutura notha [21]. It is better, however, not to extend the osteotomy toward the ethmoid sinus to prevent bleeding from the ethmoid mucosa.
4. In an endonasal dacryocystorhinostomy, relationship between the lacrimal sac fossa and the base of the middle turbinate is vital (Fig. 3.13). The base of the middle turbinate, called the "axilla," often corresponds to the lacrimal sac fossa (Fig. 3.14) [15], although there are exceptions. A high sac position is defined as the sac situated superior to the axilla, and a low sac is a position inferior to the axilla [15]. This relative position between the lacrimal sac fossa and the axilla is confirmed with a preoperative CT or intraoperative light pipe inserted from a punctum

(Fig. 3.14). A light cannot be occasionally seen in cases with thick frontal process of the maxilla, posterior location of the lacrimo-maxillary suture, cases with high sac position, or cases with anterior protrusion of the ethmoid air cells with wide distance between the lacrimal bone and the lateral wall of the nasal cavity.

5. Endoscopic clinical anatomy reveals that the posterior portion of the lacrimal bone is covered in considerable cases by the uncinate process forming the most anterior part of the ethmoid air cells [25]. The inferoposterior part of the lacrimal bone tends to be covered largerly [25]. A small protuberance called the agger nasi is seen over and medial to the lacrimal sac fossa (Fig. 3.13) [25]. Aerated agger nasi (agger nasi cell) can often reach the lacrimal sac fossa [25].
6. The uncinate process is, as suggested by its name, a bony process with a "hook" (Fig. 3.15) [15, 26]. This hook part is situated at a considerable depth corresponding to the posterior hiatus semilunaris. As the tail of the uncinate process faces anteriorly, we cannot easily see the "hook" part around the lacrimal sac fossa [26].

Anatomy of the Nasolacrimal Duct (NLD) and Canal

The lacrimal sac and the nasolacrimal duct are a continuous tissue, and anatomically speaking, the "nasolacrimal duct" (mucosal portion) is the part inferior to the superior opening of the nasolacrimal canal (bony portion) [14]. The nasolacrimal canal is formed by the lacrimal bone superonasally, the inferior turbinate bone inferonasally, and the maxillary bone temporally [5]. The superior opening is about 6 mm in diameter and, in general, is an ellipse with a little longer horizontally (Fig. 3.16). The superoinferior length of the canal is fairly short, about 12 mm [14] (Fig. 3.12). Although the longitudinal axis of the canal directs about 20° posteriorly [23] (Fig. 3.11), it directs almost vertically in most cases [24]. The nasolacrimal canal empties into the superior part of the inferior meatus (Fig. 3.12).

The angle range of the long axis of the nasolacrimal canal is 3°–40° posteriorly [23]. The frontal view shows the angle range from 12° nasally to 11° temporally and mostly directs vertically around 0° [24]. Although a general consensus of the canal course is "temporal," occasionally cases with medial course have been noted.

The nasolacrimal canal does not have a constant diameter throughout its length: some being narrower and others larger [27]. Two thirds to three-fourths of cases show the narrowest part at the superior opening, but the others have found the narrowest portion at 3.5–5.5 mm from the superior opening [27]. These narrowings may have a bearing on the etiopathogenesis of primary acquired nasolacrimal duct obstructions (PANDO) [27].

Epithelium of the NLD is a stratified columnar epithelium, similar to the lacrimal sac, and contains goblet cells and serous glands [15]. In general, the goblet cells are distributed more inferiorly, but several specimens have also demonstrated considerable number of goblet cells throughout (Figs. 3.17, 3.18 and 3.19). Although the cavernous structure is shown similar to the lacrimal sac, it is much more developed than the sac [18, 19] (Figs. 3.17 and 3.18). The wall is more thickened inferiorly, and most show a funnel shape lumen (Fig. 3.20). Cilia are similar to the nasal mucosal cells [17]. The microvilli on the epithelial surface contribute to reabsorption of the lacrimal fluid [16, 17].

The NLD occasionally shows folds called as valves of Krause [27]. In addition, septa are sometimes seen in the nasolacrimal duct or the sac [28]. The nasolacrimal duct mostly continues for several millimeters beneath the nasal mucosa after leaving its osseous channel [18, 28–30]. This part has a valve called the valve of Hasner [27]. The total length of the nasolacrimal duct is 15–18 mm, and it is longer than its bony canal. The shape of the NLD opening into inferior meatus shows four types: wide open type (12%), valve-like type (8%), sleeve-like type (14%), and adhesive type (66%), although these were studied in patients with functional epiphora [30]. These openings are situated around 30–35 mm posterior to the lateral margin of the nares [6].

Clinical Correlation

Although the lacrimal sac and the NLD are a continuous structure, and the basic structure is same, their compositions, such as number of goblet cells, development of the cavernous structure, and thickness of the wall, are considerably different. In the lacrimal system, roles are shared between these two portions: the lacrimal sac sucks the tears from the ocular surface supported by the lacrimal drainage pumps and the NLD reabsorbs them. This feature is similar to the intestinal canal, which anatomically is a long continuous structure but has different functions for each portion.

Mechanism of the Lacrimal Drainage

Physiological Relationship of Lacrimal Punctum, Lake, and Caruncle

The lacrimal caruncle derives embryologically from the lower eyelid [1], and its lateral margin smoothly continues to the lower eyelid margin [2]. As this lateral margin of the caruncle directs inferolaterally, the lower punctum is situated more temporally than the upper punctum [2]. The lacrimal lake is formed adjacent to the caruncle, where the lacrimal papilla faces it in general. This is the normal relationship of

the punctum, lake, and caruncle. Although the plica semilunaris is formed more temporally to the lacrimal lake, this buffers an imbalance of an ocular and a palpebral movement. When the trinity of the punctum, lake, and caruncle is in disproportion, that is to say, when the lacrimal papilla does not face the lacrimal lake, an epiphora may occur.

Lacrimal Drainage System of the Canaliculus

The lateral four-fifths of the lacrimal canaliculus is encircled by the Horner's muscle but not the medial one-fifth (Fig. 3.5). The canalicular drainage is easily understood by dividing the canaliculus into two parts with relation to the Horner's muscle.

During the eye closing, the Horner's muscle contracts and the temporal four-fifths part of the canaliculus is pressed and closed (Fig. 3.21). The nasal one-fifth part is pulled posteriorly and opens. In this situation, the Horner's muscle moves posteronasally toward the origin of this muscle (posterior lacrimal crest), and this movement begins from the temporal side with shortening of the canalicular length [31]. Therefore, the lacrimal fluid is effectively transported from temporal to nasal sides, finally reaching the lacrimal sac cavity [31]. During the eye opening, as the Horner's muscle relaxes, the temporal four-fifths part of the canaliculus is expanded and the nasal one-fifth part is pressed and closed via the Horner's muscle and the connective tissues (Fig. 3.22). This canalicular closure is not perfect, though. In this phase, as the whole canaliculus moves anterotemporally and is elongated, the canaliculus can pool more lacrimal fluid in it.

An aspiration from the punctum relies on a capillary phenomenon and/or negative pressure in the canalicular lumen [31]. As stated before, the protuberance on the common internal ostium is thought to be formed to buffer the movement of the common internal ostium. The sinus of Maier may be a similar buffering structure because it is notably seen in the eye closing with the Horner's muscle traction. This protuberance has been argued in relation to regurgitation. However, it is difficult to judge this structure formed for prevention of tear regurgitation because almost all patients who underwent dacryocystorhinostomy feel air reflux to the eye during sneezing.

The medial most 1 mm of the common canaliculus runs in the wall of the sac (Figs. 3.3, 3.5, 3.6 and 3.8). As the sac wall is constituted by cavernous structure [32], its thickness could be regulated by an autonomic innervation [19]. If the intra-sac canaliculus receives an autonomic regulation, then in a sympathetic dominant state, as the sac mucosa shrinks, the intra-sac canaliculus is enlarged and shortened, resulting in more drainage. To the contrary, in a parasympathetic dominant state, as the sac mucosa is thickened, the intra-sac canaliculus is pressed but elongated, resulting in less drainage. However, as its length is only 1 mm and the cavernous structure of the sac is less developed than that of the nasolacrimal duct, it is unclear whether the above phenomenon occurs.

Lacrimal Drainage System of the Lacrimal Sac

The lacrimal drainage system of the sac, just like canaliculi, can be easily understood if it is divided into two parts in relation to the Horner's muscle [9]. In addition, as the fundus of the sac has a special system, it is explained separately.

The upper part of the sac is directly affected by the Horner's muscle movement. During eye closing (when the Horner's muscle contracts), as the Horner's muscle moves away from the sac, the sac expands temporally (Fig. 3.21). During the eye opening (when the Horner's muscle relax), as the Horner's muscle moves toward the original position and pushes the sac nasally, the sac shrinks with an additional help of its elasticity (Fig. 3.22).

The lower lateral half of the sac is covered only by the lower eyelid capsulopalpebral fascia (CPF). During eye closure, as the CPF takes no tension and the orbicularis oculi muscle pushes the orbital tissues posteriorly, the lower lateral half of the sac is pushed nasally with the tensionless CPF. At the same time, shrinkage of the lower eyelid orbicularis oculi muscle pushes the anterior surface of the sac posteriorly. During eye opening, the CPF is pulled temporally with the lower lateral half of the sac under decreased orbital pressure. Then, the lower eyelid orbicularis oculi muscle is in less tension, resulting in a forward movement of the anterior sac surface.

As the fundus of the sac has an orbicularis attachment, this part is expanded superiorly during eye closure or during an orbicularis oculi muscle contraction [33]. The orbicularis oculi muscle attached to the fundus is opposed by the medial horn of the levator aponeurosis and relaxes during eye opening to an appropriate muscle length to prepare for the next contraction. As the superoanterior surface of the sac is mostly covered by the orbicularis oculi muscle and a force from the orbicularis contraction being applied only horizontally, an effect to the sac cannot be ignored. The sac movement stated above does not directly correspond with the tear movement [34]. With several times blinking, pooled fluid in the sac flows inferiorly as a cluster.

Krehbiel Flow

The Krehbiel flow is a special type of lacrimal fluid drainage [35, 36]. This is a phenomenon in which a lacrimal fluid aspiration from the lacus lacrimalis into the punctum continues for a considerable period during eye opening (without blinking). Although all the cases do not show this phenomenon,

25% of the lacrimal passage with 45° posterior inclination demonstrates it [35]. According to Prof. Ohashi and Dr. Yamaguchi in Ehime University (Japan), a velocity and a volume of the Krehbiel flow change with various eye positions (personal communication). The Krehbiel flow is believed to occur by a lower intra-sac pressure against a canalicular pressure, namely, by a pressure gradient from the canaliculus to the sac [35, 36]. To decrease the intra-sac pressure, the sac and the nasolacrimal duct cavities need to be occluded to a certain extent, and the fluid and air need to be absorbed.

Prerequisites or Factors Favoring Krehbiel Flow

1. Long valve of Hasner is necessary for making one-way valve function [6].
2. The lower nasolacrimal duct should be funnel-like with narrower lumen inferiorly, which should be able to functionally obstruct when needed.
3. The fluid and air need to be reabsorbed by the well-developed cavernous structure of the sac and the nasolacrimal duct.
4. In the upper stream, the canaliculus needs to be filled with fluid by continuous tear aspiration with much less air in the lumen.

Clinical Observations on Krehbiel Flow

1. When a person takes a lying position or a lower head position, duration of the Krehbiel flow gets shorter or nil [35]. That is to say, an effect by the gravity is only additional.
2. After dacryocystorhinostomy, as the nasal cavity pressure is relatively higher than the preoperative intra-sac pressure, the pressure gradient from the canaliculus to the sac is lost, resulting in no Krehbiel flow [35, 36].
3. A case with air in the nasolacrimal duct as shown by a CT does not demonstrate the Krehbiel flow (observational finding). Although the common internal ostium is pressed and occluded when the Horner's muscle relax [8], this closure is not perfect with a little opening. This probably contributes to the simultaneous occurrence of the Krehbiel flow and contribution to tear drainage.

Lacrimal Drainage System of the Nasolacrimal Duct

The nasolacrimal duct does not perform an active lacrimal drainage but contributes by making the flow smoother and by the way of tear reabsorption. As the cavernous tissue in the sac and the nasolacrimal duct have collagen fascicules and elastic and reticular fibers, which are helically arranged from superiorly to inferiorly [32], this complex architecture cooperates with the dynamic lacrimal drainage and the gravity and helps drain the fluid effectively toward the nasal cavity [32].

Mechanism of the Lacrimal Fluid Reabsorption

Tissue Anatomy in Relation to Lacrimal Fluid Reabsorption

The lumens of the sac and the nasolacrimal duct are covered by the stratified columnar epithelium with microvilli [15, 17]. This anatomy enlarges the surface area of the lumen and is advantageous for the lacrimal fluid reabsorption [16]. A lot of vessels exist in the subepithelial tissue, in which one barrier artery and two types of veins (throttle and capacitance veins) comprise the cavernous structure [16] (Figs. 3.17 and 3.18). This cavernous tissue of the lower nasolacrimal duct continues with that of the inferior meatus [32]. The vessel area of the cavernous tissue is smaller in the sac and larger in the nasolacrimal duct with increasing density as we move inferiorly. The more inferior the area is, the more advantageous it is for tear reabsorption (Figs. 3.17 and 3.18). As the nasolacrimal duct is embedded in the canal, a change in the lumen width most likely results from a change in thickness of the duct wall rather than a change of the outer diameter [18, 19]. This anatomy creates a greater resistance for the tear drainage, which is advantageous for tear reabsorption (Fig. 3.20).

Autonomic Regulation of the Lacrimal Fluid Reabsorption

The subepithelial tissue of the lacrimal sac and the nasolacrimal duct contains a lot of nerves [16], in which the autonomic nerves regulate mucosal thickness [32]. As the nasolacrimal duct is encircled by bone, the mucosal thickness and the lumen diameter are in inverse proportion. That is to say, in a parasympathetic dominant state, the mucosa is thickened but the lumen gets smaller. At this time, as the drainage resistance becomes higher, the lacrimal fluid flows slower, but effect of the tear reabsorption gets increased. To the contrary, in a sympathetic dominant state, because of thinning of the mucosa and enlargement of the lumen, the drainage resistance reduces, the lacrimal fluid flows faster, the tear drainage happens faster, but the reabsorption gets lesser.

When a tear secretion is accelerated from the lacrimal gland, for example, by contact of ocular surface with a foreign body,

that is to say, when the lacrimal fluid drainage needs to be blocked to wash off the foreign body, the autonomic regulation inclines to a parasympathetic dominant [19]. Then, an arterial flow increases, but a drainage from the throttle vein decreases with more blood pooling in the capacitance veins. Therefore, the walls of the sac and the nasolacrimal duct are thickened [16] and the lumen diameter gets smaller, which result in lesser flow but more effective tear reabsorption. On the other hand, when the ocular surface needs to be drier like in a situation of fight and flight, the sympathetic system predominates, the arterial flow decreases, and drainage from the throttle vein increases with less blood pooling in the capacitance vein. Therefore, the walls of the sac and the nasolacrimal duct are thinned [16] and the lumen diameter gets larger, resulting in acceleration of the tear drainage and keeping the ocular surface relatively drier for clearer vision for fight or flight!

Immune Mechanism of the Lacrimal Apparatus

Immune Mechanism in Lacrimal Fluid or Tears

The lacrimal fluid contains numerous antimicrobials like lactoferrin, lysozyme, immunoglobulins, etc., and these block proliferation of pathogens by their bactericidal effects [37].

Defense Mechanism from Pathogens on Anatomical Structures

Antigens coming via the ocular surface are dealt with lacrimal fluid and various immune systems on the ocular surface. However, the lacrimal tract also needs to protect itself from a retrograde infection from the nasal cavity.

The notable is the existence of the nasolacrimal duct running beneath the nasal mucosa after leaving the osseous channel. Although all the cases do not show this kind of duct [18, 30], invasion of pathogens may be considerably prevented mechanically by this structure. With cooperation from the dynamic lacrimal drainage and gravity, collagen fascicules and elastic and reticular fibers helically arranged from superiorly to inferiorly in the cavernous tissues of the sac and the nasolacrimal duct [32], all contributing effectively to drain the immune-rich lacrimal fluid inferiorly, resulting in defense against pathogens [38]. However, this mechanism works in a situation with thinned walls of the sac and nasolacrimal duct. It is hard to apply this theory to a situation with thickened walls of the sac and the nasolacrimal duct. Then, a mucous defense is vital for pathogen blocking [38]. The cilia also contribute to form a one-way flow from superiorly to inferiorly to prevent pathogens overgrowth [13].

Mucous Defense against Pathogens

Density of the goblet cells increases as we descend toward inferior portions of lacrimal drainage system (Figs. 3.17, 3.18 and 3.19). That is to say, more inferior area can secrete more mucus. When the walls of the sac and the nasolacrimal duct are thick and gaining an appropriate tear velocity to exclude pathogens gets difficult, the mucus can make a functional plug at the lower site of the duct and prevent pathogens from invading retrograde from the nasal cavity. As the mucus contains lactoferrin, lysozyme, and immunoglobulins, similar to the lacrimal fluid, defense against pathogens can be performed synergistically [38].

The mucus is secreted by the goblet cells in the epithelium [38] and prevents pathogens from adhering to the epithelium [38]. This adhesion block is performed by a simple covering on the epithelium and besieging adhesive agents constituted by glycoproteins and/or glycolipids expressed on the surface of pathogens or toxins [38].

However, as some pathogens have enzymes which can dissolve the mucus, the pathogen can easily adhere to the epithelium in this situation [38]. In addition, as the degradation products become nutrients for the pathogens, proliferation of the pathogens can get accelerated [15]. Therefore, only a mucus defense is insufficient for pathogens, and humoral and cellular immunities are necessary [38, 39].

Humoral and Cellular Immunity

The lacrimal tract contains a mucosa-associated lymphoid tissue (MALT) which is related to an antigen recognition and immune response [39]. This tissue functions as the main immune system. The lymphocytes and plasma cells constituting the MALT are sparsely distributed mainly in the lamina propria mucosae but some in the epithelium. This tissue is thin in the canaliculi but thick in the sac and the nasolacrimal duct.

The lymphatic follicles in the lacrimal mucosae are, in general, primary without a germinal center, but some show secondary follicles with germinal centers. As the germinal center emerges when lymphocytes with antigen stimulation proliferate actively, the ability of antigen recognition and other immune responses is weak in the lacrimal MALT. However, proliferation and differentiation of the IgA-secreting plasma cells do not simply depend on obvious follicles.

The main source of the humoral immunity in the lacrimal tract is the secretory IgA. IgM and IgG, although much less volume than the secretory IgA, are also related to the lacrimal humoral immunity. The immunoglobulin covers the mucosal surface, prevents pathogens from adhering to the epithelium, and makes them inactive, resulting in protection

from the pathogens. In addition, the immunoglobulins accelerate opsonization, a process by which bacteria are altered so that they are more readily and more efficiently engulfed by the phagocytes. As the immunoglobulins in the lacrimal tract need to cover the broad mucosal surface, a secretory mechanism which does not depend on the germinal centers carries an important role against the pathogens. Ali et al. [40] have shown that the lacrimal drainage-associated lymphoid tissue (LDALT) is altered in cases of chronic dacryocystitis and discussed the both cellular and humoral derangements that occur. Further studies on these could provide insights into LDALT and greater immunological understandings and possibly immune factors influencing lacrimal systems in health and disease.

Most lymphocytes in the lacrimal tract are T cells [41]. Although volume of the B cells is less than that of the T cells, B cells occasionally form lymphatic follicles. T cells show CD8-positive cells that are inhibitory and cytotoxic. Macrophages exist as well, distributed in the lamina propria mucosae and occasionally in the epithelium. Although the cellular immunity in the lacrimal tract appears less significant than the humoral immunity, the presence of MHC class II positive cells reflects its active role in the capture and presentation of antigens.

Updates (2015–2016)

Numerous papers have been published discussing and detailing various aspects of lacrimal drainage anatomy and physiology in the intervening years since the first edition of this textbook [42–62]. We will discuss it under six broad headings as follows.

Vertical Canaliculus Height (Fig. 3.23)

The widely reported measurement of vertical canaliculus height is 2 mm; however, most of these measurements were derived from cadaveric studies early on. That may not necessarily translate to what the actual measurements are in living individuals. Wawrzynski et al. [42] performed ocular coherence tomography (OCT) of the proximal lacrimal drainage system and reported the mean vertical canalicular height to be 753 μm with a standard deviation of 247 μm with a wide range of 392–1242 μm. Ali et al. [43] published their normative database of the proximal lacrimal drainage morphometry using the Fourier domain OCT (FDOCT) with en face imaging. The maximum vertical canaliculus height in their series of 103 eyes was 1310 μm. However, as compared to Wawrzynski, they reported higher mean values (890.41 μm), less standard deviation (154.76 μm), and less wide ranges (547–1310 μm). This disparity could be explained secondary to the active tone of the orbicularis muscle which may shorten the height of the vertical canaliculus in the living as compared to cadavers.

Bony Lacrimal Fossa and NLD

Numerous racial variations are known to influence bony structure surrounding the lacrimal drainage apparatus. Gore et al. [45] radiologically assessed the differences between black Africans ($n = 42$) and Caucasians ($n = 30$). The vertical height of the lacrimal fossa (LF) was significantly lesser ($p < 0.001$) in Africans (mean 11.4 with SD of 1.5 mm) as compared to the Caucasians (mean 12.4 with SD of 1.3 mm). The maximum thickness of the frontal process of maxilla was significantly greater ($p < 0.01$) in Africans as compared to Caucasians. Yong et al. [57] assessed the bony nasolacrimal parameters and found no difference between different ethnicities (South Asian, Southeast Asians, and Occidental races) in relation to the vertical lacrimal fossa diameters, anterior lacrimal crest thickness, and narrowest portions of the nasolacrimal duct. However, the Southeast Asians had a wider inter-frontozygomatic suture distance than the other two groups. Decreased inter-frontozygomatic suture distance was directly correlating with the narrower nasolacrimal ducts. Takahashi et al. [58] classified bony NLD into two types based on their morphological configuration as "funnel type" and "hourglass type." They found that patients with primary acquired nasolacrimal duct obstruction (PANDO) more often demonstrate a funnel type of bony NLD. The distance from the entrance of the bony NLD to its narrowest width was significantly shorter in patients with PANDO. Although most of these studies reflect on a possibility of NLD diameters as one of the causal factors for PANDO, a direct relationship has not yet been convincingly proven.

Elasticity of Lacrimal Walls and Sinus of Maier

Lacrimal wall elasticity has been proposed to be a possible factor that facilitates the lacrimal drainage functions. The distribution of the elastic fibers was recently studied [52], and it was found that it was quite variable based on anatomical locations. The area occupied by the elastic fibers was more in the intramuscular portions and Horner's muscle fascia as compared to the extra-sac extramuscular portions. The nature of the elastic fibers was different in areas with and without Horner's muscle fascia. The intramuscular portions of the canaliculi are thus hypothesized to be playing an important role in generating and maintaining various intracanalicular pressures to facilitate tear flow from the ocular surface.

Sinus of Maier as explained earlier in the text is occasionally present near the opening of the common internal ostium into the lacrimal sac. The terminology and anatomical types have been confusing because of its use in different contexts by various authors [47]. Two types of sinus of Maier have been well demonstrated anatomically and histologically. The first type is akin to diverticula with larger diameter (1.29 mm) into which the canaliculi contribute separately. The second type had a smaller diameter (0.51 mm) and was solely contributed by terminal dilatation of the common canaliculus [47]. This work could pave way for further understanding of the sinus of Maier and its possible role in the tear flow dynamics.

3D Volumetric Assessment and PANDO

Nasolacrimal diameters and their association with PANDO as causal factors have been controversial with literature supporting as well as refuting the associations [27, 58, 63–66]. Although NLD was measured three-dimensionally earlier, Estes et al. [60] showed a clear technique of 3D volumetric measurements of the nasolacrimal duct. It is interesting to note that they did not find any difference ($p = 0.23$) between the patients (0.411 ± 0.18 cm^3; $n = 35$) and controls (0.380 ± 0.13 cm^3; $n = 35$) in their volumetric analysis. Although women had smaller volume as compared to men and male patients had smaller volume than male controls, it was not on expected lines to find the female patients had a larger volume as compared to female patients. The attempt to link NLD volumes with PANDO has been discouraged by this study. Nonetheless, it has paved way for further 3D volumetric analysis of both the bony and soft tissue lacrimal drainage system.

Demonstration of Lacrimal Drainage Dynamics

Shams et al. [56] demonstrated the movements of the lacrimal drainage system in real time following a Moh's excision for a medial canthal basal cell carcinoma. They demonstrated in real time with an open sky view how with each blink the canaliculi moved medially and the lacrimal sac laterally. Dacryoendoscopy has been recently used to view the canalicular and lacrimal sac movements with positive and negative pressures [54, 55]. It was noted that there was a consistent dilatation of the canaliculi with positive pressures and contraction with negative pressures. The common canalicular portion was more dynamic than the proximal canaliculi. The lateral wall of the lacrimal sac moved outward with positive intraluminal pressures and inward when subjected to negative pressures. These findings have contributed significantly in our understanding of lacrimal drainage dynamics.

Electron Microscopy of the Normal Lacrimal Passages

Electron microscopy is a very useful modality to study the anatomical ultrastructure of the lacrimal drainage system. Scanning electron microscopy (SEM) of healthy lacrimal systems has shown demonstrable anatomical junctions between the distal portion of the punctum and the proximal most portion of the vertical canaliculus (Fig. 3.24). Such anatomical junction was also noted between the lacrimal sac and nasolacrimal ducts (Fig. 3.25). The mucosa of the canaliculus was occasionally thrown into folds with the surface showing rugae as compared to the normal smooth architecture (Fig. 3.26). These are likely to represent the valvular structures of the lacrimal system. In the vicinity of the canaliculi, the orbicularis fibers were found to be very well organized in bundles (Fig. 3.27). The fundus of the lacrimal sac showed very peculiar glands not found elsewhere (Fig. 3.28) and whose function is unknown [67].

Conclusion

The anatomy, physiology, and immunology of the lacrimal apparatus have been described in detail. With advances in nasal endoscopic and dacryoendoscopic techniques, treatment for lacrimal diseases is rapidly advancing. We would like the readers to get back again to basics and to review the findings presented here. We believe that this would enable the readers to easily understand the pathological backgrounds of each entity and to choose and perform more appropriate treatment for every lacrimal disease.

Acknowledgment Dr. Kakizaki appreciates Prof. Takashi Nakano and Prof. Ken Asamoto for usage of cadavers for this review and Prof. Hiroshi Ikeda for the tissue staining.

References

1. Whitnall SE. Anatomy of the human orbit and accessory organs of vision. 2nd ed. New York: Krieger Publishing Company; 1979. p. 164–5.
2. Kakizaki H, Valenzuela AA. Lacrimal caruncle: continuation to the lower eyelid retractors. Ophthal Plast Reconstr Surg. 2011;27:198–200.
3. Nirankari MS, Chaddah MR. Supernumerary punctum on the caruncle. Br J Ophthalmol. 1962;46:380–1.
4. Lyons CJ, Rosser PM, Welham RA. The management of punctal agenesis. Ophthalmology. 1993;100:1851–5.
5. Burkat CN, Lucarelli MJ. Anatomy of the lacrimal system. In: Cohen AJ, Brazzo B, editors. The lacrimal system: diagnosis, management, and surgery. New York: Springer; 2006. p. 3–19.
6. Linberg JV. Surgical anatomy of the lacrimal system. In: Linberg JV, editor. Lacrimal surgery. New York: Churchill-Livingstone; 1988. p. 1–18.
7. Kakizaki H, Zako M, Miyaishi O, et al. Overview of the lacrimal canaliculus in microscopic cross-section. Orbit. 2007;26:237–9.

8. Kakizaki H, Asamoto K, Nakano T, et al. Lacrimal canaliculus. Ophthalmology. 2010;117:644.
9. Zoumalan CI, Joseph JM, Lelli GJ Jr, et al. Evaluation of the canalicular entrance into the lacrimal sac: an anatomical study. Ophthal Plast Reconstr Surg. 2011;27:298–303.
10. Kakizaki H, Takahashi Y, Iwaki M, et al. Punctal and canalicular anatomy: implications for canalicular occlusion in severe dry eye. Am J Ophthalmol. 2012;153:229–37.
11. Yazici B, Yazici Z. Frequency of the common canaliculus: a radiological study. Arch Ophthalmol. 2000;118:1381–5.
12. Kurihashi K, Imada M, Yamashita A. Anatomical analysis of the human lacrimal drainage pathway under an operating microscope. Int Ophthalmol. 1991;15:411–6.
13. Kakizaki H, Zako M, Miyaishi O, et al. The lacrimal canaliculus and sac bordered by the Horner's muscle form the functional lacrimal drainage system. Ophthalmology. 2005;112:710–6.
14. Jones LT. The cure of epiphora due to canalicular disorders, trauma and surgical failures on the lacrimal passages. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:506–24.
15. Olver J. Anatomy of lacrimal system. In: Colour atlas of lacrimal surgery. Oxford: Butterworth & Heinemann; 2002. p. 8–14.
16. Paulsen F, Hallmann U, Paulsen J, et al. Innervation of the cavernous body of the human efferent tear ducts and function in tear outflow mechanism. J Anat. 2000;197:177–87.
17. Kurihashi K. Ruido no kaibo Ganka. 1996;38:301–13 (Japanese).
18. Bailey JH. Surgical anatomy of the lacrimal sac. Am J Ophthalmol. 1923;6:665–71.
19. Narioka J, Ohashi Y. Changes in lumen width of nasolacrimal drainage system after adrenergic and cholinergic stimulation. Am J Ophthalmol. 2006;141:689–98.
20. Kurihashi K. Dacryology. Tokyo Medical Aoi. 1998. p. 197–255 (Japanese).
21. Kakizaki H, Iwaki M, Asamoto K, et al. Anatomical basis for an appropriate initial osseous hole in external dacryocystorhinostomy. Nihon Ganka Gakkai Zasshi. 2008;112:39–44. (Japanese)
22. Kakizaki H, Ichinose A, Takahashi Y, et al. Anatomical relationship of Horner's muscle origin and posterior lacrimal crest. Ophthal Plast Reconstr Surg. 2012;28:66–8.
23. Park J, Takahashi Y, Nakano T, et al. The orientation of the lacrimal fossa to the bony nasolacrimal canal: an anatomic study. Ophthal Plast Reconstr Surg. 2012;28:463–6.
24. Takahashi Y, Nakamura Y, Nakano T, et al. Horizontal orientation of the bony lacrimal passage: an anatomic study. Ophthal Plast Reconstr Surg. 2013;29:128–30.
25. Woo KI, Maeng HS, Kim YD. Characteristics of intranasal structures for endonasal dacryocystorhinostomy in Asians. Am J Ophthalmol. 2011;152:491–8.
26. Yoon JH, Kim KS, Jung DH, et al. Fontanelle and uncinate process in the lateral wall of the human nasal cavity. Laryngoscope. 2000;110:281–5.
27. Takahashi Y, Nakamura Y, Nakano T, et al. The narrowest part of the bony nasolacrimal canal: an anatomical study. Ophthal Plast Reconstr Surg. 2013;29:318–22.
28. Cowen D, Hurwitz JJ. Anatomy of the lacrimal drainage system. In: Hurwitz JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 15–21.
29. Takahashi Y, Nakano T, Asamoto K, et al. Lacrimal sac septum. Orbit. 2012;31:416–7.
30. Onogi J. Nasal endoscopic findings of functional obstruction of nasolacrimal duct. Rinsho Ganka. 2012;55:650–4. (Japanese)
31. Doane MG. Blinking and the mechanism of the lacrimal drainage system. Ophthalmology. 1981;88:844–51.
32. Thale A, Paulsen F, Rochels R, et al. Functional anatomy of the human efferent tear ducts: a new theory of tear out flow mechanism. Graefe Arch Clin Exp Ophthalmol. 1998;236:674–8.
33. Kakizaki H, Zako M, Nakano T, et al. The medial horn and capsulopalpebral fascia in the medial canthus are significant antagonists of the orbicularis oculi muscle for lacrimal drainage. Ophthalmologica. 2004;218:419–23.
34. Amrith S, Goh PS, Wang SC. Tear flow dynamics in the human nasolacrimal ducts – a pilot study using dynamic magnetic resonance imaging. Graefes Arch Clin Exp Ophthalmol. 2005;243:127–31.
35. Sahlin S, Chen E. Gravity, blink rate, and lacrimal drainage capacity. Am J Ophthalmol. 1997;124:758–64.
36. Nagashima K. The carbon particles test and the tear flow. Rinsho Ganka. 1976;30:651–6. (Japanese)
37. Nakazawa M. Ruieki Rinsho Ganka. 2012;66:156–9 (Japanese).
38. Perra MT, Serra A, Sirigu P, et al. A histochemical and immunohistochemical study of certain defense mechanisms in the human lacrimal sac epithelium. Arch Histol Cytol. 1995;58:517–22.
39. Knop E, Knop N. Lacrimal drainage-associated lymphoid tissue (LDALT): a part of the human mucosal immune system. Invest Ophthalmol Vis Sci. 2001;42:566–74.
40. Ali MJ, Mulay K, Pujari A, et al. Derangements in lacrimal drainage associated lymphoid tissue in human chronic dacryocystitis. Ocul Immunol Inflamm. 2013;21:417–23.
41. Sirigu P, Maxia C, Puxeddu R, et al. The presence of a local immune system in the upper blind and lower part of the human nasolacrimal duct. Arch Histol Cytol. 2000;63:431–9.
42. Wawrzynski JR, Smith J, Sharma A, et al. Ocular coherence tomography imaging of the proximal lacrimal system. Orbit. 2014;33:428–32.
43. Kamal S, Ali MJ, Ali MH, et al. Fourier domain ocular coherence tomography with 3D and En Face imaging of the punctum and vertical canaliculus: a step towards establishing a normative database. Ophthal Plast Reconstr Surg. 2015;32:170–3.
44. El Shaarawy EAA. Morphological and morphometrical study of the nasal opening of the nasolacrimal duct in man. Folia Morphol. 2014;73:321–30.
45. Gore SK, Naveed H, Hamilton J, et al. Radiological comparison of lacrimal sac fossa anatomy between black Africans and Caucasians. Ophthal Plast Reconstr Surg. 2015;31:328–31.
46. Hashemi SM, Berjis N, Eshaghian F, et al. Applied endoscopic anatomical evaluation of lacrimal sac. Iran J Otorhinolaryngol. 2015;27:213–7.
47. Kakizaki H, Takahashi Y, Kang H, et al. Two types of sinus of Maier: an anatomic study. Orbit. 2015;34:253–6.
48. Bulbul E, Yazici A, Yanik B, et al. Morphometric evaluation of bony nasolacrimal canal in a Caucasian population with primary nasolacrimal duct obstruction: a multidetector computed tomography study. Korean J Radiol. 2016;17:271–6.
49. Paulsen F, Garreis F, Schicht M, et al. Anatomie und Physiologie der ableitenden Tranenwege. HNO. 2016;64:354–66.
50. Maliborski A, Rozycki R. Diagnostic imaging of the nasolacrimal drainage system. Part 1. Radiological anatomy of the lacrimal pathways. Physiology of tear secretion and tear outflow. Med Sci Monit. 2014;20:628–38.
51. Sobti D, Walk D, Finnerty K, et al. The J curve for navigating the nasolacrimal outflow tract. Ophthal Plast Reconstr Surg. 2016;32:58–60.
52. Kakizaki H, Takahashi Y, Nakano T. Elastic nature of the lacrimal canalicular wall. Ophthal Plast Reconstr Surg. 2014;30:521–3.
53. Mito H, Takahashi Y, Nakano T, et al. Consecutive microscopic anatomical characteristics of the lacrimal sac and nasolacrimal duct. Cases with and without inflammation. Invest Ophthalmol Vis Sci. 2014;55:5233–7.
54. Takahashi Y, Suzuki T, Kakizaki H. Lacrimal sac movement under intrasac pressure changes observed with dacryoendoscopy. Ophthal Plast Reconstr Surg. 2014;30:313–4.
55. Kakizaki H, Takahashi Y, Mito H, et al. Movement of the lacrimal canalicular wall under intracanalicular pressure changes observed with dacryoendoscopy. Ophthal Plast Reconstr Surg. 2015;31:73–4.
56. Shams PN, Verdick RE, Allen RC. In vivo demonstration of the lacrimal pump. Ophthal Plast Reconstr Surg. 2016;32:e25.

57. Yong AM, Zhao DB, Siew SC. Assessment of bony nasolacrimal parameters among Asians. Ophthal Plast Reconstr Surg. 2014;30:322–7.
58. Takahashi Y, Nakata K, Miyazaki H, et al. Comparison of bony NLD narrowing with or without primary acquired nasolacrimal duct obstruction in a Japanese population. Ophthal Plast Reconstr Surg. 2014;30:434–8.
59. Horsburgh A, Massoud TF. Normative dimensions and symmetry of the lacrimal drainage system on dacryocystography: statistical analysis of morphometric characteristics. Folia Morphol. 2013;72:137–41.
60. Estes JL, Tsiouris AJ, Christos PJ, et al. 3D volumetric assessment of the nasolacrimal duct in patients with obstruction. Ophthal Plast Reconstr Surg. 2015;31:211–4.
61. Takahashi Y, Kinoshita H, Nakano T, et al. Anatomy of the anterior ethmoidal foramen, medial canthal tendon and lacrimal fossa for transcutaneous anterior ethmoidal nerve block in Japanese individuals. Ophthal Plast Reconstr Surg. 2014;20:431–3.
62. You Y, Kao J, Zhang X, et al. In vivo and cadaver studies of the canalicular/lacrimal sac mucosal folds. J Ophthalmol. 2016 (Epub).
63. Janssen AG, Mansour K, Bos JJ, et al. Diameter of the bony lacrimal canal: normal values and values related to nasolacrimal duct obstruction: assessment with CT. Am J Neuroradiol. 2000;22:845–50.
64. McCormick A, Sloan B. The diameter of the nasolacrimal canal measured by CT: gender and racial differences. Clin Experiment Ophthalmol. 2009;37:357–61.
65. Fasina O, Ogbole G. CT assessment of the nasolacrimal canal in a black African population. Ophthal Plast Reconstr Surg. 2013;29:231–3.
66. Ramey NA, Hoang JK, Michael JR, et al. Multidetector CT of nasolacrimal canal morphology: normal variation by age, gender and race. Ophthal Plast Reconstr Surg. 2013;29:475–80.
67. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of the external and internal surfaces of normal adult lacrimal drainage system. Ophthal Plast Reconstr Surg 2015;31:414–7.

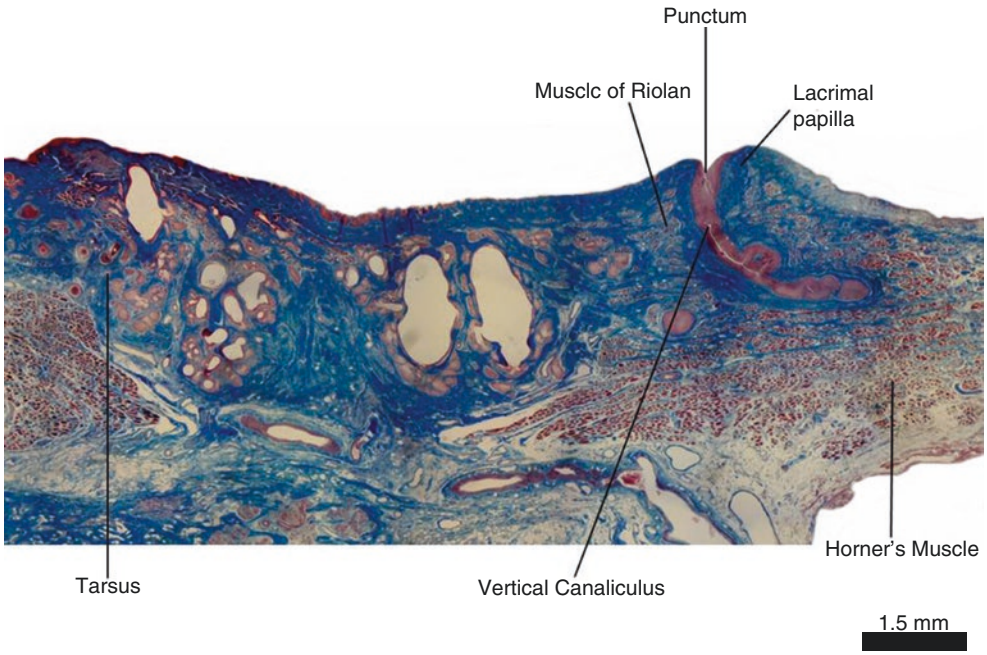


Fig. 3.1 Anatomy of the lacrimal punctum and its surrounding tissues. This section is performed parallel to the tarsal plate (Masson trichrome stain)

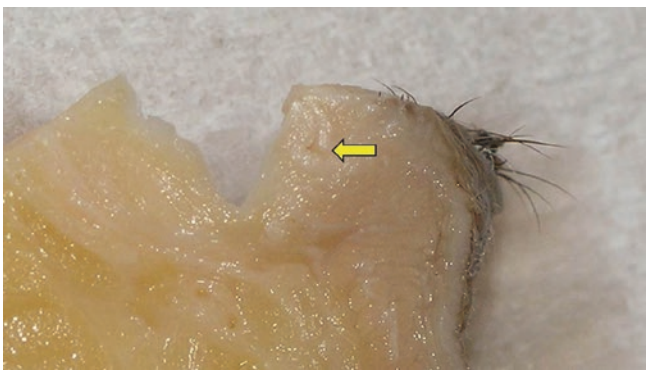


Fig. 3.2 Gross anatomy of the ampulla of a lacrimal caruncle. A left lower eyelid sagittally incised. *Yellow arrow*: ampulla

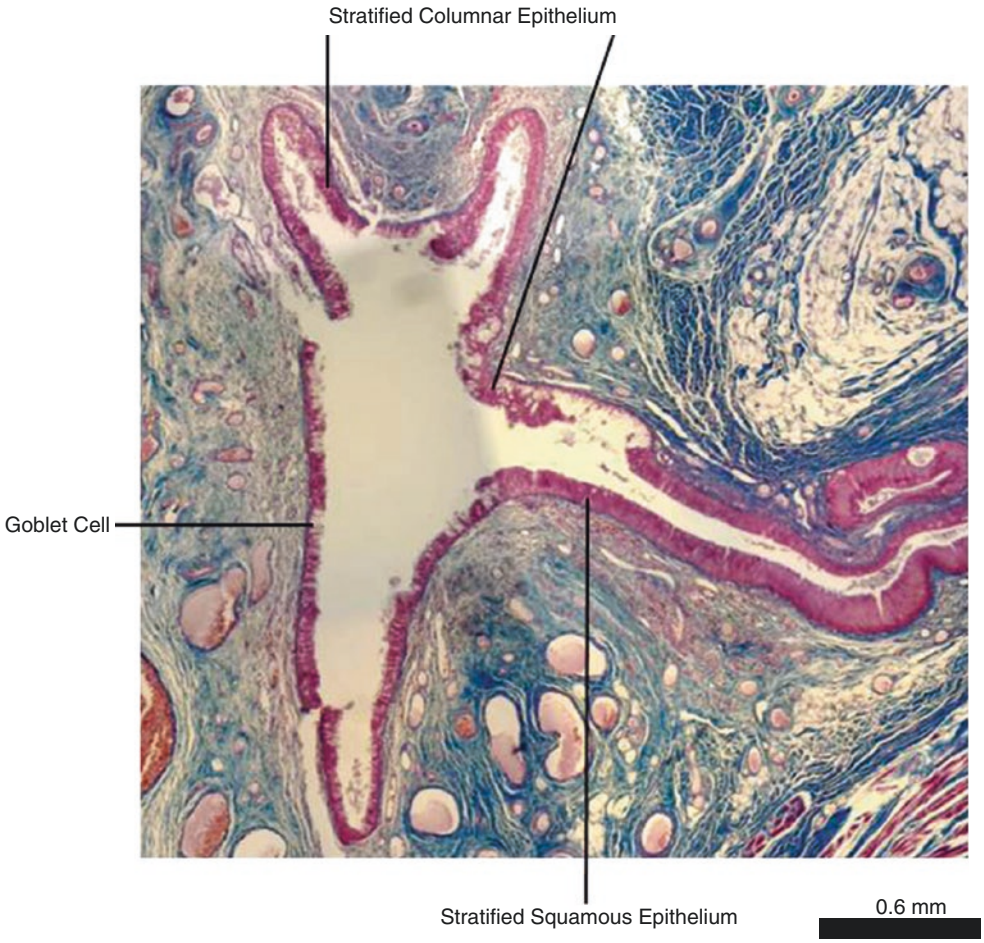


Fig. 3.3 Epithelia of the lacrimal caruncle and the sac. The canaliculus shows a nonkeratinized stratified squamous epithelium and goblet cells in part. This specimen demonstrates the stratified columnar epithelium extending to the canaliculus (Masson trichrome stain)

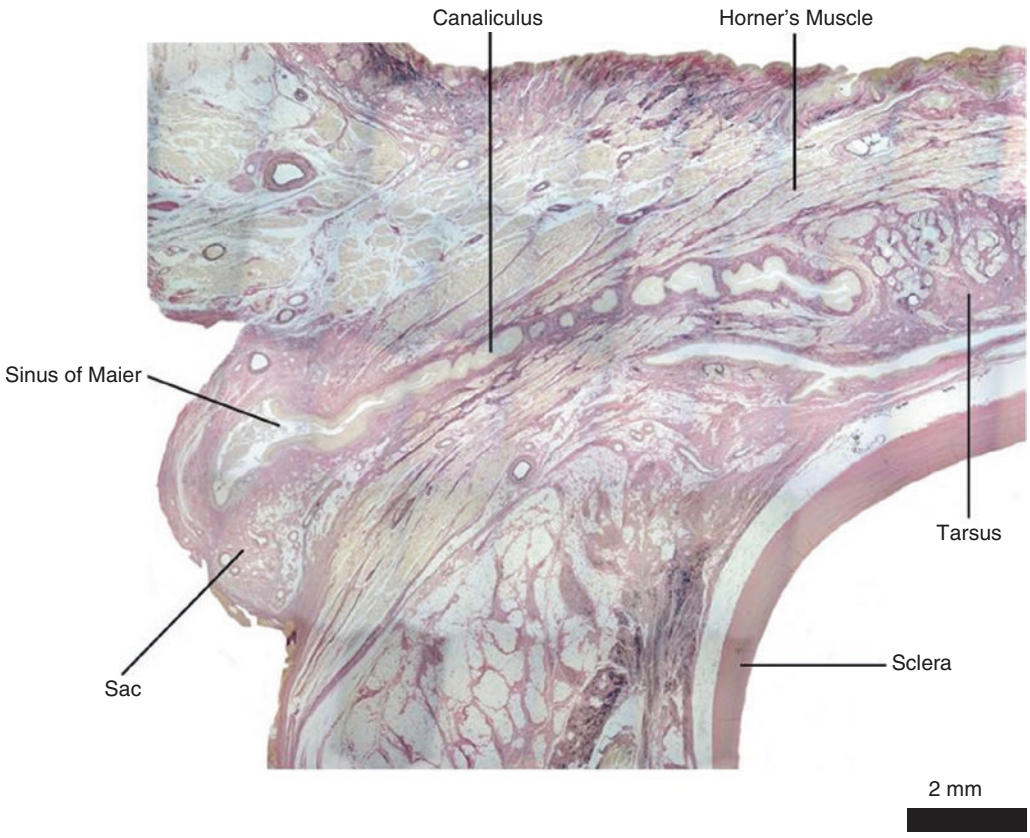


Fig. 3.4 Elastic fibers of a canalicular wall. This specimen contains a lot of elastic fibers in the canalicular wall. A sinus of Maier is shown here, into which the canalicular part is expanded (Elastica van Gieson stain)

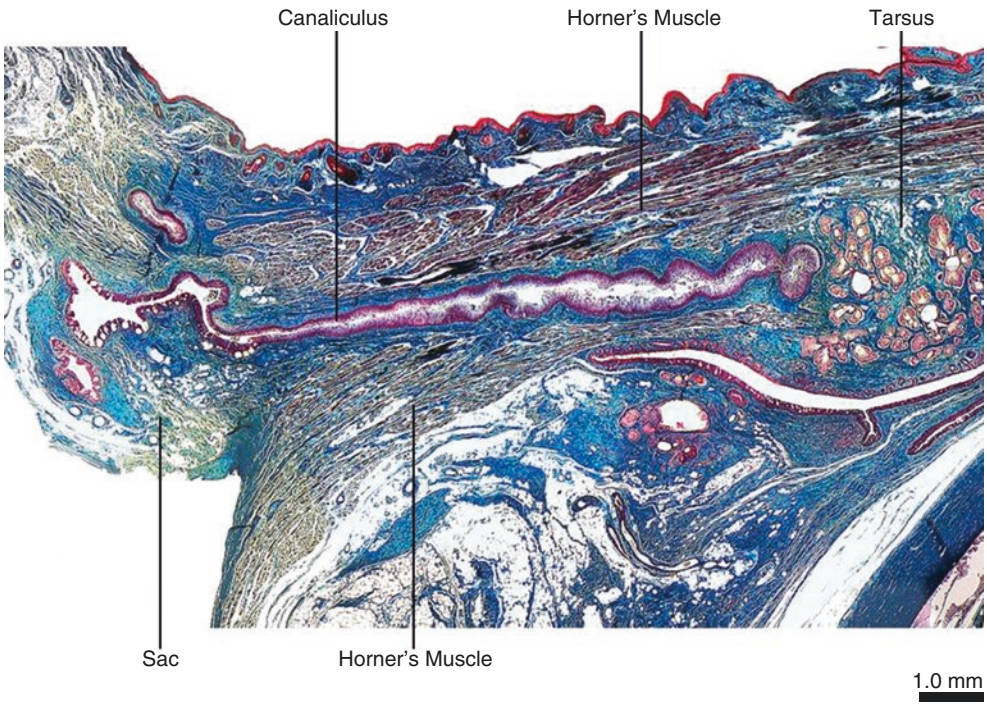


Fig. 3.5 Relationship between the lacrimal canaliculus and the Horner's muscle (Masson trichrome stain)

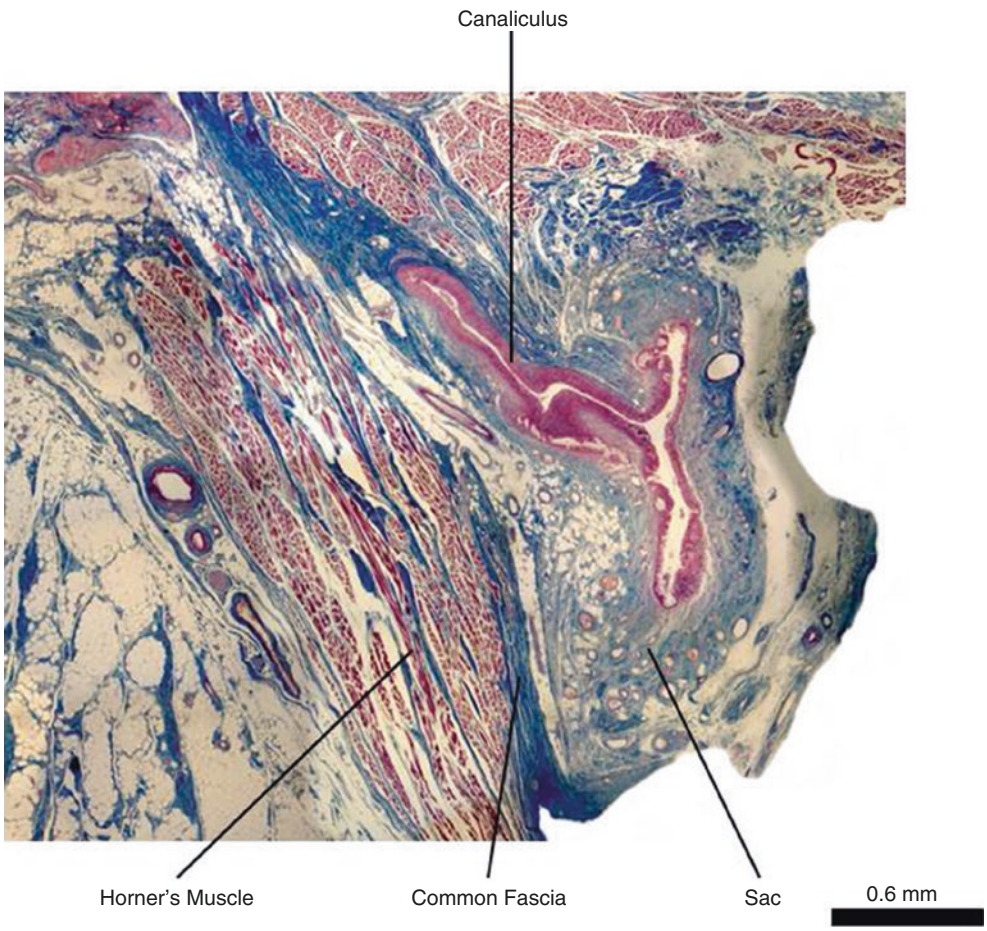


Fig. 3.6 Connection of common lacrimal canaliculus to sac. A common canaliculus occasionally empties into a sac from superiorly. A common fascia is seen between the sac and the Horner's muscle (Masson trichrome stain)

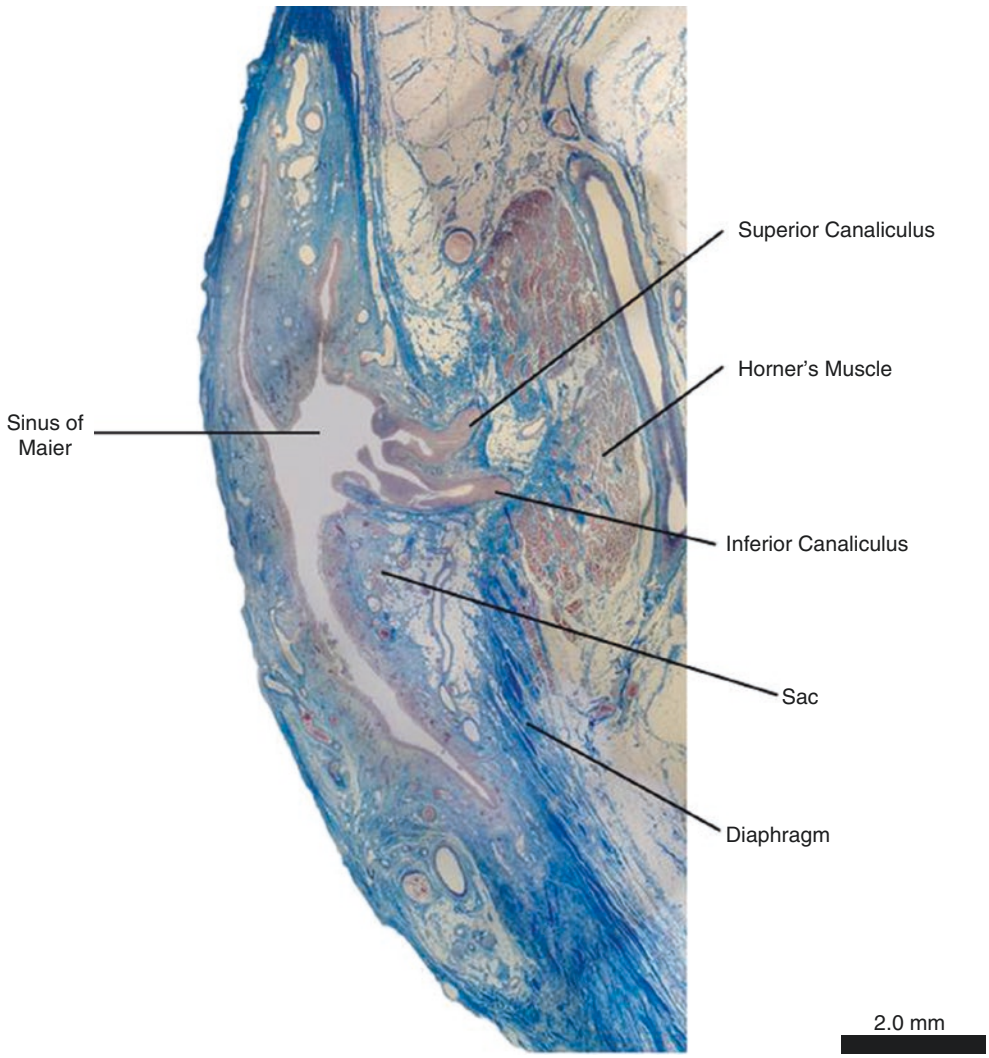


Fig. 3.7 A sinus of Maier, in which a part of sac is expanded. The superior and inferior canaliculi separately empty into the sinus of Maier (Masson trichrome stain)

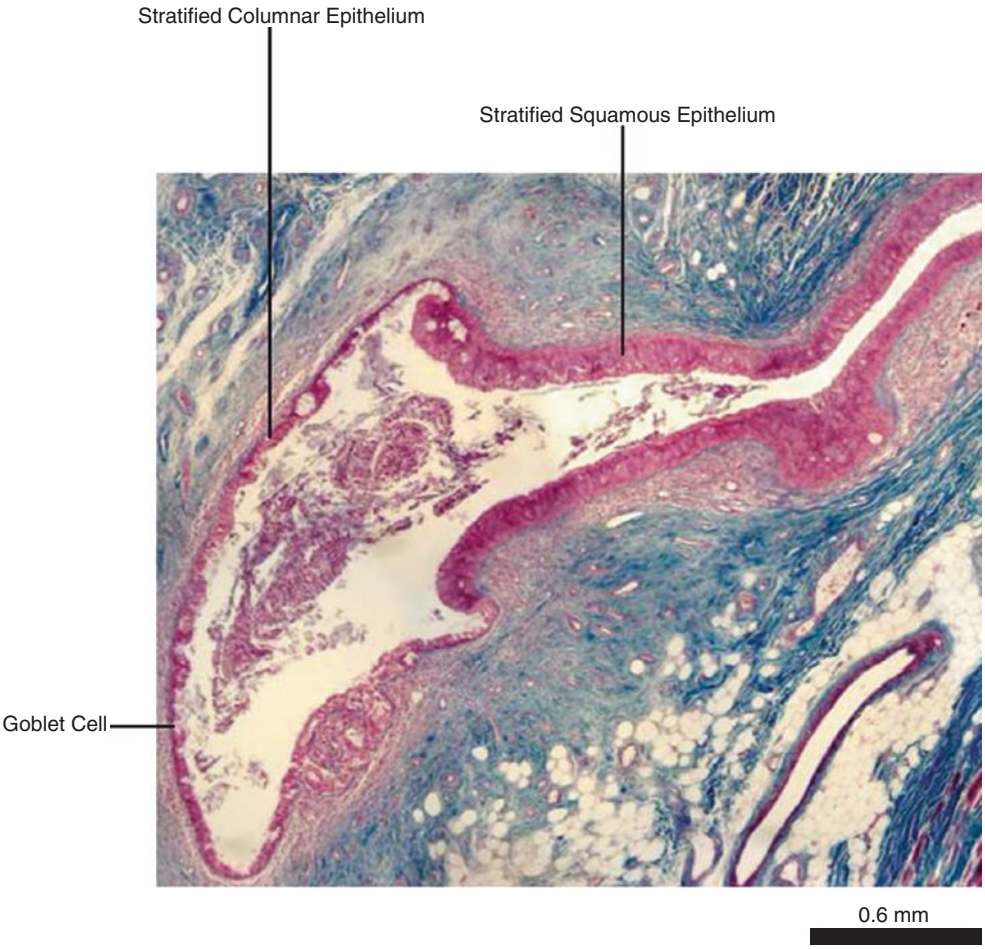


Fig. 3.8 Connection of common lacrimal canaliculus to sac. A stratified squamous epithelium in a canaliculus occasionally extends into a sac (Masson trichrome stain)

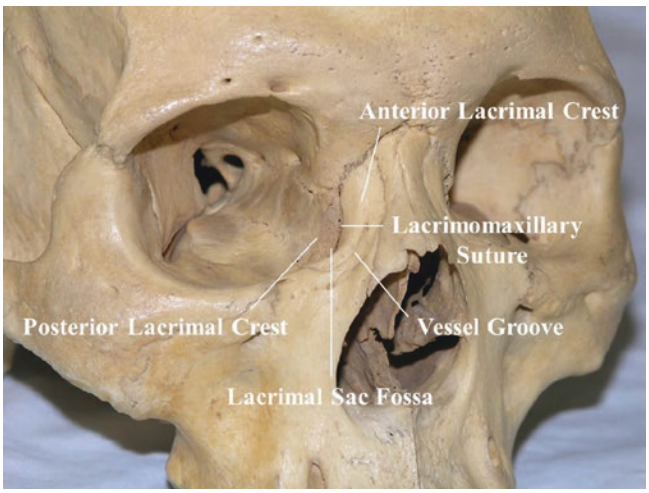


Fig. 3.9 Anatomy of lacrimal sac fossa and its surrounding tissues

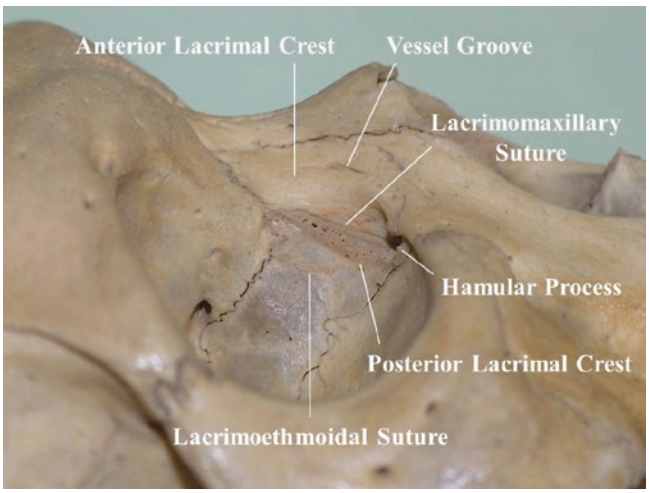


Fig. 3.10 A right lacrimal sac fossa, seen from temporally

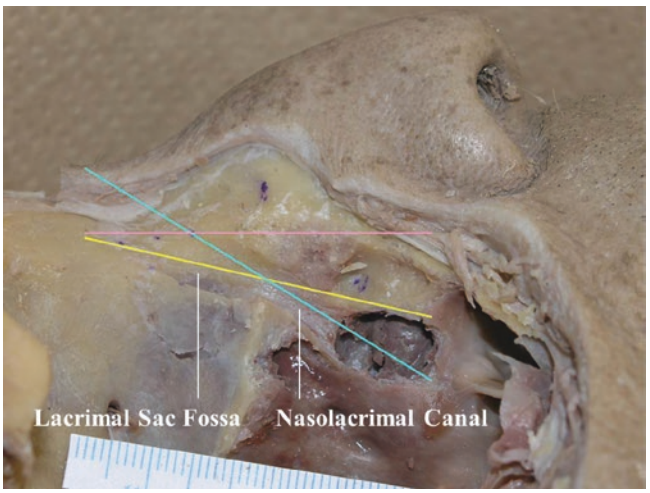


Fig. 3.11 A posterior inclination of lacrimal sac fossa and nasolacrimal canal. The nasolacrimal canal inclines more posteriorly than the lacrimal sac fossa. *Line pink*, base line; *line yellow*, long axis of lacrimal sac fossa; *line blue*, long axis of nasolacrimal canal

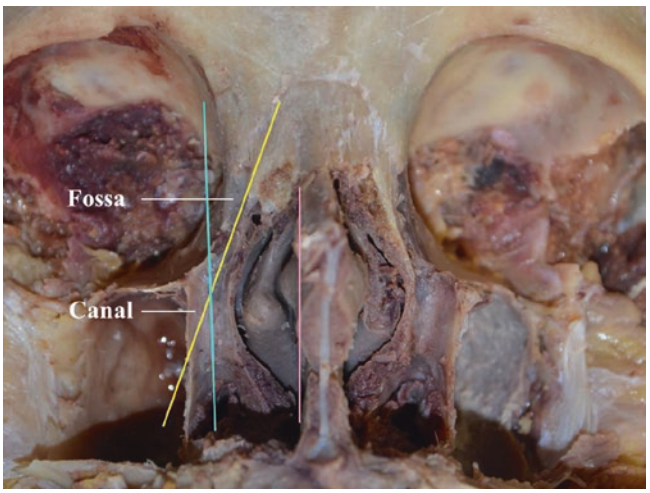


Fig. 3.12 A horizontal inclination of lacrimal sac fossa and nasolacrimal canal. Lacrimal sac fossa goes temporally without exception. Nasolacrimal canal is mostly parallel to the vertical base line. *Line pink*, base line; *line yellow*, long axis of lacrimal sac fossa; *line blue*, long axis of nasolacrimal canal

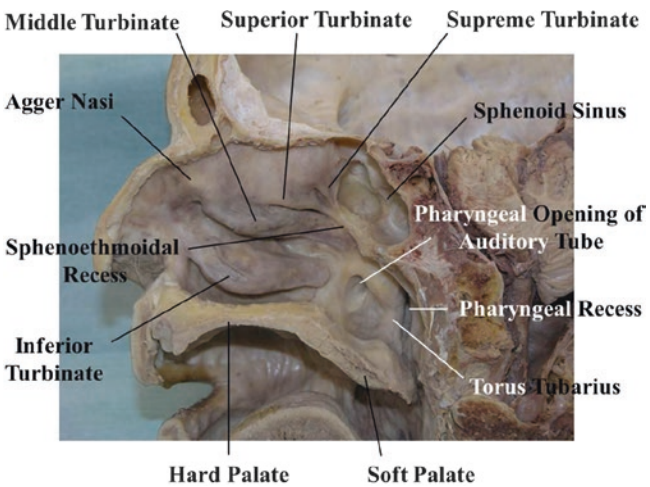


Fig. 3.13 Overview of a lateral nasal wall

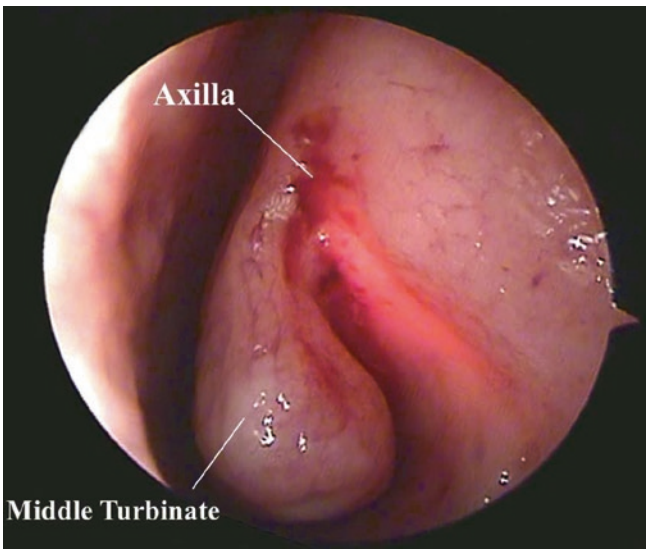


Fig. 3.14 Relationship between lacrimal sac fossa and axilla. A light is seen through the bone

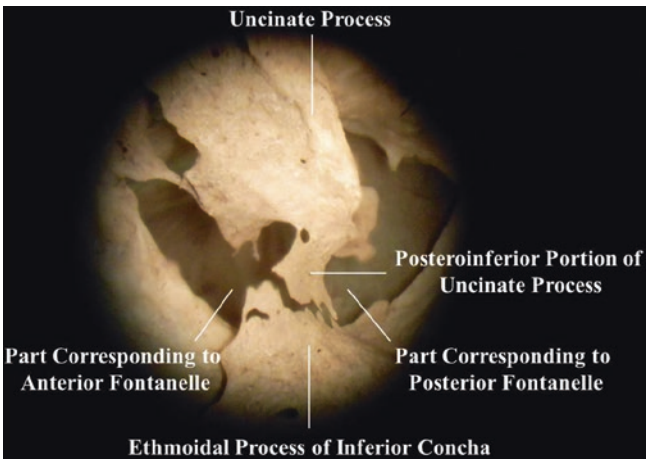


Fig. 3.15 Tip of a right uncinate process. The hook part directs posteriorly

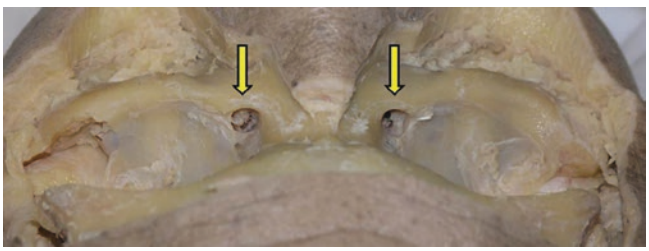


Fig. 3.16 Superior view of the opening of nasolacrimal canal (*yellow arrows*)

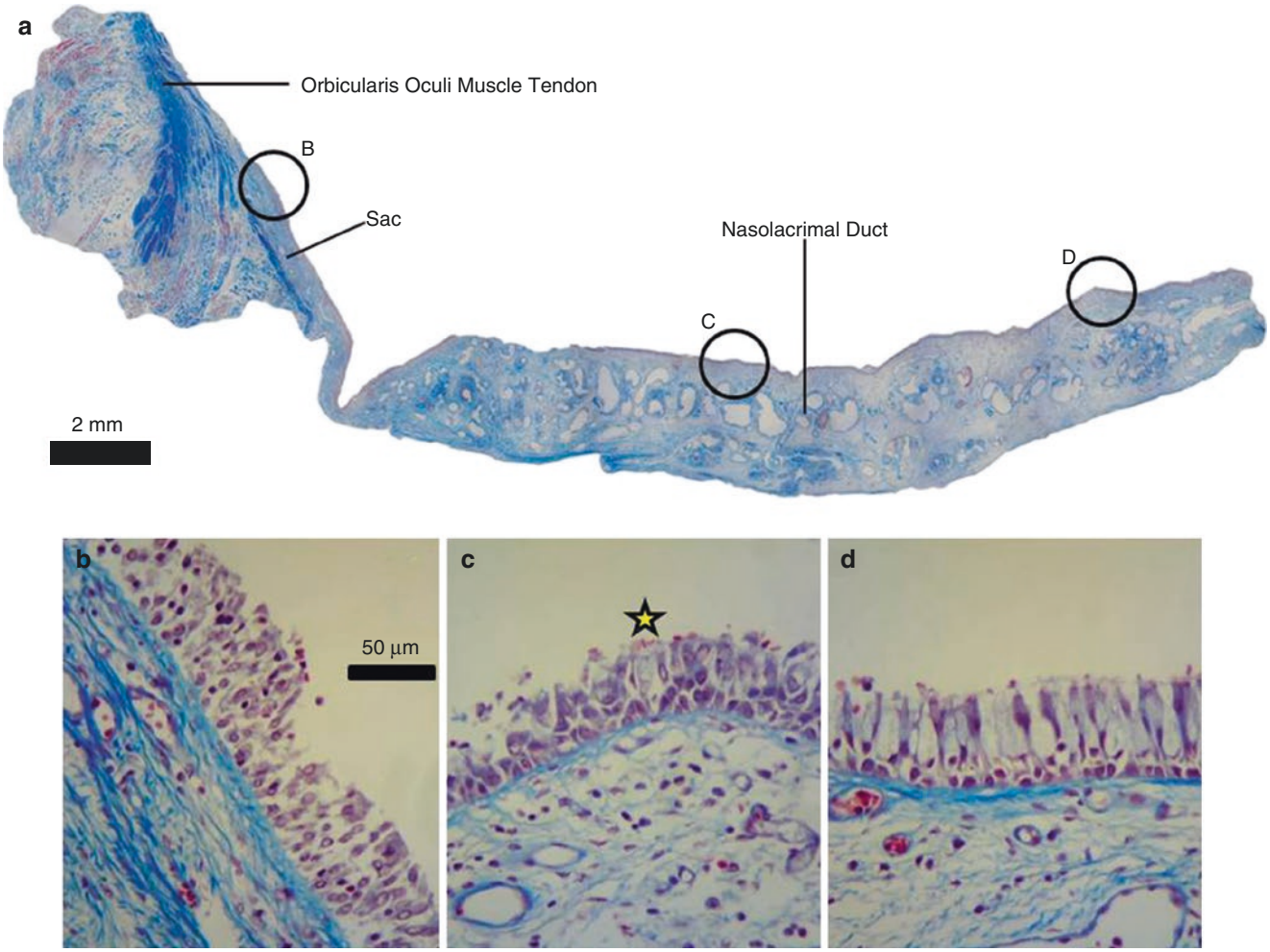


Fig. 3.17 A vertical slice from lacrimal sac to nasolacrimal duct. The (**b**)–(**d**) are enlarged photos in each part of the (**a**). (**b**) sac epithelium; (**c**) superior nasolacrimal duct epithelium; (**d**) inferior nasolacrimal duct epithelium. Numbers of goblet cells are increasing as we proceed inferiorly. The (**b**) does not show a goblet cell, but the Figs. 3.3, 3.5, 3.6 and 3.8, similarly showing lacrimal sac, demonstrate goblet cells. The (**b**)–(**d**) are the same scale. The *asterisk* in the (**c**) indicates the goblet cell (Masson trichrome stain)

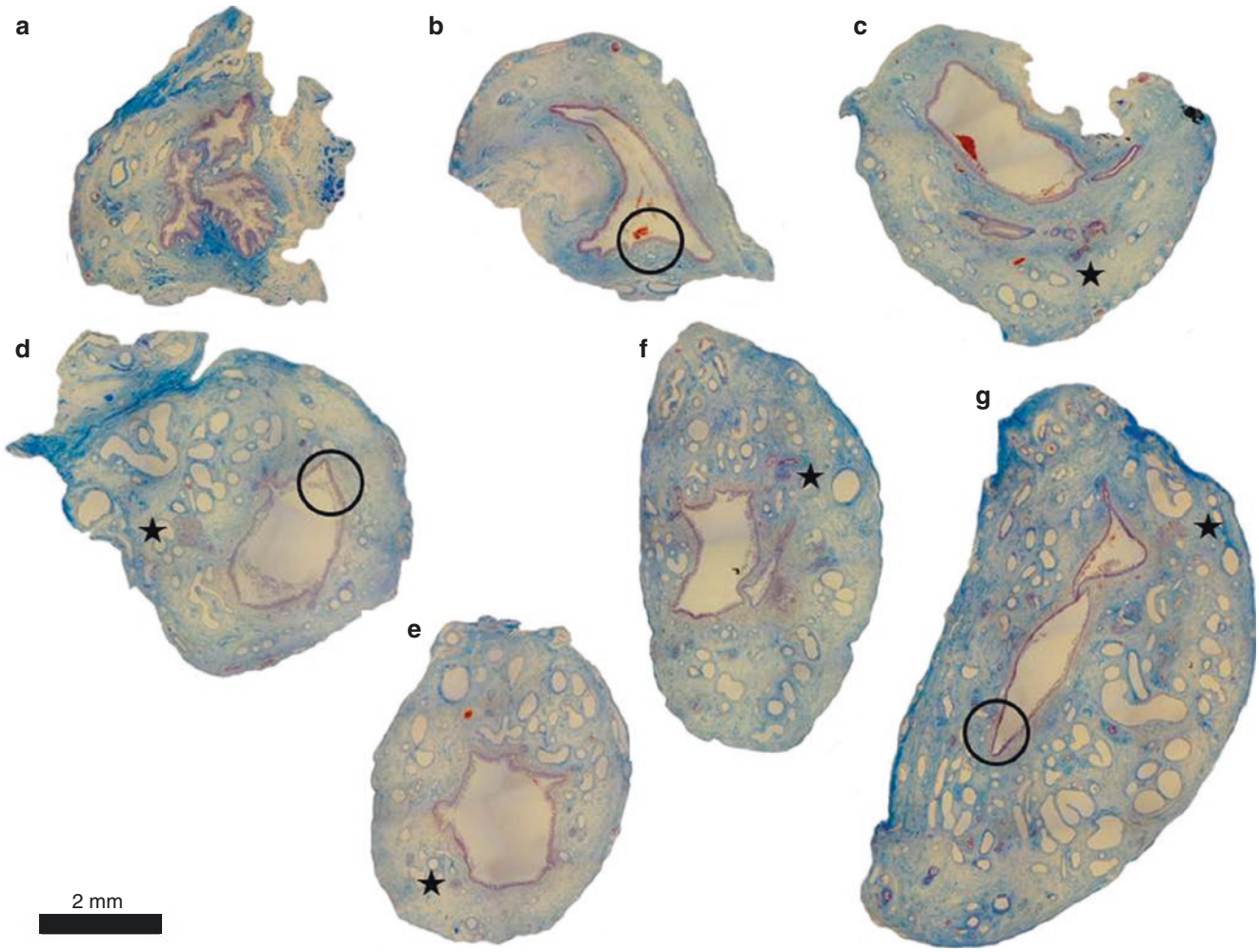


Fig. 3.18 Continuous left horizontal slices from lacrimal sac to nasolacrimal duct. The sections are made every 3 mm. The wall is more thickened as we proceed inferiorly with developing cavernous structure. Serous glands (*star*) are seen from the (**c**)–(**g**). Superior, anterior direction; left, temporal direction. (**a**) part of connection of canaliculus and sac; (**b**) sac; (**c**) part of junction of sac and nasolacrimal duct; (**d**)–(**g**) nasolacrimal duct (Masson trichrome stain)

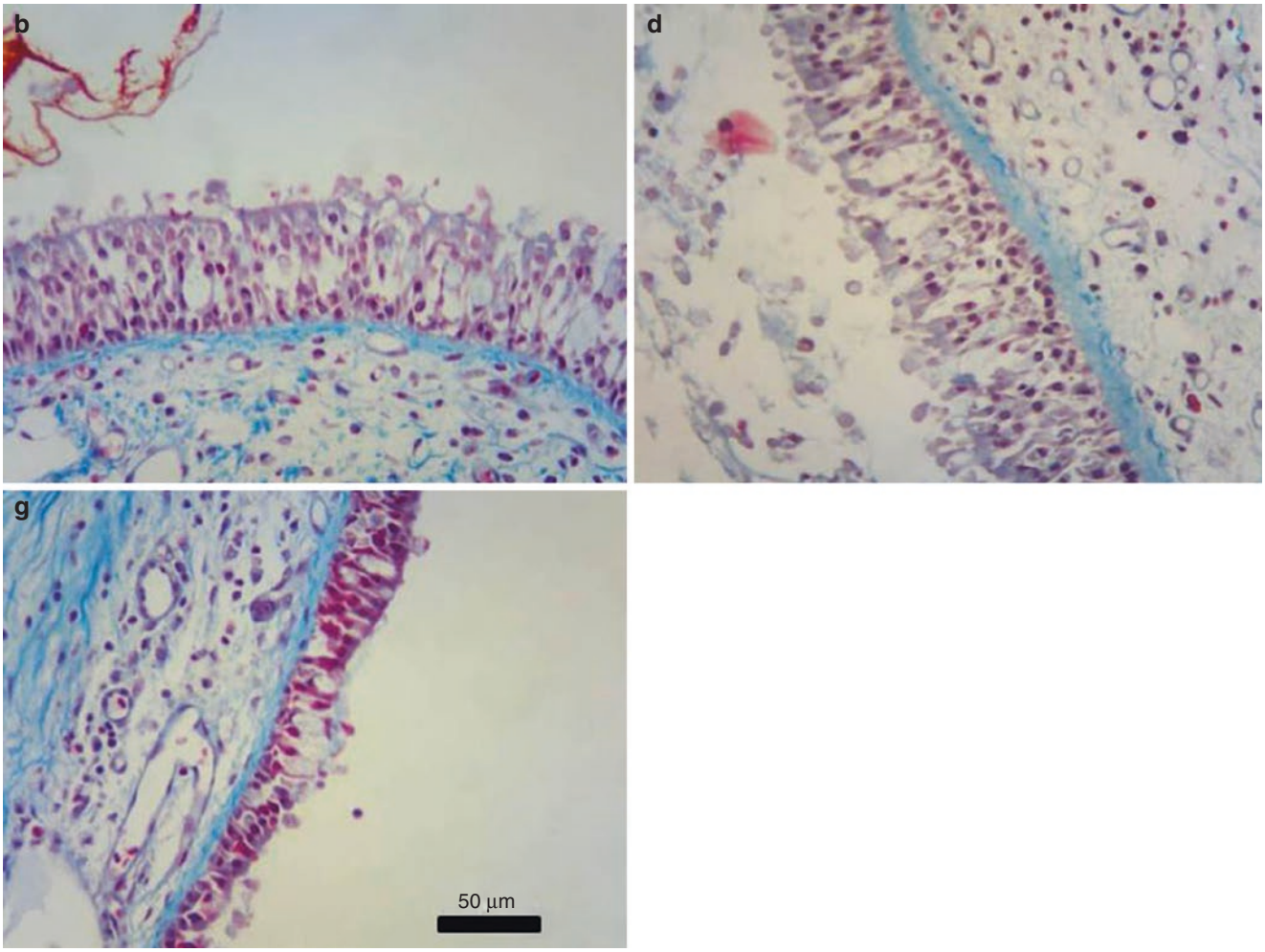


Fig. 3.19 The (**b**), (**d**), and (**g**) are enlarged photos in each part of Fig. 3.18. A lot of goblet cells are shown from the sac level. The (**b**), (**d**), and (**g**) are the same scale (Masson trichrome stain)

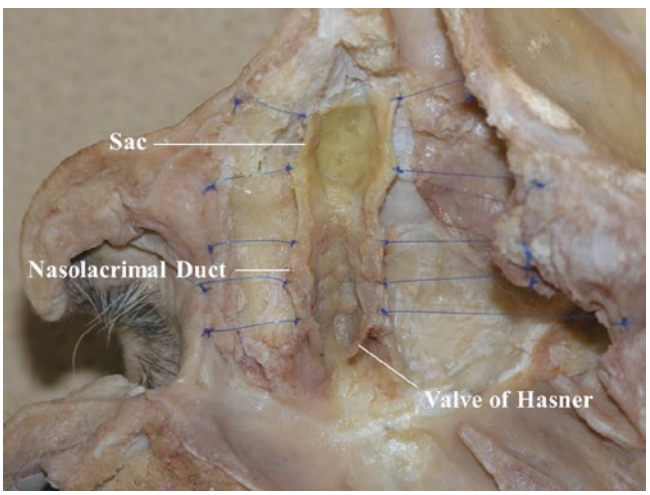


Fig. 3.20 A development view of a sac and a nasolacrimal duct. The sac and the nasolacrimal duct are contiguous. The wall is thin in the sac and more thickened with going inferiorly in the nasolacrimal duct. A valve of Hasner is shown below the inferior opening of the nasolacrimal canal. Several protuberances shown in the nasolacrimal duct are called the valves of Krause

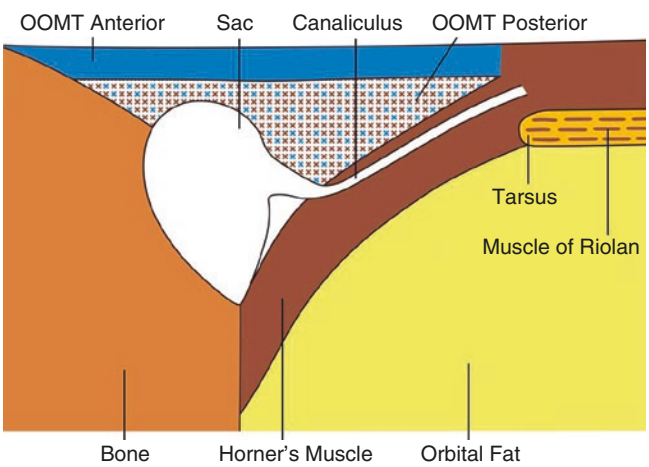


Fig. 3.21 A figure of lacrimal canaliculus and upper part of sac during eye closing. OOMT anterior: orbicularis oculi muscle tendon anterior lamella. OOMT posterior: orbicularis oculi muscle tendon posterior lamella

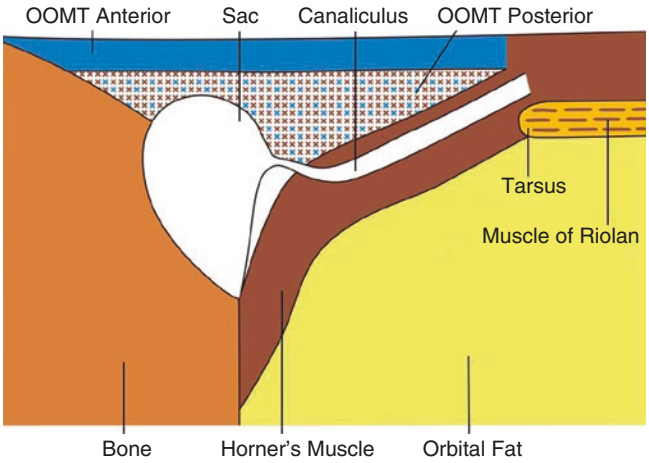


Fig. 3.22 A figure of lacrimal canaliculus and upper part of sac in eye opening. OOMT anterior: orbicularis oculi muscle tendon anterior lamella. OOMT posterior: orbicularis oculi muscle tendon posterior lamella

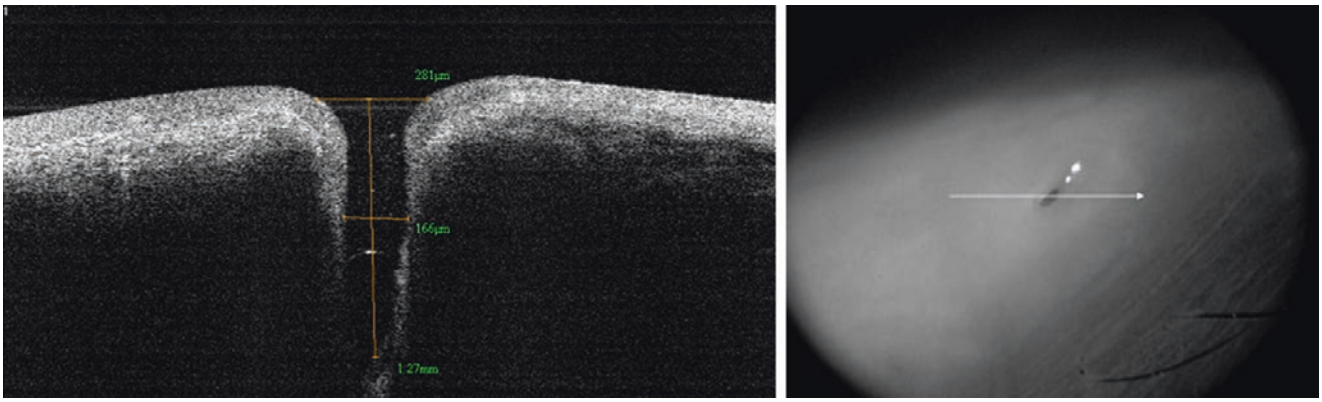


Fig. 3.23 Fourier domain OCT image showing a cross-sectional view of the punctum and the vertical canaliculus in a normal subject. The maximum punctum diameter, mid-canalicular diameter, and the vertical canalicular height have been measured. (Courtesy: Kamal et al., Ophthal Plast Reconstr Surg 2016;32:170–173)

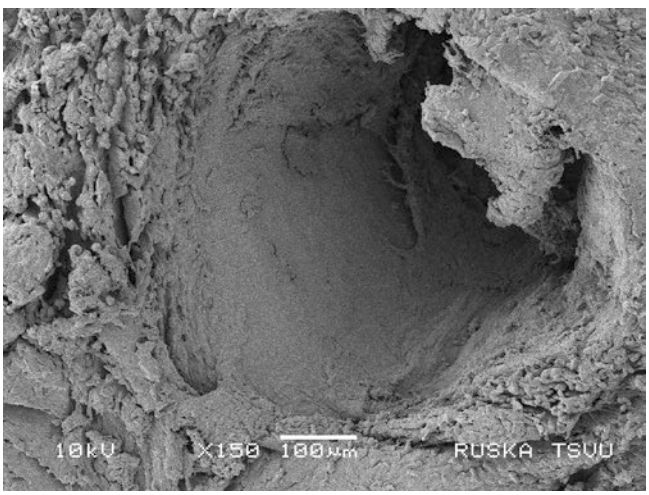


Fig. 3.24 Scanning electron microscopic (SEM) image of the punctum. Note the end on view into the lumen and the raised junctional area between the inner punctum and the beginning of the vertical canaliculus. (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

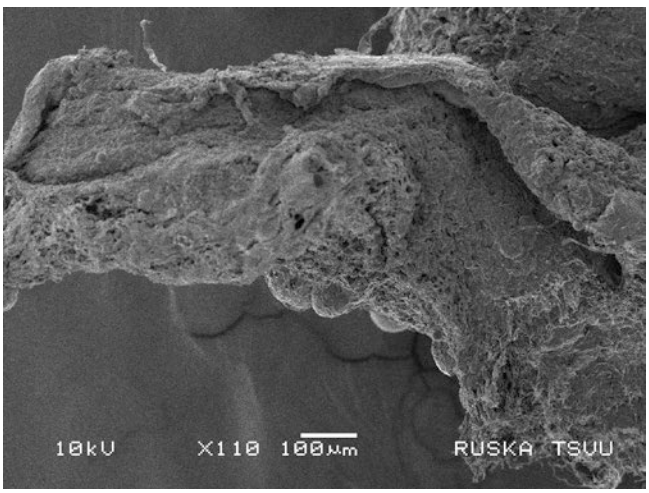


Fig. 3.25 SEM image of the junction of lacrimal sac and nasolacrimal duct. Note the little narrowing and kink at the junctional area. (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

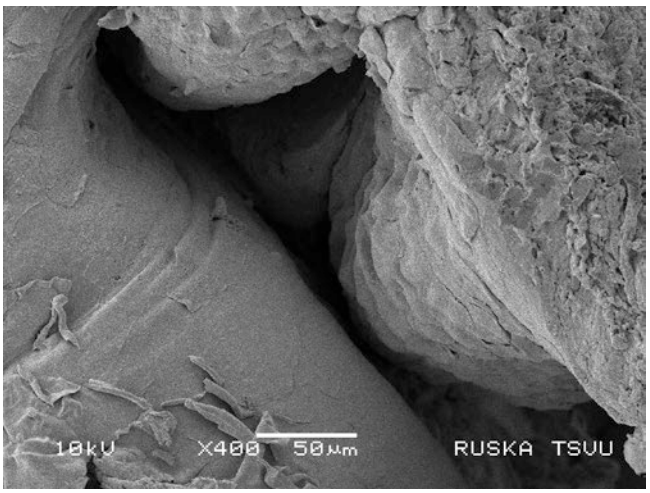


Fig. 3.26 SEM image showing an end-on view into the canalicular lumen. Note one wall of the canaliculus appearing smooth while the other is folded upon itself with surface showing the rugae. (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

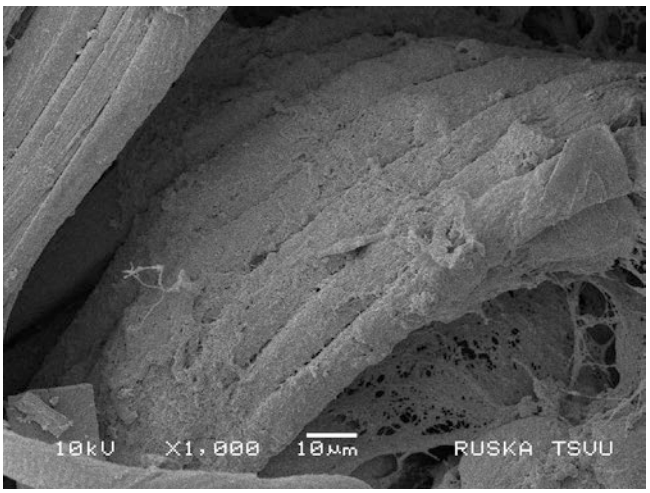


Fig. 3.27 SEM image from the vicinity of the canaliculus showing well-defined arrangement of the muscle fibers. (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

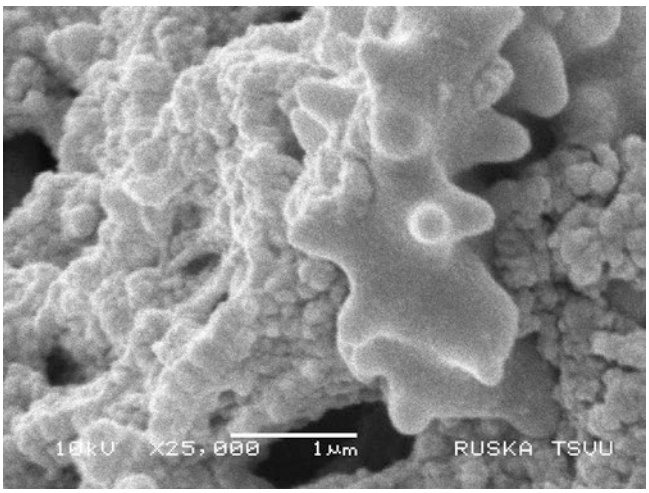


Fig. 3.28 SEM image of the epithelial surface of the fundus showing well-defined glands and opening of the ducts (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

Paradigm Shifts in Lacrimal Anatomy

4

Hirohiko Kakizaki and Mohammad Javed Ali

Introduction

Anatomical knowledge in the lacrimal drainage system is rapidly advancing year after year. This topic would need a separate update; hence we picked up two representative topics which have been believed to be gold standard but now need to be revised based on the recent evidence and hence the need for a paradigm shift here! The first part of the chapter deals with valvular system and second with the medical canthal tendon.

The Valvular Structures in the Lacrimal Passage

The lacrimal excretory passage has been believed to have several valves such as Rosenmüller, Hasner, Bochdalek, Folta, Krause, and spiral valve of Hyrtl and Taillefer (Fig. 4.1) [1, 2]. These have been thought to play an important role in the lacrimal drainage [1, 2]. However, a perfect one-way valve structure like one in the heart or vein has not been convincingly demonstrated in the lacrimal excretory passage [3]. The lacrimal valves are only mucosal folds or protuberances [1, 2]. In spite of these understanding, the true entities and functional values of the so-called valves of Rosenmüller and Hasner have not been correctly understood so far.

The Valve of Rosenmüller

The so-called valve of Rosenmüller is situated, although only in a half of cases, at the junction between the common canaliculus and the sac [4–7]. This structure is not a valve, in truth, but only a mucosal fold. A valve-like mechanism here is contributed and functionally structured by movement of the common lacrimal canaliculus in blinking, which originates from contraction and relaxation by Horner's muscle [8]. The internal canalicular orifice largely opens by a temporal traction of Horner's muscle during eye closing but moves nasally during an eye opening [8].

The sinus of Maier [1, 2] is obvious, especially during the eyelid closure, in which folds or membranes are not shown (Figs. 4.2 and 4.3). These folds or membranes only reflect a mucosal spare in the closed state of the internal canalicular orifice, allowing for expansion of the diverticulum. As the lacrimal sac comprises a cavernous structure and may not withstand dynamic movements during repetitive blinking, such a buffering structure may be necessary [9, 10]. Therefore, the movement of the internal canalicular orifice may not directly contribute to lacrimal drainage or antiregurgitation, but protects the sac against repetitive blinking.

Studies for the valve of Rosenmüller have been mostly performed using cadavers. The cadavers usually have closed eyelids with complete loss of their Horner's muscle tone [11], which is similar to an eyelid in the opening state with closing of the internal canalicular orifice. This situation may show folds or membranes at the internal canalicular orifice. Cadaveric studies would evaluate only one aspect of the above process. Live patients enable us to observe the opening and closing of the internal canalicular orifice. The valve of Rosenmüller may thus be a phantom anatomy.

The Valve of Hasner

The so-called valve of Hasner is only the terminal soft tissue component of the lacrimal excretory passage [12]. An imperforate valve will result in epiphora and signs of congenital nasolacrimal duct obstruction [12]. This soft tissue is situated at the meatal opening of the nasolacrimal duct (NLD), several millimeters inferiorly after NLD's exit from the bony

H. Kakizaki, M.D., Ph.D. (✉)
Department of Ophthalmology, Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_4

lacrimal canal [13, 14]. This soft tissue has been thought to prevent air current or fluid from within the nose being drawn up into the lacrimal duct (Fig. 4.4).

The shape of this terminal soft tissue shows four types: wide-open type (12%), valve-like type (8%), sleevelike type (14%), and adhesive type (66%) [14]. Judging from these variations, the wide-open type at least should demonstrate regurgitation of air current or fluid [12]. Bert (quoted by Aubaret) [1, 2] found that colored fluids injected in the nose escaped from the lacrimal puncta only three times in 18 experiments, whereas direct injections into the duct invariably appeared at these points, showing that the terminal soft tissue of the lacrimal excretory passage usually shows valve-like mechanism but not always. Although Bert's study has been reported more than 100 years ago, it has been appreciated by the surgeons.

Canalicular-Lacrimal Sac Mucosal Folds (CLS-MF)

The anatomical area between the common canaliculus and lacrimal sac has caught the attention of numerous anatomists over the past few decades [1, 15, 16]. The mucosal folds at the canalicular-lacrimal sac junction, also known as CLS-MF, were noted to be of six types based on their anatomical location: anterior 180°, posterior 180°, superior 180°, inferior 180°, and anterior 270° and 360° [6]. Yo et al. [17] recently described their characteristics in cadavers and in vivo. They observed CLS-MF in 62.5% ($n = 16$) of the patients and 47.4% ($n = 19$) of the cadavers. Histologically and endoscopically they could be demonstrated on one side of the openings (Fig. 4.5). They could be opened or closed if and when the related muscles contract. Hence, they may have a role to play not only in tear drainage but also in the pathogenesis of acute dacryocystitis and mucocele formation.

Ultrastructural Evidence of Mucosal Folds/Valves

Scanning electron microscopic studies of the canaliculi have revealed the occasional presence of mucosa folded on itself in focal anatomical regions (Fig. 4.6) [18]. In contrast to the uniformly appearing smooth canalicular mucosa, these folds, believed to be valves, showed numerous broad and blunt rugae-like folds on their surfaces (Fig. 4.7).

Anatomy of the Medial Canthal Tendon (MCT)

History of the MCT Anatomy

The medial canthus is a complex anatomical region, and the most striking entity here is the medial canthal tendon (MCT) [19–23]. The MCT was earlier known as the "medial canthal ligament" [24]. In view of inadequate information, some considered it to be a ligament, but others saw it simply as a large adhesion to the periosteum of the frontal process of maxilla [24].

A different opinion about the medial canthal region was published in 1970s by Lester T. Jones, who was the first to reconsider this classical anatomy. Jones and his colleague reported that the medial canthal ligament was not a ligament, but rather a tendon of the orbicularis oculi muscle (OOM) [21].

The classical teaching about MCT are its two limbs, i.e., the anterior and posterior [22, 25]. The anterior limb, which is stronger than the posterior limb [26], was thought to be situated in front of the lacrimal sac and connected to the anterior lacrimal crest and the medial aspect of the tarsal plate [22]. Ritleng et al. also stated that the anterior part of the medial canthal ligament was actually the tendon of the pretarsal OOM [3] and suggested to call it as the "medial palpebral tendon" [22]. Yamamoto et al. proposed that the MCT comprised an aggregate of muscle fibers from the orbital area of the OOM, as well as the tendon from the tarsal area [20].

The MCT anatomy was revisited and was found that the anterior limb has two lamellae, i.e., the anterior and posterior [27]. The anterior lamella is the tendon of the pretarsal part of the OOM [27]. The posterior lamella is the musculotendinous junction of the preseptal and orbital parts of the OOM [27]. The anterior limb continues to the pretarsal OOM without insertion into the tarsal plate [28].

The classical teaching with regard to the posterior limb is its attachment to the posterior lacrimal crest and tarsal plate and Horner's being related to its posterior surface (Fig. 4.8) [22]. However, true fixation of the nasal aspect of the tarsal plate is performed by Horner's muscle and the medial rectus capsulopalpebral fascia (mrCPF) [28] and not by the posterior limb of the MCT. Most researchers considered this posterior limb as a relative subsidiary structure, compared with the anterior limb [26, 29, 30], although some thought the posterior limb to have the same tough fibrous consistency as the anterior limb [31].

The Truth of the Posterior Limb of the MCT

The classical anatomical teaching has been that the medial canthus is supported by the anterior and posterior limbs of the MCT and the Horner's muscle. The posterior limb of the medial canthal ligament, as a deep or reflected part arising from the main ligament was thought to be merely a thin fascial expansion or simply a thin and weak structure to assist the anterior limb [22, 24, 30–32]. The posterior limb of the MCT was thought to be attached behind the lacrimal sac and contiguous with the lacrimal fascia, and thus helped to support the upper part of the lacrimal sac [29].

Some anatomist regards the posterior limb of the MCT as Horner's muscle [26]. Ritleng et al. [22] stated that Horner's muscle was a separate structure from the posterior limb of

the MCT and that the structure corresponding to the posterior limb was not a tendon, but Horner's muscle. Adenis et al. [26] reported that the posterior component of the MCT was more delicate and had more of a dynamic structure than the anterior portion, and Horner's muscle comprised the posterior portion of the MCT. Shinohara et al. [33] reported that the posterior connective tissue fibers of the MCT were interwoven with fibers of the lacrimal fascia and extended to the common lacrimal canaliculus and to the bifurcation of Horner's muscle.

The senior author's group revisited the anatomy of the posterior limb of the MCT as recently as 2012 but failed to detect it in any of the studied specimens, irrespective of race [34, 35]. Instead, a thick fibrous lacrimal diaphragm [36], namely, the common fascia between the lacrimal sac and Horner's muscle, was noted around the posterior lacrimal crest, which appeared to be continuous with Horner's muscle fascia and was indistinguishable from the muscle's tendon [34, 35]. This thick, fibrous diaphragm, similar to Horner's muscle tendon, may have been regarded mistakenly as the posterior limb of the MCT [34].

Way Forward: The Modified Tarsal Fixation Model

To better study, understand, and standardize the anatomical exploration of medial canthus, we believe the modified tarsal fixation model is the way forward. Horner's muscle and the mrCPF are key elements to understand the modified tarsal fixation model of the medial canthus [28]. Horner's muscle, the lacrimal part of the OOM, originates from the posterior lacrimal crest and inserts to the medial aspect of the tarsal plate in the eyelid margin and to the pretarsal OOM in others [22, 25, 28, 35]. The mrCPF is a fibrous structure, which originates from the pulley of the medial rectus muscle around the globe equator, and inserts to the medial tarsal aspect, the lacrimal caruncle, and the medial orbital wall via the medial check ligament [28, 37]. The mrCPF contains many smooth muscle fibers as well [22]. The main function of the mrCPF is connecting the medial rectus muscle and the medial aspect of the tarsal plate as the "medial eyelid retractor" during eye movement [28, 37].

Horner's muscle supports the medial side of the tarsal plate, in the area close to the eyelid margins and not by the mrCPF as was earlier believed [28]. At this level, no tendon or ligament supports the tarsal plate [28]. In the area away from the eyelid margin, the tarsal plate is supported by the mrCPF. The tarsal plate is not supported here by a tendon or a ligament [28]. The medial aspect of the tarsal plate is not, therefore, supported by the anterior or posterior limb of the MCT, but rather by Horner's muscle and the mrCPF. The anterior limb of the MCT only influences medial canthal fixation via the pretarsal OOM located on the tarsal plate [28].

MCT and the Anterior Ethmoidal Nerve Block

Anterior ethmoidal nerve is a continuation of the nasociliary nerve, a branch of the ophthalmic division of the trigeminal nerve. It is a sensory nerve which supplies to the lateral wall of the nose and its block has been recognized to be helpful in nasal and lacrimal surgeries [38–40]. Takahashi et al. explored the relationship of the medial canthal tendon (MCT), lacrimal fossa (LF), and the anterior ethmoidal foramen (AEF) [41]. They found that in Japanese cadavers, the mean distances between MCT and AEF and between MCT and LF were 9.4 and 4.2 mm, respectively. They hence proposed that for a good anterior ethmoidal nerve block, the needle entry should be 9 mm to the superior border of MCT and advancing it up to 20 mm perpendicular to the skin. Although the perpendicular advancement is more widely accepted, the point of needle entry needs to be verified in various races to formulate anatomical guidelines.

Conclusion

Anatomy in the lacrimal drainage system is increasingly showing "paradigm shifts" on many aspects. This has led to many concepts being revisited and anatomical dogmas being questioned. Since most of these paradigm shifts have clinical implications, we therefore need to update our anatomical knowledge to catch up and be at the forefront!

References

1. Aubaret E. The valves of the lacrymonasal passages. Arch Ophthalmol. 1908;28:211–36.
2. Whitnall SE. Anatomy of the human orbit and accessory organs of vision. 2nd ed. New York: Krieger Publishing Company; 1979. p. 241–3.
3. Kurihashi K. Ruido no kaibo Ganka. 1996;38:301–13 (Japanese).
4. Burkat CN, Lucarelli MJ. Anatomy of the lacrimal system. In: Cohen AJ, Brazzo B, editors. The lacrimal system: diagnosis, management, and surgery. New York: Springer; 2006. p. 3–19.
5. Katowitz JA, Hollsten DA. Silicone intubation of the nasolacrimal drainage system. In: Linberg JV, editor. Lacrimal surgery. New York: Churchill-Livingstone; 1988. p. 109–23.
6. Zoumalan CI, Joseph JM, Lelli GJ Jr, et al. Evaluation of the canalicular entrance into the lacrimal sac: an anatomical study. Ophthal Plast Reconstr Surg. 2011;27:298–303.
7. Kurihashi K, Imada M, Yamashita A. Anatomical analysis of the human lacrimal drainage pathway under an operating microscope. Int Ophthalmol. 1991;15:411–6.
8. Kakizaki H, Zako M, Miyaishi O, et al. The lacrimal canaliculus and sac bordered by the Horner's muscle form the functional lacrimal drainage system. Ophthalmology. 2005;112:710–6.
9. Thale A, Paulsen F, Rochels R, et al. Functional anatomy of the human efferent tear ducts: a new theory of tear outflow mechanism. Graefes Arch Clin Exp Ophthalmol. 1998;236:674–8.
10. Paulsen FP, Thale A, Hallmann UJ, et al. The cavernous body of the human efferent tear ducts: function in tear outflow mechanism. Invest Ophthalmol Vis Sci. 2000;41:965–70.
11. Knight B. The pathophysiology of death. In: Knight B, editor. Forensic pathology. 2nd ed. London: Arnold Publisher; 1996. p. 52–4.

12. Cowen D, Hurwitz JJ. Anatomy of the lacrimal drainage system. In: Hurwitz JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 15–21.
13. Bailey JH. Surgical anatomy of the lacrimal sac. Am J Ophthalmol. 1923;6:665–71.
14. Onogi J. Nasal endoscopic findings of functional obstruction of nasolacrimal duct. Rinsho Ganka. 2012;55:650–4. (Japanese)
15. Yazici B, Yazici Z. Frequency of common canaliculus: a radiological study. Arch Ophthalmol. 2000;118:1381–5.
16. Tucker NA, Tucker SM, Linberg JV. The anatomy of common canaliculus. Arch Ophthalmol. 1996;114:1231–4.
17. You Y, Cao J, Zhang X, et al. In-vivo and cadaveric studies of the canalicular/lacrimal sac mucosal folds. J Ophthalmol. 2016 (Epub).
18. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of the external and internal surfaces of the normal adult lacrimal drainage system. Ophthal Plast Reconstr Surg. 2015;31:414–7.
19. Kang H, Takahashi Y, Nakano T, et al. Medial canthal support structures—the medial retinaculum: a review. Ann Plast Surg. 2015;74:508–14.
20. Yamamoto H, Motikawa K, Uchinuma E, Tamashita S. An anatomical study of the medial canthus using a three-dimensional model. Aesthet Plast Surg. 2001;25:189–93.
21. Jones LT, Wobig JL. Newer concepts of tear duct and eyelid anatomy and treatment. Trans Am Acad Ophthalmol Otolaryngol. 1977;83:603–16.
22. Ritleng P, Bourgeon A, Richelme H. New concepts of the anatomy of the lacrimal apparatus. Anat Clin. 1983;5:29–34.
23. Fernandez-Valencia R, Gomez Pellico L. Functional anatomy of the human saccus lacrimaris. Acta Anat. 1990;139:54–9.
24. Couly G, Hureau J, Tessier P. The anatomy of the external palpebral ligament in man. J Maxillofac Surg. 1976;4:195–7.
25. Jones LT. Epiphora. Its relation to the anatomic structures and surgery of the medial canthal region. Am J Ophthalmol. 1957;43:203–12.
26. Adenis JP, Longueville E. Horner's muscle placation using an anterior approach. Orbit. 1991;10:187–91.
27. Kakizaki H, Zako M, Mito H, et al. The medial canthal tendon is composed of anterior and posterior lobes in Japanese eyes and fixes the eyelid complementarily with Horner's muscle. Jpn J Ophthalmol. 2004;48:493–6.
28. Kakizaki H, Zako M, Nakano T, et al. Direct insertion of the medial rectus capsulopalpebral fascia to the tarsus. Ophthal Plast Reconstr Surg. 2008;24:126–30.
29. Wolff E. Wolff's anatomy of the eye and orbit. 7th ed. Philadelphia: Saunders; 1976. p. 190.
30. Anderson RL. Medial canthal tendon branches out. Arch Ophthalmol. 1977;95:2051–2.
31. Ahl NC, Hill JC. Horner's muscle and the lacrimal system. Arch Ophthalmol. 1982;100:488–93.
32. Zide BM. Anatomy of the eyelid. Clin Plast Surg. 1981;8:623–34.
33. Shinohara H, Taniguchi Y, Kominami R, et al. The lacrimal fascia redefined. Clin Anat. 2001;6:401–5.
34. Kakizaki H, Takahashi Y, Nakano T, et al. The posterior limb in the medial canthal tendon in Asians: dose it exist? Am J Ophthalmol. 2010;150:741–3.
35. Poh E, Kakizaki H, Selva D, et al. The anatomy of medial canthal tendon in Caucasians. Clin Experiment Ophthalmol. 2012; 40:170–3.
36. Jones LT. The cure of epiphora due to canalicular disorders, trauma and surgical failures on the lacrimal passage. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:506–24.
37. Kakizaki H, Selva D, et al. Dynamic study of the medial and lateral recti capsulopalpebral fasciae using cine mode magnetic resonance imaging. Ophthalmology. 2010;117:388–91.
38. Seitchik MW. Anterior ethmoidal nerve block for the treatment of nasal fractures. Plast Reconstr Surg. 1971;48:187–9.
39. McNab AA, Simmie RJ. Effectiveness of local anesthesia for external dacryocystorhinostomy. Clin Experiment Ophthalmol. 2002;30:270–2.
40. Boulos PR, Rubin PA. A lacrimal sac abscess incision and drainage technique. Arch Ophthalmol. 2008;126:1297–300.
41. Takahashi Y, Kinoshita H, Nakano T, et al. Anatomy of anterior ethmoidal foramen, medial canthal tendon and lacrimal fossa for transcutaneous anterior ethmoidal nerve block in Japanese individuals. Ophthal Plast Reconstr Surg. 2014;30:431–3.

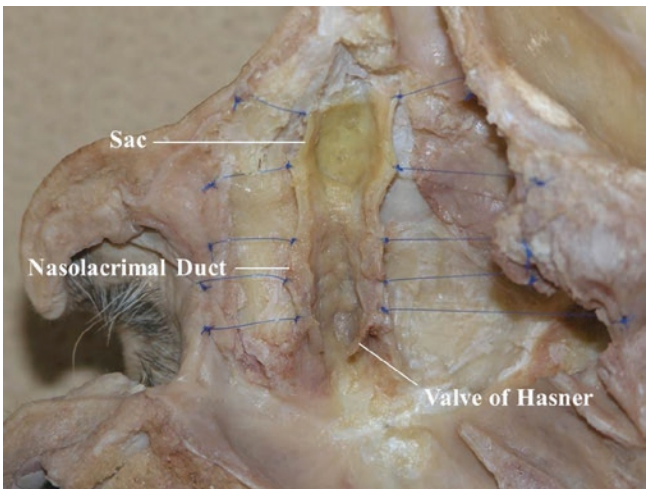


Fig. 4.1 The lacrimal drainage system has numerous mucosal folds or valves across its length

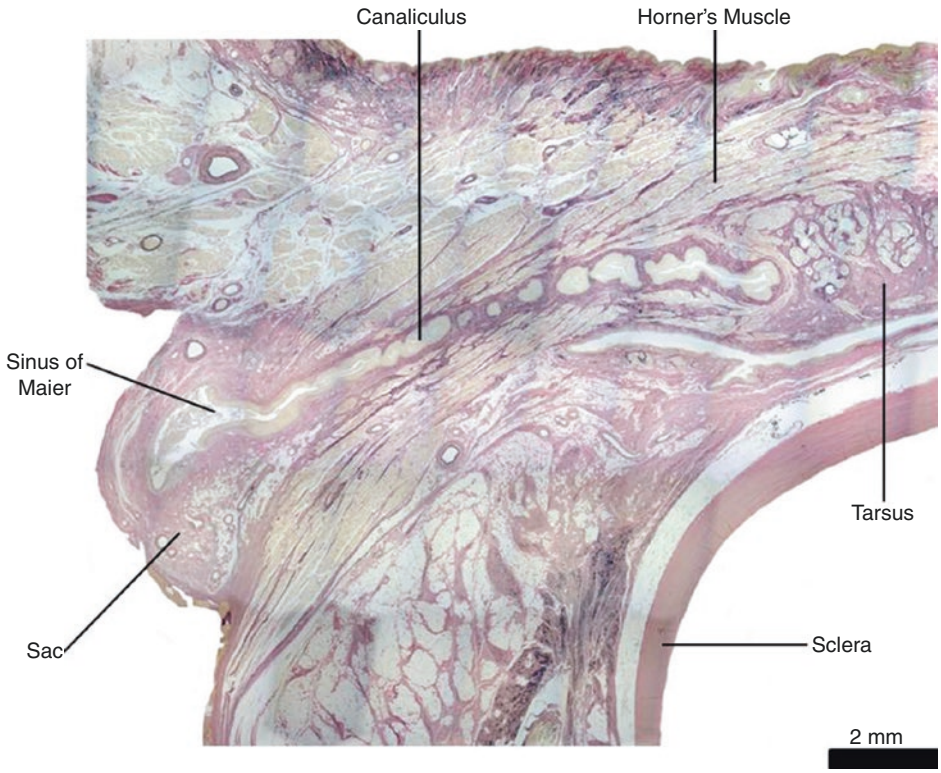


Fig. 4.2 A sinus of Maier is shown here, into which the canalicular part is expanded (Elastica van Gieson stain)

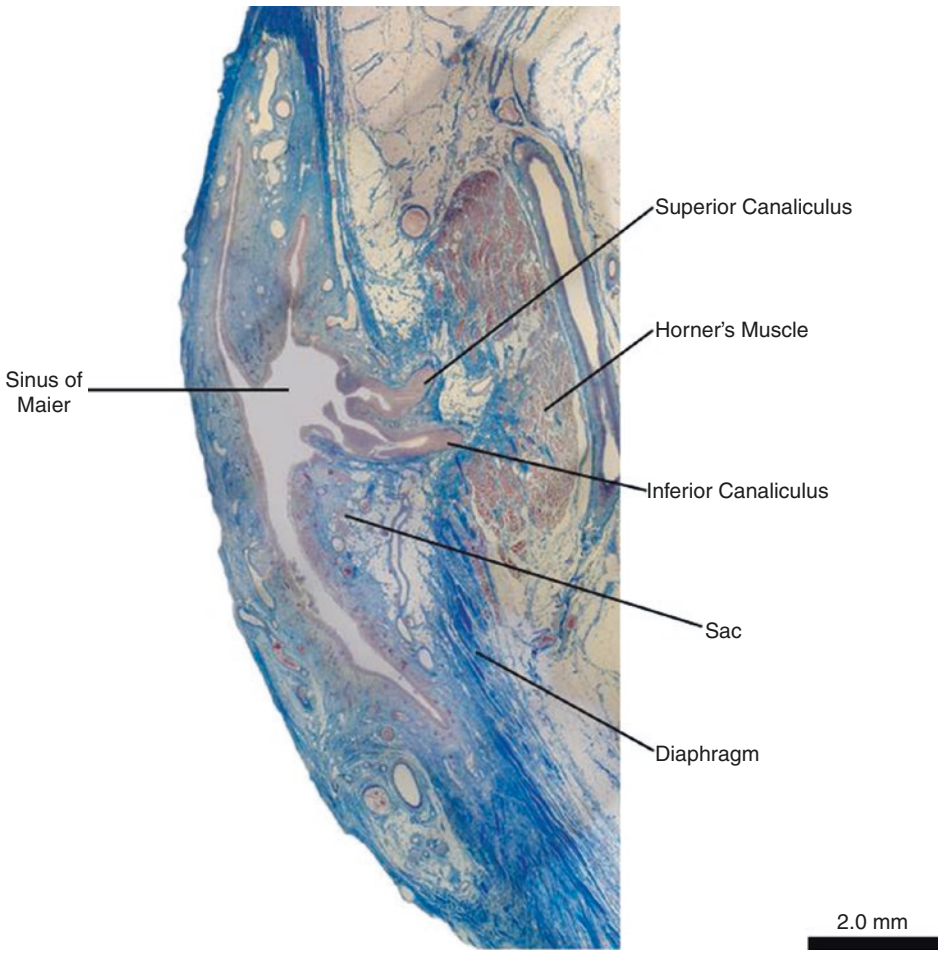


Fig. 4.3 A sinus of Maier, in which a part of the sac is expanded. The superior and inferior canaliculi separately empty into the sinus of Maier (Masson's trichrome stain)

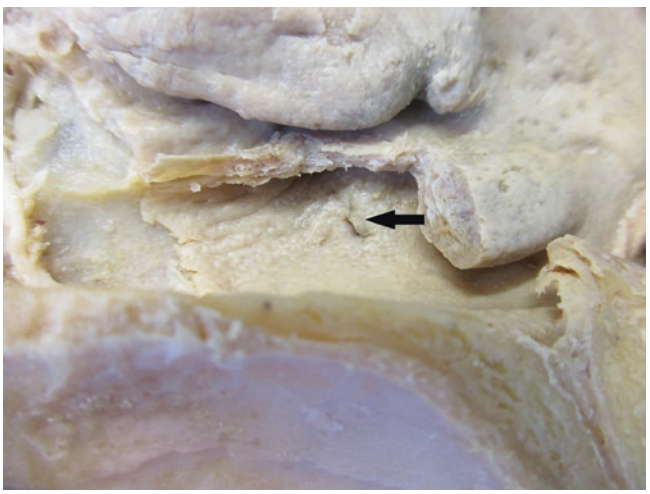


Fig. 4.4 Cadaveric lateral wall photograph after partial excision of the inferior turbinate. Note the opening of the nasolacrimal duct and the overlying fold of nasal mucosa (*black arrow*)

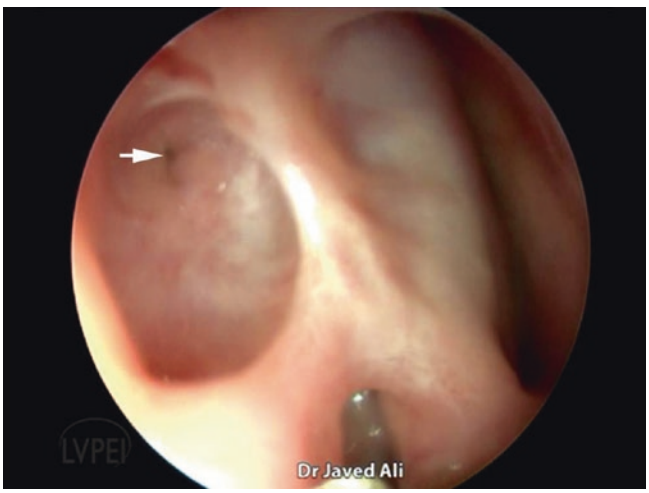


Fig. 4.5 Endoscopic view of the right nasal cavity showing a post-DCR well-healed ostium. Note the internal common opening and the anterior CLS-MF (*white arrow*)

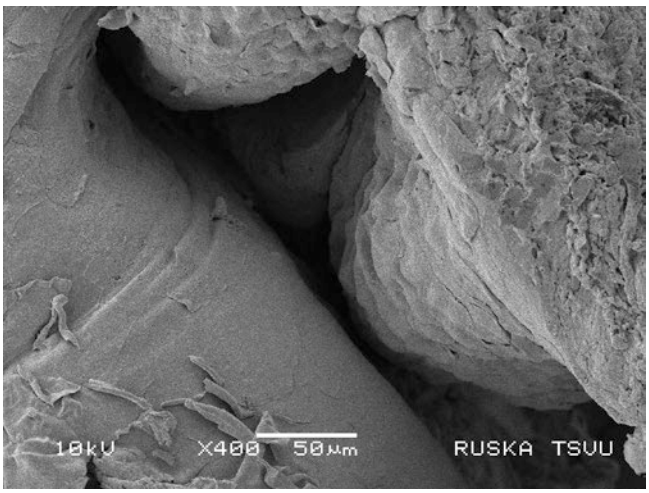


Fig. 4.6 Scanning electron microscopic photo showing the end on view of the canalicular lumen. Note the smooth appearance of one of the internal canalicular walls and the other side being folded upon itself (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

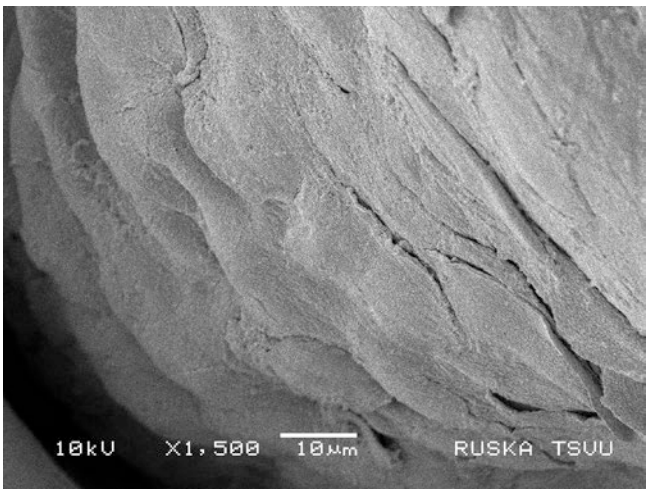


Fig. 4.7 Scanning electron microscopic photo, higher magnification showing the numerous blunt rugae on the surface of the mucosal fold (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

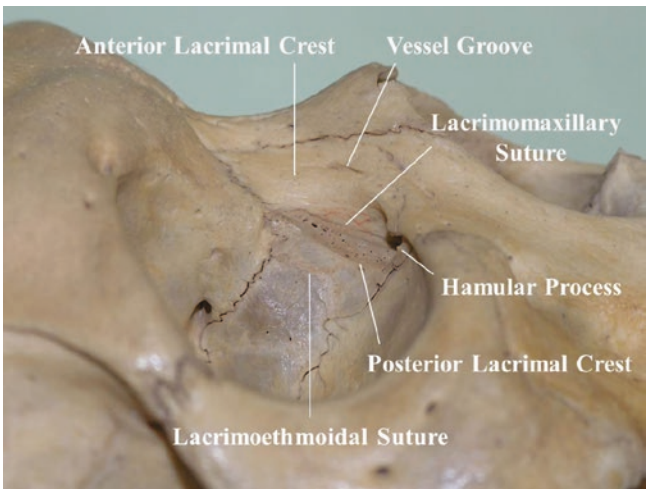


Fig. 4.8 Important bony landmarks in medial canthal anatomy

The Sinonasal Anatomy: Endoscopic Lacrimal and Orbital Perspectives

5

Hirohiko Kakizaki and Mohammad Javed Ali

Introduction

Basic knowledge of the sinonasal anatomy is required to safely perform lacrimal and orbital surgeries. We reviewed the anatomy of the nasal cavity (overview, nasal septum, lateral nasal wall including the lacrimal passage, inferior turbinate and meatus, middle turbinate and meatus, and superior and supreme turbinates and meatuses), ethmoid sinus (overview, agger nasi, uncinate process, fontanelle, ethmoid bulla, hiatus semilunaris, ethmoid infundibulum, and ostiomeatal complex), and sphenoid sinus.

Anatomy of the Nasal Cavity

Overview of the Nasal Cavity

The nares or nostrils are the two openings into the nasal cavity [1]. The nasal septum divides the nasal cavity into two sides [2]. The vestibule is the anterior, skin-lined portion containing nasal hairs (Fig. 5.1a) [1]. The junction of the skin and nasal mucosa occurs at a variable distance inside the nose and is usually clearly discernible by different colors between the skin and mucosa (Fig. 5.1a) [1]. The weblike structure at this junction corresponds to the base of the ala nasi (Fig. 5.1b–d).

The choanae, the round, larger posterior nares, are the spaces representing the posterior limits of the nasal cavities and divide the nose from the superior epipharynx (Fig. 5.2a and b). The choanae are clearly visible from the front using nasal endoscopy (Fig. 5.2a). The floor of the nasal cavity is bordered by the hard and soft palates (Fig. 5.3) [1].

H. Kakizaki, M.D., Ph.D. (✉)
Department of Ophthalmology, Aichi Medical University, Aichi, Japan
e-mail: cosme_geka@yahoo.com.jp

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

The lateral wall of the nose is a complex structure [1]. There are three or four paired nasal turbinates with a corresponding meatus under each turbinate (Fig. 5.4) [1]. The most important paranasal structures are concentrated in the middle meatus, and the nasolacrimal duct empties into the inferior meatus [1–3].

The effect of the nasal conchae and meatuses on the inspired airstream sets the parameters for nasal breathing and treatment of air before it is directed down into the lungs [4]. The turbulent airflow caused by the conchae adds to the perceived resistance of nasal airflow and the sensation of adequate breathing [4]. Turbulent airflow allows for the wafting of molecules to the sensory cells of the olfactory system, aiding the senses of taste and smell [4].

The external proportions of the nose are expected to influence the internal anatomy and thus cause differences in nasal physiology. Populations adapted to cold and dry environments tend to have large, protruding external noses, downwardly directed nostrils, and narrower skeletal nasal apertures [5]. These characteristics are thought to induce turbulence of nasal airflow, thereby maximizing filtration, heat, and humidification of air within the nasal passages [5–7]. Conversely, those with smaller, flatter external noses, more anteriorly directed nares, and shorter piriform apertures are better adapted to hot, humid environments. Because much of the energy required for breathing is expended in the nasal passages, a broader, flatter nasal structure favors less turbulent airflow, which is physiologically more economical because of the lower nasal airway resistance. In the platyrrhine nose, inspiratory airstreams passing through the more horizontally placed nostrils are directed toward the inferior portion of the nasal chamber to condition very warm air, and the region anterior to the turbinates typically plays a lesser role in black than in white individuals [5, 8].

Nasal Septum

The nasal septum comprises cartilage anteriorly (quadrilateral/septal cartilage) and bone posteriorly (vertical plate of the ethmoid bone posterosuperiorly and vomer bone

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_5

posteroinferiorly) (Fig. 5.5) [1]. A membranous columella that divides the nares is present in the anteroinferior area [9], and the vomerine cartilage occupies the posteroinferior area [10]. The nasal septum divides the nasal cavity into two portions and forms most of the nasal bridge [2].

Although the vertical plate of the ethmoid bone and the nasal septum comprise hyaline cartilage in neonates, the vomer is already a bone [10]. From 1 to 2 months after birth, the hyaline cartilage begins to ossify posteriorly and forms the vertical plate of the ethmoid bone [10]. The nasal septum begins to grow rapidly from puberty and raises the external nose [10]. With its growth, the cartilage occasionally bends, forming protuberances and spurs at the junction with the vomer [3, 10]. Approximately 90% of adults show variable extents of septal bending that is directed both anteroposteriorly and transversely [3]. The nasal septum and bone continue to grow until the end of puberty [10]. The posterior edge of the cartilage grows posteriorly from puberty, resulting in formation of the sphenoid or vomerine processes [10].

The septal mucosa is thickest centrally in the superoinferior direction with a tendency to be thicker anteriorly in the anteroposterior direction (Fig. 5.5) [10]. The mucosa of the olfactory cleavage is comparatively thin [10]. Kiesselbach's area, a common site of nasal bleeding, is situated in the anteroinferior part of the septal mucosa [10].

Clinical Correlations

1. Nasal septal surgery should be performed after puberty because removal of the septal cartilage before puberty may prevent growth of the external nose [10]. For the same reason, it should be avoided or a minimal focal septoplasty should be done, if greatly needed in pediatric DCR.
2. Excessive removal of the anteriorly located septal cartilage occasionally causes ptosis of the nasal tip [10]. A saddle nose may occur by overharvesting the septal cartilage in the dorsum nasi [10]. Therefore, at least 10-mm width of the dorsum nasi tissue should not to be removed. Incision of the nasal septum is usually performed 10 mm from the anterior tip of the septal cartilage, which approximately corresponds to the mucocutaneous junction. Incision of the cartilage is started approximately 3 mm posterior from the mucosal incision [3]. The current concepts hover around cartilage sparing septoplasties.
2. Endonasal dacryocystorhinostomy (DCR) occasionally requires a septoplasty, particularly if a Jones bypass tube is planned for insertion, because its aftercare requires easy endonasal access [2].

Lateral Nasal Wall

Lacrimal Passage

The anterior lacrimal crest, ridge, or maxillary line is formed by the underlying frontal process of the maxilla and corresponds to the anterior surface of the nasolacrimal duct [2].

The maxillary line is a curvilinear mucosal eminence projecting from the anterior middle turbinate attachment superiorly and extending inferiorly along the lateral nasal wall to the dorsum of the inferior turbinate (Fig 5.6a and b) [11]. It corresponds intranasally to the junction of the maxilla and uncinate process and extranasally to the suture between the maxilla and lacrimal bone within the lacrimal fossa [11, 12]. A line drawn through the midpoint of the maxillary line is just inferior to the lacrimal sac–duct junction [11]. The thickness and proportion of the maxillary bone in the lacrimal sac fossa increases as the level increases from lower to upper [13]. When the height and length of the nasal bone are small, the frontal process of the maxilla is thick in the lacrimal fossa [13]. In this respect, Asians tend to have a thicker maxillary frontal process than that of Caucasians [13].

The lacrimal bone, which has a mean thickness of 0.057 [14] to 0.106 mm [15], is located posterior to the maxillary line. The lacrimal bone is also situated just anterior to the middle third of the uncinate process, which has an average length and width of 7.2 and 2.5 mm, respectively [14].

The nasolacrimal canal, which has an average length of 12 mm and drains into the inferior meatus (Figs. 5.1d and 5.6b) [9], originates at the base of the lacrimal fossa and is formed by the maxillary bone laterally and inferior turbinate bones medially [9]. The average width of the superior opening of the canal is 4.5–5.7 mm transversely [16–18] and 6.5–6.9 mm anteroposteriorly [17, 18]. The canal courses posteroinferiorly at an average of 12°–27° (Fig. 5.1d) [17, 19–21] and almost parallel to the sagittal plane (Fig. 5.6c) [22]. However, in approximately half of individuals, the canal is directed inward against the sagittal line irrespective of the outward course of the lacrimal fossa [22, 23].

The nasolacrimal duct opening is present on the lateral nasal wall in the inferior meatus (Fig. 5.6b) [2]. The bony opening is most commonly located high up in the inferior meatus [2]. A duct orifice is present at this site in only about 10% of individuals [24]. In most cases, a certain length of the mucosal duct extends anteroinferiorly from there [24] and reaches approximately 1 cm posterior to the anterior tip of the inferior turbinate (Fig. 5.6d) [2]. This mucosal duct is often called the valve of Hasner [2]. The shape of the opening varies considerably from round to slit-like or may simply be a pit or fold [2, 24].

The relationship between the lacrimal sac and lateral nasal wall is variable; the sac may be relatively high, normal,

or low compared with the adjacent anterior nasal space (Fig. 5.7a and b) [2]. This may simply reflect differently sized nasal spaces and midface bony development [2]. Anterior ethmoid air cells are usually found between the lacrimal fossa and lateral nasal wall in most subjects [2]. These air cells are more common in the posterior superior lacrimal fossa [2].

The anterior end of the middle turbinate has been thought to be a constant anatomical landmark of the lacrimal sac [2, 25, 26]. However, whether this structure can serve as a useful landmark of the lacrimal sac fossa in the vertical or anteroposterior position is unclear [27]. Up to 20% of the lacrimal sac was reported to be situated above the axilla of the middle turbinate [28, 29]. However, another study suggested that a large part of the lacrimal sac fossa was above the axilla of the middle turbinate [30–32]. In an Asian study, the axilla of the middle turbinate was attached to the lacrimal sac fossa in more than 90% of cases and located above the lacrimal sac fossa in 4% [13]. A wide positional variation was shown in relation to the lacrimal sac fossa.

The horizontal position of the axilla of the middle turbinate in Asians differs from that of Caucasians. A Caucasian study [33] demonstrated that in 53.2% of cases, the axilla of the middle turbinate was located within the lacrimal sac fossa in contrast to the conventional notion that the axilla of the middle turbinate is posterior to the lacrimal sac fossa. In an Asian study [13], the axilla of the middle turbinate was located posterior to the posterior lacrimal crest in only 2% of cases.

More than 90% of Caucasian specimens demonstrate the uncinate process extending beyond the posterior lacrimal crest [34]. However, in Asians, 100% of the uncinate process reportedly attaches to the lacrimal fossa [13]. The ethmoid air cells are positioned more anteriorly in Asians than in Caucasians [13]. The anterior insertion of the uncinate process is oblique; the uncinate process generally attaches to the lacrimal bone at the lower level, becomes anterior to the maxillary bone–lacrimal bone at the middle level, and then joins the middle turbinate at the upper level [13]. The uncinate process is also helpful when approaching the lower portion of the lacrimal sac fossa [13].

Clinical Correlations

(a) The lacrimal bone is very thin [14, 15] and easily penetrated for entrance into the nasal cavity during endonasal DCR [2]. In patients with a maxillary bone dominant fossa, the thicker bone makes it more difficult to create the osteotomy [2]. Special surgical techniques and instruments, such as a surgical drills or ultrasound aspirators, must be equipped for patients with a thick maxillary frontal process to expose the upper portion of the lacrimal sac fossa [13, 26]. In this respect, DCR for Caucasian patients with a thinner maxillary frontal process [13] may not require the use of such instruments.

(b) Osteotomy can be easily started at the lower portion of the lacrimal sac fossa, in which the lacrimal bone constitutes the lacrimal fossa in the highest proportion and the frontal process of the maxilla is thinnest (Fig. 5.8) [13].

(c) The uncinate process, which mostly extends beyond the posterior lacrimal crest, is an important factor to consider when creating an osteotomy during DCR [25, 34]. However, the sac and duct usually lie immediately anteriorly and laterally to the uncinate process, which does not need to be disturbed during surgery [2]. This notion is mostly applied to Caucasians, but not to Asians. Because the anterior ethmoid air cells always extend to the posterior lacrimal crest in Asians [2], an uncinectomy may be required to clearly expose the lacrimal sac fossa to create a sufficient ostium.

(d) The nasolacrimal canal opening (bony opening) is located in the ceiling of the inferior meatus [2]. However, the nasolacrimal mucosal orifice empties fairly anteriorly [24]. Therefore, a specific technique is needed to clearly observe this mucosal orifice, such as preexamination fluorescein staining or medializing the inferior turbinate.

(e) Because of variability in the relationship between the lacrimal sac and lateral nasal wall [2], and because of the thick maxillary frontal process in patients with a low nasal bridge [13], the precise position of the lacrimal sac is best to be confirmed by a transcanalicular illumination device during endonasal DCR, especially for the beginners [13]. However, this may not be needed by experienced surgeons or those trained well in rhinology. When used, the structures intervening between the lacrimal sac fossa and nasal cavity must be defined by moving the light device up and down and back and forth [13]. Diffuse light is expected in cases with an anteriorly displaced uncinate process or large agger nasi cell [13]. Difficulties in visualization in spite of light source may arise in cases of thick bones.

(f) Asians may sometimes need a partial middle turbinoplasty for creation of a sufficient ostium because most of the posterior lacrimal crest is covered by the axilla of the middle turbinate [13].

(g) As described in the “Ethmoid Infundibulum” section, bone exposure after mucosal resection induces granulation [3]. Although anterior and posterior mucosal flaps are created during external DCR, bone in the upper and lower portions of the osteotomy is still exposed. These

parts are at risk of granulation formation. Although the use of mitomycin C [35] or a stent [36] may prevent granulation to some extent, covering the whole osteotomy margin with the mucosal flap without bone exposure leads to a decreased risk of granulation. This has led to the concept of 360° mucosa to mucosa approximation in a powered endoscopic DCR.

Inferior Turbinate and Meatus

The inferior turbinate is the largest turbinate and occupies the lower third of the lateral nasal wall (Fig. 5.4) [2]. It arises from the medial wall of the maxillary sinus; the other turbinates arise from the ethmoid bone [9]. Its anterior tip is located 1.5–2.0 cm inside the nasal space in adults [2]. Its medial surface is usually concave, and its lateral surface is usually convex [2]. The inferior turbinate is covered by thick vascular mucosa, which often makes it susceptible to hypertrophy [2]. The nasolacrimal canal opening is located on the lateral nasal wall in the inferior meatus (Fig. 5.6b) [2].

The size of the meatus under each turbinate may be large or small, corresponding to the size of the bone making up the turbinate and varying with the state of mucosal and vascular engorgement of the overlying epithelium [1]. These anatomic and mucosal factors can dramatically influence the structures draining into each meatus [1].

Middle Turbinate and Meatus

The middle turbinate is part of the ethmoid bone (Fig. 5.4) [2]. When this turbinate is enlarged by air cells, it is called the "concha bullosa" (Fig. 5.9) [2] or sometimes the "interlamellar cell" [3]. The concha bullosa is classified into three types: pneumatization of the vertical lamella (lamellar type), pneumatization of the inferior bulbous portion (bulbous type), and pneumatization of the entire turbinate (extensive type) [37, 38]. These air cells usually originate from the agger nasi [2]. Normally, its lateral wall is convex and its medial wall is concave. It protects the middle meatus and its important physiological structures [2].

The middle meatus contains the uncinate process, hiatus semilunaris with the infundibulum, and ethmoid bulla [2] and receives drainage from the frontal, anterior ethmoid, and maxillary sinuses (Fig. 5.10) [9]. This area is important pathophysiologically because it forms part of the ostiomeatal complex [2]. The detailed anatomy of this structure is described later [2].

The middle meatus divides the paranasal sinuses into anterior and posterior portions [3]. The anterior paranasal sinuses are the general term for the paranasal sinuses emptying into the middle meatus and comprise the frontal, anterior ethmoid, and maxillary sinuses [3]. The posterior paranasal sinuses are located posterior to the middle turbinate, the opening of which is around the ceiling of the posterior nasal cavity [3]. The posterior paranasal sinuses are constituted by the posterior ethmoid cells emptying into the superior meatus and the sphenoid sinus with its orifice opening to the sphenoethmoidal recess (Fig. 5.11) [3]. Conditions such as sinusitis are usually sectioned, such as anterior or posterior types [3].

Superior and Supreme Turbinates and Meatuses

These structures and spaces are usually small and insignificant in size compared with the other two turbinates (Fig. 5.4) [1]. These turbinates originate from the ethmoid bone. The superior turbinate has the common attachment with the middle turbinate to the skull base [39]. The supreme turbinate may be found in up to 65% of specimens [9]. The air cells forming the posterior ethmoid sinus drain into the superior meatus with two or three ducts and occasionally into the supreme meatus [1, 40]. The olfactory neuroepithelium, which is centered principally on the area of the cribriform plate, extends to the superior turbinate and superior part of the middle turbinate to varying degrees [41].

Anatomy of Ethmoid Sinus

Overview of the Ethmoid Sinus

The ethmoid air cells are cavities comprising various sizes of honeycomb-like air cells (Fig. 5.1a) [3, 42]. The superior border is the comparatively flat roof of the ethmoid, the lateral border is the lamina papyracea, and the medial border is the lateral wall of the middle and superior meatuses and middle turbinate [3, 42]. The space is narrower anteriorly and becomes larger posteriorly, finally reaching the anterior wall of the sphenoid sinus (Fig. 5.11) [3, 42].

The cribriform plate is not a part of the ethmoid sinus, but is located medial to the attachment of the middle turbinate, separating the nose from the anterior cranial fossa (Fig. 5.12a) [1]. The two cribriform plates are separated from each other by the crista galli, and both plates lie posterior to the posterior table of the frontal sinus [1]. Each cribriform plate measures approximately 2 cm from anterior to posterior and 0.5 cm from medial to lateral [1]. The olfactory nerve endings traverse small openings in each cribriform plate to reach the olfactory bulb [1]. The narrow nasal cavity inferior to the cribriform plate is the olfactory cleavage [42]. The cribriform plates are often located lower than the roof of the ethmoid sinus, called the fovea ethmoidalis (Fig. 5.12b) [42].

Although the inside of the ethmoid sinus is complexly divided into many cells, there are several partitions dividing the sinus from anterior to posterior [3]. These are called the "basal lamellae" or "ground lamellae" [3]. When this is used in a singular form, it represents the "third basal lamella" [3]. Because the term "ground lamella" is not cited in Nomina Anatomica, the term "basal lamellae" is mainly used at present [3].

The basal lamellae of the ethmoid sinus are walls connecting the lateral nasal wall and the lamina papyracea [3]. However, only the third basal lamella clearly reaches the lamina papyracea from the lateral nasal wall [3]. Whether most of the other basal lamellae reach the lamina papyracea cannot be confirmed because of their complex structure [3]. Therefore, they are termed the "incomplete basal lamellae" [3].

The ethmoid sinus generally shows five basal lamellae that are numbered from anterior to posterior (Fig. 5.13) [3]. The first basal lamella continues to the uncinate process. The second generally originates from the anterior wall of the ethmoid bulla, occasionally including the whole ethmoid bulla with its posterior wall [43]. The third is the largest and most obvious lamella and hangs the middle turbinate [3]. This third basal lamella clearly divides the ethmoid sinus into anterior and posterior portions [3]. The fourth supports the superior turbinate, and the fifth originates at the supreme turbinate [3]. The central portion of the middle turbinate is all hung by the third basal lamella, but the anterior and posterior edges attach to the lateral nasal wall [3].

The three-dimensional positional relationship between the middle meatus and third basal lamella is similar to the relationship between the body of a pigeon and its half-opened wing when its body is regarded as the lamina papyracea [3]. That is to say, the portion of the body close to the half-opened wing is the third basal lamella, and the wing inferiorly hanging from that site is the suspended middle turbinate [3].

Haller cells (Fig. 5.14a) and Onodi cells (Fig. 5.14b) are known as special cells [3]. Haller cells, also called infraorbital cells, extend beneath the orbit and often narrow the ostiomeatal complex [3]. Onodi cells develop from the lateral wall of the ethmoid sinus and are specifically named when the optic canal protuberates into this sinus [3].

Clinical Correlations

(a) Knowledge of the anatomy described herein is vital for the performance of endoscopic sinus surgery and endoscopic orbital surgeries like orbitotomies or orbital and optic nerve decompression.
(b) Mucoceles and sinusitis in Onodi cells occasionally cause optic neuropathy because the optic nerve often runs close to the small cavities of Onodi cell [44–46]. Imaging studies are vital to detect these lesions, and endoscopic sinus surgery and antibiotic administration are effective treatments [44–46]. When operating in the vicinity of Onodi cells, optic nerve injury must be prevented [3].

Agger Nasi

The agger nasi is a mound situated above the axilla of the middle turbinate (Fig. 5.4). It is a remnant of the first ethmoturbinal region and is a pneumatized portion of the most anterior part of the ethmoid cell (Figs. 5.6b and 5.15a). The ascending portion of the first ethmoturbinal regresses as the agger nasi, and the descending portion remains as the uncinate process [12]. The agger nasi can lie within the lacrimal fossa, between the lacrimal bone and the nasofrontal fossa [2, 42]. It is present in 78% to 100% of cases [13, 47]. When the axilla of the middle turbinate is situated lower, the agger nasi is also positioned lower, with tendency to be adjacent to the lacrimal sac fossa [13]. This type is present in one-third to one-half of lacrimal sac fossas [13, 48]. The agger nasi cell is medially, superiorly, and inferiorly bound by the uncinate process [12]. Its anterior wall is the frontal process of the maxilla, and its lateral wall is the lacrimal bone [12]. Posterior pneumatization of the agger nasi cell pushes the posterosuperior attachment of the uncinate process backward to the lamina papyracea to form the terminal recess [12].

Clinical Correlation

(a) If the axilla of the middle turbinate is located lower than the lacrimal sac fossa, the agger nasi cell must be removed during DCR (Fig. 5.15b and c) [13].
(b) Because there is a close relationship between the agger nasi and the uncinate process, it is important to examine and analyze these structures as one unit.
(c) When confirmation of the frontonasal duct is difficult, removal of the agger nasi helps to detect it (Fig. 5.15d and e) [42]. In addition, the agger nasi cell is a key to understanding the anatomy of the frontal recess [49]. The frontal recess originally indicated a part of the ethmoid cells extending the frontal bone and clinically indicates a part of the anterior ethmoid cells around the frontonasal canal.

Uncinate Process

The uncinate process is a winglike or boomerang-like structure covering the ethmoid infundibulum in the anterior part of the middle meatus (Fig. 5.10) [2, 42]. "Uncinate" is Latin for "hook" and refers to the shape of a thin leaf of bone lying

almost parallel to the lateral nasal wall [2]. The hook part is covered by the fontanelle and located too posteroinferiorly (Fig. 5.16a) to see its shape [50, 51]. It comprises a plate of a cortical bone with no cells (Fig. 5.16b) [42].

The inferior border of the uncinate process is curvilinear and directed anterosuperiorly [48]. An anteriorly attached uncinate process covering at least 50% of the lacrimal fossa is present in 63% of individuals [48] and can be expected to totally obstruct the access to the lacrimal sac fossa [13]. Fifty percent of the uncinate process reaches anterior to the frontal process of the maxilla, and 40% articulates on the lacrimal bone [52–54].

The uncinate process is divided into eight patterns based on the shape or articulation pattern of its posteroinferior portion [50, 51]: articulation only to the inferior concha (42%); articulation to the inferior concha inferiorly with simultaneous attachment to the lower portion of the bulla ethmoidalis superiorly (24%); a small or absent anterior fontanelle because of attachment of the lower margin of the posteroinferior portion of the uncinate process to the inferior concha in close proximity (11%); attachment only to fibrous tissues without any bony attachment to the landmarks of the fontanelle such as the inferior concha, the perpendicular plate of the palatine bone, or the lower portion of the bulla ethmoidalis (10%); articulation to the perpendicular plate of the palatine bone (5%); complete ossification over the location of the posterior fontanelle (4%); upward bending and attachment to only the lower portion of the bulla ethmoidalis (3%); and simultaneous articulation to the lower portion of the bulla ethmoidalis, perpendicular process of the palatine bone, and inferior concha (1%).

The superior attachment of the uncinate process is divided into three major variants: attachment to the lamina papyracea laterally, to the skull base centrally, and to the middle turbinate medially [12]. The single superior attachment of the uncinate process to the lamina papyracea shows the highest prevalence (33%), followed by that to the skull base (10%) [12]. Other specimens show more than one superior attachment (57%) either to the lamina papyracea and skull base (31%) or to the lamina papyracea and middle turbinate (21%) [12]. Taken together, the uncinate process attaches to the lamina papyracea in 86% of cases [12]. This rate of 86% is close to the prevalence of the agger nasi cell (78–100%) [12]. The two close rates indicate that most of the upper part of the uncinate process extends backward and laterally to further connect the agger nasi cell with the terminal recess [12]. The cells between the uncinate process and the lamina papyracea in the posterosuperior portion comprise the "terminal recess" [3, 12].

The site of attachment of the uncinate process determines the frontal sinus drainage pathway [42]. When the uncinate process attaches to the lamina papyracea inferolateral to the frontonasal fossa, the frontonasal duct drains into the nasal cavity, and when the uncinate process attaches to the roof of the ethmoid bone or middle turbinate medial to the nasofrontal fossa, the nasofrontal duct drains into the ethmoid infundibulum [42]. The frontal sinus empties via the nasofrontal duct into the nasal cavity in 86% of cases and into the ethmoid infundibulum in 14% [12, 42]. Because the nasofrontal duct threads the ethmoid cells, it is not actually a simple duct, but an irregular passway [3].

Fontanelle

The fontanelle, the membranous part of the maxillary sinus, must be described in relation to the uncinate process (Figs. 5.10 and 5.16a) [42]. The boundaries of the fontanelle were recently well described [50]. The anterior boundary is the lacrimal bone, and the posterior boundary is the perpendicular plate of the palatine bone [50]. The superior boundary comprises the orbital floor in the anterior one-fifth, the lower horizontal portion of the bulla ethmoidalis in the middle section, and the horizontal portion of the basal lamella of the middle turbinate in the last one-fifth [50]. Therefore, the superior margin of the fontanelle corresponds to the inferior margin of the orbital floor [42]. The inferior boundary is the superior border of the inferior turbinate [50]. In most cases, the posteroinferior portion of the uncinate process crosses the anterior portion of the fontanelle and is attached to the ethmoid process of the inferior concha [50]. The fontanelle is usually divided into anteroinferior and posterosuperior parts by the posteroinferior portion of the uncinate process (Fig. 5.10) [3, 50, 51].

The fontanelle shows three major shapes when observed from the medial to lateral aspects: triangular, pencil-like, and oval [50]. In the triangular type, the posterior height is higher than the anterior height, while the anterior and posterior heights of the pencil-like type are almost identical [50]. The pencil-like type has an anterior end that is similar in shape to the blunt tip of a pencil [50]. In the oval type, the midportion of the fontanelle is the highest, with less anterior and posterior height [50]. The triangular type is the most common (57.3%), followed by the pencil-like type (25%) and oval type (20%) [51]. In one study, the anteroposterior length of the whole fontanelle was 18.1 ± 3.8 mm (mean ± SD), and the greatest height of the whole fontanelle was 9.2 ± 2.2 mm [50].

Clinical Correlation

It is important to know the anatomical landmarks of the fontanelle, since this is utilized as a landmark in sphenopalatine artery (SPA) ligation. The SPA ligation is one of the last resorts in the management of recalcitrant epistaxis, and this is an important tool in the armamentarium of any nasal endoscopic surgeon.

Ethmoid Bulla

The ethmoid bulla is a thin-walled bony prominence representing the largest and most consistent air cell of the anterior ethmoid complex, like a bleb on the lamina papyracea (Figs. 5.10 and 5.17a) [2]. The orifice of this cell is located at a cavity in the back side facing the third basal lamella [3] called the lateral recess or retrobulbar recess (Fig. 5.17b and c) [3, 55]. When no air cell exists in the ethmoid bulla, it is termed the torus ethmoidalis or torus lateralis [3]. The part forming a dome in the roof of the anterior ethmoid cells is called the fovea ethmoidalis and is part of the skull base formed by the frontal bone [3].

The ethmoid bulla is classified into three types based on its development [56]. The simple bulla is a single cavity with one opening, generally to the hiatus semilunaris [56]. The compound bulla has two or three separate compartments that communicate with the hiatus semilunaris [56]. The complex bulla also has two or three compartments, each of which communicates with the hiatus semilunaris, ethmoid infundibulum, or superior meatus [56]. In individuals with compound and complex bullae, there is no communication between the compartments [56]. About 50%, 25%, and 25% of ethmoid bullae are simple, compound, and complex bullae, respectively [56].

Hiatus Semilunaris

The superior and posterior free margin borders of the uncinate process create the hiatus semilunaris with the ethmoid bulla (Figs. 5.10 and 5.15d and e), which is an important crescent-shaped cleft leading to the infundibulum and into which the frontal, anterior ethmoid, and maxillary sinuses drain [2]. In general, the cleft situated anteroinferior to the ethmoid bulla is known as the hiatus semilunaris. This is typically 1–2 mm wide, but can be up to 3 mm wide [58]. The posterosuperior cleft to the ethmoid bulla is occasionally called the hiatus semilunaris superior [3]. In this situation, the general hiatus semilunaris is called the hiatus semilunaris inferior [3]. The hiatus semilunaris superior is continuous with the lateral recess of the ethmoid bulla and third basal lamella (Fig. 5.17b and c) [3, 57]. Including the ethmoid infundibulum, the hiatus semilunaris is not a term describing a structure or a tissue, but a space encircled by tissues [3].

Ethmoid Infundibulum

The ethmoid infundibulum is a funnel-shaped space bordered medially by the hiatus semilunaris and laterally by the lamina papyracea (Figs. 5.1a, 5.9 and 5.14a) [2]. The maxillary sinus ostium is found at the floor and lateral aspect of the infundibulum, where it is usually hidden by the uncinate process and cannot be observed by nasal endoscopy (Figs. 5.15d, e and 5.16a) [2, 42]. The ostium of the maxillary sinus lies in an approximate vertical line to the anterior ethmoid foramen [10]. In most specimens, the position of the maxillary ostium is situated on the second and half quarter of the anterior surface of the ethmoid bulla [59] with a 7- to 11-mm length and 2- to 6-mm width [60]. The average distance from the maxillary ostium to the nasolacrimal canal is 5.5 mm [59]. Ten to fifty percent of specimens show more than one accessory ostium opening at the anterior, posterior, or both fontanelles (Figs. 5.1a, 5.15d, e and 5.16a) [3, 59, 61]. These accessory ostia can be observed by nasal endoscopy [3].

The anterior and posterior ethmoid air cells show several openings, respectively [3]. The ethmoid infundibular area is important pathophysiologically because it forms part of the ostiomeatal complex [2].

Clinical Correlations

(a) Silent sinus syndrome, also called imploding antrum syndrome [62], is a rare disorder characterized by unilateral or bilateral enophthalmos and hypoglobus caused by an alteration of the orbital architecture due to maxillary sinus collapse with chronic hypoventilation [62–64]. Its basic pathology involves negative maxillary antral pressure because of obstruction of the ethmoid infundibulum, which generates negative pressure over time [65]. This entity is idiopathic, occurs postoperatively following bony decompression for Graves' orbitopathy [66], or develops after facial trauma, especially orbital floor fracture [65]. The conditions after surgery and radiotherapy for sinonasal malignancy are excluded [64, 67]. Frontal silent sinus syndrome was recently reported as well [68].

(b) Bone exposure after mucosal resection induces granulation [3]. In medial orbital wall decompression, mucosal removal [69] may not cause granulation because the escaped orbital contents occupy the space. However, after surgery for smooth ventilation against sinusitis, mucosal removal may increase granulation to an extent that negates the surgical purpose [3]. In this kind of surgery the intact mucosa must therefore be preserved as much as possible [3].

Ostiomeatal Complex

The ostiomeatal complex is also called the ostiomeatal unit [3]. This complex is considered to be a unified apparatus comprising the anterior ethmoid sinus openings and their passages [3]. It is a functional and conceptual unit containing the open-

ings and passages of the frontal, anterior ethmoid, and maxillary sinuses [3]. Therefore, the ostiomeatal complex is not an anatomical term [3], but corresponds to the middle meatus, anterior ethmoid sinus, and orifices of each paranasal sinus emptying around them. Specifically, the ostiomeatal complex contains the agger nasi cells, frontal sinus orifice, nasofrontal duct, natural ostium of the maxillary sinus, ethmoid infundibulum, hiatus semilunaris, and middle meatus [3].

Ventilation and drainage of the frontal, ethmoid, and maxillary sinuses largely depend on the state of the ostiomeatal complex [3]. Functional deficiency of the ostiomeatal complex is mainly caused by anatomical disorders, obstructive lesions, and functional changes [3]. Anatomical disorders involve the concha bullosa, paradoxical middle nasal turbinate, paradoxical uncinate process, septal deviation, and distention of agger nasi cells and Haller cells [3]. Ciliary disorders are enumerated as functional disorders [3]. These disorders do not always result in disorders of the ostiomeatal complex [3].

Anatomy of the Sphenoid Sinuses

The sphenoid sinuses are located at the most posterior part of all the paranasal sinuses (Figs. 5.1a, 5.3, 5.4 and 5.11) [42] and within the body of the sphenoid bone. They vary greatly in size and shape [1, 34]. The length from the nostril to the anterior wall of the sinus is about 7 cm [42]. They are commonly deep in their anteroposterior dimensions [1, 34]. Laterally, they may extend into various parts of the sphenoid bone, including the greater and lesser wings, pterygoid processes, and lateral pterygoid plates [1, 34]. The midline septum usually divides the two sinuses unequally (Fig. 5.11) [1, 34].

The sphenoid ostia are located superiorly and medially on the anterior wall and drain into the sphenoethmoidal recess [1, 34], the highest point of which is about the center between the choanae and the roof of the nasal cavity [42]. From an endoscopic viewpoint, the sphenoid ostium is located, in most cases, medial to the posterior part of the superior turbinate [40, 70, 71]. The lateral one-half to two-thirds of the anterior wall of the sphenoid sinus abuts against the posterior ethmoid air cells and is called the pars ethmoidalis [1, 34, 35]. The medial one-third to one-half faces the posterosuperior nasal cavity between the superior turbinate and the nasal septum and is called the pars nasalis [42].

The sphenoid sinuses have several important relationships with surrounding structures (Figs. 5.1a, 5.3, 5.4 and 5.15a) [1, 34]. The brain stem (pons, basilar artery) lies posterior to the ethmoid sinus (Figs. 5.3 and 5.4) [1, 34]. The optic chiasm and pituitary gland lie superior to the sinus, and the pituitary gland commonly bulges into the superior wall (Figs. 5.3, 5.4 and 5.15d, e) [1, 34]. The optic nerves, carotid artery, and cavernous sinus are important lateral relationships (Figs. 5.1a and 5.12a) [1, 34]. The nasopharynx is inferior to the sphenoid sinus (Figs. 5.3 and 5.4) [1, 34].

Clinical Tips

(a) When the sphenoid sinus is pneumatized to a large extent, only a thin wall of bone and mucoperiosteum separate it from the surrounding tissue [34]. In such a situation, serious cases of sphenoid sinusitis may compromise the optic nerve [34].
(b) Invasive fungal sphenoiditis is an ophthalmic emergency. Fungal elements penetrate the sinus mucosa, submucosa, blood vessels, or bone in invasive sphenoiditis [72], often causing an orbital apex syndrome and further extending to the meninges, cavernous sinus, and cavernous carotid artery [73]. Early treatment including aggressive surgical debridement and antimycotic drugs is essential to preserve vision and life [73].
(c) An injury to the head, especially to the brow, may result in an optic canal fracture [74, 75]. Causes of vision loss include bone fracture or tissue swelling within the optic canal that compresses the optic nerve or a bone fragment penetrating into the optic nerve [76]. Optic nerve decompression via the sphenoid sinus may result in vision improvement in patients with light perception [76]. On the other hand, this procedure may not be indicated for patients with no light perception who have a lateral wall fracture of the optic canal or a bone fragment penetrating the optic nerve [76].

Updates (2015–2016)

Endoscopic Anatomy, Lateral Wall Landmarks, and NLD

Variations in the relationships of various lacrimal landmarks to the lateral wall have puzzled surgeons. A thorough knowledge of these variations help in performance of safe and successful sinonasal and lacrimal surgeries. A recent cadaveric study [77] explored the relationship between NLD and various lateral wall landmarks, precisely defined in axial planes. At the level of the maxillary ostium, the mean distance between the alar rims and NLD was 43.05 ± 4.76 mm on the right and 41.25 ± 4.56 mm on the left side. The most anterior projection of the middle turbinate head (MTH) was anterior to the NLD in 70% of the cases. Of the samples, 55% showed the maxillary line (ML) to be posterior to the NLD in positional relationship. Hence it was found that in spite of being considered as useful guides, the spatial relationships of MTH and ML with the NLD are not consistent and cannot be solely relied upon during the surgeries for precision.

Angulation Between Inferior Turbinate and Maxillary Sinus

The nasolacrimal duct opens into the inferior meatus and is surrounded by the inferior turbinate (IT) medially and the medial wall of the maxillary sinus (MS) laterally. Gul et al. [78] radiologically investigated the angle between the inferior turbinate and upper part of the medial wall of the maxillary sinus in patients with unilateral PANDO ($n = 35$) and in a control group ($n = 50$). The mean angles reported were 53.2° (diseased side of patients), 58.6° (healthy side of patients), and 56.8° (control group), and the difference in angulations between the patients and the controls was significant ($p < 0.05$). Hence the hypothesis was narrower angles between the IT and medial wall of MS can be a predictor, if not a causal factor for PANDO.

Sinonasal Surgeries and NLD Injury

It is well known in the literature that few surgeries, medial maxillectomy, rhinoplasty, maxillofacial trauma repair, and middle meatal antrostomy in functional endoscopic sinus surgery, can predispose to a NLD injury due to its intricate relationship on the lateral wall of the nose [79–82]. However the apprehension generated in the literature earlier that reported high incidence of such injuries was not found to be so in a recent analysis [83]. The bony NLD dehiscence prior to surgery was noted in 6.8% of the cases ($n = 118$) and only 3.3% of the patients showing bony NLD dehiscence following the surgery (seen only with trainee surgeons). Preoperative lacrimal assessment of patients undergoing FESS and active supervision of the trainees during the middle meatal antrostomy can help manage this complication in a better way.

Conclusion

The sinonasal anatomy was illustrated in detail with the use of cadaver specimens, CT, and nasal endoscopic figures. Although each lacrimal or orbital surgery requires different portions of the knowledge presented in this chapter, we believe that these surgeries can be performed safely and with confidence endoscopically by understanding each surgical field as a part of the whole.

References

1. Witterick IJ, Hurwitz JJ. Anatomy of the nose and sinuses. In: Hurwits JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 31–7.
2. Olver J. Colour atlas of lacrimal surgery. Oxford: Butterworth & Heinemann; 2002. p. 14–8.
3. Ohnishi T, Ozawa M, Kasahara Y, et al. Endoscopic sinus surgery. Tokyo Medical View. 1995;32–104 (Japanese).
4. Mirante JP. Nasal anatomy and evaluation. In: Cohen AJ, Mercandetti M, Brazzo BJ, editors. The lacrimal system: diagnosis, management, and surgery. New York: Springer; 2006. p. 25–32.
5. Leong SC, Eccles R. A systematic review of the nasal index and the significance of the shape and size of the nose in rhinology. Clin Otolaryngol. 2009;34:191–8.
6. Elad D, Wolf M, Keck T. Air-conditioning in the human nasal cavity. Respir Physiol Neurobiol. 2008;163:121–7.
7. Wolf M, Naftali S, Schroter RC. Air-conditioning characteristics of the human nose. J Laryngol Otol. 2004;118:87–92.
8. Cottle MH. The structure and function of the nasal vestibule. In: Maurice H, Cottle MD, Barelli PA, editors. Rhinology. Philadelphia: American Rhinologic Society; 1987. p. 74–86.
9. Burkat CN, Lucareli MJ. Anatomy of the lacrimal system. In: Cohen AJ, Mercandetti M, Brazzo BJ, editors. The lacrimal system: diagnosis, management, and surgery. New York: Springer; 2006. p. 3–19.
10. Haruna S. Clinical anatomy for endoscopic endonasal surgery. In: Kishimoto S, editor. Practical otolaryngology: clinical anatomy for otolaryngology, and head & neck surgery. Tokyo: Bunkodo Publishers; 2002. p. 120–5. (Japanese).
11. Chastain JB, Cooper MH, Sindwani R. The maxillary line: anatomic characterization and clinical utility of an important surgical landmark. Laryngoscope. 2005;115:990–2.
12. Zhang L, Han D, Ge W, et al. Anatomical and computed tomographic analysis of the interaction between the uncinate process and the agger nasi cell. Acta Otolaryngol. 2006;126:845–52.
13. Woo KI, Maeng HS, Kim YD. Characteristics of intranasal structures for endonasal dacryocystorhinostomy in Asians. Am J Ophthalmol. 2011;152:491–8.
14. Yung MW, Logan BM. The anatomy of the lacrimal bone at the lateral wall of the nose: its significance to the lacrimal surgeon. Clin Otolaryngol Allied Sci. 1999;24:262–5.
15. Hartikainen J, Aho HJ, Seppa H, Grenman R. Lacrimal bone thickness at the lacrimal sac fossa. Ophthalmic Surg Lasers. 1996;27:679–84.
16. Duke-Elder S. The development, form and function of the visual apparatus. In: Elder S, editor. Textbook of ophthalmology, vol. 1. London: Henry Kimpton Publisher; 1932. p. 235–9.
17. Lee H, Ha S, Lee Y, et al. Anatomical and morphometric study of the bony nasolacrimal canal using computed tomography. Ophthalmologica. 2012;227:153–9.
18. Takahashi Y, Kakizaki H, Nakano T. Bony nasolacrimal duct entrance diameter: gender difference in cadaveric study. Ophthal Plast Reconstr Surg. 2011;27:204–5.
19. Janssen AG, Mansour K, Bos JJ, et al. Diameter of the bony lacrimal canal: normal values and values related to nasolacrimal duct obstruction: assessment with CT. AJNR Am J Neuroradiol. 2001;22:845–50.
20. Shigeta K, Takegoshi H, Kikuchi S. Sex and age differences in the bony nasolacrimal canal: an anatomical study. Arch Ophthalmol. 2007;125:1677–81.
21. Park J, Takahashi Y, Nakano T, et al. The orientation of the lacrimal fossa to the bony nasolacrimal canal: an anatomical study. Ophthal Plast Reconstr Surg. 2012;28:463–6.
22. Takahashi Y, Nakamura Y, Nakano T, et al. Horizontal orientation of the bony lacrimal passage: an anatomical study. Ophthal Plast Reconstr Surg. 2013;29:128–30.
23. Narioka J, Matsuda S, Ohashi Y. Correlation between anthropometric facial features and characteristics of nasolacrimal drainage system in connection to false passage. Clin Experiment Ophthalmol. 2007;35:651–6.
24. Ohnogi J. Endoscopic observation of inferior aperture of the nasolacrimal duct. Jpn J Clin Ophthalmol. 2001;55:650–4. (Japanese)
25. Fayet B, Racy E, Assouline M. Systematic unciformectomy for a standardized endonasal dacryocystorhinostomy. Ophthalmology. 2002;109:530–6.

26. Wormald PJ. Powered endoscopic dacryocystorhinostomy. Otolaryngol Clin N Am. 2006;39:539–49.
27. Tsirbas A, Davis G, Wormald PJ. Mechanical endonasal dacryocystorhinostomy versus external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2004;20:50–6.
28. Steadman MG. Transnasal dacryocystorhinostomy. Otolaryngol Clin N Am. 1985;18:107–11.
29. McDonogh M, Meiring JH. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–7.
30. Whittet HB, Shun-Shin GA, Awdry P. Functional endoscopic transnasal dacryocystorhinostomy. Eye. 1993;7:545–9.
31. Pearlman SJ, Michalos P, Leib ML, et al. Translacrimal transnasal laser-assisted dacryocystorhinostomy. Laryngoscope. 1997;107:1362–5.
32. Wormald PJ, Kew J, Van Hasselt A. Intranasal anatomy of the nasolacrimal sac in endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2000;123:307–10.
33. Fayet B, Racy E, Assouline M, et al. Surgical anatomy of the lacrimal fossa a prospective computed tomography densitometry scans analysis. Ophthalmology. 2005;112:1119–28.
34. Rose JG Jr, Lucarelli MJ, Lemke BN. Lacrimal, orbital and sinus anatomy. In: Woog JJ, editor. Manual of endoscopic lacrimal and orbital surgery. Philadelphia: Butterworth & Heinemann; 2004. p. 1–16.
35. Henson RD, Cruz HL, Henson RG Jr, et al. Postoperative application of mitomycin-C in endocanalicular laser dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2012;28:192–5.
36. Callejas CA, Tewfik MA, Wormald PJ. Powered endoscopic dacryocystorhinostomy with selective stenting. Laryngoscope. 2010;120:1449–52.
37. Hatipoğlu HG, Çetin MA, Yüksel E. Concha bullosa types: their relationship with sinusitis, ostiomeatal and frontal recess disease. Diagn Interv Radiol. 2005;11:145–9.
38. Bolger WE, Butzin CA, Parsons DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope. 1991;101:56–64.
39. Orlandi RR, Lanza DC, Bolger WE, et al. The forgotten turbinate: the role of the superior turbinate in endoscopic sinus surgery. Am J Rhinol. 1999;13:251–9.
40. Eweiss AZ, Ibrahim AA, Khalil HS. The safe gate to the posterior paranasal sinuses: reassessing the role of the superior turbinate. Eur Arch Otorhinolaryngol. 2012;269:1451–6.
41. Lane AP, Gomez G, Dankulich T, et al. The superior turbinate as a source of functional human olfactory receptor neurons. Laryngoscope. 2002;112:1183–9.
42. Ikeda K. Clinical anatomy for endoscopic sinus surgery. In: Kishimoto S, editor. Practical otolaryngology 8: clinical anatomy for otolaryngology, and head & neck surgery. Tokyo: Bunkodo Publishers; 2002. p. 126–31. (Japanese).
43. Wormald PJ. Three-dimensional reconstruction and surgery of the bulla ethmoidalis, middle turbinate, posterior ethmoid and sphenoid. In: Wormald PJ, editor. Endoscopic sinus surgery: anatomy, three-dimensional reconstruction, and surgical technique. 3rd ed. New York: Thieme; 2013. p. 103–16.
44. Chee E, Looi A. Onodi sinusitis presenting with orbital apex syndrome. Orbit. 2009;28:422–4.
45. Kitagawa K, Hayasaka S, Shimizu K, Nagaki Y. Optic neuropathy produced by a compressed mucocele in an Onodi cell. Am J Ophthalmol. 2003;135:253–4.
46. Klink T, Pahnke J, Hoppe F, Lieb W. Acute visual loss by an Onodi cell. Br J Ophthalmol. 2000;84:801–2.
47. Ercan I, Cakir BO, Sayin I, et al. Relationship between the superior attachment type of uncinate process and presence of agger nasi cell: a computer-assisted anatomic study. Otolaryngol Head Neck Surg. 2006;134:1010–4.
48. Soyka MB, Treumann T, Schlegel CT. The Agger Nasi cell and uncinate process, the keys to proper access to the nasolacrimal drainage system. Rhinology. 2010;48:364–7.
49. Wormald PJ. The agger nasi cell: the key to understanding the anatomy of the frontal recess. Otolaryngol Head Neck Surg. 2003;129:497–507.
50. Yoon JH, Kim KS, Jung DH, et al. Fontanelle and uncinate process in the lateral wall of the human nasal cavity. Laryngoscope. 2000;110:281–5.
51. Isobe M, Murakami G, Kataura A. Variations of the uncinate process of the lateral nasal wall with clinical implications. Clin Anat. 1998;11:295–303.
52. Whitnall SE. The relations of the lacrimal fossa to the ethmoid cells. Ophthalmic Rev. 1911;30:321–5.
53. Blaylock WK, Moor CA, Linberg JV. Anterior ethmoid anatomy facilitates dacryocystorhinostomy. Arch Ophthalmol. 1990; 108:1774–7.
54. Tsirbus A. Lacrimal fossa anatomy. Ophthalmology. 2006;113: 1475–6.
55. Simmen D, Jones N. In: Stuttgart, editor. Manual of endoscopic sinus surgery and its extended application. New York: Thieme; 2005. p. 66.
56. Setliff RC, Catalano PJ, Catalano LA, et al. An anatomic classification of the ethmoidal bulla. Otolaryngol Head Neck Surg. 2001; 125:598–602.
57. Iinuma T. History of infundibulum. Jibiinkoukatembo. 2001; 44:168–73. (Japanese)
58. Yanagisawa E, Weaver EM. Endoscopic view of the hiatus semilunaris superior and inferior. Ear Nose Throat J. 1996;75:460–2.
59. Unlü HH, Gövsa F, Mutlu C, et al. Anatomical guidelines for intranasal surgery of the lacrimal drainage system. Rhinology. 1997;35:11–5.
60. Rice DH. Management of the middle turbinate in endoscopic surgery. Oper Tech Otolaryngol Head Neck Surg. 1995;6:144–8.
61. Prasanna LC, Mamatha H. The location of maxillary sinus ostium and its clinical application. Indian J Otolaryngol Head Neck Surg. 2010;62:335–7.
62. Gaudino S, Di Lella GM, Piludu F, et al. CT and MRI diagnosis of silent sinus syndrome. Radiol Med. 2013;118:265–75.
63. Soparker CNS, Patrinely JR, Cuaycong MJ, et al. The silent sinus syndrome: a cause of spontaneous enophthalmos. Ophthalmology. 1994;101:772–8.
64. Ferri A, Ferri T, Sesenna E. Bilateral silent sinus syndrome: case report and surgical solution. J Oral Maxillofac Surg. 2012;70: e103–6.
65. Cobb AR, Murthy R, Cousin GC, et al. Silent sinus syndrome. Br J Oral Maxillofac Surg. 2012;50:e81–5.
66. Rose GE, Lund VJ. Clinical features and treatment of late enophthalmos after orbital decompression: a condition suggesting cause for idiopathic “imploding antrum” (silent sinus) syndrome. Ophthalmology. 2003;110:819–26.
67. Brandt MG, Wright ED. The silent sinus syndrome is a form of chronic maxillary atelectasis: a systemic review of all reported cases. Am J Rhinol. 2008;22:68–73.
68. Naik RM, Khemani S, Saleh HA. Frontal silent sinus syndrome. Otolaryngol Head Neck Surg. 2013;148:354–5.
69. Leone CR Jr, Piest KL, Newman RJ. Medial and lateral wall decompression for thyroid ophthalmopathy. Am J Ophthalmol. 1989;108:160–6.
70. Gupta T, Aggarwal A, Sahni D. Anatomical landmarks for locating the sphenoid ostium during endoscopic endonasal approach: a cadaveric study. Surg Radiol Anat. 2013;35:137–42.
71. Millar DA, Orlandi RR. The sphenoid sinus natural ostium is consistently medial to the superior turbinate. Am J Rhinol. 2006;20:180–1.

72. Deshazo RD. Syndromes of invasive fungal sinusitis. Med Mycol. 2009;47:S309–14.
73. Thurtell MJ, Chiu ALS, Goold LA, et al. Neuro-ophthalmology of invasive fungal sinusitis: 14 consecutive patients and a review of the literature. Clin Experiment Ophthalmol. 2013;41:567–76.
74. Duke-Elder S, MacFaul PA. Indirect orbital fractures associated with head injury. In: Duke-Elder S, editor. System of ophthalmology, vol XIV. Injury. Part 1. Mechanical injuries. London: Henry Kimpton Publisher; 1972. p. 265–8.
75. Guyon JJ, Brant-Zawadzki M, Seiff SR. CT demonstration of optic canal fractures. Am J Radiol. 1984;143:1031–4.
76. Yang QT, Zhang GH, Liu X, et al. The therapeutic efficacy of endoscopic optic nerve decompression and its effects on the prognosis of 96 cases of traumatic optic neuropathy. J Trauma. 2012;72:1350–5.
77. Ali MJ, Nayak JV, Vaezeafshar R, et al. Anatomic relationship of nasolacrimal duct and major lateral wall landmarks: cadaveric study with surgical implications. Int Forum Allergy Rhinol. 2014;4:684–8.
78. Gul A, Aslan K, Karli R, et al. A possible cause of nasolacrimal duct obstruction. Narrow angle between inferior turbinate and upper part of the medial wall of the maxillary sinus. Curr Eye Res. 2016;41:729–33.
79. Sieskiewicz A, Buczko K, Janica J, et al. Minimally invasive medial maxillectomy and the position of nasolacrimal duct: the CT study. Eur Arch Otorhinolaryngol. 2016 (Epub).
80. Osguthorpe JD, Hoang G. Nasolacrimal injuries: evaluation and management. Otolaryngol Clin N Am. 1991;24:59–78.
81. Demas PN, Sotereanos GC. Incidence of nasolacrimal injury and turbinectomy-associated atrophic rhinitis with Le Fort I osteotomies. J Craniomaxillofac Surg. 1989;17:116–8.
82. Serdahl CL, Berries CE, Chole RA. Nasolacrimal duct injury after endoscopic sinus surgery. Arch Ophthalmol. 1990;108:391–2.
83. Ali MJ, Murphy J, Wormald PJ, et al. Bony nasolacrimal dehiscence in functional endoscopic sinus surgery: radiological study and discussion of surgical implications. J Laryngol Otol. 2015;129:S35–40.

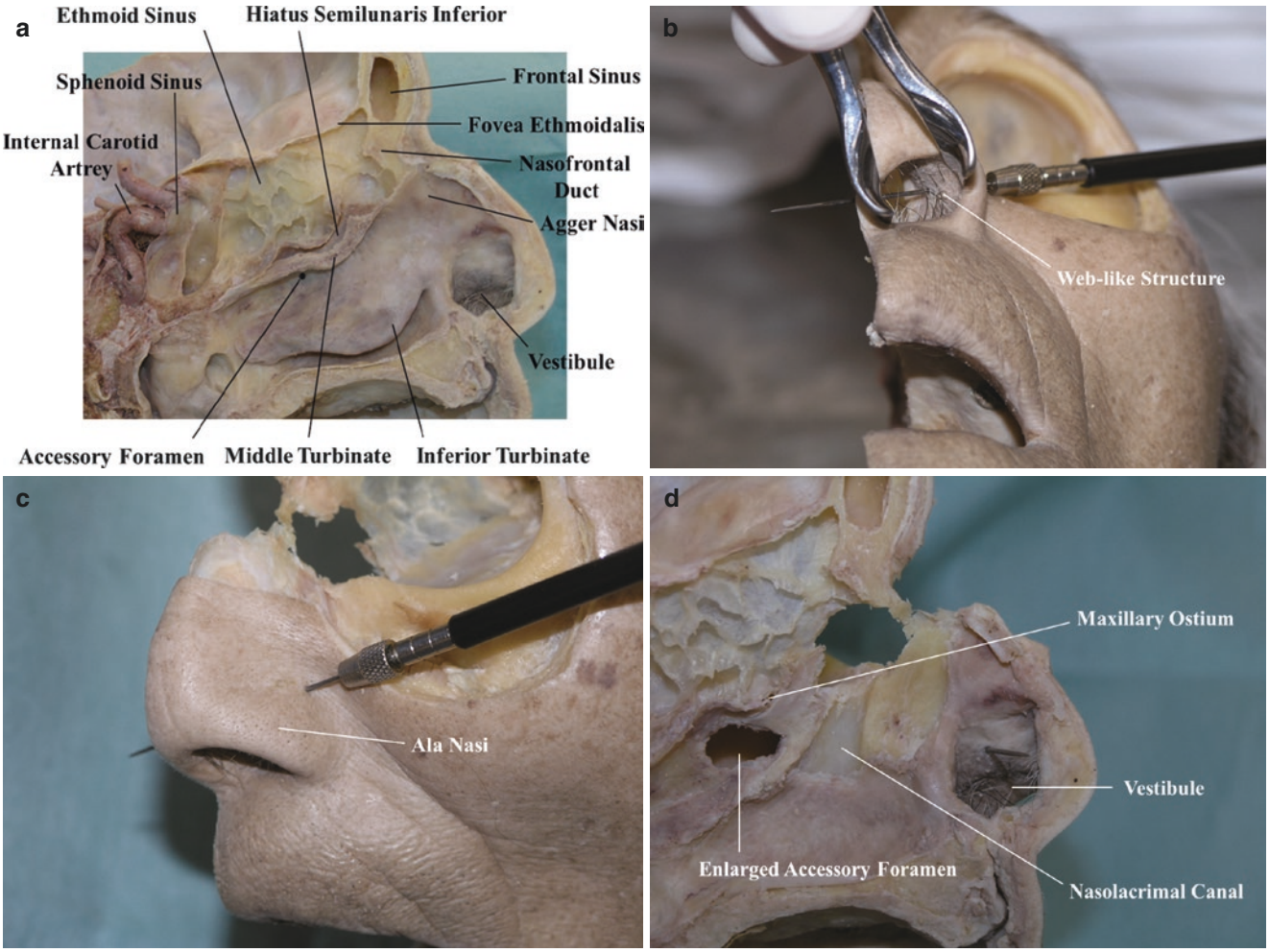


Fig. 5.1 (**a**) Anterior nasal space, lateral nasal space, and ethmoid and frontal sinuses. The middle turbinate is removed (cadaver, 89-year-old male). (**b**) Weblike structure seen from the inferior aspect (cadaver, 89-year-old male). (**c**) Pin piercing the base of the ala nasi (cadaver, 89-year-old male). (**d**) Pin emerged at the superior border of the nasal vestibule. The nasolacrimal canal is directed posteriorly (cadaver, 89-year-old male)

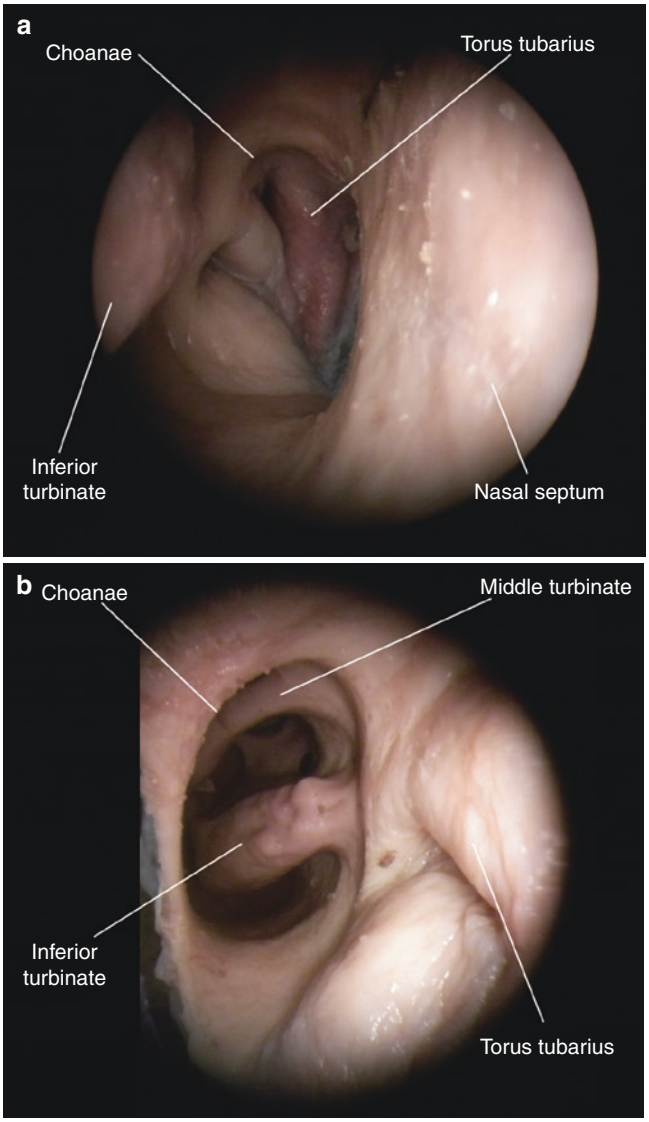


Fig. 5.2 (**a**) Appearance of the choanae seen from the front (cadaver, 97-year-old female). (**b**) Appearance of the choanae seen from the back (cadaver, 97-year-old female)

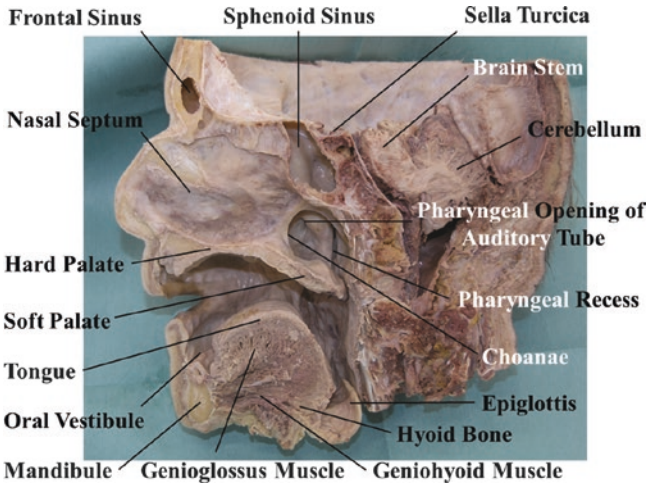


Fig. 5.3 Appearance of the facial half including the nasal septum (cadaver, 89-year-old male)

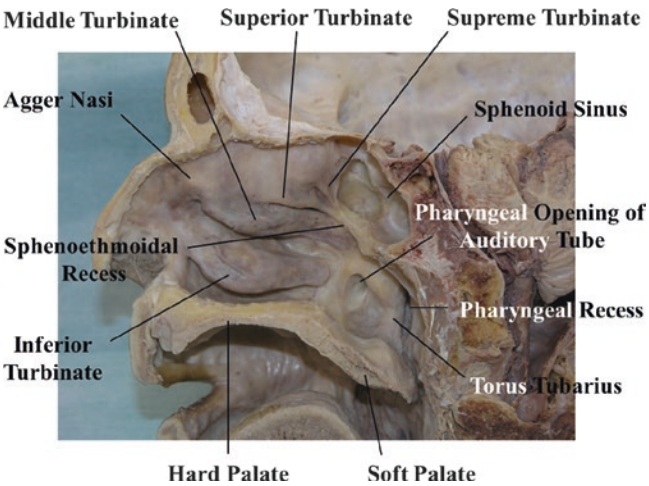


Fig. 5.4 Appearance of the lateral nasal wall with surrounding structures (cadaver, 89-year-old male)

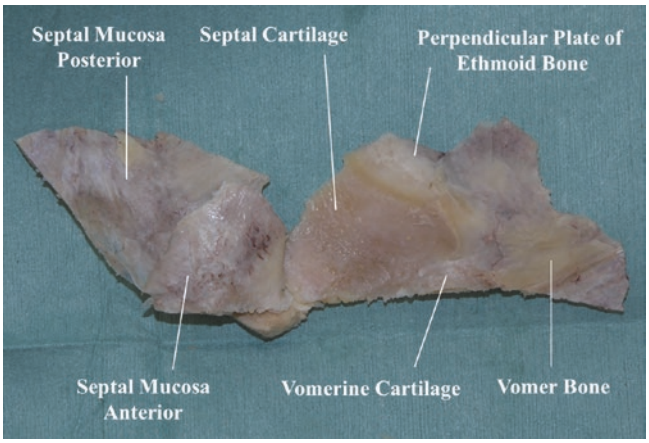


Fig. 5.5 Appearance of the nasal septum and mucosa. The septal mucosa has been placed inside out (cadaver, 89-year-old male)

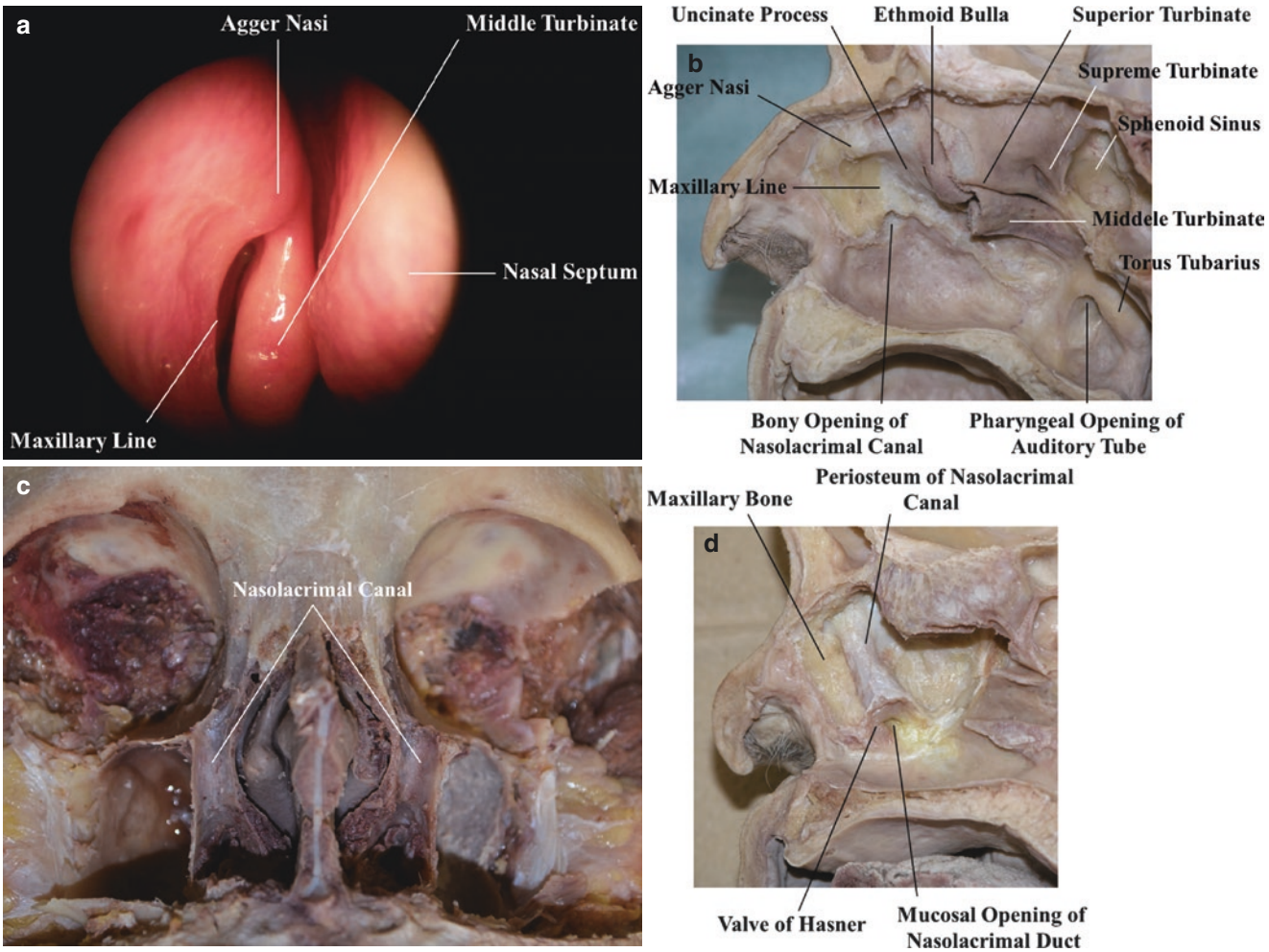


Fig. 5.6 (**a**) Maxillary line, agger nasi, and middle turbinate (34-year-old female). (**b**) Appearance of the lateral nasal wall. The inferior turbinate and half of the middle and superior turbinates are removed. The bony opening of the nasolacrimal canal is seen (cadaver, 89-year-old male). (**c**) The nasolacrimal canal courses almost parallel to the sagittal plane (cadaver, 70-year-old male). (**d**) Certain length of mucosal duct, termed the valve of Hasner, extends from the bony opening of the nasolacrimal canal (cadaver, 97-year-old female)

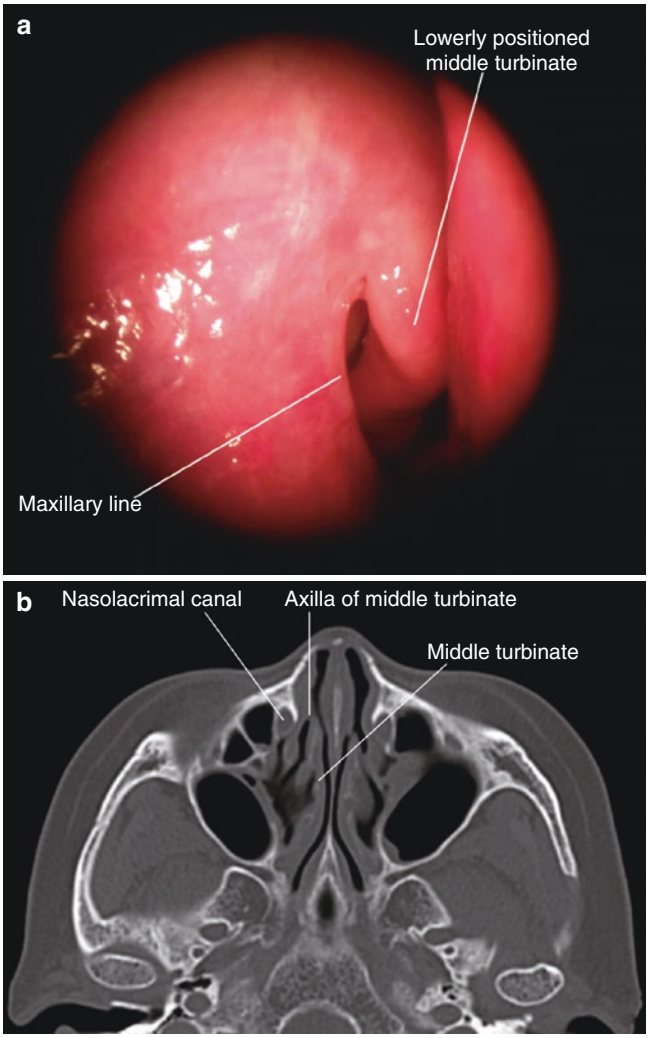


Fig. 5.7 (**a**, **b**) Relationship between the lacrimal sac and the middle turbinate is variable. These figures show high sac positions (61-year-old female)

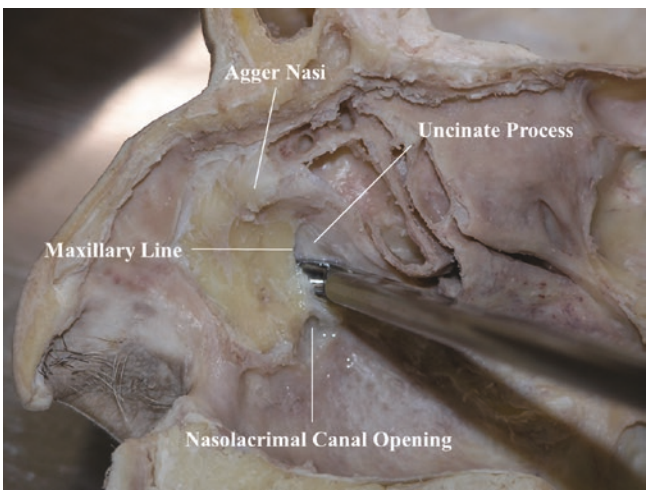


Fig. 5.8 Osteotomy during an endonasal dacryocystorhinostomy can be easily started at the lower portion of the lacrimal sac fossa, where the lacrimal bone constitutes the lacrimal sac fossa in the highest proportion and the frontal process of the maxilla is thinnest. For ease of understanding, the rongeur is inserted into the nasolacrimal canal (cadaver, 89-year-old male)

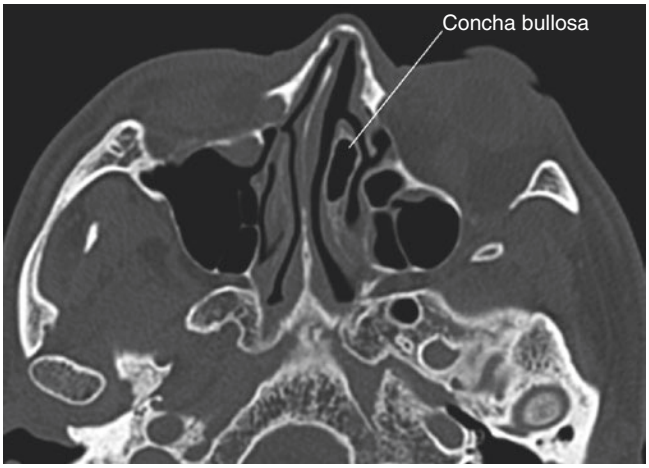


Fig. 5.9 Concha bullosa (43-year-old male)

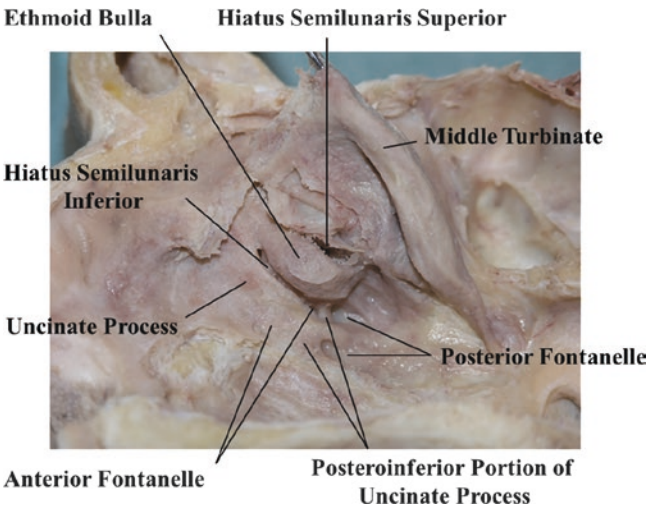


Fig. 5.10 Appearance of the middle meatus. This contains the uncinate process, hiatus semilunaris with the infundibulum, and ethmoid bulla and receives drainage from the frontal, anterior ethmoid, and maxillary sinuses. The posterior portion of the uncinate process divides the fontanelle into anterior and posterior parts (cadaver, 89-year-old male)

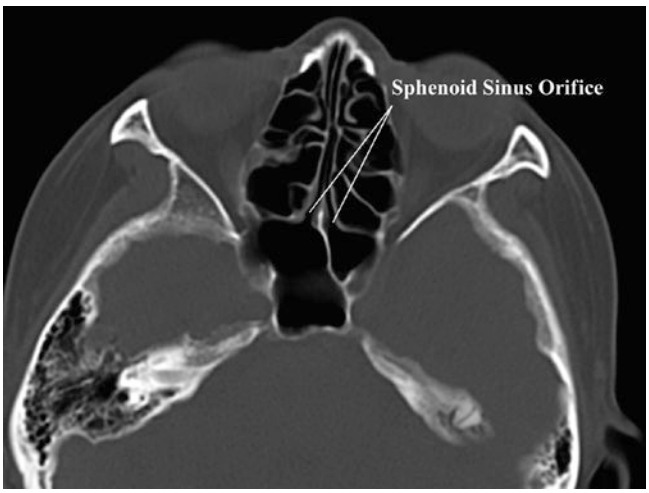


Fig. 5.11 Sphenoid sinus orifices (38-year-old female)

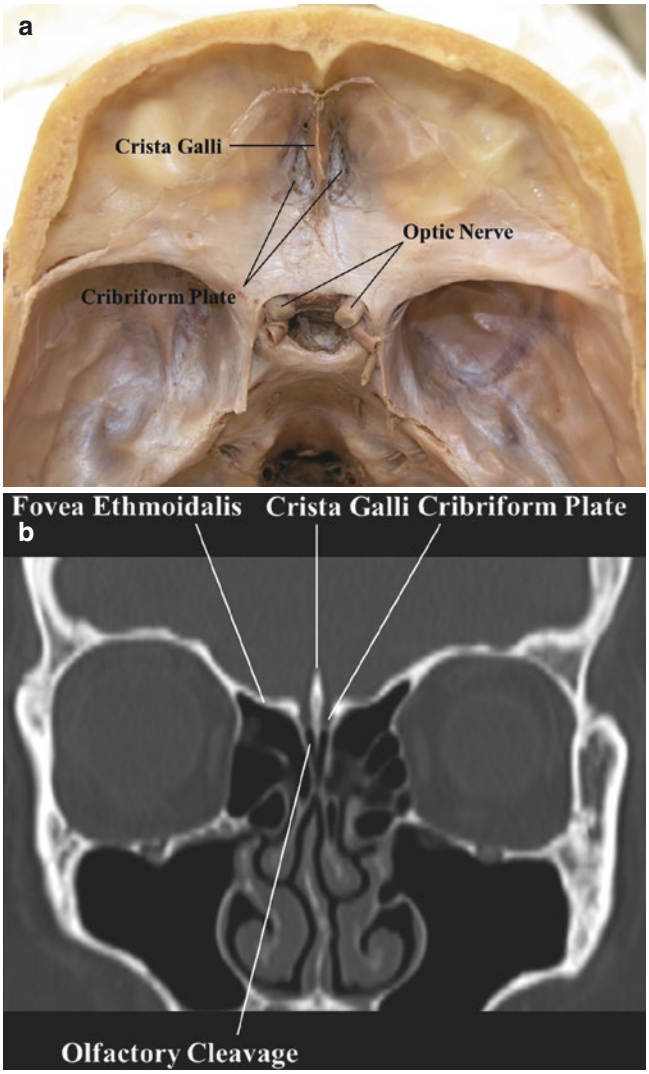


Fig. 5.12 (**a**) Appearance of the skull base with special features of the cribriform plate, crista galli, and optic nerve (cadaver, 81-year-old male). (**b**) Cribriform plate separates the nose from the anterior cranial fossa. The cribriform plates are often located lower than the fovea ethmoidalis (42-year-old male)

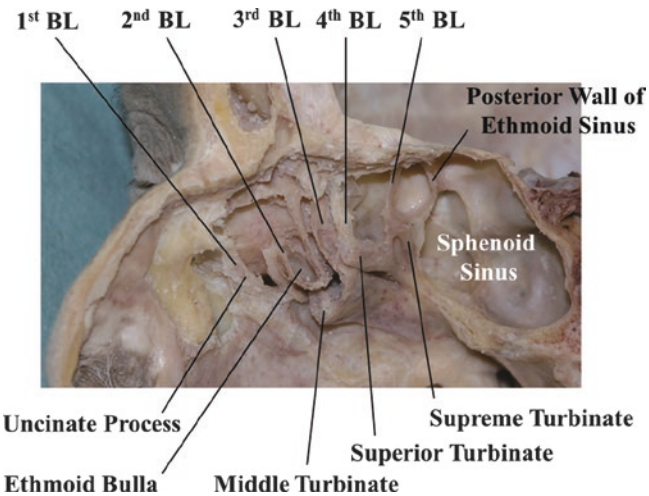


Fig. 5.13 Five basal lamellae of the ethmoid sinus. *BL* basal lamella (cadaver, 89-year-old male)

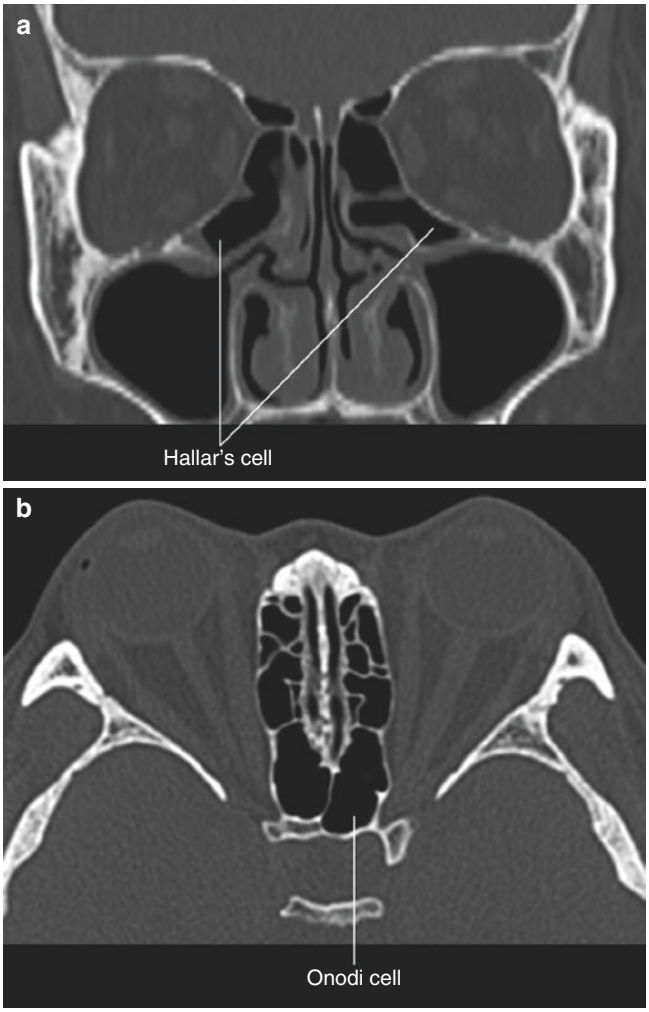


Fig. 5.14 (**a**) Haller cell (49-year-old male). (**b**) Onodi cell (52-year-old female)

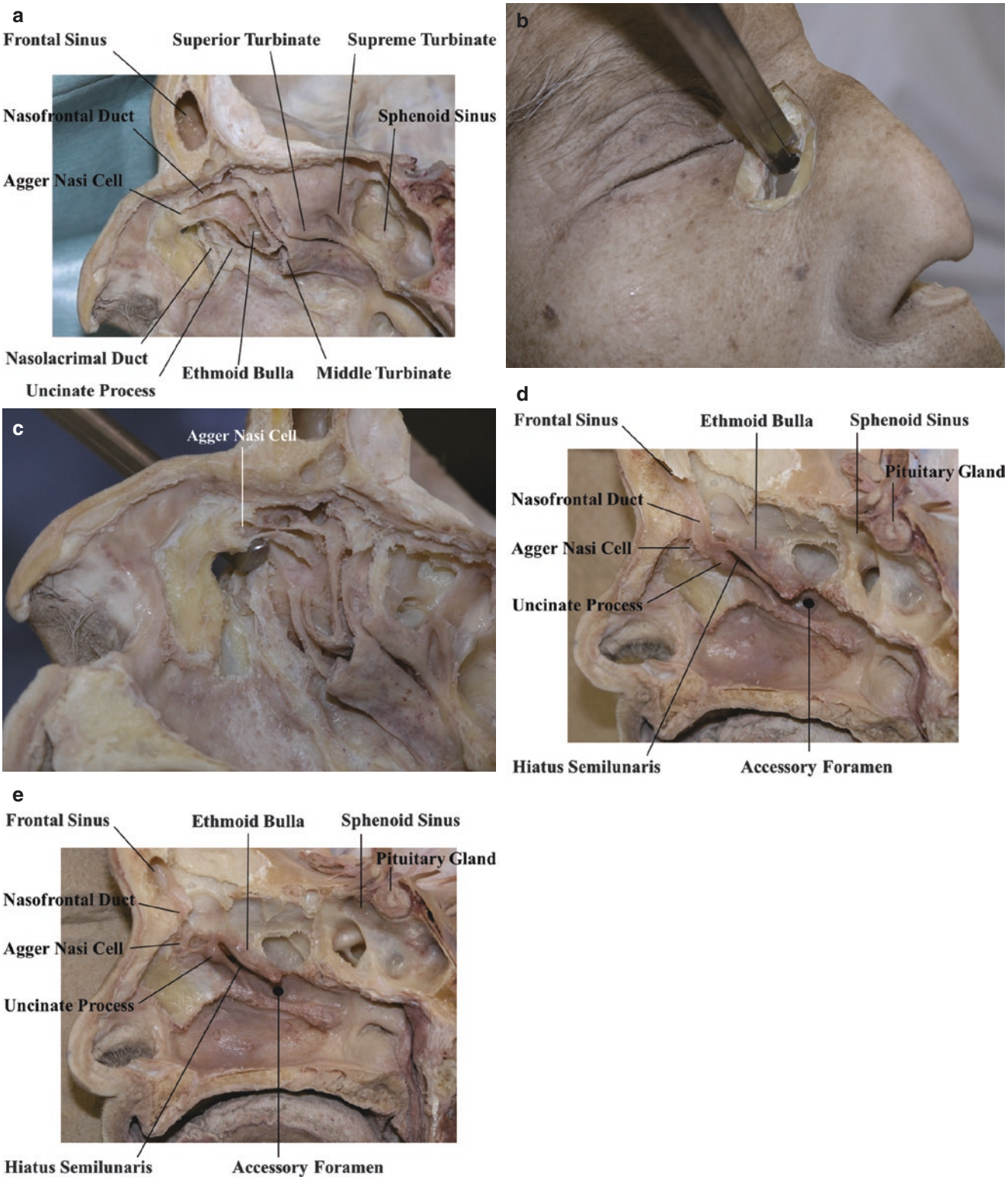


Fig. 5.15 (**a**) Agger nasi cell is a pneumatized part of the most anterior portion of the ethmoid air cell (cadaver, 89-year-old male). (**b**, **c**) When the axilla of the middle turbinate is located lower than the lacrimal sac fossa, the agger nasi cell must be removed during dacryocystorhinostomy (cadaver, 89-year-old male). (**d**) The agger nasi cell is situated in front of the nasofrontal duct. Accessory foramen is shown. The inferior and middle turbinates are removed (cadaver, 97-year-old female). (**e**) Removing the lower part of the nasolacrimal duct, the agger nasi cell is situated below and behind the frontonasal duct. The maxillary ostium is shown through the hiatus semilunaris (cadaver, 97-year-old female)

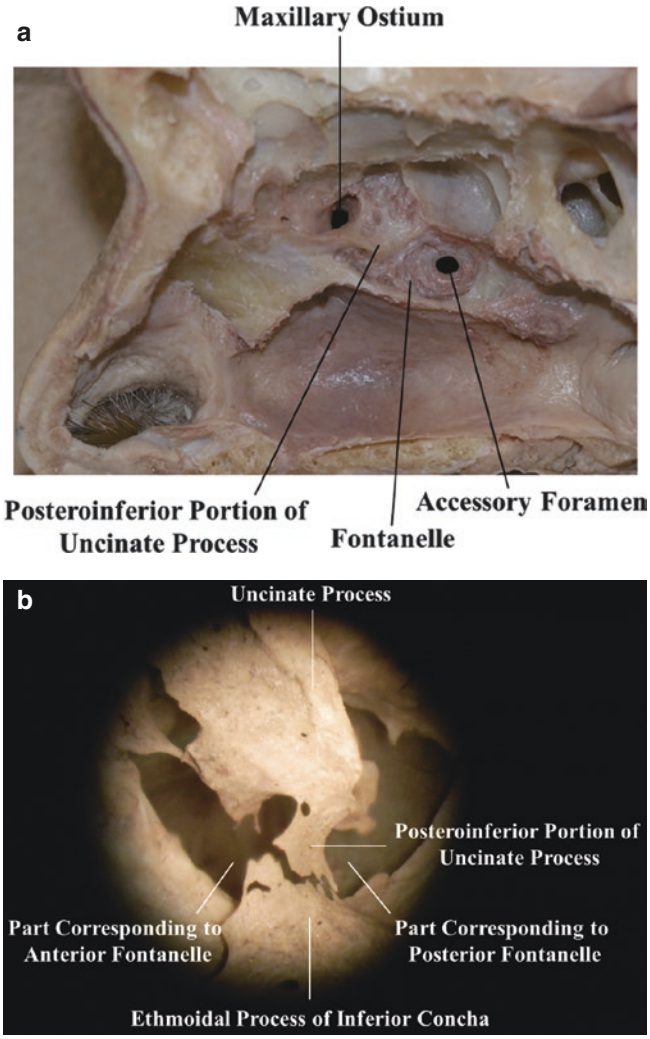


Fig. 5.16 (**a**) The uncinate hook is covered by the fontanelle and located too posteroinferiorly. This figure shows a posteroinferior portion of the uncinate process with upward bending with attachment to only the lower portion of the ethmoid bulla. Accessory foramen opens at the fontanelle. The maxillary ostium is shown in front of the posteroinferior portion of the uncinate process (97-year-old female). (**b**) The posteroinferior portion of the uncinate process comprises a plate of a cortical bone with no cells (dry skull of unknown nationality, sex, and age)

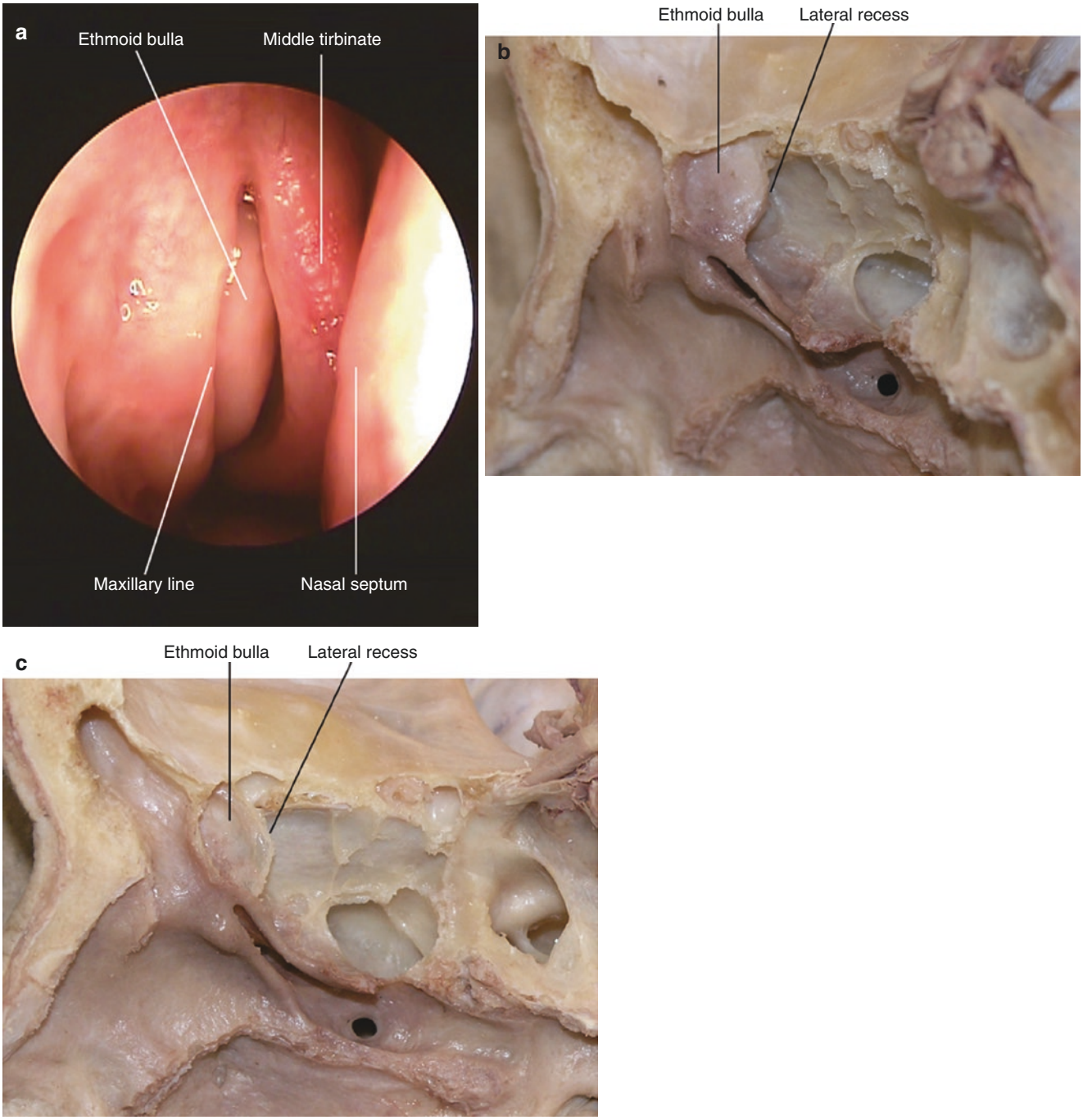


Fig. 5.17 (**a**) Ethmoid bulla occasionally bulges anteriorly (67-year-old female). (**b**) The lateral recess of the ethmoid bulla is a cavity in the posterolateral side facing the third basal lamella (cadaver, 97-year-old female). (**c**) The lateral recess of the ethmoid bulla. The medial aspect of the ethmoid bulla is removed (cadaver, 97-year-old female)

Evaluation of Epiphora

6

Sima Das

Epiphora or watering is one of the most common symptoms of any ocular pathology. Though most cases of watering are due to non-patency in the lacrimal outflow pathway, others like eyelid and adnexal disorders and corneal and ocular surface pathology can also manifest as watering. In this context, it is important to distinguish between the terms epiphora and pseudoepiphora or hyperlacrimation [1, 2]. True epiphora refers to watering due to obstruction in the lacrimal outflow pathway, while hyerlacrimation refers to excessive watering due to reflex irritation of the corneal and conjunctival surface as in cases of dry eye, corneal abrasion, corneal foreign body, etc. (Fig. 6.1a–f). It is also important to differentiate between anatomical and functional lacrimal pathway obstruction. Anatomical obstruction refers to any structural pathology in the lacrimal outflow pathway which hinders tear drainage. Conditions like punctal and canalicular stenosis and block, nasolacrimal duct obstruction (NLDO), etc. are the causes of anatomical obstruction. In functional dysfunctions, the lacrimal outflow pathway is anatomically patent, but there is a failure of lacrimal pump mechanisms. This could also be due to pathologies outside the lacrimal pathway like facial palsy, eyelid laxity, and ectropion. Hence, a detailed and comprehensive evaluation is needed to identify the cause of watering and initiate appropriate management. The goal of the evaluation is to differentiate true epiphora from hyperlacrimation, to differentiate obstructive cause of epiphora from non-obstructive cause, and to localize the site of pathology in cases of obstructive epiphora. The evaluation can be divided into history taking, local examination, lacrimal system vital signs, ancillary investigations, and nasal evaluation.

History

A detailed history will provide a clue to the appropriate diagnosis in most cases of watering. This is especially important in children where tests like irrigation and probing, which are usual part of evaluation in adult patients, may not be possible. History should be taken from the patient or the primary caregiver in case of a child and should include details about the onset, frequency, type, intermittency, laterality of the symptoms, and previous interventions. Epiphora due to congenital nasolacrimal duct obstruction (CNLDO) will be present since shortly after birth. CNLDO is usually caused by imperforate valve of Hasner, and the symptom of watering is mostly constant in these patients [3]. Epiphora which starts a few months after birth may not be due to CNLDO and warrants further evaluation to determine the cause. Epiphora due to complete nasolacrimal duct obstruction (NLDO) is usually continuous with associated intermittent mucoid or purulent discharge. History of intermittency with exacerbation during episodes of upper respiratory tract infection points toward a partial obstruction or nasolacrimal duct stenosis. History of bluish swelling in lacrimal sac area present since early days of life is suggestive of dacryocele and an underlying complex CNLDO. History suggestive of acute dacryocystitis in a child with CNLDO should also be elicited as it might warrant an early probing. Associated history of systemic conditions like craniofacial syndromes like Down and Treacher Collins syndrome should also be noted as these syndromes can have associated bilateral NLDO and more likely to have complex NLDO. Symptoms of associated photophobia should raise suspicion of associated corneal or ocular surface disorders or eyelid conditions like entropion or lid margin keratinization as seen in cases of Steven Johnson syndrome. Congenital glaucoma is a vision-threatening condition and can manifest initially with watering and photophobia [4]. Epiphora due to anatomical obstruction in the nasolacrimal duct or canaliculi is more likely to be unilateral, while bilateral watering especially if associated with history of itching and seasonal exacerbation more likely points toward a reflex cause of epiphora like allergic conjunctivitis.

History of trauma to the ocular adnexa or nose should be elicited as injury to the punctum or canaliculus can give rise to watering and naso-orbito-ethmoidal fracture can cause acquired NLDO [5].

S. Das, M.S.
Ophthalmic Plastics Surgery, Schroff Eye Hospital, Delhi, India
e-mail: contactsima@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_6

History of previous medical therapies should also be elicited, especially the use of topical antiglaucoma and antiviral medications as these can cause punctal stenosis and scarring [6]. Occasionally a history of antineoplastic drugs like paclitaxel and 5-fluorouracil may similarly give a clue toward possible punctal and canalicular stenosis. History of nasal symptoms and previous nasal surgery like sinus surgery can provide a clue to the cause of watering. Any history of previous surgical intervention for epiphora like previous sac surgery, probing or incision, and drainage for lacrimal abscess should be elicited as it has a bearing on the subsequent management A general overview and evaluation details are mentioned in tables 6.1– 6.3.

External Examination

External examination should begin with inspection of the face and periorbital region (Figs. 6.2a–d and 6.3a–f). Position of the eyelids, punctum, gross nasal deformity, and facial symmetry should be looked for. Presence of any swelling or mass in the lacrimal sac area should be noted.

Severe entropion and trichiasis with lashes rubbing on the ocular surface can cause reflex watering. Ectropion due to facial palsy can affect the lacrimal pump mechanism and thus cause epiphora. Ectropion and eyelid laxity can also cause epiphora by causing lagophthalmos and displacement of the punctum from the tear lake thereby decreasing the tear outflow. Horizontal laxity of the eyelid can be checked by doing the pinch test where the lower eyelid is pinched at the center and pulled away from the globe [1, 2]. More than 6 mm distance between the pinched eyelid and cornea indicates a lax eyelid which can cause epiphora due to disturbed tear flow. The tone of the orbicularis muscle is tested by performing the snapback test where the lower eyelid is pulled away from the globe and released, and the speed with which the eyelid goes back to its normal position is assessed. When the orbicularis tone is good, the eyelid snaps back immediately and quickly to its normal position. In cases of decreased orbicularis tone as in cases of facial palsy, the eyelid moves slowly or sometimes after a blink to its actual position. Such cases can have associated weakness of the lacrimal pump function and can manifest as epiphora. Poor orbicularis tone can also cause watering by disturbing the tear flow along the lower eyelid margin.

Any eyelid retraction or lagophthalmos as seen in cases of thyroid eye disease and facial palsy can cause reflex hypersecretion due to corneal or conjunctival exposure [7, 8]. In addition, in thyroid eye disease, the tear outflow facility is also disturbed due to a caruncular swelling or due to disturbance of the canalicular function.

Anterior insertion of the medial canthal tendon is seen in patients with Centurion syndrome [9]. This clinical condition is usually detected in the older children and has a spectrum of facial and ocular findings including steep nasal bridge, anterior insertion of medial canthal tendon, punctal ectropion, punctal stenosis, lagophthalmos, etc. Presentation is usually with an unexplained epiphora. Treatment is required in symptomatic patients and is usually done by a medial canthoplasty with or without punctoplasty.

Inspection of the medial canthal area can also reveal swelling below the canthus suggestive of a lacrimal mucocele [1, 2]. Mucocele of the sac rarely extends above the level of medial canthal tendon, and extension of the swelling above the level of canthus might indicate a malignant sac swelling or mass lesion arising from the surrounding structures like cranial cavity, nasal cavity, or ethmoid sinus. Swelling arising from ethmoid sinus or nasal cavity can cause secondary NLDO and can extend to the medial orbit causing unilateral telecanthus which if present points to an underlying sinonasal pathology. Presence of any skin scar from previous surgery or fistulae in the medial canthal area should be noted. Congenital lacrimal fistulae are located inferolateral to the canthus and are usually single [10]. Acquired lacrimal fistulae following trauma or a granulomatous sac infection can be situated above or below the canthus and can be multiple.

Palpation of the lacrimal sac area might reveal the presence of mucocele or occasionally lacrimal sac masses (Fig. 6.4a and b). Pressure over the lacrimal sac can cause mucopurulent material to regurgitate through the punctum confirming a diagnosis of chronic dacryocystitis or lacrimal mucocele [1, 2]. If pressure regurgitation over the lacrimal sac (ROPLAS) is positive, note is made of the type of the regurgitated material (watery, mucoid, mucopurulent, blood stained) and whether it is coming from the same or opposite punctum. To avoid false negative results, it is important to apply pressure over the lacrimal sac in the lacrimal fossa in a slightly backward and upward direction. A positive regurgitation test is a confirmatory test for chronic dacryocystitis with NLDO, and no further diagnostic testing is usually necessary in these cases. Interpretation of ROPLAS test results is given in Table 6.1.

Table 6.1 Interpretation of ROPLAS findings

ROPLAS test finding	Interpretation
• Clear, mucoid, or mucopurulent regurgitation on pressure over the sac	Nasolacrimal duct obstruction
• Regurgitation test positive with blood-tinged fluid	Rule out dacryolith or lacrimal sac tumor
• No regurgitation of fluid through the punctum while pressing over a distended sac and the sac remains dilated	Encysted mucocele
• No regurgitation of fluid through the punctum while pressing over a distended sac but the sac empties into the nose	Atonic sac or internal fistulae

A detailed slit-lamp evaluation is also a must in cases of watering (Fig. 6.5a–c). Size, site, and position of the punctum should be noted to rule out any stenosis or agenesis of the punctum. The normal position of the punctum is at the summit of the lacrimal papilla facing the tear lake. Eversion of the punctum out of the tear lake can occur due to eyelid laxity or loss of eyelid tone as in cases of facial palsy. A red, swollen, pouting punctum can be a sign of canaliculitis. The diagnosis of canaliculitis can additionally be confirmed by expressing out concretions through the punctum by applying pressure with cotton bud. Blepharitis and meibomitis can also be detected on slit-lamp examination which can cause watering due to disturbance of the tear film layer. Blepharitis can also be associated with marginal keratitis and can cause reflex watering. Watering in cases of allergic conjunctivitis will have associated conjunctival papillae and follicles on slit-lamp examination. Presence of punctate corneal staining due to corneal exposure and xerosis can cause reflex watering in patients with lagophthalmos. Height of the marginal tear meniscus is noted by staining the tear film with fluorescein dye (Fig. 6.6). Increase tear meniscus height is seen in cases of obstructive and functional epiphora, and a decreased meniscus height if associated with other signs like corneal filaments, ocular surface inflammation, and punctate staining and low Schirmer's values can indicate a dry eye disease.

Diagnostic Clinical Tests

Diagnostic tests in cases of watery eyes include both excretory and secretory tests [2]. The excretory tests check for the anatomical patency and function of the lacrimal outflow pathway, whereas the secretory tests check for any evidence of dry eye which can cause reflex hypersecretion. The anatomical patency of the lacrimal outflow pathway is tested by lacrimal irrigation, diagnostic probing, and dacryocystography.

Lacrimal Irrigation

Lacrimal irrigation is an anatomical test which checks for the patency of the nasolacrimal duct (NLD) [11]. This is not a physiological test as passage of the fluid through the NLD in case of irrigation occurs at a higher hydrostatic pressure than in normal physiological conditions. A stenosis of the NLD might hinder the outflow of tears in normal physiological condition and can cause epiphora, while the system might still seem patent on irrigation as fluid is pushed at a higher hydrostatic pressure during irrigation which might be able to overcome the area of stenosis. On contrary, in cases of atonic sac, there is a dysfunction of the pump mechanism of the lacrimal sac, and although the irrigation is patent freely, these patients usually complain of epiphora. Hence the results of the lacrimal irrigation must always be interpreted in conjunction with clinical evaluation and physiological tests.

Following are the steps for performing lacrimal irrigation (Fig. 6.7a–f):

- The conjunctiva is anesthetized with 2% paracaine eye drops. Lacrimal irrigation can be performed with the patient reclining or lying down position. Appropriate sized lacrimal cannula is selected for doing the irrigation. For adult patients, a 15° smoothly curved cannula or a straight cannula of 24 G or 25 G size fitted to two syringes filled with sterile water or normal saline is appropriate. It is important to know that straight cannulas are better and less traumatic than any curved ones.
- Diagnostic irrigation is preferably done through the upper punctum as it technically aids in intrasac irrigation.
- Patient is advised to look down, and the medial eyelid is gently pulled up (for upper lid) and down (for lower lid) to evert the punctum. The upper punctum is dilated using a Nettleship punctum dilator. The lacrimal cannula attached to the syringe is inserted into the punctum vertically and then horizontally to reach the horizontal canaliculus. A gentle lateral traction is maintained on the eyelid while inserting the cannula to straighten the canaliculus. The cannula is advanced into the horizontal canaliculus, and a small amount of fluid is gently pushed slowly (intracanalicular irrigation). This is primarily to dilate the incoming lacrimal pathway and thus aids in avoiding inadvertent canalicular wall touch. The cannula is advanced into the sac and irrigation is performed. Note is made whether fluid passes to the nasal cavity immediately, after a delay, or if there is regurgitation of fluid from the same or opposite punctum. In case of fluid regurgitation, note is made of the type of the fluid regurgitating and associated swelling of the sac. In case of obstruction in the upper canaliculus or punctum, irrigation is repeated through the lower punctum. If any stenosis is noted in the canaliculus while doing irrigation, attempt is made to gently advance and bypass the cannula beyond the area of stenosis into the lacrimal sac before irrigation (intrasac irrigation). No attempts should be made to overcome any stenosis forcefully. Any resistance to passage of fluid while performing irrigation along with swelling in the medial canthal area and patient reporting severe pain indicates a possible false passage formation.

Interpretation of Lacrimal Irrigation

Interpretation of lacrimal irrigation should be carried out in conjunction with diagnostic probing and other tests. Conclusions about the anatomical patency of lacrimal pathway at various levels can be arrived at based on irrigation findings which are listed in Table 6.2.

Table 6.2 Interpretation of lacrimal irrigation findings

Irrigation finding	Interpretation
• Regurgitation of clear fluid from the opposite punctum	Indicates an obstruction in the common canaliculi, lacrimal sac, or nasolacrimal duct. Further diagnostic probing is needed to differentiate common canalicular block from more distal obstruction
• Mucoid or mucopurulent regurgitation from the opposite punctum after some delay with dilatation of the sac	Nasolacrimal duct obstruction
• Immediate regurgitation of clear fluid through same punctum while performing irrigation through one of the punctum	Individual canalicular block
• Regurgitation of mucoid or mucopurulent material through lower punctum only while doing irrigation from lower punctum with a hard stop	Nasolacrimal duct block associated with upper canalicular block
• Patent irrigation with sac dilatation and residual stasis in patient complaining of epiphora	Atonic sac
• Patent irrigation with regurgitation of some clear or mucoid fluid	Partial NLDO

Diagnostic Probing

Probing is indicated if irrigation reveals an obstruction in the lacrimal outflow system. It is performed to confirm the site of the blockage (Fig. 6.8a–c). Probing is done using the Bowman's lacrimal probe. After installing topical anesthetic, one of the puncta is dilated, and appropriate sized lacrimal probe is passed following the direction of the canaliculi and advanced gently till it reaches a stop. The interpretations of probing findings are described as either hard stop or soft stop.

Hard Stop (Fig. 6.9a)

When the probe is advanced into the sac to touch the medial wall of the sac and underlying bone, a hard stop is encountered. Hard stop indicates that the probe has gone beyond the common canaliculus into the lumen of the sac, and presence of a hard stop on probing in patients whose irrigation finding reveals clear fluid regurgitation from opposite punctum rules out the diagnosis of common canalicular block and confirms diagnosis of NLD block.

Soft Stop (Fig. 6.9b and c)

In cases of common canalicular or individual canalicular block, a soft stop is encountered. Here the probe stops at site of the blockage near the canaliculus and presses the lateral wall of the sac giving a spongy feel which is known as soft stop. In addition to soft stop, movement of the medial canthus is also noted while performing probing. In canalicular block, the probe pushes the soft tissue of the canaliculus medially toward the sac which causes the medial canthus to move, whereas in cases of hard stop, the probe enters the lumen of the sac, and hence no movement of the canthus is noted. In case of canalicular block, the length of the probe which can be passed through the punctum is measured as it helps in deciding the surgical management [12, 13].

While performing probing, it is important to give a gentle lateral traction on the eyelid to straighten the canaliculus and make the insertion of the canaliculus to the sac as perpendicular as possible. A false soft stop can sometimes be felt if there is a kink at the junction of sac and common canaliculus, and the probe instead of passing through common canalicular opening pushes the roof of the canaliculus against the lateral wall of sac giving a false spongy feel.

Fluorescein Dye Disappearance Test (Fig. 6.6)

Fluorescence dye disappearance test is a physiological test for checking the function of the lacrimal outflow pathway with a high specificity of 94.8% and positive predictive value of 93.5% [14, 15]. It is a noninvasive test and is extremely useful in children with epiphora, who are not suitable for other diagnostic office procedures like irrigation and probing. A positive test indicates dysfunction in the lacrimal outflow pathway. However, this test cannot differentiate a functional from anatomical obstruction and cannot pinpoint the site of the block in cases of anatomical obstruction. This is a good screening test, and patients with a dye retention need further evaluation with other tests like irrigation and probing.

A drop of 2% fluorescein is placed in the non-anesthetized conjunctival cul-de-sac inferiorly, and after 5 min residual fluorescein is looked for in the tear film using a cobalt blue filter. The tear film should not be wiped or the eye should not be rubbed during this period. Normally, the fluorescein should drain into the nose within 5 min; any persistence of fluorescein beyond this period indicates a possible obstruction in the outflow pathway. The height of the stained tear film can also be measured using the slit lamp or scale, and results of the test are graded on scale from 0 to 3, grades 0 and 1 indicating no or a very thin fluorescein marginal tear strip and a negative test and grades 2 and 3 a positive test. In cases of large mucocele or lacrimal sac diverticula, there can be pooling of the dye into the sac, and fluorescein dye test can give false negative result giving the impression of a

Table 6.3 A comprehensive epiphora evaluation sheet in Professor PJ Wormald's practice at Adelaide, Australia

EPIPHORA EVALUATION FORM – First Visit Patient Label

Date:

Chief complaint:

HISTORY

Side	Right Left Both	**Past Ocular History**	
Duration of Symptoms	____ Month(s)		☐ cicatricial disease ☐ eyelid trauma ☐ dacryocystitis
Associated Symptoms	☐ discharge ☐ stickiness or crusting ☐ blurred vision ☐ skin irritation/excoriation	**Past Medical History**	
	Symptoms of Chronic Rhinosinusitis: ☐ facial pain/pressure/fullness ☐ nasal obstruction/blockage ☐ nasal or postnasal discharge ☐ hyposmia/anosmia		☐ facial/nasal trauma ☐ chronic sinus/nasal disease ☐ sinus/nasal surgery
Precipitating Factors	☐ time of day (AM/PM) ☐ reading/computer/tv ☐ cold or wind ☐ other _____	**Medications** **Allergies**	☐ drops _____ ☐ chemotherapy _____ ☐ anticoagulants _____ ☐ antiplatelets _____

Symptoms Score

(Never Rarely Sometimes Frequently Always)

1. Does your watery eye bother you?	0	1	2	3	4
2. Does it interfere with:					
a. Sight	0	1	2	3	4
b. Driving	0	1	2	3	4
c. Reading	0	1	2	3	4
d. Mood	0	1	2	3	4
e. Work	0	1	2	3	4
3. Does your watery eye become embarrassing?	0	1	2	3	4

Total ____

Severity Score

	RIGHT (Circle One)	LEFT (Circle One)
Never	0	0
Occasional tearing	1	1
Dabbing 2-4 times a day	2	2
Dabbing 5-10 times a day	3	3
Dabbing more than 10 times a day	4	4
Constant tear flow	5	5

EXAMINATION

Parameter	Right Eye	Left Eye
Tear Mensicus Height	☐ ≤ 1 mm ☐ > 1 mm	☐ ≤ 1 mm ☐ > 1 mm
Schirmer's Test I* *(complete if necessary) Schirmer's Test II** **(complete if Schirmer's I< 10 mm)	☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm ☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm	☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm ☐< 10 mm ☐ 10 – 30 mm ☐> 30 mm
Tear Film Break Up Time	☐ ≤ 10 seconds ☐ > 10 seconds	☐ ≤ 10 seconds ☐ > 10 seconds
Lid Margin Disease(ant/post blepharitis)	☐ present	☐ present
Trichiasis/Distichiasis	☐ present	☐ present
ConjunctivalChalasis	☐ medial ☐ occluding punctum	☐ medial ☐ occluding punctum
Cornea: Punctate Erosions Ulcer Other:	 ☐ present ☐ present	 ☐ present ☐ present
Mucocele	☐ refluxable ☐ non-refluxable	☐ refluxable ☐ non-refluxable

(continued)

Table 6.3 (continued)

EXAMINATION (cont'd) Page 1

Parameter	Right Eye	Left Eye
Snap Back Test 1 – 2-3 sec 3 - >5 sec 2 – 4-5 sec 4 – remains ectropic	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
Distraction Test	____ mm	____ mm
MCT Laxity 1 – 2 mm 3 - >3 mm 2 – 3 mm 4 – remains despite blink	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
LCT Laxity 1 – 2-4 mm 3 - >6 mm 2 – 4-6 mm 4 – remains despite blink	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4
Punctal Position	☐ apposed ☐ upward ☐ everted	☐ apposed ☐ upward ☐ everted

OTHER FINDINGS

LACRIMAL SYRINGING

☐ hard stop ☐ soft stop at: ____ mm partial ☐ complete ☐ ☐ thick reflux	☐ hard stop ☐ soft stop at: ____ mm partial ☐ complete ☐ ☐ thick reflux

NASAL ENDOSCOPY

☐ narrow ☐ septal deviation ☐ polyps ☐ rhinosinusitis (purulence) ☐ other:	☐ narrow ☐ septal deviation ☐ polyps ☐ rhinosinusitis (purulence) ☐ other:

IMPRESSION:

INVESTIGATIONS:

☐ dacryocystogram
☐ lacrimal scintigraphy
☐ CT
☐ Other:

PLAN:

Name and Signature Date

patent system. This should be kept in mind while interpreting the test result in cases with hugely distended sac. Similarly functional endoscopic dye test (FEDT) is performed following a dacryocystorhinostomy to assess the anatomical and functional clearance of the dye using an endoscope.

Imaging of the Lacrimal System

Radiological investigations for evaluation of the lacrimal system are rarely indicated in selected cases where other anatomical and physiological tests cannot provide a conclusive diagnosis (Fig. 6.10a–f). Imaging of the lacrimal system

includes dacryocystography (DCG), nuclear lacrimal scintigraphy, and CT-DCG and MR-DCG scan [16]. Dacryocystography is a radiological test where radiopaque dye is injected through the lacrimal punctum, and the passage of dye through the canaliculi, sac, and NLD is captured on images [16, 17]. It outlines the lacrimal outflow system, and the area of blockage can be picked up on the images. DCG is indicated in patients with failed lacrimal surgery to determine the extent of the sac remnant and in patients with suspected lacrimal sac diverticula, dacryoliths, or lacrimal sac tumors. While DCG is an anatomical tests and is performed to visualize the site of the obstruction, scintigraphy is a physiological test and is useful in determining the site of delay in the tear outflow in patients with a functional epiphora [18]. CT-DCG and MR-DCG are structural investigations and are mainly indicated to rule out and any secondary causes of obstruction of the sac or NLD like tumor, trauma, sinus disease, etc [16].

Nasal Endoscopy

Examination of the nasal cavity and nasal endoscopy is an important part of evaluation of any patient with lacrimal outflow pathway obstruction [19–21]. Anterior rhinoscopy with nasal speculum might not be able to provide a complete information about any underlying nasal pathology, and an endoscopic evaluation is a must to diagnose pathologies if any. Nasal endoscopy can detect conditions like deviated nasal septum, hypertrophied turbinate, or any anatomical abnormality which might be having a bearing on the surgical decision making. Tumors and granulomatous infection and inflammations of the nasal cavity can cause nasolacrimal duct obstruction which can be detected by nasal endoscopy. It is of utmost value in assessing the etiology of failed DCRs. Endoscopic nasal examination is also essential in postoperative care following a dacryocystorhinostomy (DCR) to look for the site and status of the ostium, internal common opening movements, and functional endoscopic dye test. The details of nasal endoscopy will be discussed in the subsequent chapters.

Secretory Tests

Secretory tests check for any evidence of dry eye or to rule out any reflex cause of watering. Schirmer's test, tear film breakup time, and rose bengal staining are the commonly performed secretory tests. These tests provide information about the quantity of tear production and quality of precorneal tear film and are part of the diagnostic workup for patients with suspected dry eye disease as the cause of watering. Schirmer's tests are commonly performed office test for dry eye evaluation. In Schirmer's I test, a Whatman filter paper of 35 mm × 5 mm dimension is folded 5 mm from the tip and placed at the inferior conjunctival fornix laterally, and the amount of wetting of the filter paper strip is noted. This checks for both basal and reflex secretion from the main and accessory lacrimal glands. The same test performed after anesthetizing the conjunctiva measures only the basal secretion from the accessory lacrimal glands. Schirmer's II test measures only reflex secretion and is performed by placing the filter paper strip in the anesthetized conjunctiva and stimulating secretion from the main lacrimal gland by placing a cotton applicator on nasal mucosa which stimulates the trigeminal nerve. Tear film breakup time is a function of the mucin layer of tear film. Normal breakup time is 10–15 s, and values less than 10 s indicate a mucin deficiency dry eye disease.

Updates (2015–2016)

Evaluation of epiphora, especially in children, involves doing a simple fluorescein dye disappearance test (FDDT). Though dye disappearance test is used widely in clinical practice, the sensitivity and specificity of this test have not been studied in detail. The sensitivity and specificity of dye disappearance test at 2 and 5 min, especially in adults, have been studied by Kashkouli et al. [14] They found that a positive 5 min FDDT indicates a higher chance of nasolacrimal duct obstruction than 2 min FDDT. Also a negative 2 min FDDT predicts a higher chance of normal lacrimal system. Hence the longer the duration of FDDT, higher the specificity and lower the sensitivity. FDDT can also be used as a less invasive approach for evaluation of the anatomical success of dacryocystorhinostomy procedure [22].

Anatomy and pathology of the lacrimal drainage system has been studied using advance techniques in various investigative modalities like MR-DCG and thermography [23, 24]. These findings have helped in better understanding of the pathophysiology of the lacrimal drainage pathway disorders and thus help decide an appropriate management.

Fourier domain anterior segment OCT (FD-OCT) and spectral domain anterior segment OCT have been used to determine the diameter of the punctum and height of the canaliculus [25–27]. This imaging modality can be used for monitoring the effect of topical medications, punctal surgery, and ocular surface disease on the punctal morphology. A scoring system of the punctal size can also be devised from these studies which may help in correlating the punctal size and shape with epiphora symptoms. The maximum measured vertical canalicular dimension is this study has been found to be much less than the 2 mm measurement which is usually reported. This may have implications for punctal plugs.

Unusual causes of epiphora have been described. Isolated maxillary sinus aspergillosis presented as unilateral epiphora with ipsilateral facial pain [28]. A blood-stained epiphora was reported years after an orbital floor fracture and was caused by erosion of the NLD by the displaced implant in an anticoagulated patient [29].

Chemotherapy-induced epiphora is widely known to occur following docetaxel, paclitaxel, and 5-fluorouracil. However there are others which are being increasingly implicated and include imatinib, capecitabine, mitomycin C, and radioactive iodine [30, 31]. It has been reported that weekly administration of docetaxel has a high risk of inducing canalicular stenosis as compared to 3 weekly schedules. Silicone stent has been found to be very effective in curbing the progression of docetaxel-induced canalicular stenosis, provided it is performed upon detection of the earliest sign of pathology.

Conclusion

Watery eye is a common complaint and can be due hypersecretion or due to obstruction in the lacrimal outflow pathway. The goal of evaluation of a patient with epiphora is to differentiate the two and to find out the cause and site of obstruction in cases with lacrimal outflow pathway problem. A detailed clinical history, local examination of the adnexal structures, and lacrimal sac area coupled with diagnostic tests like lacrimal irrigation, probing, and fluorescein dye disappearance test will clinch the diagnosis in most patients. Ancillary investigations like dacryocystography, lacrimal scintigraphy, and imaging are required in selected patients to determine the underlying cause of watering. The management decision for epiphora depends on cause, type, and level of the anatomical obstruction, any previous surgery, and age of the patient. Each of these aspects would be dealt with in subsequent chapters.

References

1. Hurwitz JJ. The lacrimal system. Philadelphia: Lippincott-Raven Publishers; 1996. p. 23–9.
2. Kominek P, Della Rocca RC, Rosebaum S. Diagnostics. In: Weber RK, Keerl R, Schaefer SC, Della Rocca RC, editors. Atlas of lacrimal surgery. New York: Springer Publishers; 2007. p. 29–51.
3. Lavrich JB, Nelson LB. Disorders of the lacrimal system apparatus. Pediatr Clin N Am. 1993;40:767–76.
4. Davey J, Billson FA. Watering eyes: an important sign of congenital glaucoma. Med J Aust. 1974;2:531–2.
5. Ali MJ, Naik MN, Honavar SG. Acquired nasolacrimal duct obstructions secondary to naso-orbito-ethmoid fractures: patterns and outcomes. Ophthal Plast Reconstr Surg. 2012;28:242–5.
6. Lehto I. Side effects of topical treatment in pigmentary glaucoma. Acta Ophthalmol. 1992;70:225–7.
7. Collin JR. Epiphora in facial paralysis. Br J Plast Surg. 1993;46:149–50.
8. Gürdal C, Saraç O, Genç I, et al. Ocular surface and dry eye in Graves' disease. Curr Eye Res. 2011;36:8–13.
9. Murthy R, Honavar SG, Naik M, et al. Centurion syndrome: clinical presentation and surgical outcome. Orbit. 2009;28:269–74.
10. Welham RA, Bates AK, Stasior GO. Congenital lacrimal fistula. Eye (Lond). 1992;6:211–4.
11. Thomas R, Thomas S, Braganza A, et al. Evaluation of the role of irrigation prior to cataract surgery. Indian J Ophthalmol. 1997;45:211–4.
12. Liarakos VS, Boboridis KG, Mavrikakis E, et al. Management of canalicular obstructions. Curr Opin Ophthalmol. 2009;20:395–400.
13. Khoubian JF, Kikkawa DO, Gonnering RS. Trephination and silicone stent intubation for the treatment of canalicular obstruction: effect of the level of obstruction. Ophthal Plast Reconstr Surg. 2006;22:248–52.
14. Kashkouli MB, Mirzajani H, Jamshidian-Tehrani M. Reliability of fluorescein dye disappearance test in assessment of adults with nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2013;29:167–9.
15. MacEwen CJ, Young JD. The fluorescein disappearance test (FDT): an evaluation of its use in infants. J Pediatr Ophthalmol Strabismus. 1991;28:302–5.
16. Lefebvre DR, Freitag SK. Update on imaging of the lacrimal drainage system. Semin Ophthalmol. 2012;27:175–86.
17. Francisco FC, Carvalho AC, Francisco VF, et al. Evaluation of 1000 lacrimal ducts by dacryocystography. Br J Ophthalmol. 2007;91:43–6.
18. Sagili S, Selva D, Malhotra R. Lacrimal scintigraphy: "interpretation more art than science". Orbit. 2012;31:77–85.
19. Elmorsy SM, Fayk HM. Nasal endoscopic assessment of failure after external dacryocystorhinostomy. Orbit. 2010;29:197–201.
20. Hakim OM, Mandour W, Elbaz E. Nasal endoscopic visualization and management of the leading causes of probing failure. J Pediatr Ophthalmol Strabismus. 2010;47:214–9.
21. Ghose S, Chhabra MS, Thakar A, et al. Nasal endoscopy in congenital dacryocystitis. Pediatr Ophthalmol Strabismus. 2006;43:341–5.
22. Kashkouli MB, Mirzajani H, Jamshidian-Tehrani M, et al. Fluorescein dye disappearance test: a reliable test in assessment of success after dacryocystorhinostomy procedure. Ophthal Plast Reconstr Surg. 2015;31:296–9.
23. Somma F, d'Agostino V, Tortora F, et al. Magnetic resonance imaging in the pre-operative evaluation of obstructive epiphora: true FISP and VIBE vs gadolinium. Radiol Med. 2017;122:123–30.
24. Machado MA, Silva JA, Brioschi ML, et al. Using thermography for obstruction of the lower lacrimal system. Arq Bras Oftalmol. 2016;79:47.
25. Kamal S, Ali MJ, Ali MH, Naik MN. Fourier domain optical coherence tomography with 3D and En Face imaging of the punctum and vertical canaliculus: a step toward establishing a normative database. Ophthal Plast Reconstr Surg. 2016;32:170–3.
26. Kamal S, Ali MJ, Naik MN. Incomplete punctal canalization: report of Fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2015;31:251–2.
27. Allam RS, Ahmed RA. Evaluation of the lower punctum parameters and morphology using spectral domain anterior segment optical coherence tomography. J Ophthalmol. 2015;2015:591845.
28. Kauh CY, Gentry LR, Hartig GK. Aspergillus mycetoma causing epiphora and ipsilateral facial pain. Ophthal Plast Reconstr Surg. 2016 (Epub).
29. Chon BH, Zhang R, Bardenstein DS, et al. Blood epiphora (hemolacria) years after repair of orbital floor fracture. Ophthal Plast Reconstr Surg. 2016 (Epub).
30. Mansur C, Pfeiffer ML, Esmaeli B. Evaluation and management of chemotherapy induced epiphora, punctal and canalicular stenosis and nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2017;33:9–12.
31. Ali MJ. Iodine-131 therapy and nasolacrimal duct obstructions. What we know and what we need to know. Ophthal Plast Reconstr Surg. 2016;32:243–8.

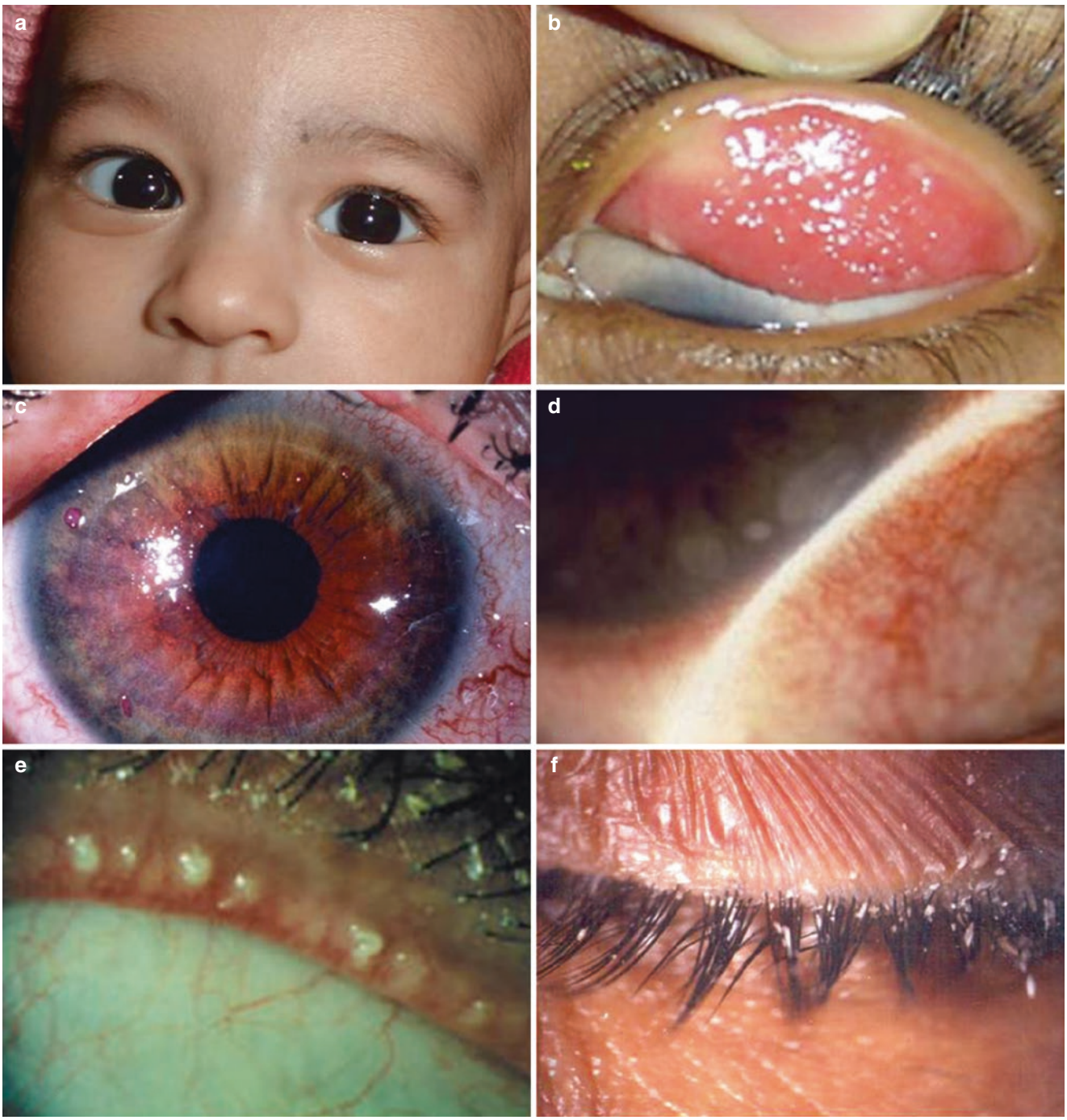


Fig. 6.1 Common causes of hypersecretion or reflex watering. Congenital entropion in a child (**a**), conjunctival papillae in a case of allergic conjunctivitis (**b**), dry eye with corneal filaments causing reflex hypersecretion (**c**), marginal keratitis as the cause of epiphora in cases with blepharitis (**d**), severe meibomitis, and blepharitis causing watering due to tear film disturbance (**e**, **f**)

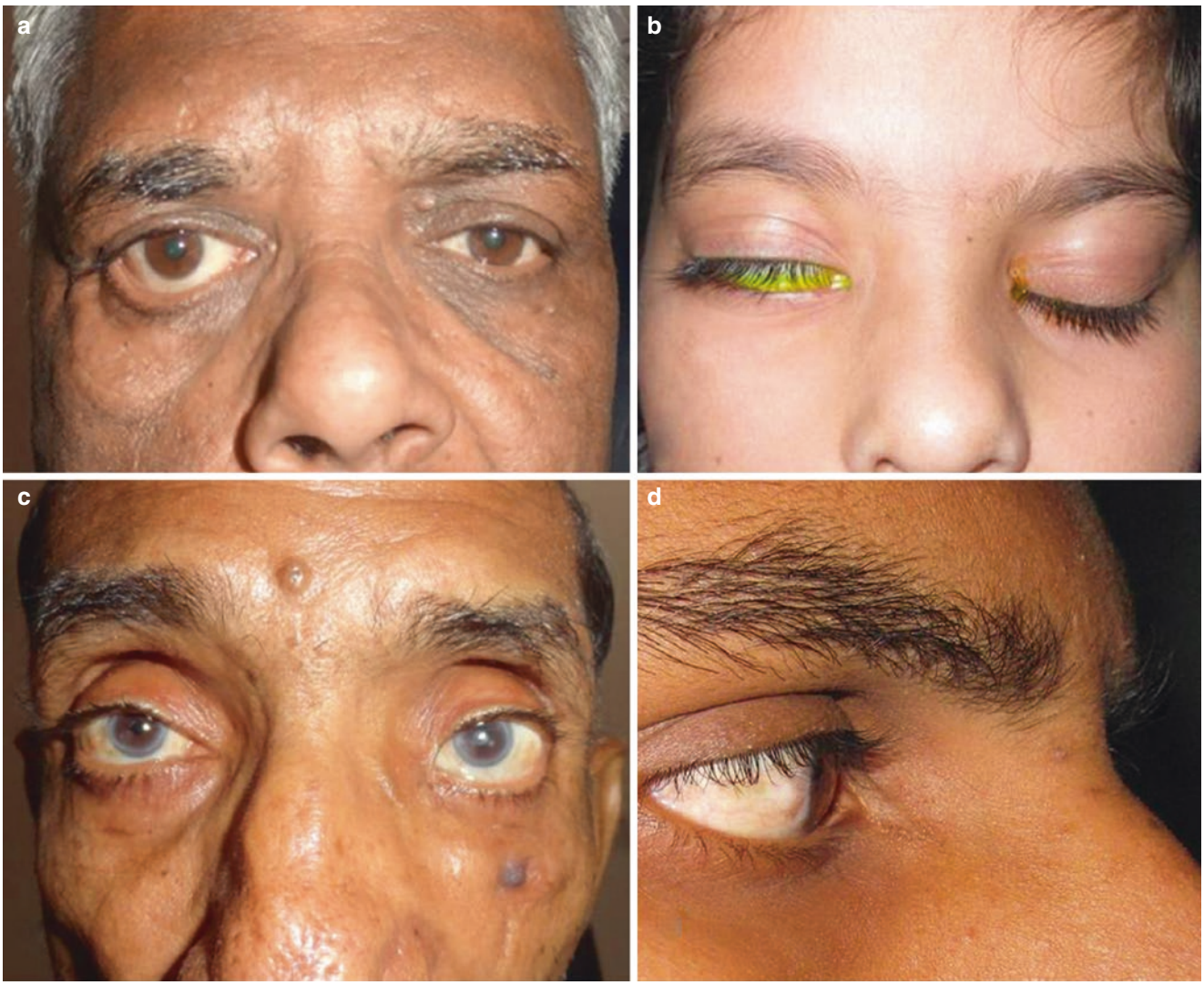


Fig. 6.2 Inspection findings of the adnexa and periocular area. Epiphora with lower eyelid laxity and ectropion in a patient with long-standing right-sided facial palsy (**a**). Lagophthalmos due to right facial palsy causing epiphora due to lacrimal pump dysfunction. Note the increased tear meniscus height on right side (**b**). Rounding of the medial canthus and unilateral telecanthus in a patient with history of trauma and poorly repaired eyelid laceration resulting in a bicanalicular block and cosmetic blemish (**c**). Steep nasal bridge and anterior insertion of the medial canthal tendon in young patient with Centurion syndrome (**d**)

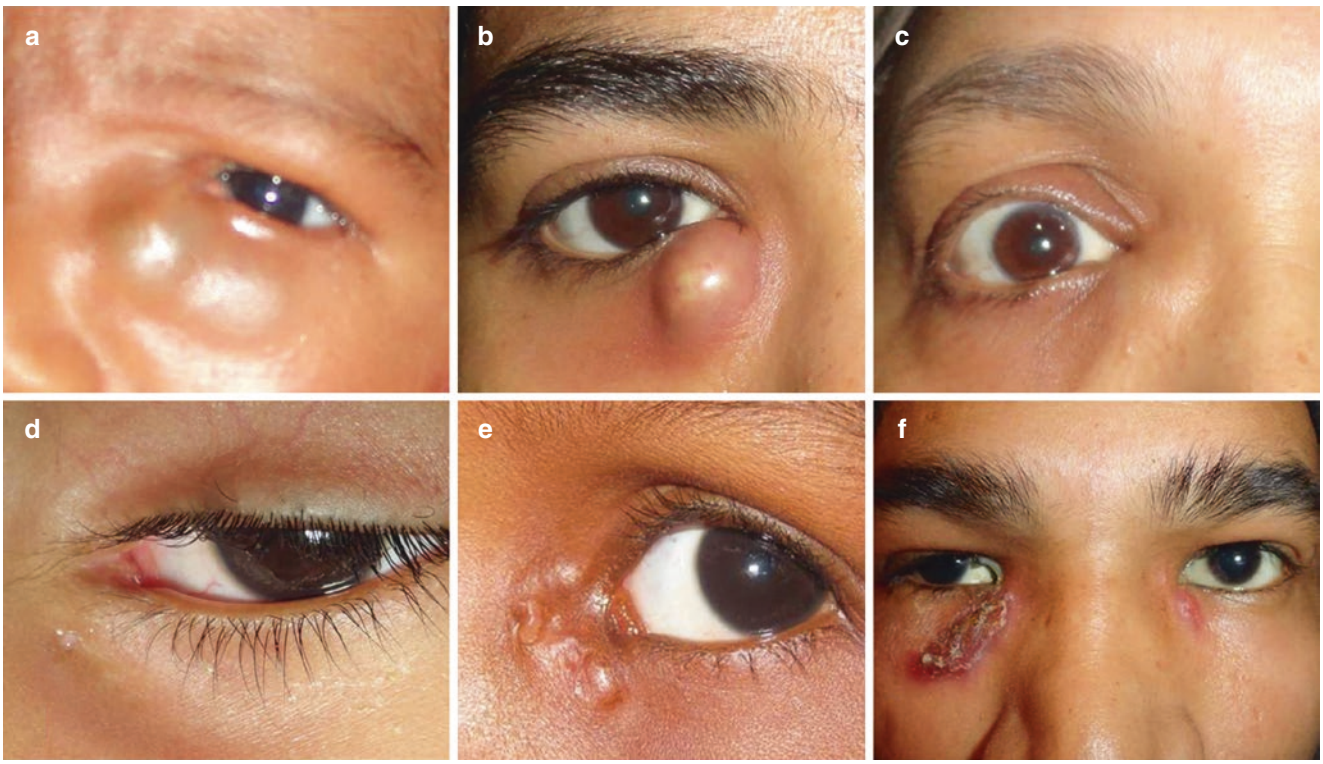


Fig. 6.3 Examination findings of the lacrimal sac and medial canthal area. Bluish, tense cystic swelling below the level of medial canthus in a newborn suggestive of dacryocele (**a**). Acute dacryocystitis with lacrimal abscess in a patient with nasolacrimal duct obstruction. Note the overlying skin erythema and edema (**b**). Chronic dacryocystitis with lacrimal mucocele (**c**). Congenital lacrimal fistulae located just inferolateral to the medial canthus (**d**). Acquired lacrimal fistulae following spontaneously drained lacrimal abscess. Note scarring of the surrounding skin (**e**). Bilateral chronic dacryocystitis with multiple fistulae formation and skin ulceration following spontaneously drained lacrimal abscess in a patient with lacrimal sac tuberculosis (**f**)

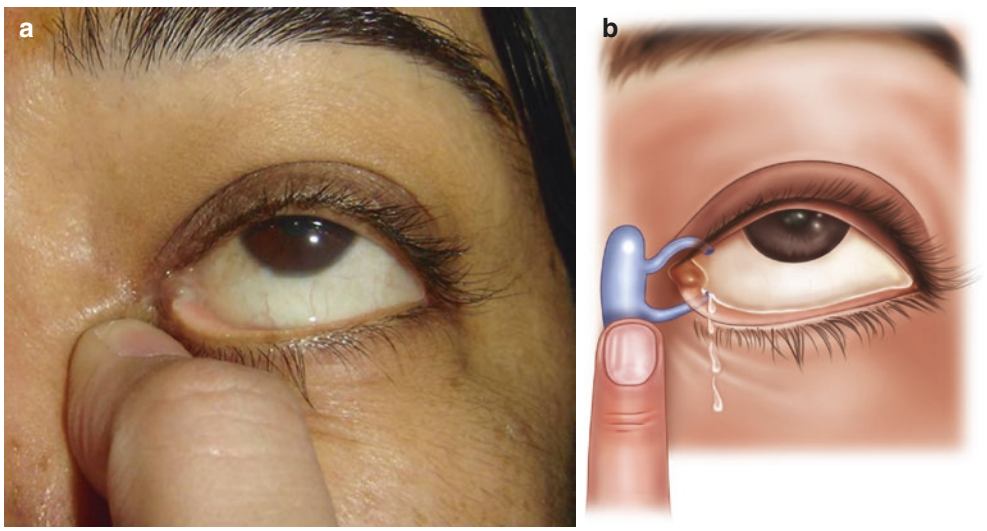


Fig. 6.4 ROPLAS test. Eliciting the ROPLAS test by pressing upon the lacrimal sac in the lacrimal fossa. Regurgitation of fluid from same or opposite punctum is noted (**a**). Schematic diagram showing ROPLAS test (**b**)

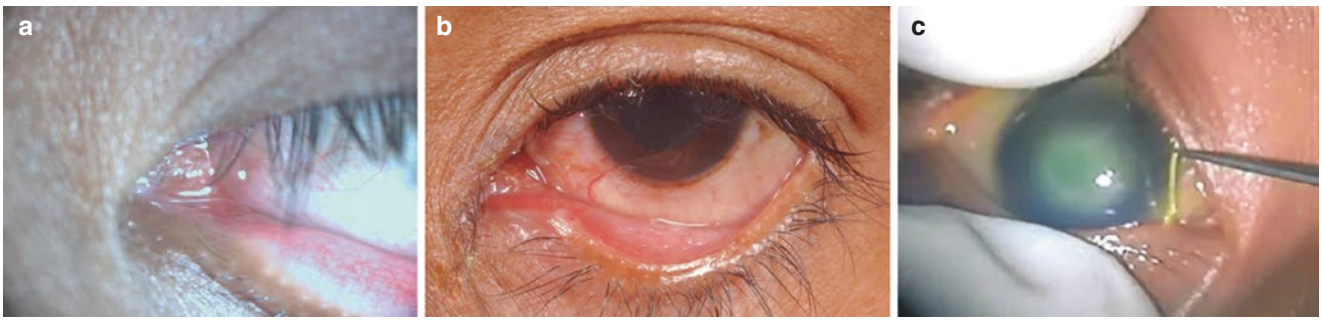
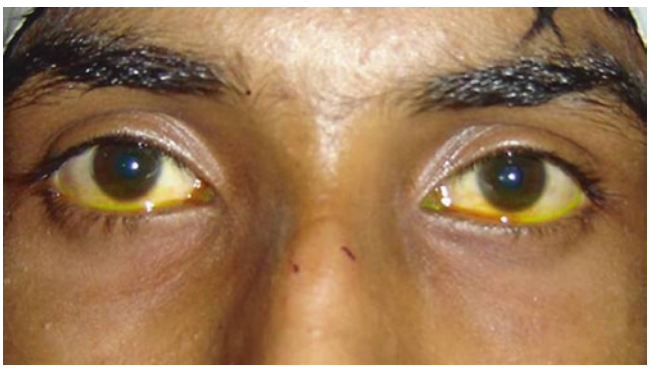


Fig. 6.5 Slit-lamp evaluation of the punctum and adnexa. A case of punctal agenesis (**a**). Canaliculitis causing epiphora and discharge. Note the erythema, edema, and pouting of the lower punctum (**b**). Canaliculitis and secondary keratitis caused by a parasitic worm blocking the canaliculus and punctum (**c**)

Fig. 6.6 Fluorescein dye disappearance test. Positive test showing retention of the dye in the cul-de-sac after 5 min



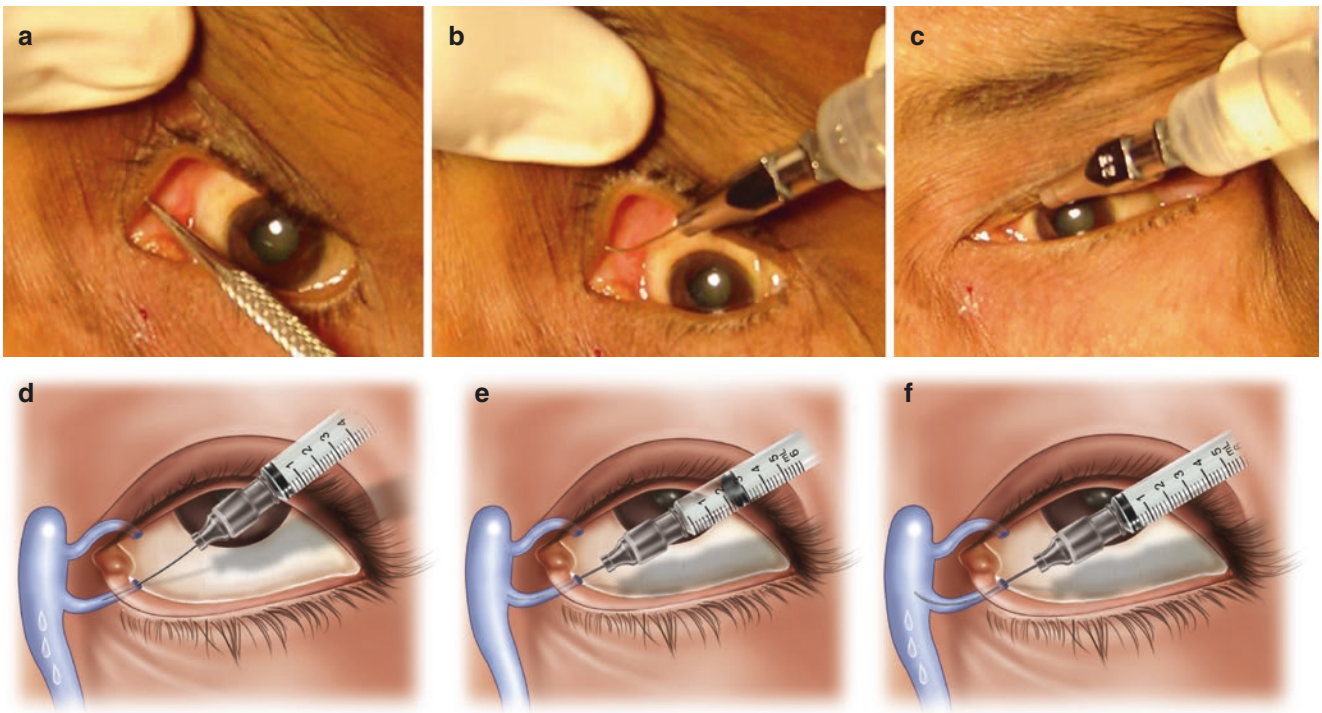


Fig. 6.7 Lacrimal irrigation procedure. Dilatation of punctum with the Nettleship's punctum dilator (**a**). The lacrimal cannula inserted into the canaliculus first vertically (**b**) and then in a horizontal direction. Note the lateral traction is given to the eyelid to straighten the canaliculi before the horizontal pass (**c**). Schematic diagram showing intracanalicular irrigation. A very little amount is irrigated to dilate the lacrimal passage to avoid the risk of mucosal trauma (**d**). Intrasac irrigation is the desired goal for better interpretation unless there is a canalicular obstruction (**e**, **f**)

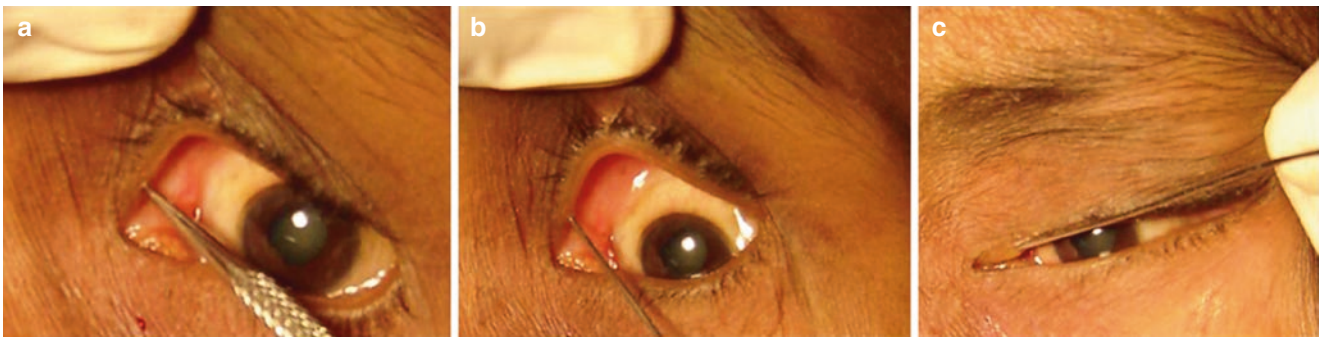


Fig. 6.8 Technique of lacrimal probing. Dilatation of the punctum (**a**). Appropriate sized Bowman's lacrimal probe inserted into the canaliculi first vertically (**b**) and then in a horizontal direction. Note the lateral traction is given to the eyelid to straighten the canaliculi before the horizontal pass (**c**)

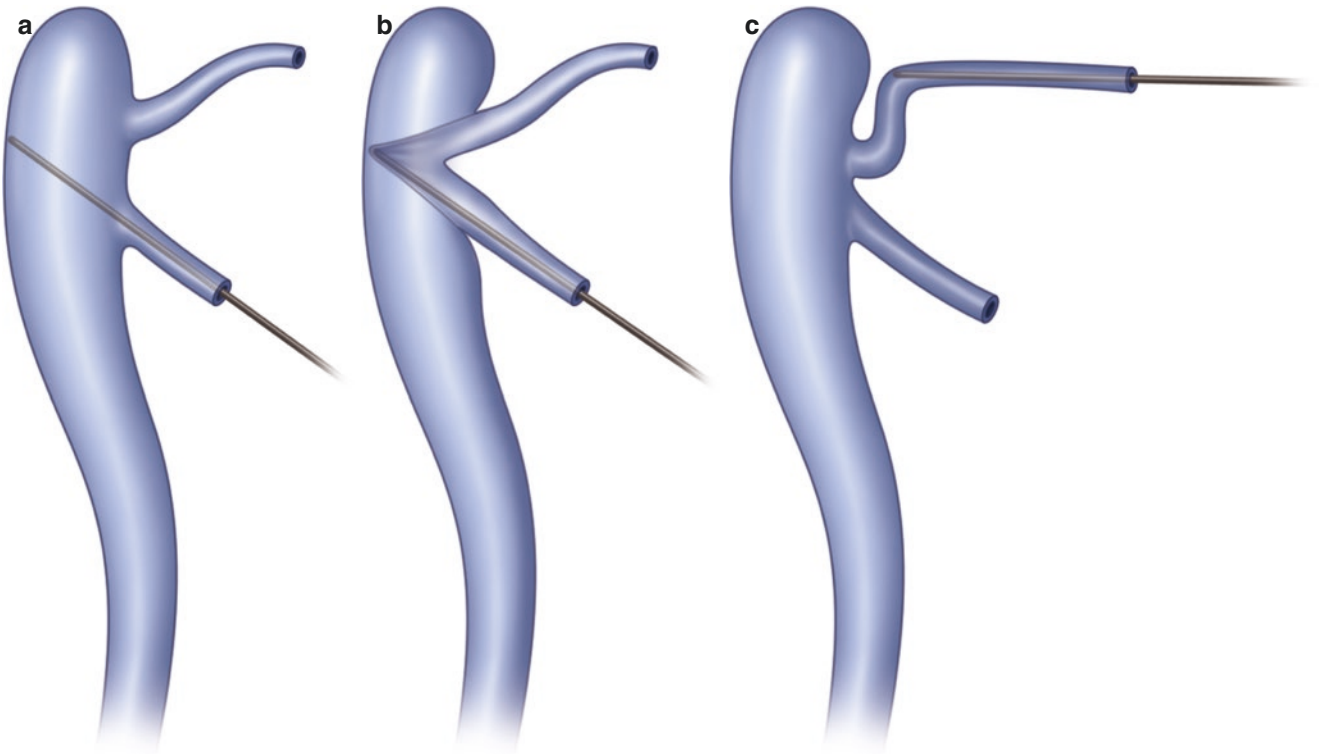


Fig. 6.9 Interpretation of lacrimal probing. Hard stop is felt when the probe hits the medial wall of the sac and underlying bone (**a**). Soft stop is felt when the probe drags the lateral wall of the sac toward the medial wall in cases of canalicular obstructions (**b**). False positive soft stop can be felt if adequate lateral traction is not given on the eyelid to straighten the canaliculi while passing the probe through it, and the probe drags the roof or floor of the canaliculi against the sac (**c**)

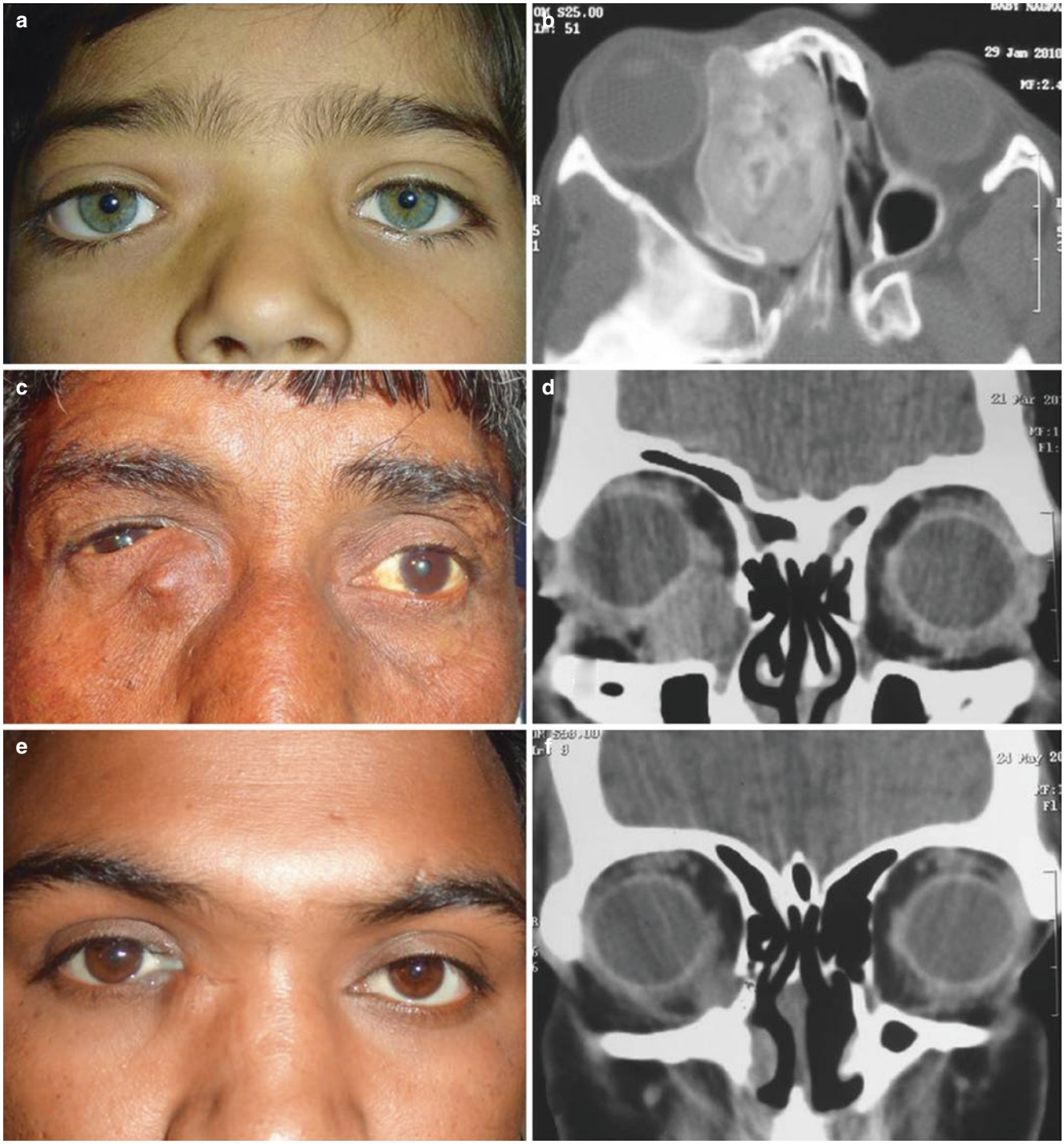


Fig. 6.10 Imaging findings in patients with epiphora. Young child with unilateral telecanthus complaining of watering from right eye (**a**). CT scan revealed an ethmoid sinus mass (fibrous dysplasia) extending to nasal cavity causing secondary NLD obstruction (**b**). Adult patient with distended lacrimal sac and partially patent irrigation (**c**). CT scan revealed lacrimal sac mass and later confirmed to be a benign fibrous histiocytoma (**d**). Right-sided chronic dacryocystitis with mucocele following facial trauma (**e**). CT scan showing fracture of the ethmoid bone near the upper end of NLD (**f**)

Setup for Nasal Endoscopy and Endoscopic Surgery

7

Hesham Saleh and Natasha Choudhury

Introduction

Nasal examination should be obligatory in any patient who is being considered for lacrimal surgery. Preoperative assessment should include nasal endoscopy to allow the evaluation of anatomical variations or any concurrent intranasal pathology. Furthermore, lacrimal surgery itself is now widely practiced via an endoscopic approach, and therefore ophthalmologists performing lacrimal surgery should familiarize themselves with the use of nasal endoscopes.

Nasal Endoscopes

The use of rigid nasal endoscopes (Hopkins telescopes) is now the standard practice for clinical examination of the nose as it provides a detailed, magnified, high-quality view of the nose and sinus passages. Nasal endoscopes are available in a variety of different sizes and angulations. Standard nasal endoscopes are available in 2.7 and 4 mm caliber thickness (Fig. 7.1), with varying viewing angles ranging from 0° to 120°, which are used for both clinical examination and operative procedures. The most suitable endoscope to use during a clinical examination is a 30°, 2.7 mm diameter Hopkins endoscope. The 30°-angled endoscope allows for a panoramic view of the nasal cavity, and the smaller diameter is best used to avoid inflicting any discomfort to the patient. Intraoperatively, however, the wider 4 mm nasal endoscopes are preferred as they offer better illumination and view through the wider caliber telescope. For most purposes, it is sufficient to use either 0° or 30° endoscopes for operative procedures. The 0° endoscope offers a straight-line view and is the easiest to use. It is often possible to perform a full dacryocystorhinostomy using this endoscope. In some cases, however, a 30° endoscope is necessary for better visualization of the lateral nasal wall when the anatomy dictates.

Adjunct Equipment

In addition to the selected endoscope, a good halogen or xenon light source is essential for the best possible illumination while visualizing using the endoscopes. This also requires good-quality fiber-optic cables to connect with light source. Handheld light sources that can connect to Hopkins endoscopes are available, but a light cable and a separate light source are preferable and easier to use.

Outpatient Setup for Nasal Endoscopy

Before starting nasal endoscopy, the patient's nose should be prepared by applying topical local anesthetic with decongestant. Our preference is to use two sprays of co-phenylcaine spray (5% lignocaine with 0.5% phenylephrine) into each nasal cavity (Fig. 7.2), which should be left for at least 5 min before attempting any instrumentation, to allow sufficient time for the anesthetic and vasoconstrictive effect. The patient should then be positioned appropriately, either sitting upright facing the examiner or lying down, with head elevation of about 45°, and turned toward the examiner who should be on the patient's right side. Diagnostic nasal endoscopy in the clinic can then be performed with a 2.7 mm, 30° nasal endoscope, using a three-pass technique. The endoscope should be held in the right hand and supported between the thumb and index finger of the left hand, to avoid any sudden movements. With each pass, the condition of the nasal mucosa and anatomical structures are examined, as well as carefully noting of any anatomical variations or intranasal pathology.

H. Saleh, F.R.C.S, F.R.C.S. (O.R.L.-H.N.S.) (✉)
Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK
e-mail: hesham.saleh@btinternet.com

N. Choudhury, F.R.C.S. (O.R.L.-H.N.S.)
Surrey and Sussex NHS Trust, Surrey, UK

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_7

Setup for Endoscopic Surgery

Endoscopic lacrimal surgery is almost always performed between two surgeons: the ophthalmologist and the rhinologist. A full set of all nasal endoscopes, as well as sinus and ophthalmology instruments, are ideally desirable [1, 2]. The endoscope needs to be connected to a light cable and high-quality light source, as well as a camera and large viewing stack (Fig. 7.3), which can be seen by both sets of surgeons and theatre scrub nurse. The operating surgeon should be positioned onto the right side of the patient with the assisting surgeon adjacent to them. A good interaction between the two surgeons is essential to facilitate the surgery, for example, in guiding the light probe to demonstrate the extent of bone removal required for adequate exposure of the lacrimal sac and also in supporting the sac while the other surgeon is opening it. The scrub nurse and instrument tray should be positioned on the opposite side of the patient, and the anesthetist needs to be away from the operating head end (Fig. 7.4a and b).

Before commencing endoscopic surgery, the patient's nose should be prepared in the anesthetic room, following the induction of anesthesia. Any one of the variety of different nasal preparations which permit decongestion via their vasoconstrictive effect can be used, including Moffett's solution (2 ml of 10% cocaine, 1 m of 1:1000 adrenaline, and 2 ml of sodium bicarbonate), oxymetazoline nasal drops, or co-phenylcaine spray, depending on local availability and personal preference. After its application, the patient can be positioned for surgery in the reverse Trendelenburg position, with 30° head elevation. Where possible, hypotensive anesthesia should be maintained throughout the surgery to minimize intraoperative bleeding.

For endoscopic surgery, the wider caliber 4 mm endoscopes are used throughout. Initially, the 4 mm 0° nasal endoscope should be used to inspect each nasal cavity and apply topical adrenaline (1 in 1000) on Merocel patties or ribbon gauze, within the middle meatus, for at least 5 min. Following that, a standard dental syringe is used to inject 1 ml of 1:80,000 adrenaline and lignocaine 2% into the area of the planned mucosal flap for further decongestion and to facilitate dissection (Fig. 7.5).Once the nose is adequately decongested, the surgery can commence. Endoscopic surgery is performed mainly with the 4 mm 0° endoscope but can be changed to the 4 mm 30° endoscope for a better-angled view of the lateral nasal wall.

A newer-generation continuously variable endoscope, the EndoCameleon® (Karl Storz, Tuttlingen) which rotates from 15 to 90°, is also now available; this can be used as an operative endoscope and can potentially make surgery easier with the varied angulation it permits, to allow full visualization of the lateral nasal wall (Fig. 7.6) [3]. There is also emerging technology with 3D endoscopes surfacing on the market which is likely to provide high-definition three-dimensional endoscopic images. These emerging technologies may provide more precise spatial orientation and potentially more enhanced surgical precision, once mastered [4].

Surgical Instruments

For a trans-nasal endoscopic lacrimal surgery, a limited functional endoscopic sinus surgery set as well as ophthalmic set is required for all the necessary instruments. These should include a fiber-optic light probe to guide to the position of the lacrimal sac (Fig. 7.7); a 15 blade on a long, slim handle to provide adequate length for access within the nose (Fig. 7.8); a Freer's elevator for elevating the mucosal flap (Fig. 7.9); a straight and 45° upturned Blakesley forceps for grasping bony and mucosal fragments (Figs. 7.10 and 7.11); a microdebrider with a 4 mm Tru-cut blade (Fig. 7.12) for mucosal trimming and 2.5 mm diamond burr (Fig. 7.13) for bone removal; a standard sinus suction (Fig. 7.14); a keratome for opening the lacrimal sac (Fig. 7.15); and silicone lacrimal tubes if intubation is planned (Fig. 7.16).

Traditionally, a Freer's elevator is used to elevate the mucosal flap. This is still the most suitable instrument for this purpose; however, it has been modified to include a suction port which can be connected to a suction pump. The advantage of this suction Freer's elevator (Fig. 7.17) is that the surgical field can be kept clear of blood while raising the flap and thus avoid repeated exchange between a separate Freer's and suction device.

A microdebrider is not essential in the standard technique for routine lacrimal surgery, where a Kerrison's rongeur can be used to remove the lacrimal bone. However, modern microdebriders are highly powered ENT instruments that can be used to remove soft tissue as well as bone, with high functionality and precision. They can therefore be utilized in lacrimal surgery for both mucosal trimming and superior osteotomy in the thick bone as in certain Asian ethnicities. The newest-generation microdebrider is the Medtronic™ Straightshot M5 (Fig. 7.18) which is available with burs that oscillate at the highest speed of 30,000 rpm, thus allowing efficient bone removal.

Conclusion

Nasal endoscopy is a key technique that should be mastered by anyone practicing lacrimal surgery. It is vital as part of the preoperative assessment to evaluate for any coexisting nasal pathology or anatomical abnormalities that may impede surgical access. It also now forms the cornerstone for an endoscopic approach for lacrimal surgery and should therefore be familiarized by ophthalmologists who are interested in this area of surgery. A number of practical tips and considerations for the setup of nasal endoscopy, both in the clinic and operating theatre, have been highlighted here within to facilitate its practice.

References

1. Olver J. Adult lacrimal Surgery. In: Olver J, editor. Colour atlas of lacrimal surgery. I ed. Oxford: Butterworth-Heinemann; 2002. p. 91–145.
2. Tsirbas A, Wormald PJ. Mechanical endonasal dacryocystorhinostomy with mucosal flaps. Br J Ophthalmol. 2002;87:43–7.
3. Ali MJ, Singh S, Naik MN. The utility of continuously variable view rigid endoscope in lacrimal surgeries: first intraoperative experience. Ophthal Plast Reconstr Surg. 2016;32:477–80.
4. Ali MJ, Naik MN. First intraoperative experience with 3-Dimensional high definition (HD) nasal endoscopy for lacrimal surgeries. Eur Arch Otorhinolaryngol. 2017;274:2161–4 (Epub).

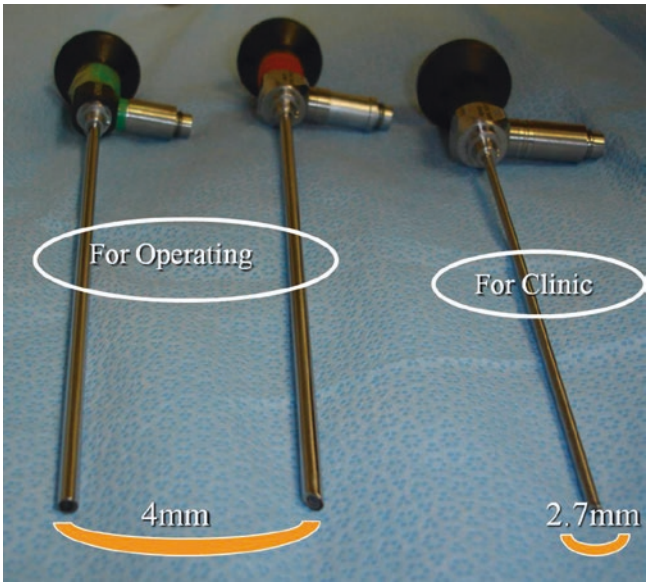


Fig. 7.1 Nasal endoscopes; from left to right 0° 4 mm, 30° 4 mm, and 30° 2.7 mm endoscopes

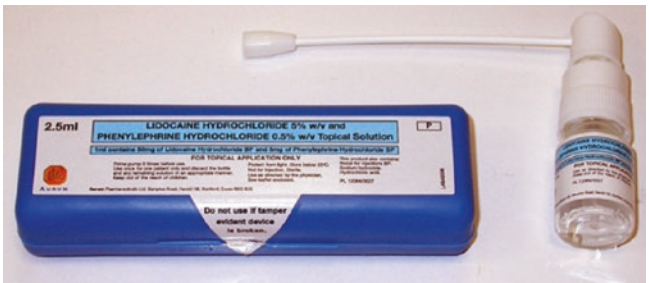


Fig. 7.2 Co-phenylcaine (5% lignocaine with 0.5% phenylephrine)

Fig. 7.3 Stack system with high-definition screen, connected to a camera and endoscope

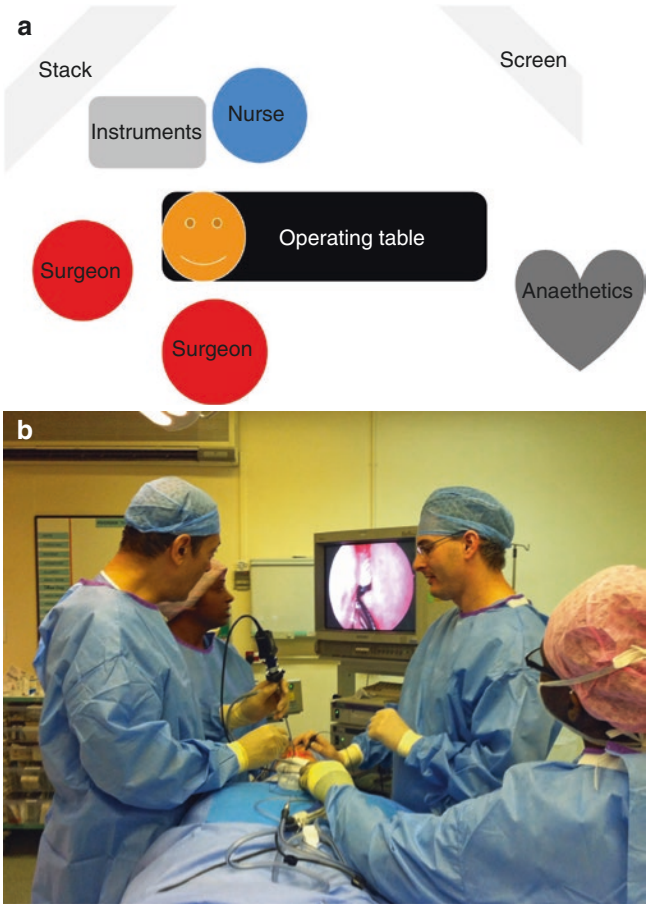


Fig. 7.4 (**a**) A schematic representation of the intraoperative setup for endoscopic surgery. A second screen at the foot of the table is included for better visualization by the second surgeon. (**b**) A photograph of the operating team during an endoscopic dacryocystorhinostomy. In this setting, an assistant surgeon is seen holding the lacrimal light probe, and the operating surgeons are at the right side of the patient

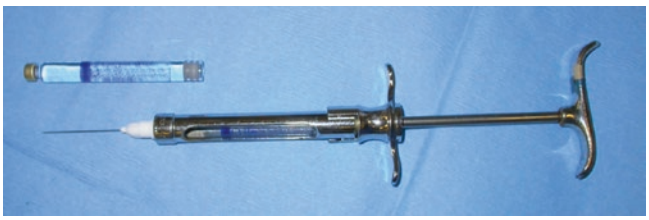


Fig. 7.5 A dental syringe with 1:80,000 adrenaline and 2% lignocaine cartilages

Fig. 7.6 The continuously variable EndoCameleon® telescope

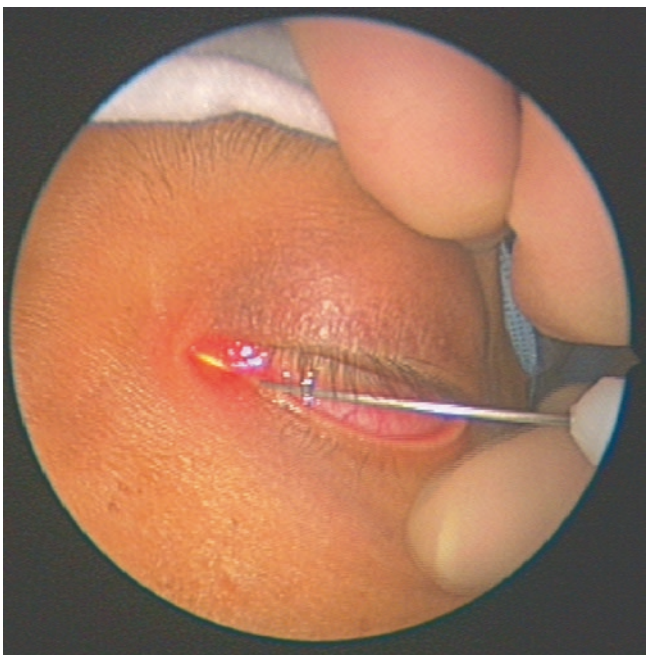


Fig. 7.7 A fiber-optic light probe is being inserted into the lower canaliculus

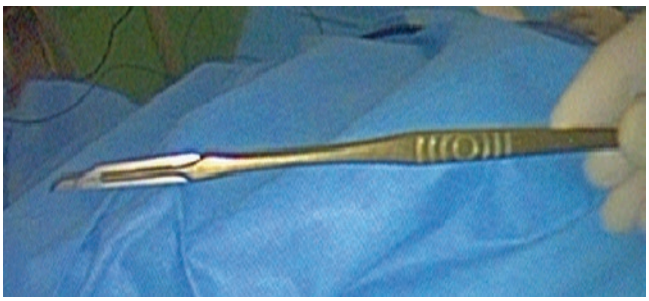


Fig. 7.8 A 15 blade armed onto a long, slim handle to provide adequate length for access within the nose

Fig. 7.9 A Freer's elevator which can be used to elevate mucosal flap

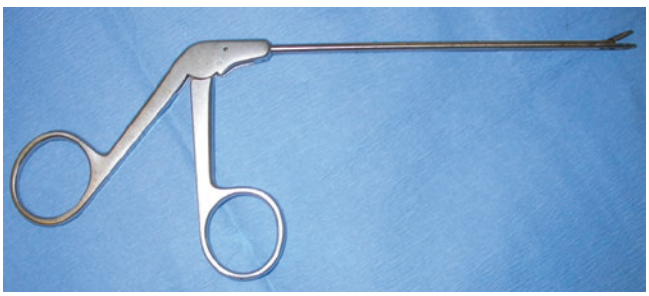


Fig. 7.10 Straight Blakesley forceps

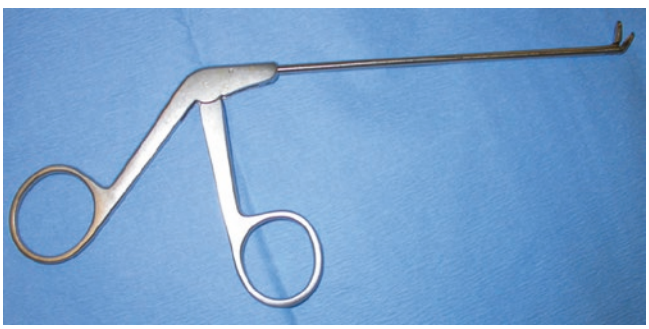


Fig. 7.11 45° upturned Blakesley forceps

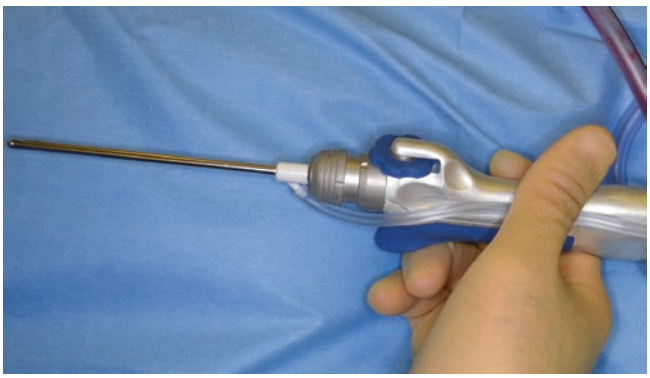


Fig. 7.12 A microdebrider handle attached to a straight 4 mm Tru-cut blade

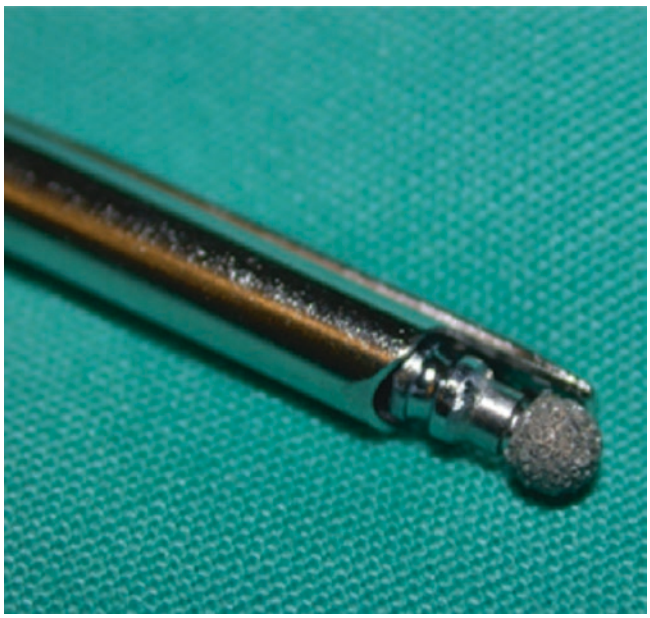


Fig. 7.13 A 2.5 mm DCR diamond burr

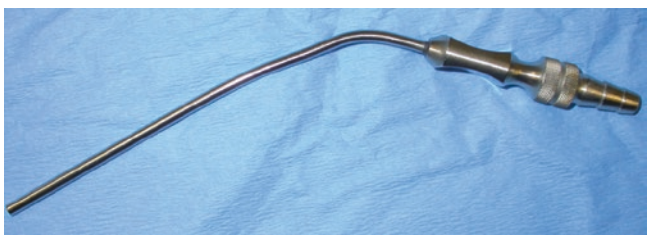


Fig. 7.14 A metal Fergusson suction

Fig. 7.15 A keratome blade

Fig. 7.17 A suction Freer's elevator

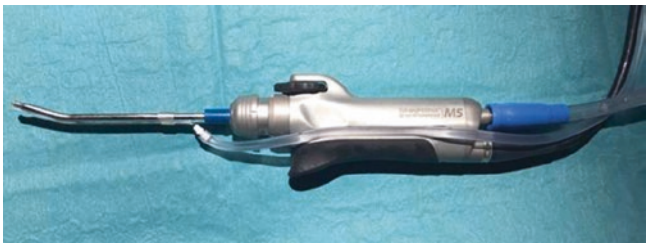


Fig. 7.18 The M5 microdebrider

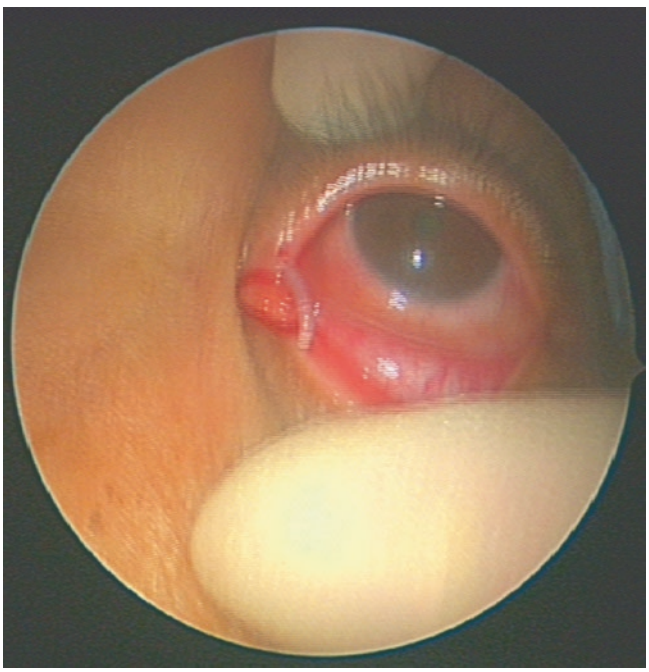


Fig. 7.16 Silicone intubation

Nasal Endoscopic Evaluation

8

Hesham Saleh and Natasha Choudhury

Introduction

Dacryocystorhinostomy (DCR) via an endoscopic approach is now widely favored and considered to result in comparable outcomes to similar surgery via an external approach [1–3]. Such surgery is usually done jointly between ophthalmologists and otolaryngologists. If endoscopic surgery is to be considered, patients should have a complete preoperative assessment to facilitate surgical planning. Clearly, patients with lacrimal obstruction require a comprehensive ophthalmologic assessment to confirm the diagnosis. However, in addition, nasal examination should be considered obligatory in such patients, for evaluation of any concurrent intranasal pathology or anatomical variations, and therefore ophthalmologists practicing lacrimal surgery should familiarize themselves with the use of the nasal endoscopes. An examination with a nasal speculum and headlight provides only a limited view of the anterior nasal passages, and therefore rigid nasal endoscopy should be performed as part of the standard preoperative assessment.

Nasal Endoscopes

The advent of nasal endoscopes (Hopkins telescopes) has revolutionized clinical examination of the nose in providing a magnified, high-quality view of the nose and sinus passages. A variety of nasal endoscopes are available in different sizes and angulations. Standard nasal endoscopes are available in 2.7 mm and 4 mm caliber thickness (Fig. 8.1). Each size is also available with different viewing angles including 0°, 30°, 45°, and 70°, to facilitate a complete view of the lateral nasal wall. The 2.7 mm endoscope is typically used for diagnostic nasal endoscopy in the outpatient clinic and also in children. For diagnostic nasal endoscopy, we prefer to use the 2.7 mm, 30° nasal endoscope, which provides adequate angulations to include a view of the lateral nasal wall. Intraoperatively, however, the wider 4 mm nasal endoscopes are preferred as they offer better illumination and view through the wider caliber telescope. Both the 0° and 30° 4 mm endoscopes should be made available for optimum visualization of the surgical field. In addition to the selected endoscope, a high-quality light source and light cable are required as well as suction equipment to clear any secretions and provide the optimum view.

Technique

Prior to nasal endoscopy, the nose is inspected for any visible abnormalities such as structural deviations, using a headlight (Fig. 8.2). For nasal endoscopy, the patient's nose should be prepared by applying a topical local anesthetic with a decongestant, to anesthetize the nasal cavity before the procedure. Our preference is to use two sprays of co-phenylcaine spray (5% lignocaine with 0.5% phenylephrine) into each nasal cavity (Fig. 8.3), which should be left for at least 5 min before attempting any instrumentation, to allow sufficient time for the anesthetic and vasoconstrictive effect. The patient can be examined in either a sitting position, facing the examiner, or if preferred lying down, and then the examiner would be on his/her right side. Diagnostic nasal endoscopy can then be performed with a 2.7 mm, 30° nasal endoscope, using a three-pass technique. The endoscope should be held with the right hand and supported between the thumb and index finger of the left hand to avoid any sudden movements (Fig. 8.4). With each pass, the condition of the nasal mucosa and normal anatomical structures are examined, as well as carefully noting of any anatomical variations or intranasal pathology. During the first pass, the endoscope is introduced along the floor of the nasal cavity, between the inferior turbinate and the septum,

H. Saleh, F.R.C.S, F.R.C.S. (O.R.L.-H.N.S.) (✉)
Department of Otolaryngology, Charing Cross Hospital and Imperial College, London, UK
e-mail: hesham.saleh@btinternet.com

N. Choudhury, F.R.C.S. (O.R.L.-H.N.S.)
Surrey and Sussex NHS Trust, Surrey, UK

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_8

toward the choana. This first pass allows examination of the inferior part of the nasal cavity including the inferior meatus where the nasolacrimal duct drains, and the nasal septum, as well as the nasopharynx and Eustachian tube openings. The endoscope is then withdrawn and gently reinserted for the second pass between the middle and inferior turbinate, to examine the middle meatus. It is during the second pass that the lateral nasal wall is inspected including the maxillary line and attachment of the middle turbinate (Fig. 8.5). For the third pass, the endoscope should be gently maneuvered medial and posterior to the middle turbinate to examine the sphenoethmoid recess where the posterior ethmoid and sphenoid sinus drain.

Clinical Findings

A wide spectrum of anatomical variations and pathologies may be noted while examining the nasal cavity with endoscopy. Careful assessment is essential to help plan any endoscopic lacrimal surgery, and, in particular, anatomical variations that may impede access during such surgery need specific consideration. Significant anterosuperior septal deviations (Fig. 8.6) or septal spurs (Fig. 8.7) may limit access of the endoscope or additional instruments for surgery, and in such cases, endoscopic septoplasty may need to be performed in order to create adequate space for safe instrumentation. Indeed, Tsirbas and Wormald [4] quoted a 46% rate of concomitant septoplasty, in their original landmark paper in lacrimal surgery describing endonasal dacryocystorhinostomy, thereby highlighting the need to carefully assess septal alignment during the preoperative nasal examination. Subsequently from the same group, a larger series later showed 53.4% rate of adjunctive procedures that included septoplasty, sinus procedures, and middle turbinoplasty [5]. In our experience, endoscopic septoplasty for such localized deviations is required in about 30% of patients. For more severe septal deviations where the airway is significantly obstructed, a formal septoplasty may be required (Fig. 8.7). Another important anatomical variant is the large concha bullosa of the middle turbinate (pneumatized middle turbinate) (Fig. 8.8a and b) which may also impede surgical access and therefore require adjuvant endoscopic reduction.

Alternatively, postoperative clinical examination for a detailed evaluation of a DCR ostium may reveal many factors that would need an endoscopic management to avoid or prevent surgical failures [6]. Endoscopic evaluations may reveal intranasal pathologies that may require preoperative treatment. For example, significant rhinitis (Fig. 8.9) may result in marked inflammation in the nasal mucosa causing edema around the orifice of the nasolacrimal duct, resulting in epiphora. Any signs of rhinitis should be treated medically in the first instance, which may in itself reduce the symptoms of epiphora and avoid the need for surgery [7, 8]. Other sinonasal pathologies including chronic sinus infection [9], chronic sinusitis [10] (Fig. 8.10), or granulomatous disease [11, 12] (Fig. 8.11) should also be evaluated for and treated medically in the first instance. In one study, Kallman et al. [13] identified an 87% prevalence of one or more radiological finding of sinus disease or rhinological abnormality in patients with acquired nasolacrimal duct obstruction, thereby highlighting the importance of nasal endoscopic evaluation for concomitant nasal and sinus disease in this group of patients.

Conclusion

Mastering nasal endoscopy is essential for any surgeon performing lacrimal surgery. Following the structure mentioned above, the surgeon will gradually attain experience and skill to recognize most encountered pathologies.

References

1. Ali MJ, Psaltis AJ, Bassiouni A, et al. Long-term outcomes in primary powered endoscopic dacryocystorhinostomy. Br J Ophthalmol. 2014;98:1678–80.
2. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomy. Int Forum Allergy Rhinol. 2014;4:1016–9.
3. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes in powered endoscopic dacryocystorhinostomy: comparison between experienced and less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.
4. Tsirbas A, Wormald PJ. Mechanical endonasal dacryocystorhinostomy with mucosal flaps. Br J Ophthalmol. 2003;87:43–7.
5. Ali MJ, Psaltis AJ, Wormald PJ. The frequency of concomitant adjunctive nasal procedures in powered endoscopic dacryocystorhinostomy. Orbit. 2015;34:142–5.
6. Ali MJ, Psaltis AJ, Wormald PJ. Dacryocystorhinostomy ostium: parameters to evaluate and DCR ostium scoring. Clin Ophthalmol. 2014;8:2491–9.
7. Kubba H, Robson AK, Bearn MA. Epiphora: the role of rhinitis. Am J Rhinol. 1998;12:273–4.
8. McNeill EJ, Kubba H, Bearn MA, et al. The management of rhinitis in patients with functional epiphora: a randomized controlled crossover trial. Am J Rhinol. 2005;19:588–90.
9. Ergin NT, Akman A, Aktas A, et al. Evaluation of nasolacrimal duct function in chronic paranasal sinus infection with Tc^{99} dacroscintigraphy. Laryngorhinootologie. 1999;78:382–6.
10. Annamalai S, Kumar NA, Madkour MB, et al. An association between acquired epiphora and the signs and symptoms of chronic rhinosinusitis: a prospective case-controlled study. Am J Rhinol. 2003;17:111–4.
11. Kwan AS, Rose GE. Lacrimal drainage surgery in Wegener's granulomatosis. Br J Ophthalmol. 2000;84:329–31.
12. Cannady SB, Batra PS, Koening C, et al. Sinonasal Wegener granulomatosis: a single institution experience with 120 cases. Laryngoscope. 2009;119:757–61.
13. Kallman JE, Foster JA, Wulc AE, et al. Computed tomography in lacrimal flow obstruction. Ophthalmology. 1997;104:676–82.

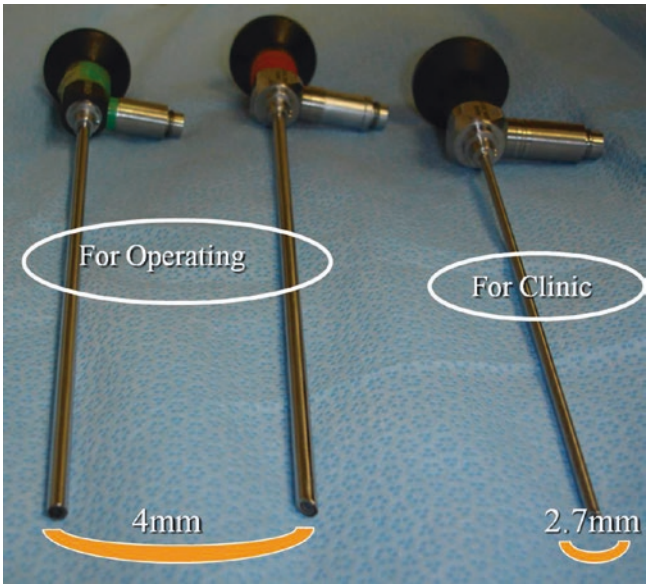


Fig. 8.1 Nasal endoscopes; from left to right 0° 4 mm, 30° 4 mm, and 30° 2.7 mm endoscopes

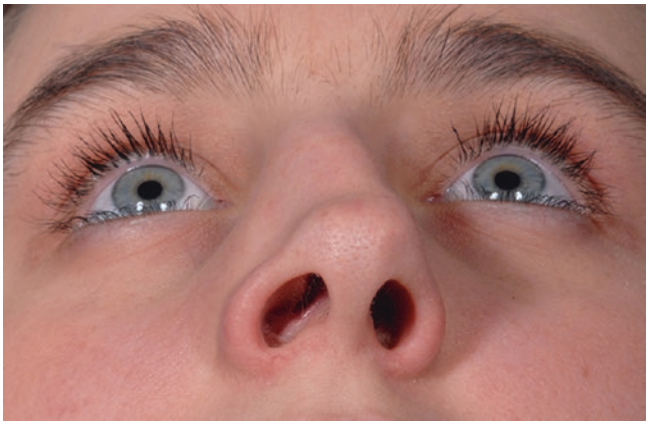


Fig. 8.2 Severe right-sided deviation of the nasal septum with deviation of the external nasal structures to the left side

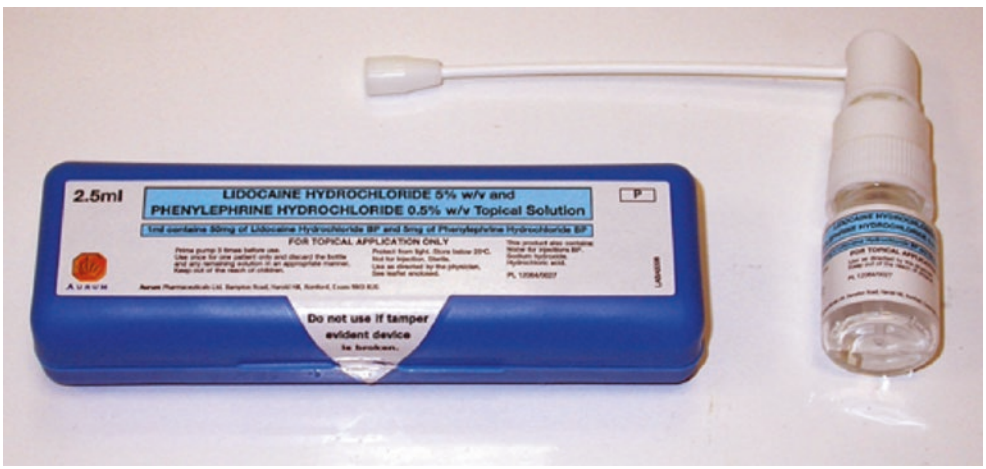


Fig. 8.3 Co-phenylcaine (5% lignocaine with 0.5% phenylephrine)

Fig. 8.4 Nasal endoscopy in the sitting position. Note the support of the endoscope between the index finger and thumb

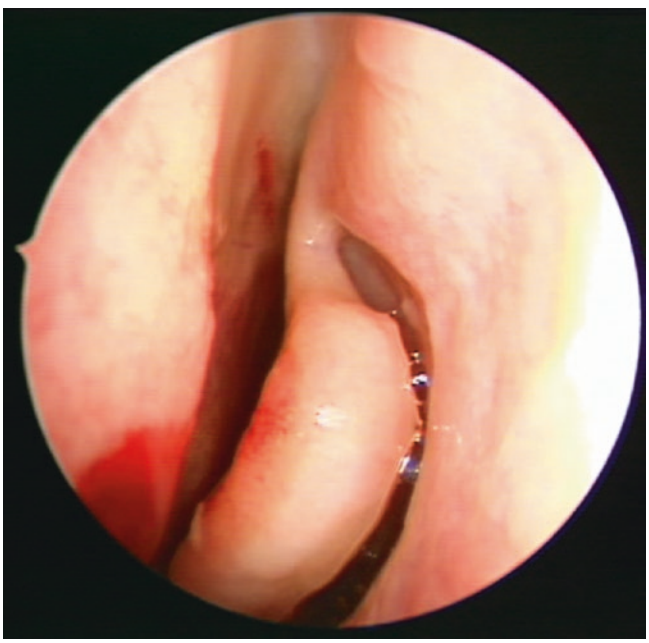


Fig. 8.5 An endoscopic view of the left middle meatus during second pass

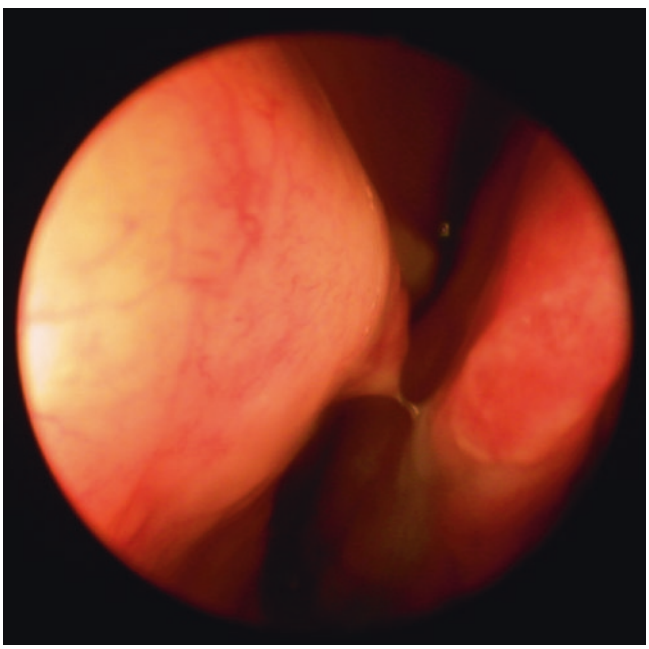


Fig. 8.6 Endoscopic view of the left nasal cavity showing a significant deviation of the nasal septum to the left resulting in a limited view of the middle turbinate

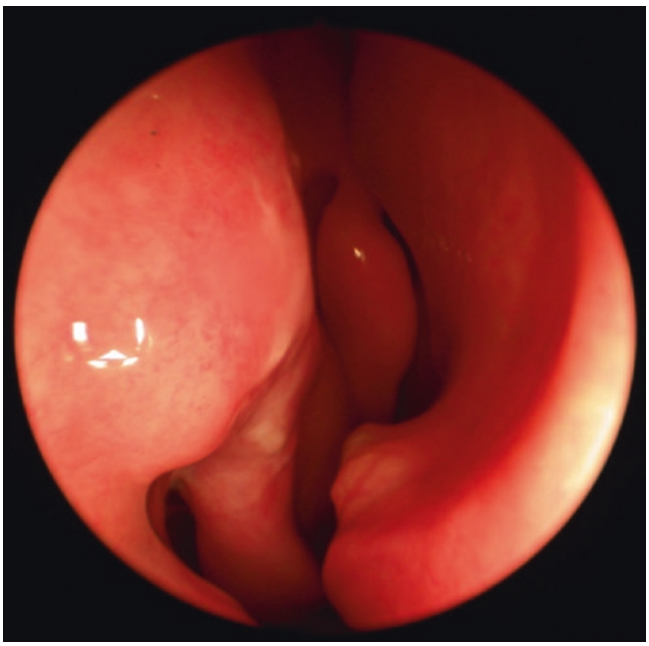


Fig. 8.7 Endoscopic view of the right nasal cavity showing a right inferior septal spur

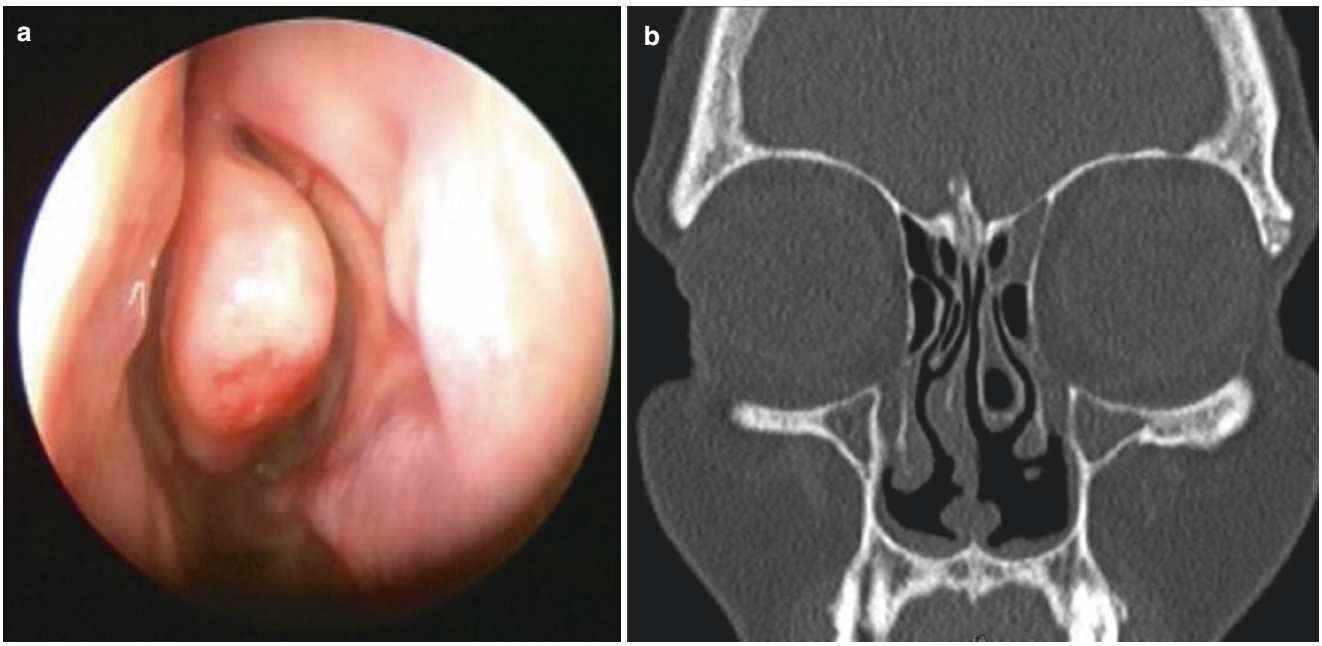


Fig. 8.8 (**a**) Endoscopic view of the left nasal cavity showing a concha bullosa of the left middle turbinate. (**b**) Corresponding CT scan of the sinuses in the coronal plane of the patient in (**a**), illustrating the left concha bullosa

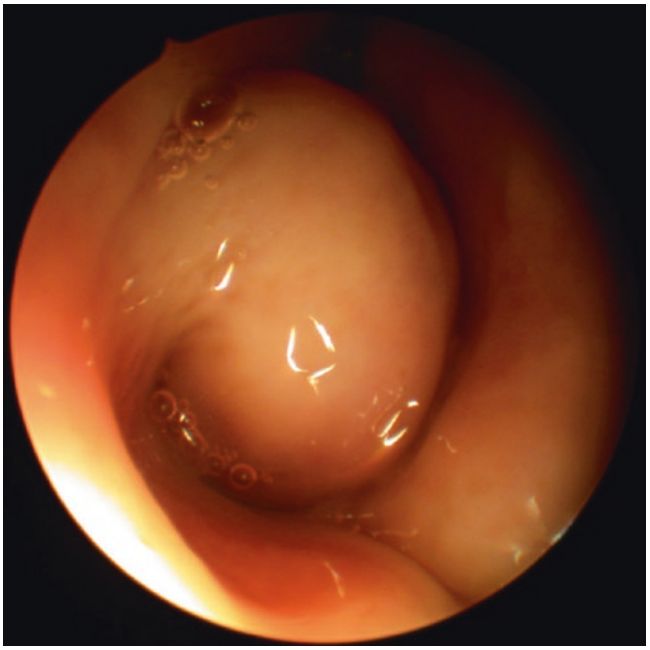


Fig. 8.9 Endoscopic view of the right nasal cavity showing an enlarged, hypertrophic inferior turbinate with marked rhinitis

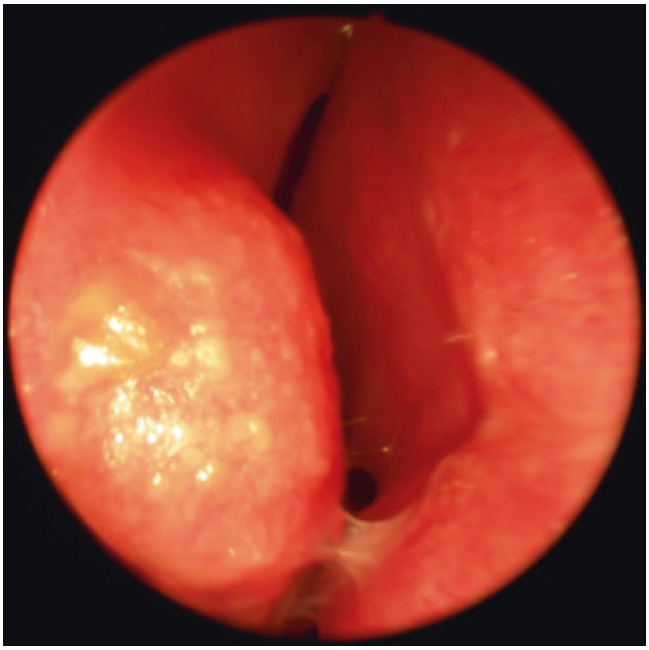


Fig. 8.11 An endoscopic view of the left nasal cavity in a patient with sarcoidosis. Note the inflammation, crusting, and severe edema

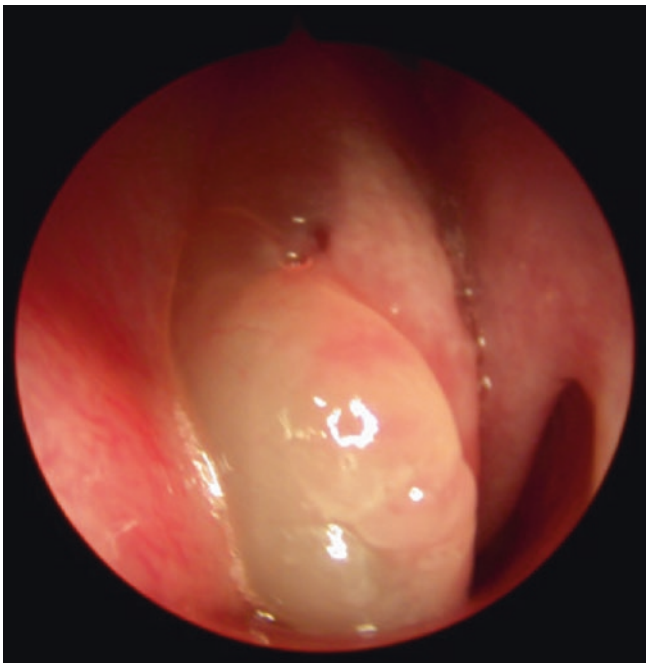


Fig. 8.10 Endoscopic view of the left nasal cavity showing obstructive nasal polyps

Newer Endoscopes and Three-Dimensional Nasal Endoscopy

9

Mohammad Javed Ali

Introduction

Any lacrimal armamentarium today cannot be imagined without endoscopes in it. Endoscopy is an essential tool in the diagnosis and management of numerous lacrimal disorders. The commonly used nasal endoscopes today come in two diameters: 2.7 mm for pediatric use or office endoscopies and 4 mm for routine adult surgeries. They have working length of 18 cm and come in a wide range of angulations: 0°, 30°, 45°, 70°, and 90° for different viewing purposes. However, the disadvantage of these would be constant change of these during surgery as per the requirements, repeated adjustments of the surgical area of interest, and the risk of tissue trauma. A continuously variable endoscope would exactly take care of all these disadvantages. Another major drawback is that most surgeries are visualized in two dimensions by the surgeons and numerous optical clues are then gathered by the brain to reconstruct a three-dimensional picture. A 3D endoscopy would overcome this problem and greatly enhance the visual and surgical experience. This chapter would discuss these modalities and their benefits and challenges in lacrimal surgeries.

Continuously Variable Endoscopy

Continuously variable endoscopes have rotatable camera tips which enable visualization over a wide range of angles without actually moving the endoscope. This is achieved using a specialized Hopkins telescope aptly named EndoCAMeleon® or simply ECAM® (Karl Storz, Tuttlingen, Germany). It looks like a regular standard 4 mm rigid telescope but has a wider proximal body that fits into the camera head (Fig. 9.1). This body has a rotatable black knob (Fig. 9.1) that is coupled with the optomechanics at the shaft tip. The knob can be rotated for varying the angles from 15° to 90°. The angulations are depicted on the body of the telescope with arrows (Fig. 9.2); the vertical arrow at one end represents 15°, the horizontal at the other end represents 90°, and the multiple arrow points in between represent 30°, 45°, and 70°, respectively. The tip of the shaft has a swiveling V-block (Fig. 9.3), which has rotatable optics that respond to the rotation of the knob.

Technique

The direction of the open face of the shaft tip reflects the direction of the plane and can be changed to any plane, one at a time to cover entire 360°. The commonly used directions are superior, inferior, medial, and lateral but may vary based on the orientation of the area of interest (Fig. 9.4). Keeping the ECAM® rotatable knob at 15°, the endoscope is advanced to a target point. The direction of the shaft is shifted by a simple rotation as per the desired object of interest without the need to move the telescope. Once the focus is adjusted, the second hand of the surgeon or the assistant can gently rotate the knob, one step at a time to achieve the desired angulations from a range of 15°–90°. Views can be assessed as the angulations change. Images and videos can be captured at each step. After assessing the full range of angulations in one plane, multiple planes were then assessed after changing the direction of the endoscopic shaft (Fig. 9.4).

Outcomes

The literature on continuously variable endoscopy is limited mostly to laparoscopy and neuroendoscopic procedures [1–4]. Cadaveric skull base studies have shown ECAM® to provide maximum number of visible structures per defined position as compared to the standard endoscopes [1]. The accessibility to arterial walls was enhanced with better planning and application of artery clips [2]. Laparoscopic studies showed a very short learning curve of only three cases and enhance accessibility to deeper structures like the posterior peritoneum [3, 4].

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Hyderabad, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_9

Ali et al. [5] presented their experience with the use of ECAM® in lacrimal surgeries. They needed two sides of a bilateral dacryocystorhinostomy (DCR) to get comfortable with the device. Four lacrimal surgical scenarios were studied to assess the superiority of range of visualization, ease of handling, and optical performance. It was noted that accurate assessment with enhanced visualization was achieved with regard to the extent of cicatrization, synechiae, and ostium evaluations and monitoring of the internal common opening during Sisler's canalicular trephination. They noted detailed inspections were possible in shorter times. Certain limitations reported were the need for shaft directions to change for obtaining simultaneous multiplanar views and the need to refocus images when sudden shifts to extreme angles are desired. Overall, the intraoperative benefits in lacrimal surgeries were perceptible with quicker and detailed assessment and optimization of visualization in a continuous mode.

High-Definition 3D Endoscopy

The current standard telescopes provide a two-dimensional view, and the major disadvantage with this is the lack of depth perception. The significance of depth perceptions in areas with critical anatomical proximities like the head and neck is obvious.

The TIPCAM® 1S 3D ORL Endoscope

The TIPCAM® 1S 3D ORL (Karl Storz, Tuttlingen, Germany) is a specialized Hopkins telescope, rigid with 4 mm shaft diameter, 18 cm length, and available with 0° and 30° angulations (Figs. 9.5 and 9.6). The endoscopic system consists of the Image 1S modular platform (Karl Storz, Tuttlingen, Germany), on which the existing endoscopic systems can be expanded. The HD 3D display monitor (26 or 32 in.) (Fig. 9.7) is provided with multiple video input and output options and has inbuilt visualization modes, namely, clara, clara + chorma, and spectra for delineation of tissue structures like vascular structures. The 3D video endoscopic system has a full HD image sensor with a frame rate of 50/60 hertz and resolution of 1920 × 1080 pixels. The camera head is provided with freely programmable buttons (Fig. 9.6). The telescope and the camera head are steam and plasma sterilizable. For the viewing, either a fogless, passive 3D polarization glass or a circularly polarized 3D clip on glasses can be used (Fig. 9.8). The recording can be performed using the AIDA® 3D software (Karl Storz, Tuttlingen, Germany). The 3D monitor is ideally placed straight in front of the observer at a distance of 2 m. The separation of images (Figs. 9.9 and 9.10) gives the reader an idea of depth perception that can be achieved.

Outcomes

The literature on 3D endoscopy is mostly limited to laparoscopy and neuroendoscopic procedures [6–9]. Few systematic reviews and meta-analysis of this literature have revealed numerous benefits of 3D over 2D in terms of surgical time, blood loss, surgical errors, perioperative complications, and hospital stay. However, the major limitation in most of these studies was unknown stereoacuity of the surgeons or participants [7–9].

Ali et al. [10] published their experiences with HD 3D endoscopy for lacrimal surgeries. They studied the superiority of visualization, optical performance, handling of tissues and complications in 15 lacrimal surgeries, endoscopic-guided probing and intubation, cruciate marsupialization of intranasal cysts in dacryoceles, powered endoscopic dacryocystorhinostomy, and postoperative ostium evaluations and granuloma excision. In addition, ten surgical observers filled up a questionnaire in comparison between 2D and 3D. All the participants and the surgeon had their stereoacuity checked and was normal. They found that the intraoperative tissue handling and surgical maneuverability was more precise without depending on the spatial cues. Greater anatomical delineation facilitated improved hand-eye coordination. The surgical observers unanimously noted enhanced tissue differentiation and surgical learning experience. The setup was easy on endoscopic platforms and did not consume additional time. Overall, operating in 3D enhances depth perception, dexterity, and precision.

References

1. Ebner FH, Marquardt JS, Hirt B, et al. Broadening horizons of neuroendoscopy with a variable view rigid endoscope: an anatomical study. Eur J Surg Oncol. 2010;36:195–200.
2. Ebner FH, Marquardt JS, Hirt B, et al. Visualization of the anterior cerebral artery complex with a continuously variable rigid endoscope: new options in aneurysm surgery. Neurosurgery. 2010;67:321–4.
3. Eskef K, Oehmke F, Tchartchian G, et al. A new variable-view rigid endoscope evaluated in advanced gynecologic laparoscopy: a pilot study. Surg Endosc. 2011;25:3260–5.
4. Hackethal A, Ionesi-Pasacica J, Eskef K, et al. Transvaginal NOTES with semi-rigid and rigid endoscopes that allow adjustable viewing angles. Arch Gynecol Obstet. 2011;283:131–2.
5. Ali MJ, Singh S, Naik MN. The usefulness of continuously variable view rigid endoscope in lacrimal surgery: first intraoperative experience. Ophthal Plast Reconstr Surg. 2016;32:477–80.
6. Altieri R, Tardivo V, Pacca P, et al. 3D HD endoscopy in skull base surgeries: from darkness to light. Surg Technol Int. XXIX:359–65.
7. Cheng J, Gao J, Shuai X, et al. Two dimensional versus three-dimensional laparoscopy in surgical efficacy: a systematic review and meta-analysis. Oncotarget. 2016;7:70979.
8. Fergo C, Burchart J, Pommergaard HC, et al. Three dimensional laparoscopy vs 2-dimensional laparoscopy with high-definition technology for abdominal surgery: a systematic review. Am J Surg. 2016;213:159–70.
9. Sakata S, Watson MO, Grove PM, et al. The conflicting evidence of three-dimensional displays in laparoscopy. A review of systems old and new. Ann Surg. 2016;263:234–9.
10. Ali MJ, Naik MN. First intraoperative experience with three-dimensional (3D) high-definition (HD) nasal endoscopy for lacrimal system. Eur Arch Otorhinolaryngol. 2017;274:2161–4 (Epub).

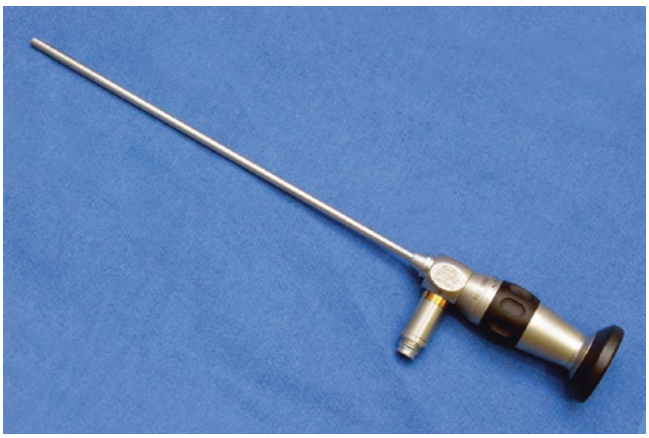


Fig. 9.1 The EndoCAMeleon® continuously variable telescope

Fig. 9.2 The knob at the distal end controls the angulations from 15° to 90°

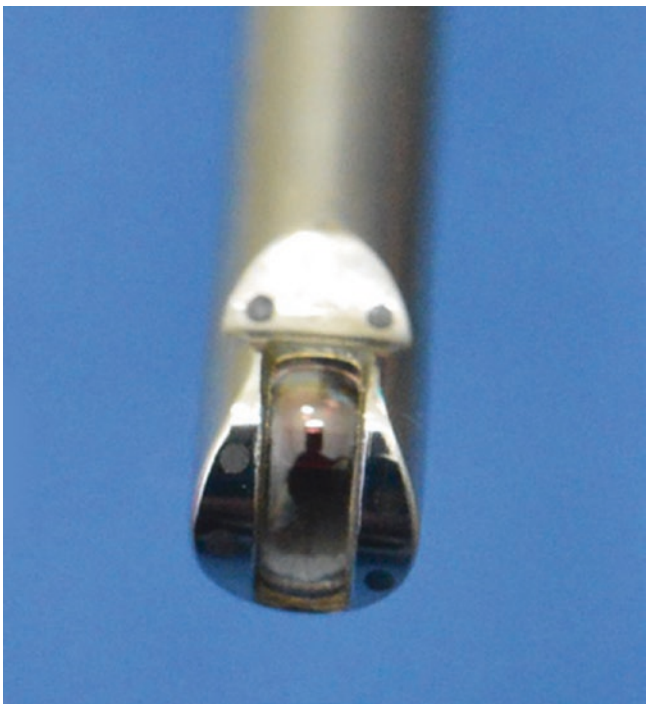


Fig. 9.3 The camera tip with internal rotatable mirrors

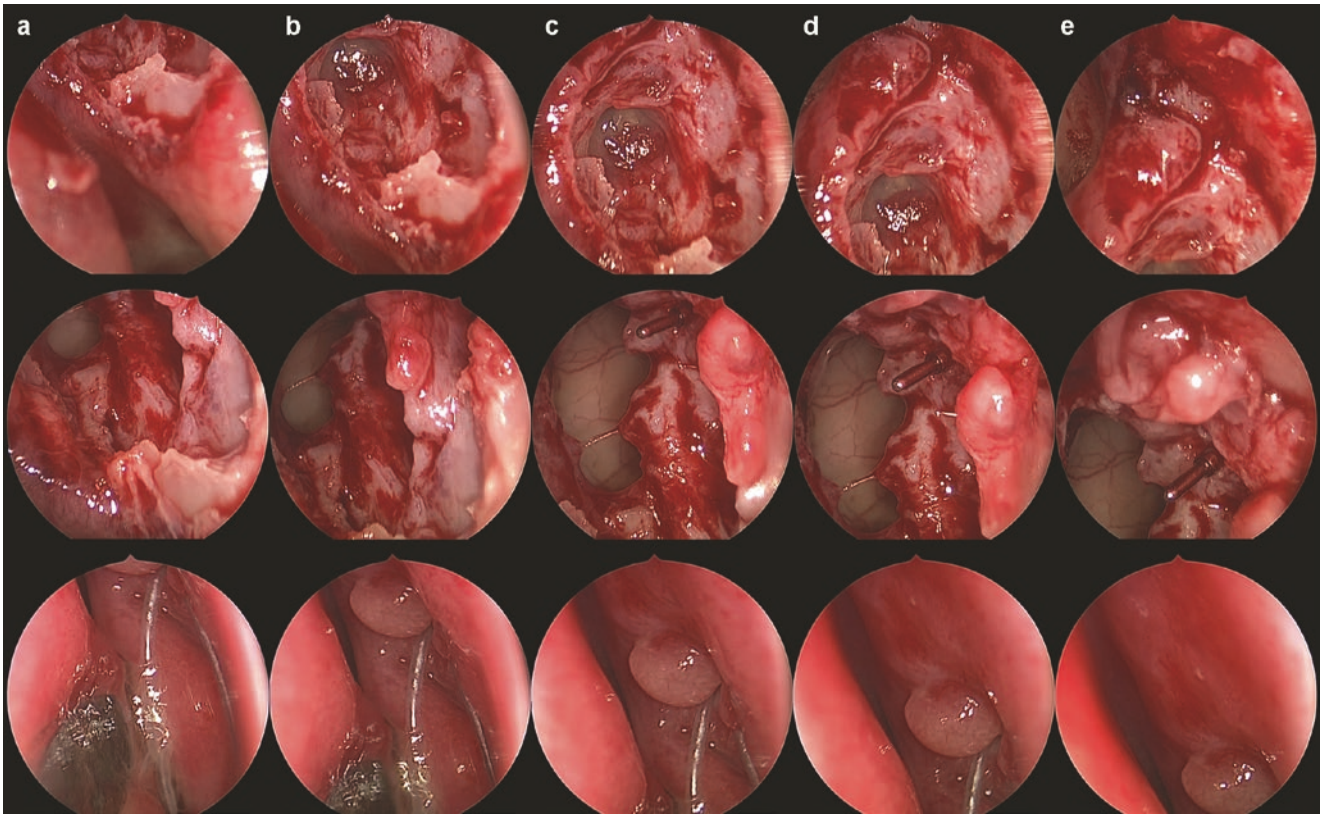


Fig. 9.4 Operative lacrimal scenarios with ECAM®. Endoscopic pictures of an earlier failed endoscopic DCR (*first row*). Note the posterior location of the sac and its relation to the ethmoid sinus. Also note the previous lacrimal sac flap and nasal mucosal anastomosis (*first row*, column **c**). Endoscopic visualization during a Sisler's canalicular trephination (*second row*). Note the continuous monitoring of the internal common opening and the trephine with its shaft (*second row*, column **d**). Endoscopic assessment of the DCR ostium at postoperative 4 weeks (*third row*). Note the ease of overall assessment of the ostium, stents, and the superior edge canalicular granuloma. (*third row*, column **c**) (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2016;32:477–480)

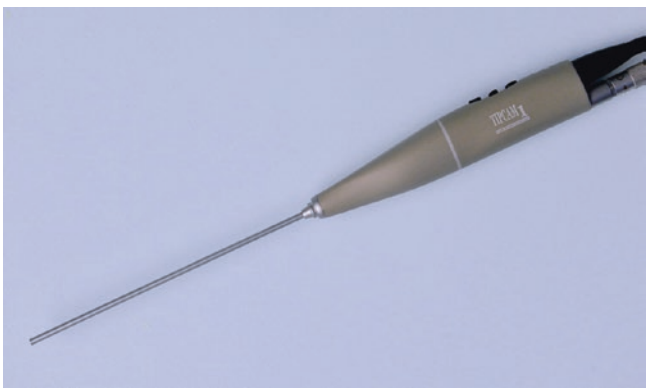


Fig. 9.5 The TIPCAM® 3D ORL endoscope

Fig. 9.6 The programmable buttons on the camera head

Fig. 9.7 The 3D screen

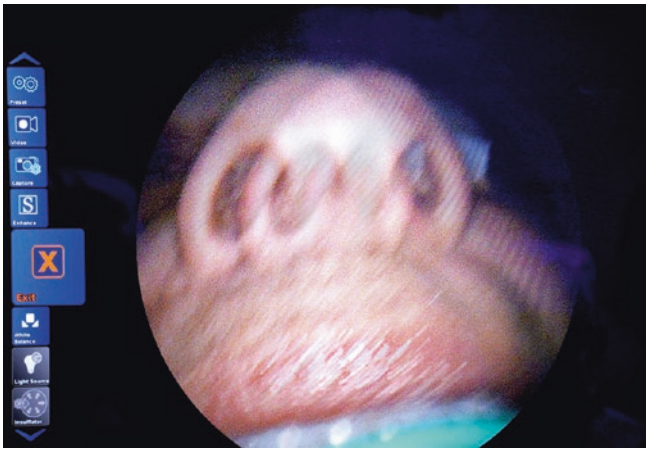


Fig. 9.9 Image separation noted of an external nasal image

Fig. 9.8 The 3D glasses, individual as well as clippable

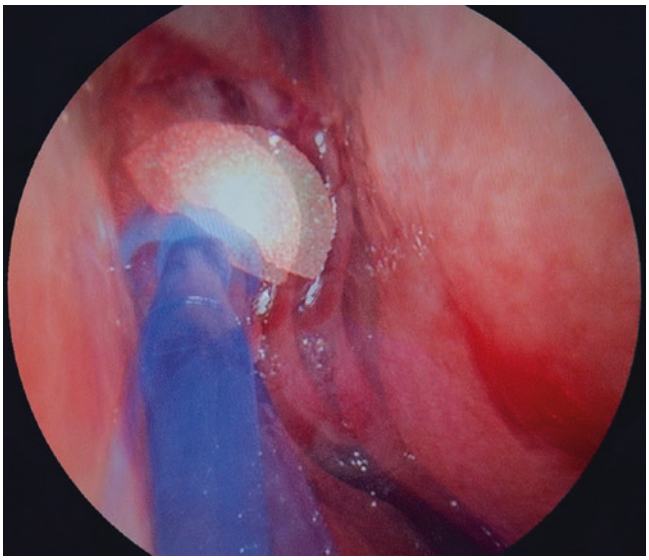


Fig. 9.10 Note the image separation during mitomycin c application

Dacryoendoscopic Examination of the Lacrimal System

10

Mohammad Javed Ali

Introduction

Dacryoendoscopy is a procedure utilizing microendoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [1–10]. It is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders, thus having many diagnostic and potential therapeutic implications [1–10]. Till the late 1990s, the microendoscopic systems were not well developed; however, with the advancement in other specialties like endoscopic retrograde cholangiopancreatography (ERCP), numerous microendoscopes with a good image quality were designed. Dacryoendoscopes used in the past include the Junemann probe and the Vitroptic. Additional channels were added, for example, for laser delivery of KTP-YAG or erbium-YAG laser for laser dacryoplasty and micropunches for sample collection. The author performs it using a 0.6 mm microendoscope (Karl Storz, Tuttlingen, Germany) which was adapted and partly modified from the original sialoendoscope. The current chapter will discuss the instruments, indications, techniques, and findings of a normal dacryoendoscopic examination.

Instruments and Techniques

1. Dacryoendoscope
2. 1 ml syringe with saline
3. Camera head
4. Endoscopic viewing system
5. Antifog solutions (ex-diluted chlorhexidine or cetrimide)

The dacryoendoscope has a thin, rigid fiber endoscope and a side port on the hand piece (Figs. 10.1 and 10.2). The rigid fiber endoscope is attached to the eyepiece through a fiberoptic cable (Fig. 10.1). The eyepiece of the dacryoendoscope is connected to the camera head and secured. The camera head is then connected to the endoscopic viewing system (Fig. 10.3); the tip of the scope is gently cleaned with antifog solution and image quality is assessed.

Recently a full-fledged dacryoendoscope specifically innovated and designed for the lacrimal system had been launched (FiberTech, Japan). This unit has a separate illumination system (Fig. 10.4), an imaging system (Fig. 10.5), and an image capture foot switch (Fig. 10.6). Numerous specific lacrimal ductoscopes (Ruido Fiberscopes®) have been devised. They come with straight (Fig. 10.7), smooth angulated (Fig. 10.8), and sharp angulated (Fig. 10.9) tips with diameters varying from 0.7 to 0.9 mm, channel diameters of 0.3 mm, 50 cm working length, and up to 60° field of view. The resolution is better than the previous dacryoendoscopes. The scopes have a continuous irrigation channel; however, no other working channel has yet been designed on these scopes. These scopes have distal ends (Fig. 10.10) which can be connected to and assembled with the main unit (Fig. 10.11).

The dacryoendoscopy can be performed in an anterograde or a retrograde manner. In the anterograde technique, evaluation sequence starts at the puncta, and subsequently the canaliculus, lacrimal sac, and the nasolacrimal ducts are studied. This is technically demanding, and bumping into the mucosal walls is not uncommon especially for the beginners. In the retrograde technique, the punctum is dilated with a Nettleship's punctum dilator (Fig. 10.12), and the dacryoendoscope is gently passed into the horizontal canaliculus from the upper punctum on an outstretched eyelid (Fig. 10.13) and gently turned 90° just as in probing and descends down till the inferior meatus (Fig. 10.14). Now the scope is gently retracted back very slowly to study each part of the lacrimal drainage system. Gentle forward and backward movements are continued all through to help evaluate the system thoroughly. The retrograde technique is much easier in technical terms. It is important to know that illumination may need to

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Hyderabad, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_10

vary in different parts of the lacrimal system. For example, the illumination needs to be more while examining the interiors of the lacrimal sac as compared to the nasolacrimal duct or canaliculi.

Indications

The indications for which dacryoendoscopy is gaining popularity are as follows [1–10], but by no means this list is exhaustive or complete:

1. Acquired internal punctal stenosis
2. Incomplete punctal canalizations (IPC) [11]
3. Canalicular explorations following IPC membranotomy
4. Canalicular wall dysgenesis (CWD) [12]
5. Canalicular stenosis
6. Patchy or multifocal canalicular strictures
7. Partial and complete canalicular obstructions
8. Dacryoendoscopic-guided canalicular trephination
9. Laser dacryoplasty
10. Microdrill canaliculoplasty
11. Balloon canaliculoplasty
12. Monitoring stages of canalicular recanalizations
13. Assessment of the mucosal folds across the lacrimal system
14. Lacrimal sac inflammations
15. Focal and suspicious mucosal elevations ± guided punch biopsy
16. Residual lacrimal sac septum
17. Lacrimal sac diverticula
18. Chronic dacryocystitis to assess intrasac synechiae
19. Lacrimal sac entrapments following bony trauma
20. Dacryocele
21. Lacrimal drainage system tumors
22. Assessment of unusual types of sac discharges
23. Assessment of foreign bodies and migrated punctal plugs
24. Dacryolithiasis—assessment and guided removal
25. Assessment of lacrimal fistulas
26. Etiopathogenesis of congenital nasolacrimal duct obstructions
27. Functional nasolacrimal duct obstructions (to rule out anatomical issues)
28. Dacryoendoscopic-guided probing
29. Assessment of false passage
30. Buried probes
31. Assessment of etiopathogenesis of primary acquired nasolacrimal duct obstruction (PANDO)

Normal Dacryoendoscopy

Canaliculus

The normal canaliculus has a narrow lumen which progressively constricts toward the distal segment. The mucosa classically appears white to whitish pink unless there is an inflammation (Fig. 10.15). The walls of the canaliculus are homogenous and smooth (Fig. 10.15). The canaliculus can be arbitrarily divided into four walls, anterior, posterior, roof, and floor, and findings of each can be described separately (Fig. 10.16). The change of angulations from the canaliculus to common canaliculi and at entry into lacrimal sac should be kept in mind especially in anterograde technique. Valvular folds (elevated mucosal folds) may be seen at these junctions (Fig. 10.17), and occasionally one may be able to capture the valve of Rosenmuller.

Lacrimal Sac

As the dacryoendoscope enters the lacrimal sac, the lumen is noted to become very wide (Fig. 10.18). The illumination usually appears to become dull and may need to be increased for clearer images. The mucosa of the lacrimal sac is pinkish to pinkish red. The mucosal folds are sparse and less elevated on the walls as against the elevated mucosal folds noted in the common canaliculus or at canalicular sac junction. The play for endoscope is more here, but occasionally undue touch to the walls may cause bleeding. Mucus secretions on the wall and lumen may be noticed and can be gently washed away with saline from the side port. As the scope descends down, the lumen is found to narrow down significantly at one point, the sac-duct junction, and may be guarded by mucosal valves (Fig. 10.19).

Nasolacrimal Duct

The nasolacrimal duct begins soon after the sac-duct junction as described earlier. The lumen is narrow and the mucosa is reddish in color (Fig. 10.20). The walls usually are flat with no elevated mucosal folds (Fig. 10.20). Occasionally a peripheral rim of residual Hasner's valve may be noticed. The end of nasolacrimal duct can be assessed by the change to intense red appearance of the nasal mucosa and the enormously wide cavity.

Common Pathologies on Dacryoendoscopy

The list of indications for dacryoendoscopy described earlier in the chapter elucidates a host of lacrimal drainage system disorders that can be diagnosed and managed under guidance. Diagnosis of a few common pathologies should be learnt and include acquired internal punctal stenosis (Fig. 10.21), canalicular stenosis (Fig. 10.22), partial and complete canalicular obstructions (Figs. 10.23 and 10.24), and mucosal inflammations (Fig. 10.25).

Advantages of Dacryoendoscopy

Direct visualization of the lacrimal drainage system and pathologies obviates the need for many cumbersome investigations in most of the cases. Many therapeutic procedures as mentioned in the indications can be accurately performed under dacryoendoscopic guidance and hence prevent false passages. The biggest advantage that this guidance gives is in terms of visualizing what we are doing rather than blind interventions. It also helps in the better understanding of the disorders which will ultimately translate to better patient care.

Difficulties with Dacryoendoscopy

Procuring dacryoendoscopy is limited in the developing world because of the cost issues, but the author believes that increased usage would indirectly enhance affordability. The learning curve can be steep initially as with any new modality, but once on track, the procedure takes very less time. For the same reason, it is advised that this learning be done under supervision since occasionally damage to the lacrimal system may occur if one is not careful. Not able to get good images can be frustrating initially, and sometimes even the best of hands may not be able to visualize and capture good images. However, following reasonable practice, the use of dacryoendoscopy contributes significantly in the diagnosis and management of lacrimal disorders.

References

1. Sasaki T, Miyashita H, Miyanaga T, et al. Dacryoendoscopic observation and incidence of canalicular obstruction or stenosis associated withS-1, an oral anticancer drug. Jpn J Ophthalmol. 2012;56:214–8.
2. Kakizaki H, Takahashi Y, Sa HS, et al. Congenital dacryocystocele: comparative findings of dacryoendoscopy and histopathology in a patient. Ophthal Plast Reconstr Surg. 2012;28:e85–6.
3. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal dacryorhinotomy. Part II: Inferior meatal dacryorhinotomy. Am J Ophthalmol. 2005;140:1070–4.
4. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal dacryorhinotomy. Part I: Positional diagnosis of primary nasolacrimal duct obstruction with dacryoendoscope. Am J Ophthalmol. 2005;140:1065–9.
5. Küstner M, Clemens S, Tost F. Minimally invasive endoscopic surgery of the lacrimal drainage system—two case reports. Klin Monatsbl Augenheilkd. 2005;222:928–32.
6. Maier M, Schmidt T, Schmidt M. Endoscopically controlled surgery with the micro-drill and intubation of the lacrimal ducts. Ophthalmologe. 2000;97:870–3.
7. Emmerich KH, Steinhauer J, Meyer-Rüsenberg HW, et al. Dacryoendoscopy—current status. Ophthalmologe. 1998;95:820–2.
8. Emmerich KH, Lüchtenberg M, Meyer-Rüsenberg HW, et al. Dacryoendoscopy and laser dacryoplasty: technique and results. Klin Monatsbl Augenheilkd. 1997;211:375–9.
9. Emmerich KH, Meyer-Rüsenberg HW, Simko P. [Endoscopy of the lacrimal ducts]. Ophthalmologe. 1997;94:732–5. Klin Monatsbl Augenheilkd. 1997;94:732–5.
10. Haefliger IO, Piffaretti JM. Lacrimal drainage system endoscopic examination and surgery through the lacrimal punctum. Klin Monatsbl Augenheilkd. 2001;218:384–7.
11. Ali MJ, Mohapatra S, Mulay K, et al. Incomplete punctal canalization: the external and internal punctal membranes. Outcomes of membranotomy and adjunctive procedures. Br J Ophthalmol. 2013;97:92–5.
12. Ali MJ, Naik MN. Canalicular wall dysgenesis: the clinical profile of canalicular hypoplasia and aplasia, associated systemic and lacrimal anomalies, and clinical implications. Ophthal Plast Reconstr Surg. 2013;29:464–8.

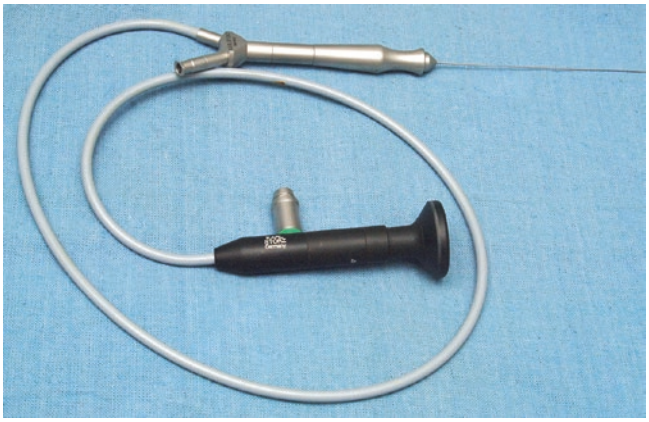


Fig. 10.1 A dacryoendoscope

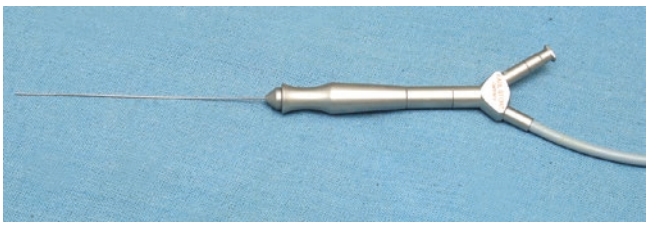


Fig. 10.2 Closer view of the side port

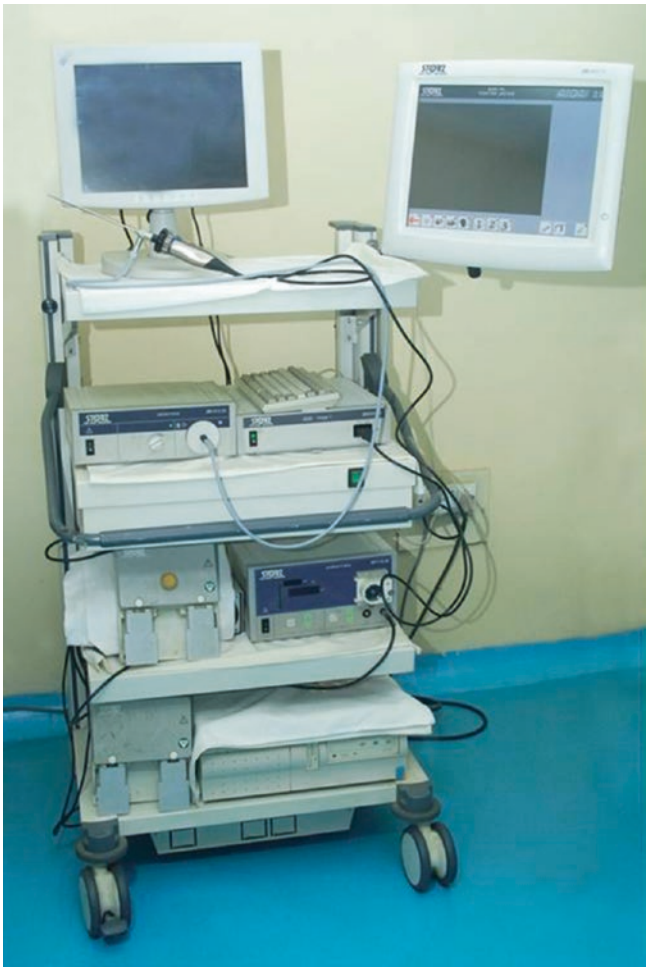


Fig. 10.3 Endoscopic viewing system

Fig. 10.4 The FiberTech® illumination system

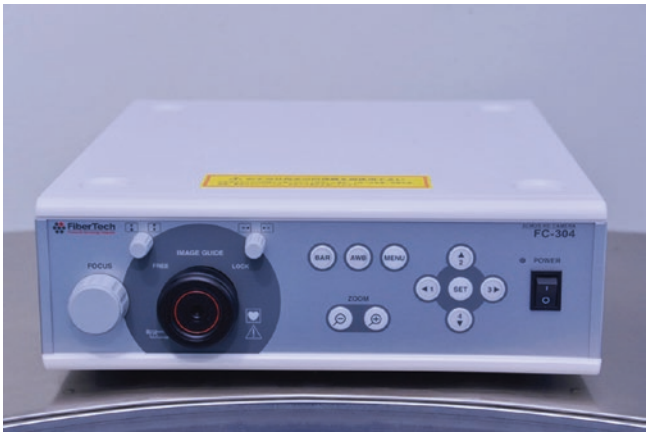


Fig. 10.5 The imaging system

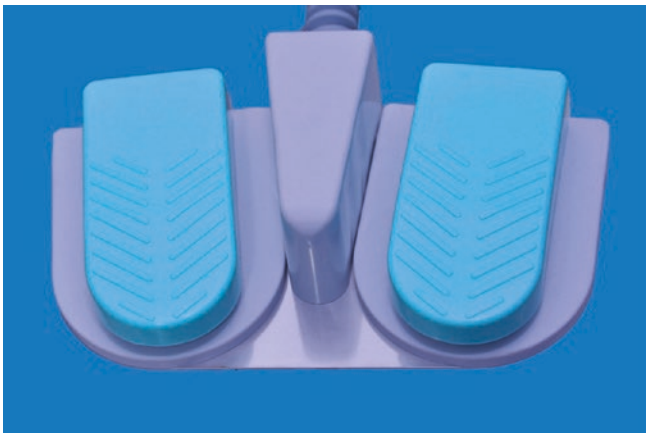


Fig. 10.6 Foot switch for image controlling of dacryoendoscope

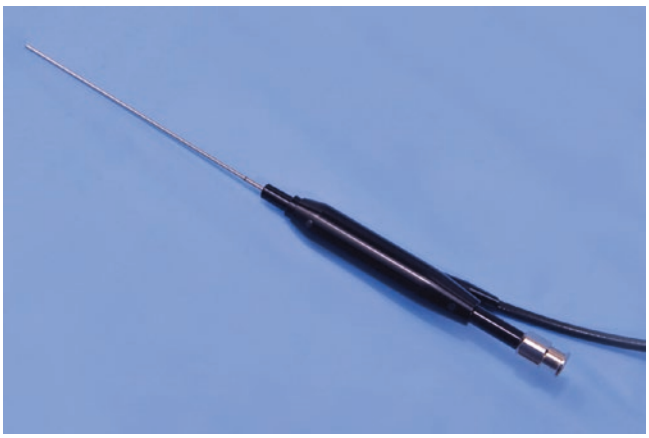


Fig. 10.7 The straight Ruido Fiberscope®

Fig. 10.8 The smooth-curved Ruido Fiberscope®

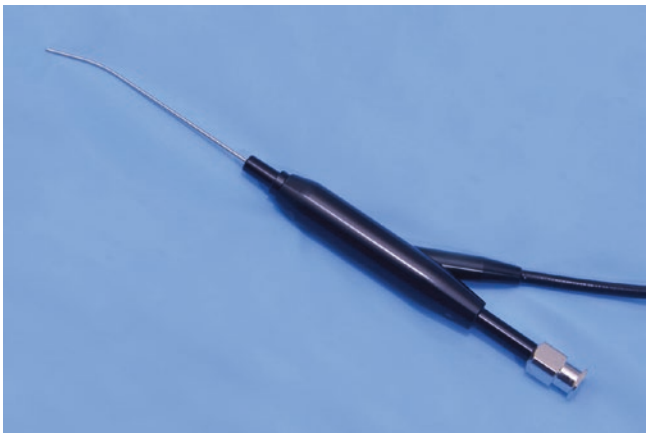


Fig. 10.9 The angulated Ruido Fiberscope®

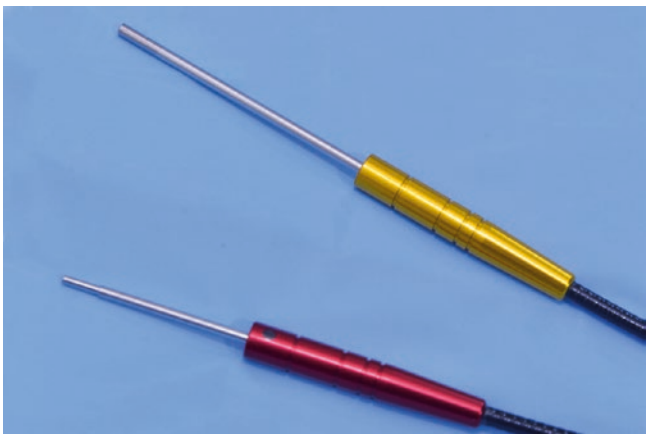


Fig. 10.10 Distal ends of the Ruido Fiberscopes®

Fig. 10.11 The assembly into one unit

Fig. 10.13 Canalicular pass of the dacryoendoscope

Fig. 10.12 Punctal dilatation

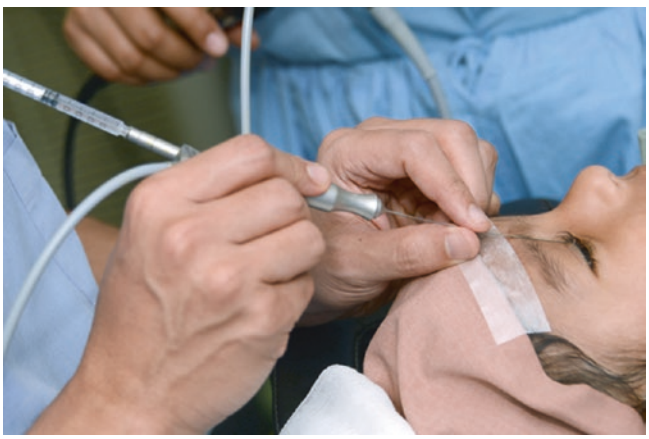


Fig. 10.14 Vertical pass of the dacryoendoscope. Note the saline syringe to side port

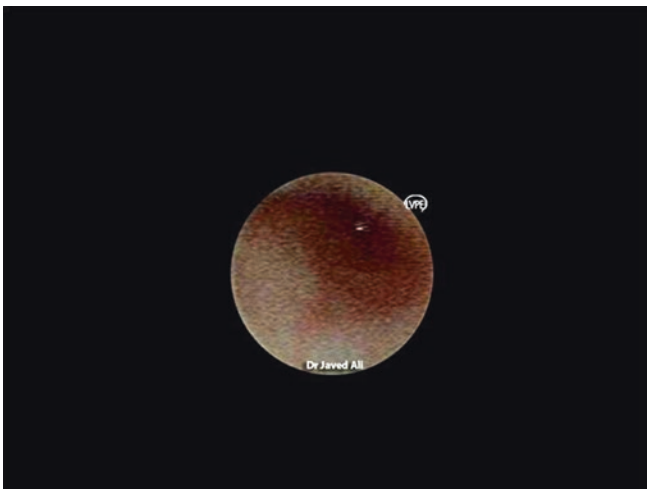


Fig. 10.15 A normal canaliculus

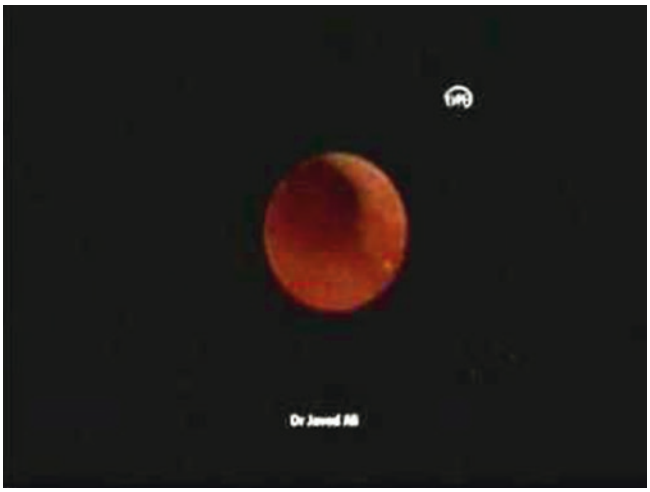


Fig. 10.18 Normal lacrimal sac

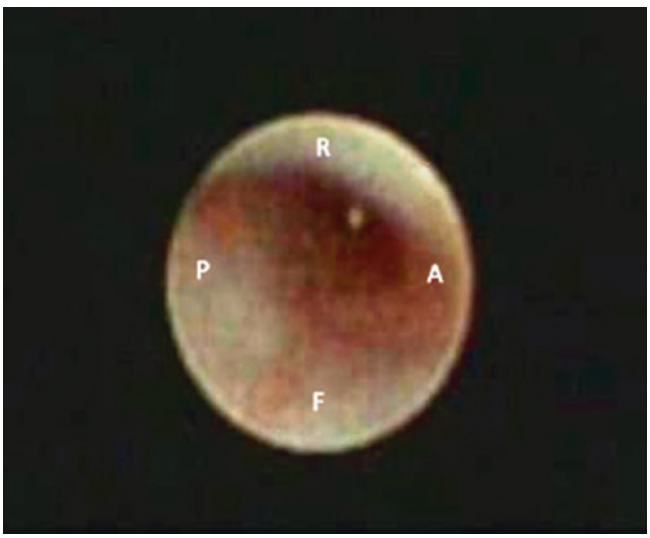


Fig. 10.16 Walls of a normal canaliculus

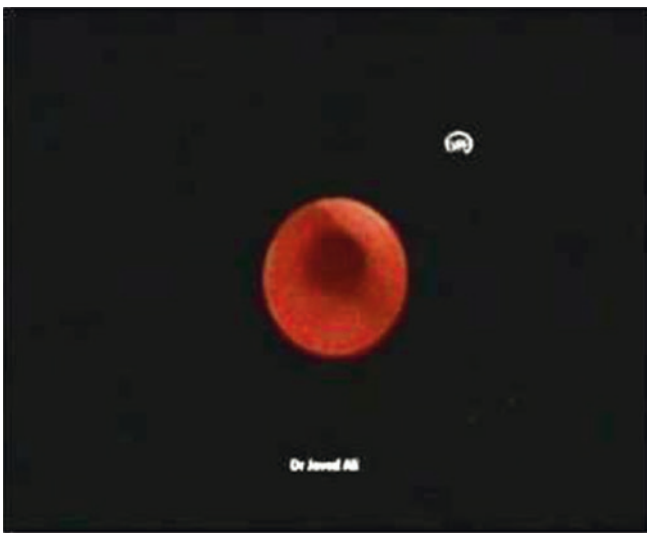


Fig. 10.19 Sac-duct junction

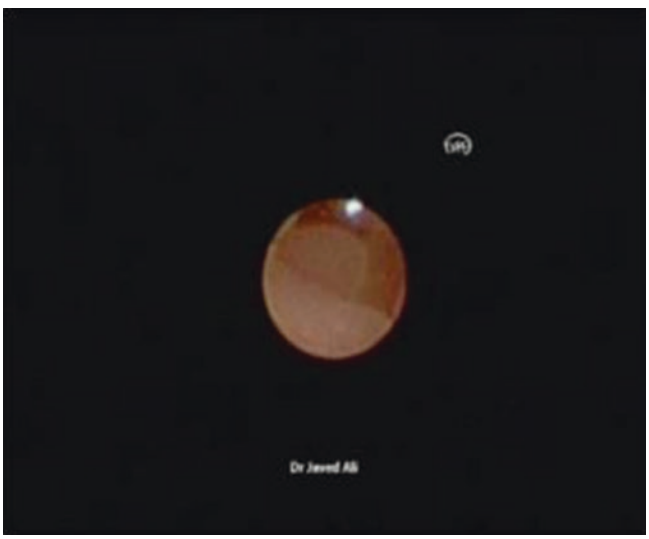


Fig. 10.17 Dacryoendoscopic view (DEN) showing valves

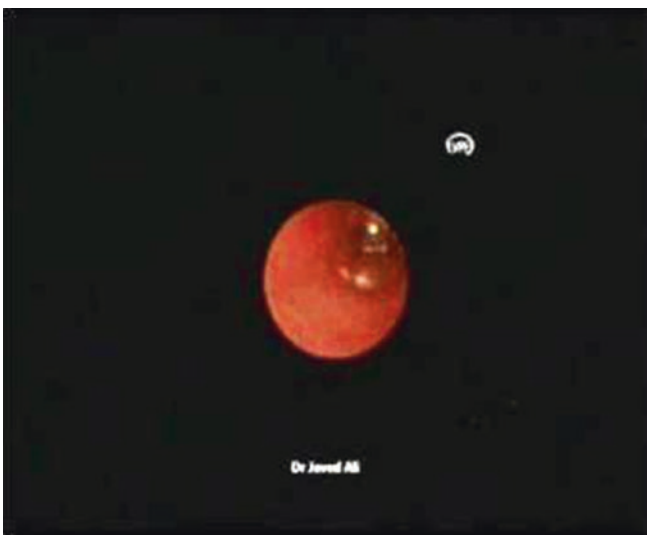


Fig. 10.20 Nasolacrimal duct

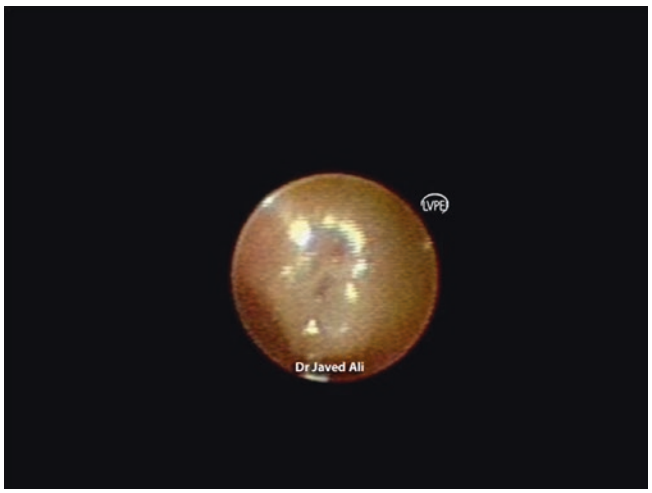


Fig. 10.21 Acquired internal punctal stenosis

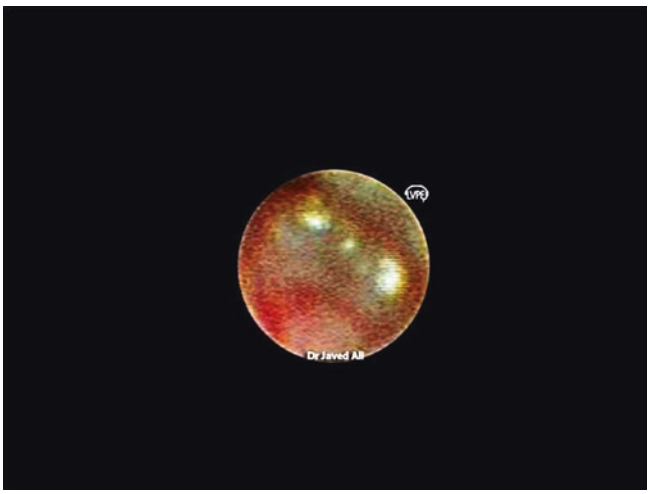


Fig. 10.24 Complete canalicular obstruction

Fig. 10.22 Canalicular stenosis

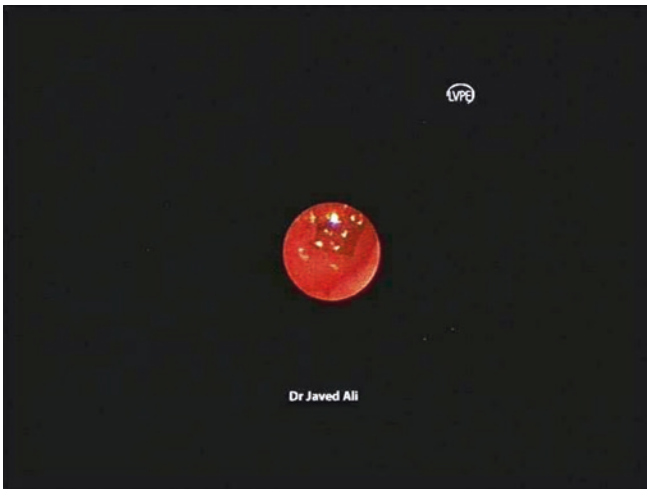


Fig. 10.25 Mucosal inflammation

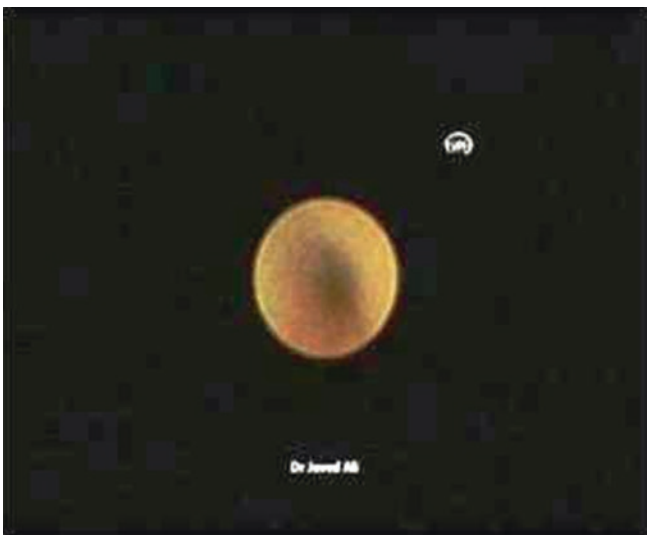


Fig. 10.23 Partial canalicular obstruction

Imaging Modalities for Lacrimal Disorders

11

Lakshmi Mahesh and Mohammad Javed Ali

Introduction

Disorders of the lacrimal system are not uncommon. The spectrum of disease varies from congenital absence or aberrant anlage to acquired stenosis and obstructions of adult onset. Primary acquired nasolacrimal duct obstruction with associated infection is relatively common, whereas certain other disorders like primary sac and duct tumors are very rare. Radiologic evaluation of the lacrimal system has evolved over the past decades to include a variety of studies ranging from plain dacryocystography (Fig. 11.1) to digital subtraction dacryocystography (DCG), nuclear medicine isotope studies dacryoscintigraphy (DSG), lacrimal ultrasonography (USG), computed tomography (CT), combined CT-DCG, and magnetic resonance imaging DCG (MR-DCG) [1]. Technological advances and enhanced imaging processing have allowed development of techniques that provide three-dimensional (3D) visualization of the nasolacrimal duct system.

Digital Subtraction Dacryocystography (DS-DCG)

DS-DCG was first described by Galloway et al. in 1984 [2]. DCG is a useful modality to study the anatomical abnormalities of the lacrimal system like stenosis, obstructions, and diverticulae and to detect dacryolithiasis [2–6]. Digital subtraction dacryocystography is currently the most favored among conventional X-ray techniques. As the name reflects, this technique can subtract background images and noises to give clear contrast-filled lacrimal images for the study (Figs. 11.2 and 11.3). Its other advantages include reduced radiation exposure as compared to conventional techniques, ability to digitally manipulate the image contrast and brightness (Figs. 11.4 and 11.5), and cinematic view helping with understanding the flow dynamics.

The technique is performed after canulating the canalicular system and gently injecting 1 ml of contrast material (Lipiodol, Omnipaque, or gadobutrol) [4]. As the dye is injected, the frames are obtained at a rate of 1 s each. Since the entire lacrimal system would typically fill up in 10 s, frames are obtained for similar duration. During the injection stage, apart from the anteroposterior images, both oblique frontal projections and off-lateral views are captured to yield a better delineation (Figs. 11.6, 11.7, and 11.8). DS-DCG has been reported to not only be useful in differentiating presaccal from post-saccal stenosis but also in evaluating results of a dacryocystorhinostomy [5].

Dacryoscintigraphy (DSG)

Rossomondo et al. first described the radionucleotide evaluation of lacrimal system in 1972 [7]. The advances in nuclear medicine have made dacryoscintigraphy a fairly safe and easy method for assessing the flow dynamics and other physiological aspects of lacrimal system [6–9]. It has a complementary role to anatomic studies and can be useful in evaluating pediatric epiphora, partial obstructions, and functional nasolacrimal duct obstructions (Figs. 11.9, 11.10, and 11.11). The test is performed by instilling 10 μl of technetium 99 pertechnetate into the conjunctival cul-de-sac and tracing the dye through the lacrimal system using a pinhole-collimated gamma camera. Patients are instructed to blink normally, and images are acquired in real time for up to 30 min. The study end point is the detection of radionucleotide dye in the nasal cavity. In a typical normal DSG, visualization of canaliculi and sac occurs before 30 s and with passage into the nasal cavity in 10–20 min (Fig. 11.9). Areas of interest can be marked on the DSG images, and quantity

L. Mahesh, M.S. (✉)
Department of Ophthalmology, Manipal Hospital, Bangalore, India
e-mail: lakshmimahesh1@gmail.com

M. Javed Ali, F.R.C.S.
Govindram Seksaria Insitute of Dacryology, L.V. Prasad Eye Institute, Hyderabad, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_11

of tracer and times taken can be plotted on the time-activity scales. For example, if the system is obstructed at a point, the time-activity slope there would be flat. Disadvantages of DSG include poor anatomical details, poor resolution, and variable transit times throughout the lacrimal system [6–9].

Ultrasonography (USG)

Lacrimal ultrasonography was first described by Oksala in 1959 [10]. Using the B-scan mode, gross lacrimal anomalies like diverticulae, abscess, canaliculus (Fig. 11.12), and dacryolithiasis could be identified [10, 11]. The normal lacrimal system appears as echo-free tubular structures as compared to a completely filled sac with an echogenic stone or tumor. The advantages of USG are easy technique, can be performed in an outpatient setting, and no radiation exposure. The disadvantages of USG include lack of anatomical details and inability to accurately localize abnormalities. However, with increasing technological improvements, there is a resurgence of interest in lacrimal USG. Determining the DCR ostium size and features in the postoperative period by serial ultrasonic measurements have been reported; however, with the advent of endoscopes, a simple outpatient examination with a variety of measuring tools has been favored over a USG [12]. Anatomical and physiological utility of USG biomicroscopy have also been reported to be effective in examining the entire lacrimal drainage system as well as demonstrating the lacrimal sac turbulent flow, but has not gained popularity as a clinical tool [11, 13].

Computed Tomography-Dacryocystography (CT-DCG)

Freitag et al. [14] first described CT-DCG in 2002. CT-DCG is an excellent tool for delineating the bony structures around the lacrimal system and to some extent soft tissue study of lacrimal system [1, 15–17]. Technique employed can be either by dye instillation (drop method) or cannulation technique. The drop method is particularly useful in children and in patients unable to cooperate for irrigation. Serial coronal and axial images (2 mm slices) of the lacrimal area should be requested. Its advantages are listed in Table 11.1. By using modern spiral CT techniques with contrast material, high-resolution thin sections of the system are obtained (Figs. 11.13, 11.14, 11.15, and 11.16). Shorter acquisition time and three-dimensional (3D) reconstruction (Fig. 11.17) offer very good imaging and patient compliance.

This procedure is contraindicated in pregnancy and in those with history of iodine allergy. Children and uncooperative patients can have sedation for the procedure. Radiological acquisition is performed immediately after the dye is irrigated through the respective canaliculi.

Table 11.1 Indications for lacrimal imaging

• Midface trauma	• Failed DCR status of the ostium size, patency, etc.
• Medial canthal masses	
• Previous lacrimal (failed DCR/sino-nasal surgery)	• Patients uncooperative to clinical evaluation
• Anatomical variations	• Uncertainty as to the cause of epiphora

CT-DCG plays a useful role in the evaluation of the patient with tearing when an anatomic abnormality is suspected and is particularly helpful for surgical planning. In axial scans through the lower orbit, the lacrimal sac fossa appears as a depression in the anteromedial wall. In successively lower sections, the duct appears as a round to oval defect in the frontal process of the maxillary bone at the anteromedial corner of the antrum (Fig. 11.16). In absence of contrast, the duct may be filled with air or fluid. As the duct is traced inferiorly, it can be seen to open beneath the inferior turbinate. Cross sections of the system are seen in coronal reformatted images because the line of section is oriented downward and obliquely backward. Parasagittal reformatted images will reveal the entire length of the system in longitudinal section (Fig. 11.15). This view is indispensable in picking up the exact level of the obstruction [15–17]. In trauma cases, it offers additional benefits of more exact localization of the lacrimal drainage system fractures, bone displacements, location of previously placed miniplates, wires or sheets used in fracture repair, etc. (Figs. 11.18 and 11.19) [15].

In our unpublished series of 39 patients who underwent CT-DCG, 23 were males and 16 females. The age ranged from 6 to 78 years. All the cases were performed at a single center by the first author (LM) who performed the irrigation of the dye while the patient underwent the scan. There were two pediatric patients in the study who cooperated for the same under topical anesthesia. In majority of the cases, the initial plain scan was avoided to minimize exposure to radiation. The total procedure time takes about 10–15 min. The dye (water soluble iodine-based dye—Omnipaque, ioversol) containing 300 mg iodine/ml was diluted either in 1:5 or 1:10 concentrations. This was loaded into a 1 cc disposable syringe with a lacrimal cannula (26 gauge), and after application of topical anesthetic, cannulation was carried out to inject the dye into the system. Simultaneous evaluation of the other side was also carried out for comparison. Seven patients had bilateral disease with partial or total obstruction of the system on the other side. The rest of the patients had unilateral disease. No untoward effect or allergy to the dye was noted in any case.

The indications for CT-DCG are listed in Table 11.2. Traumatic obstructions are a major indication in which displacement of the sac and its precise location could be

Table 11.2 Advantages of CT-DCG

• Assessment of the anatomical variations
• Assesses immediate bony confines
• 3D lacrimal fossa evaluation
• Evaluation of orbit and facial skeleton
• Evaluates paranasal sinus contributions

ascertained. This was especially helpful in cases where there was persisting dacryocystitis following maxillofacial repair and medial canthal masses (Figs. 11.20 and 11.21) [15]. CT-DCG is very helpful to note the involvement of the sac in tumors initially and also for noting the features of post-treatment such as irradiation where further reconstruction along with epiphora management is contemplated. Unusual features such as diverticulum of sac, canalicular pouch along with foreign bodies, could be picked up. Tracking of the fistulous tract is also feasible [15–17]. In an unpublished series by first author (LM), 20 patients underwent surgery after the imaging procedure. In all patients who underwent subsequent surgery, the findings on CT-DCG correlated well with the intraoperative findings. Seventeen patients had features of associated sinus disease, which could be picked up very well as imaging of the paranasal sinuses could be done simultaneously. These patients were also treated for the sinusitis. At present CT-DCG is an invaluable tool in the diagnosis and management of complex lacrimal duct obstructions.

Magnetic Resonance Imaging Dacryocystography (MR-DCG)

MR-DCG was first described by Goldberg et al. in 1993 [18]. MR-DCG is a very useful lacrimal imaging modality that offers a superior soft tissue delineation and can differentiate lacrimal system fluid signals from surrounding tissues [18–22]. Table 11.3 lists the advantages of MR-DCG. However, the disadvantages are long acquisition times, lack of bony details, and higher costs as compared to others. The technique can be performed similar to that of CT-DCG, however, the contrast used in 0.5% gadolinium meglumine. T1-weighted images with fat suppression in any plane desired are acquired between 5 and 10 min following the contrast instillation but not later since the dye is not retained beyond 20 min. Although the anatomical delineation is excellent, it's superiority over CT-DCG for anatomical abnormalities in lacrimal system has not been established [20]. MR-DCG is preferred for congenital dacryocystoceles, but with the advent of endoscopic examinations, this can well be avoided in favor of a less cumbersome and outpatient procedure. The half-Fourier single-shot technique of HASTE using fast sequence of T2-weighted images and dynamic MR studies has been found useful for functional studies of lacrimal system but has not gained wide clinical acceptance [21, 22].

Table 11.3 Advantages of MR-DCG

• High tissue contrast
• Better soft tissue delineation
• Imaging in any obliquity desired
• Clear identification of fluid signals
• No ionizing radiations
• Noninvasive contrasts

Updates (2015–2016)

1. ***Three-dimensional volumetric lacrimal analysis***
   Three-dimensional volumetric analysis of the nasolacrimal ducts has been carried out using the GE Advantage Workstation^{R}. The mean NLD volumes were $0.493 \pm 0.14\ cm^3$ and $0.328 \pm 0.08\ cm^3$ in normal Caucasian males and females, respectively [23]. Although no correlation could be established with PANDO, various volumetric studies of different segments of lacrimal drainage can provide useful insights into the anatomical and functional aspects.
2. ***SPECT CT***
   Single-photon emission computed tomography has been shown recently to provide good delineation in accurately differentiating nasolacrimal stenosis from obstructions, hence making surgical decisions easier [24]. SPECT has also been used recently to demonstrate the localization of radioactive iodine in the nasolacrimal ducts of patients who take it for thyroid carcinomas [25].
3. ***Fast spin echo and 3D MR-DCG***
   T2-weighted fast spin echo sequence MR-DCG has been shown to be effective in accurately localizing the level of obstruction in 84% of the patients when compared with a dacryoendoscopy [26]. This reflects a high degree of accuracy and can be utilized at least in complex cases and those with uncertain epiphora. Three-dimensional fast spin echo (3D FSE) cube MR-DCG provides high-quality volumetric images with high spatial resolution in lacrimal obstructions. This 3D FSE cube MR-DCG was found to provide better visibility as compared to the regular fast spin echo techniques, although the numbers of lacrimal segments visualized were high in both the groups [27].
4. ***Prenatal ultrasound for dacryocele***
   Prenatal detection of a dacryoceles on USG is not a routine, and very interesting information has come up in the literature [28, 29]. The incidence of dacryoceles among routine obstetric USG was 0.43%. No gender predilection was apparent. The highest detections were around 27 weeks of gestational age and reduced at term. Most

were unilateral with a mean maximum diameter of 7 mm. Of them, 76% had a spontaneous resolution at birth [28]. These newer findings reflect that although uncommon, dacryoceles usually resolve spontaneously. Hence their antenatal presence may not even be realized in a healthy infant. It is interesting to note that when the routine prenatal scans were visited in a case of a neonatal dacryoceles, it was noted to be present very clearly but was missed [29]. Prenatal detections can help in better management in persistent cases and hence reduce the morbidity.

5. ***Thermography***

Circulation of blood and heat transfer to tissues can be detected by using infrared technology. Although its use for lacrimal drainage is not new [30], but there has been a resurgent interest in these techniques because of better technology; very quick, noninvasive nature; and without the need for contrast. Dacryocystitis has been shown as a hot colour area of lacrimal sac on thermography [31]. Although promising, it lacks accurate localization, and its use as of now is limited to acute infections or inflammations.

Conclusion

There is no single gold standard imaging modality among the battery of techniques described in this chapter. Each modality has its own niche and unique set of advantages and contributes significantly in its own way. Regardless of the radiologic studies requested, good communication between the clinician and the radiologist in reference to the patient's symptoms, examination findings, and possible diagnosis is helpful to ensure that the maximum amount of useful information is obtained in every study.

References

1. Mahesh L. Imaging in lacrimal surgery. In: Isloor S, editor. Lacrimal drainage surgery. New Delhi: Jaypee Brothers; 2014. p. 17–22.
2. Galloway JE, Kavie TA, Raflo GT. Digital subtraction macrodacryocystography: a new method of lacrimal system imaging. Ophthalmology. 1984;91:956–62.
3. Kousoubris PD. Radiological evaluation of lacrimal and orbital disease. In: Woog JJ, editor. Endoscopic lacrimal and orbital surgery. 1st ed. Oxford: Butterworth-Hienemann; 2004. p. 79–104.
4. Priebe M, Mohr A, Brossman J, et al. Gadobutrol: an alternative contrast agent for digital subtraction dacryocystography. Eur Radiol. 2002;12:2083–6.
5. Walther EK, Herberhold C, Lippel R. Digital subtraction dacryocystography (DS-DCG) and evaluation of results of endonasal lacrimal duct surgery. Laryngorhinootologie. 1994;73:609–13.
6. Lefebvre DR, Freitag SR. Update on imaging of the lacrimal drainage system. Surv Ophthalmol. 2012;27:175–86.
7. Rossomondo RM, Carlton WH, Trueblood JH, et al. A new method of evaluating lacrimal drainage. Arch Ophthalmol. 1972;88:523–5.
8. Hurwitz JJ, Maisey MN, Welham RAN. Quantitative lacrimal scintillography. Br J Ophthalmol. 1975;59:313–22.
9. Sagili S, Selva D, Malhotra R. Lacrimal scintigraphy: interpretation more art than science. Orbit. 2012;31:77–85.
10. Oksala A. Diagnosis by ultrasound in acute dacryocystitis. Acta Ophthalmol. 1959;37:176–80.
11. Al-Faky YH. Anatomical utility of ultrasound biomicroscopy in the lacrimal drainage system. Br J Ophthalmol. 2011;95:1446–50.
12. Ezra E, Restori M, Mannor GE. Ultrasonic assessment of rhinostomy size following external dacryocystorhinostomy. Br J Ophthalmol. 1998;82:786–9.
13. Al-Faky YH. Physiological utility of ultrasound biomicroscopy in the lacrimal drainage system. Br J Ophthalmol. 2013;97:1325–9.
14. Frietag SK, Woog JJ, Kousoubris PD, et al. Helical computed tomographic dacryocystography with three-dimensional reconstruction: a new view of lacrimal drainage system. Ophthal Plast Reconstr Surg. 2002;18:121–32.
15. Ashenhurst M, Jaffer N, Hurwitz JJ, et al. Combined computed tomography and dacryocystography for complex lacrimal problems. Can J Ophthalmol. 1991;26:27–31.
16. Udhay P, Noronha OV, Mohan RE. Helical computed tomographic dacryosystography and its role in the diagnosis and management of lacrimal drainage system blocks and medial canthal masses. Indian J Ophthalmol. 2008;56:31–7.
17. Hurwitz JJ, Edward Kassel EE, Jaffer N. Computed tomography and combined CT-dacryocystography (CT-DCG). In: Hurwitz JJ, editor. The lacrimal system. New York: Raven Press; 1996. p. 83–5.
18. Goldberg RA, Hienz GW, Chiu L. Gadolinium magnetic resonance imaging dacryocystography. Am J Ophthalmol. 1993;115:738–41.
19. Coskun B, Ilgit E, Onal B, et al. Magnetic resonance dacryocystography in evaluation of patients with obstructive epiphora treated by means of interventional radiological procedures. Am J Neuroradiol. 2012;33:141–7.
20. Manfre L, de Maria M, Todaro E, et al. Magnetic resonance dacryocystography: comparison with dacryocystography and CT-dacryocystography. Am J Neuroradiol. 2000;21:1145–50.
21. Cubuk R, Tasali N, Aydin S, et al. Dynamic MR dacryocystography in patients with epiphora. Eur J Radiol. 2010;73:230–3.
22. Amrit S, Goh PS, Wang SC. Tear flow dynamics in human nasolacrimal ducts: a pilot study using dynamic magnetic resonance imaging. Graefes Arch Clin Exp Ophthalmol. 2005;243:127–31.
23. Estes JL, Tsiouris AJ, Christos PJ, et al. 3-D volumetric assessment of the nasolacrimal duct in patients with obstructions. Ophthal Plast Reconstr Surg. 2015;31:211–4.
24. At'Kova EL, Yartsev VD, Tomashevsky IO, et al. Treatment choice in dacryostenosis based on single-photon emission computed tomography and X-ray computed tomography findings. Vestn oftalmol. 2016;132:15–20.
25. Ali MJ, Vyakaranam AR, Rao JE, et al. Iodine-131 and lacrimal drainage system toxicity: nasal localization studies using the whole body nuclear scintigraphy and SPECT CT. Ophthal Plast Reconstr Surg. 2017;33:13–6.
26. Higashi H, Tamada T, Mizukawa K, et al. MR dacryocystography: comparison with Dacryoendoscopy in positional diagnosis of nasolacrimal duct obstruction. Radiol Med. 2016;121:580–7.
27. Zhang J, Chen L, Wang QX, et al. Isotropic three-dimensional fast spin- echo cube magnetic resonance dacryocystography: comparison with three-dimensional fast-recovery fast spin-echo technique. Neuroradiology. 2015;57:357–65.
28. Kim YH, Lee YJ, Song MJ, et al. Dacryocystocele on prenatal ultrasonography: diagnosis and postnatal outcomes. Ultrasonography. 2015;34:51–7.
29. Machado MA, Abreu Junior LD, Silva JA, et al. Congenital dacryocystocele: diagnosis using ante and post-natal ultrasonography. Arq Bras Oftalmol. 2014;77:261–3.
30. Hinton P, Hurwitz JJ, Chart PL. Liquid crystal contact thermography and lacrimal tract inflammation: a preliminary report. Can J Ophthalmol. 1984;19:176–7.
31. Machado MA, Silva JA, Brioschi ML, et al. Using thermography for obstruction of the lower lacrimal system. Arq Bras Oftalmol. 2016;79:46–7.

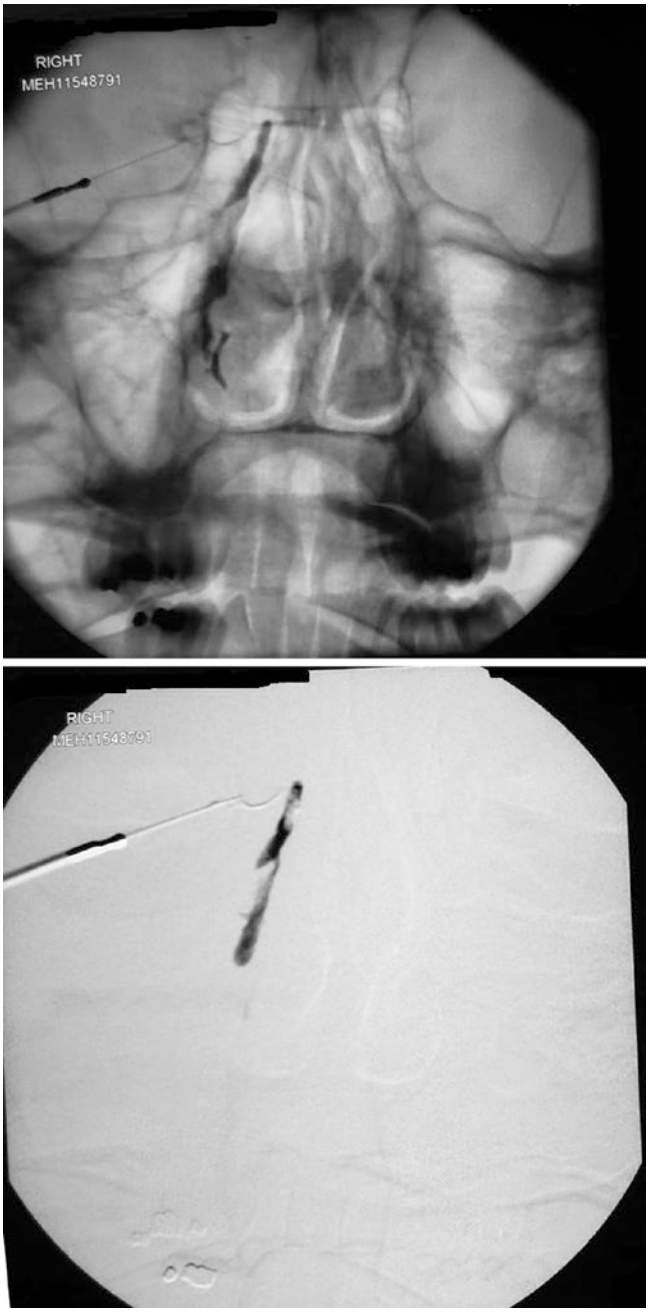


Fig. 11.1 Plain DCG in a trauma setting showing a right distal nasolacrimal duct obstruction (Photo courtesy: Gangadhara Sundar, Singapore)

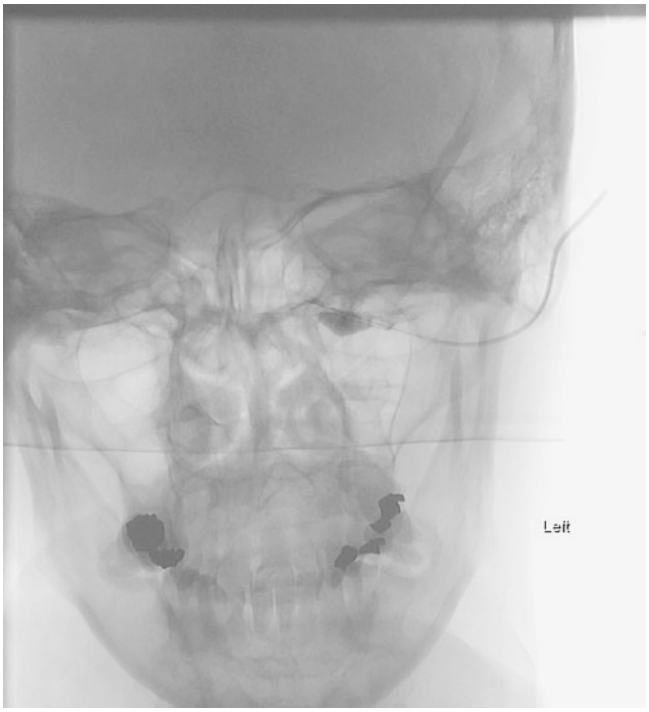


Fig. 11.2 Plain DCG before digital subtraction

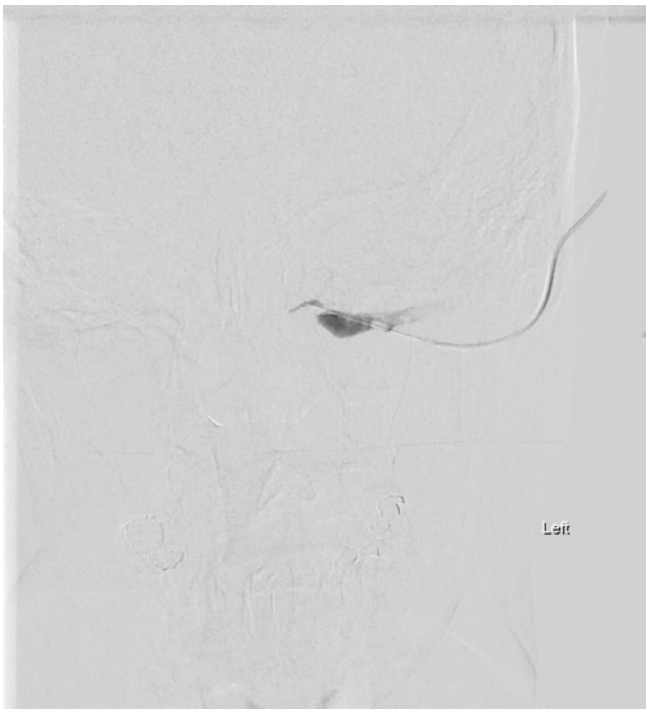


Fig. 11.3 DCG after digital subtraction of the same patient as in Fig. 11.2

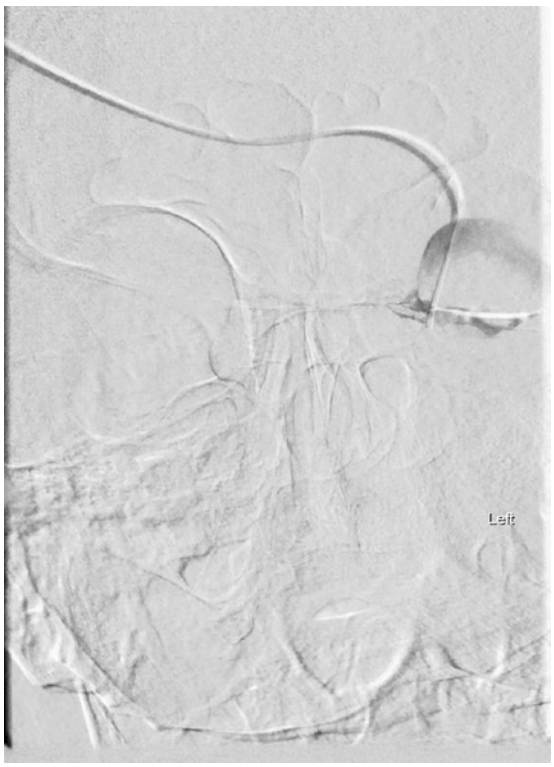


Fig. 11.4 Digitally subtracted image with a cannula in left lacrimal system (Photo courtesy: Alkis Psaltis, Adelaide)

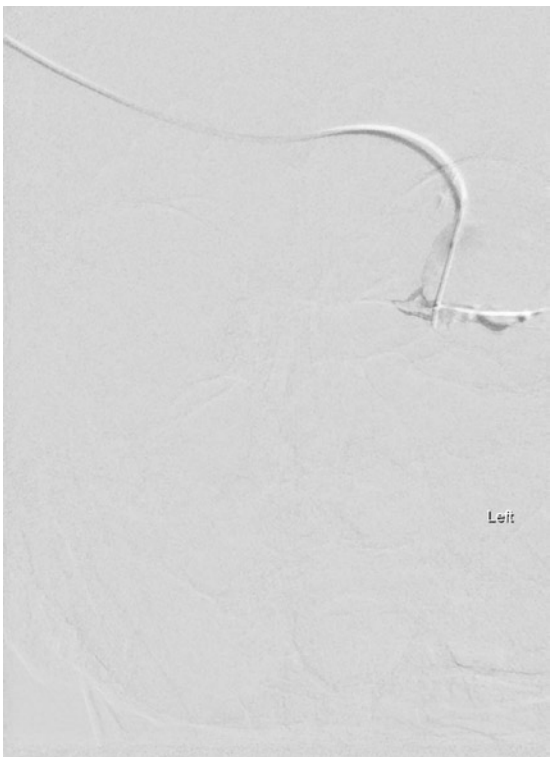


Fig. 11.5 Image contrast and brightness manipulation of the same patient as in Fig. 11.4 for better lacrimal delineation (Photo courtesy: Alkis Psaltis, Adelaide)

Fig. 11.6 Lateral view of DS-DCG showing canalicular filling with dye (Photo courtesy: Alkis Psaltis, Adelaide)

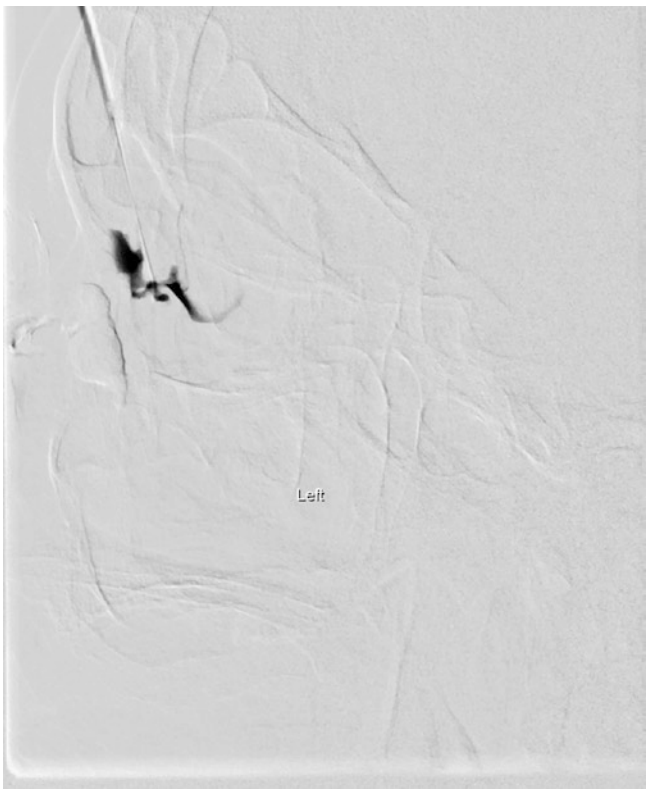


Fig. 11.7 Sequential DCG of same patient as in Fig. 11.6, showing early sac filling (Photo courtesy: Alkis Psaltis, Adelaide)

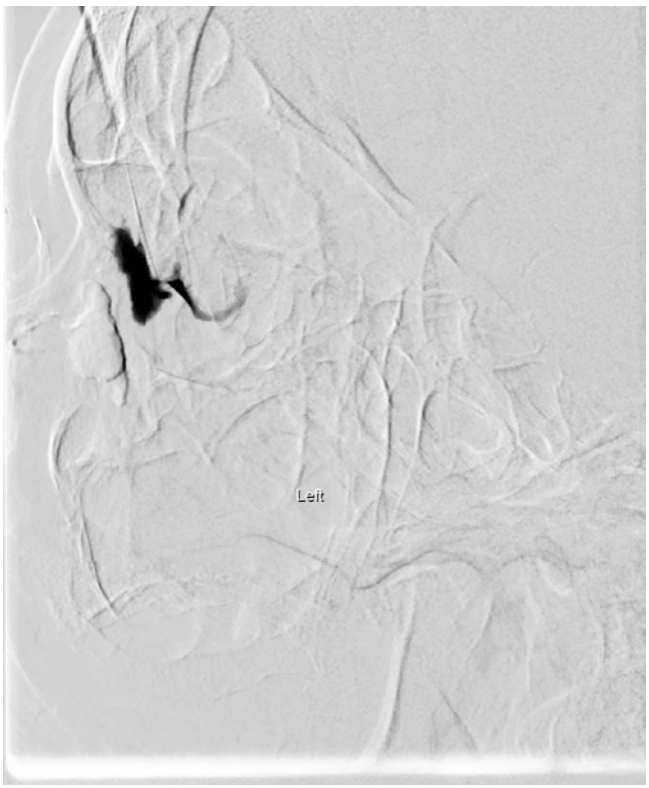


Fig. 11.8 Sequential DCG of same patient as in Figs. 11.6 and 11.7, showing complete filling of the sac but obstruction at the sac-duct junction. (Photo courtesy: Alkis Psaltis, Adelaide)

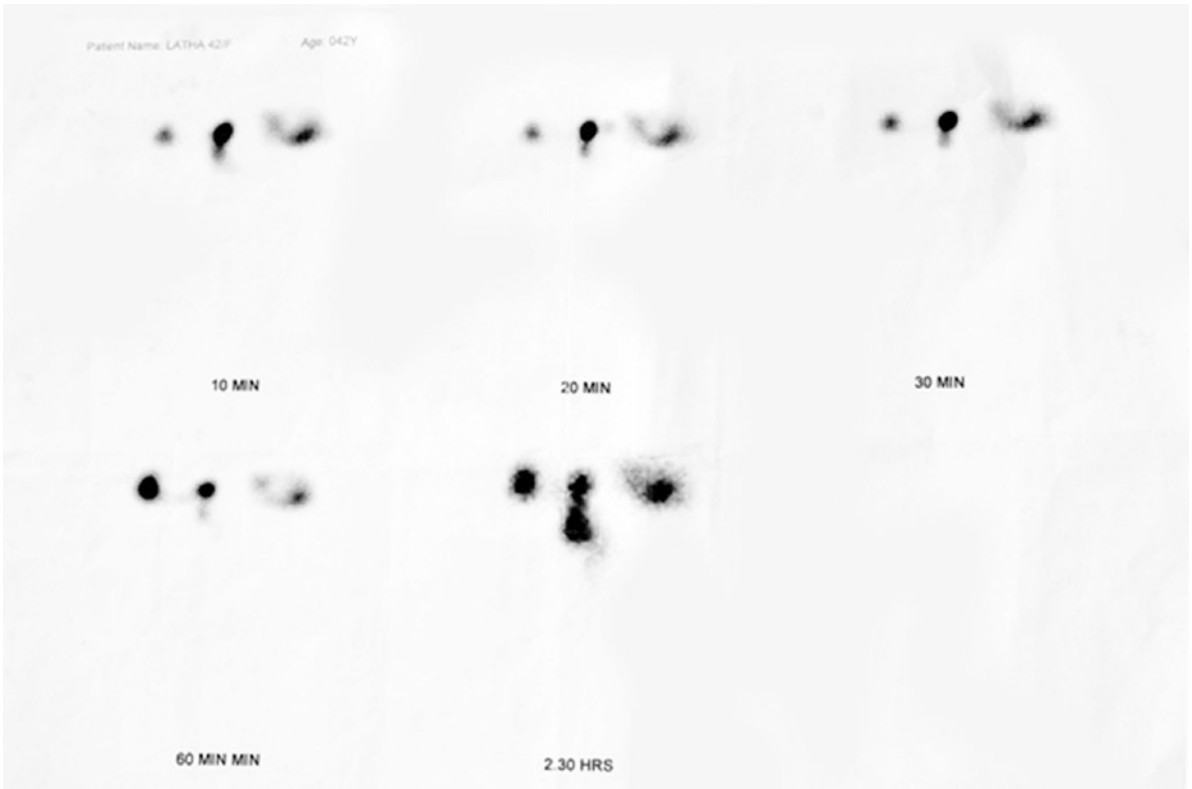


Fig. 11.9 Dacryoscintigraphy showing a normal right lacrimal system and a left distal canalicular obstruction

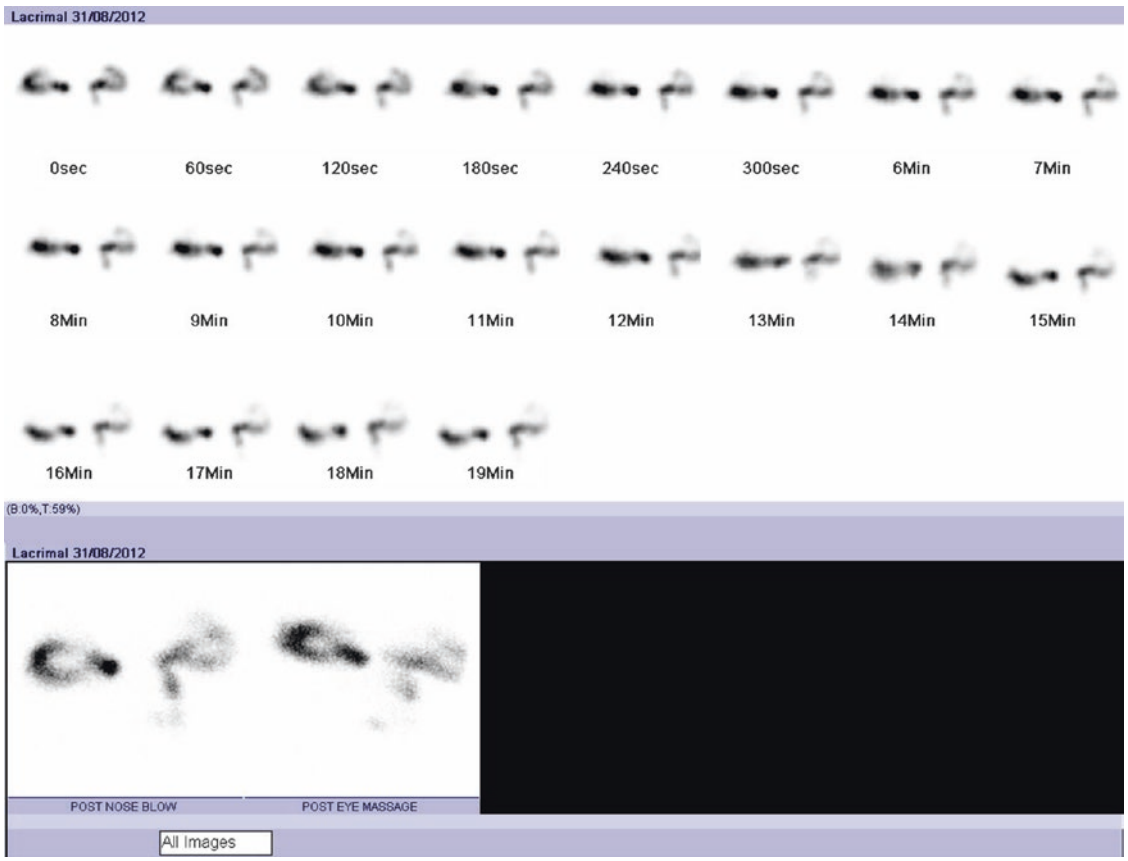


Fig. 11.10 Dacryoscintigraphy showing right pre-saccal and left post-saccal obstructions

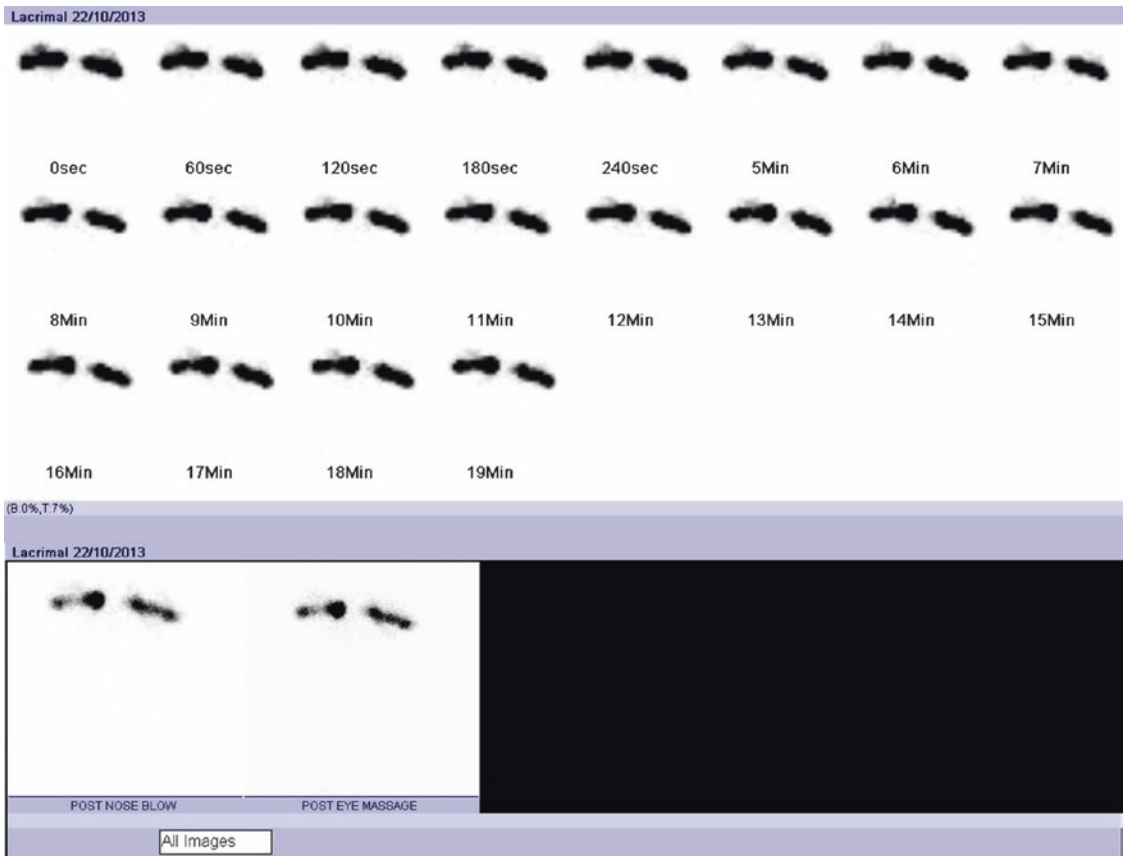


Fig. 11.11 Dacryoscintigraphy showing bilateral pre-saccal obstructions (Photo courtesy: Alkis Psaltis, Adelaide)

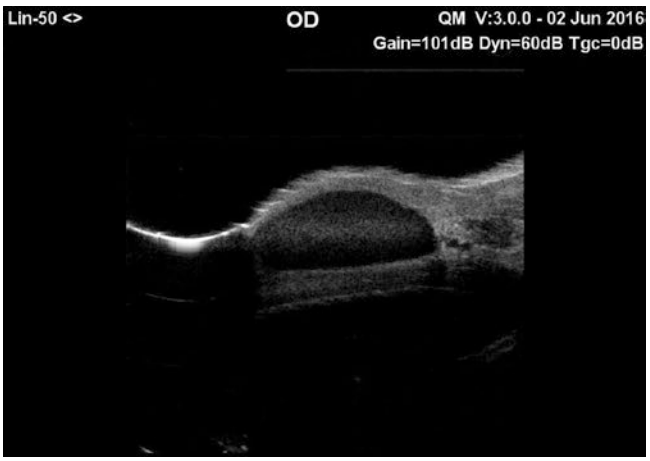


Fig. 11.12 Ultrasound biomicroscopy of a right upper canaliculus. No well-delineated boundaries and adjacent small lumen of the normal canalicular segment

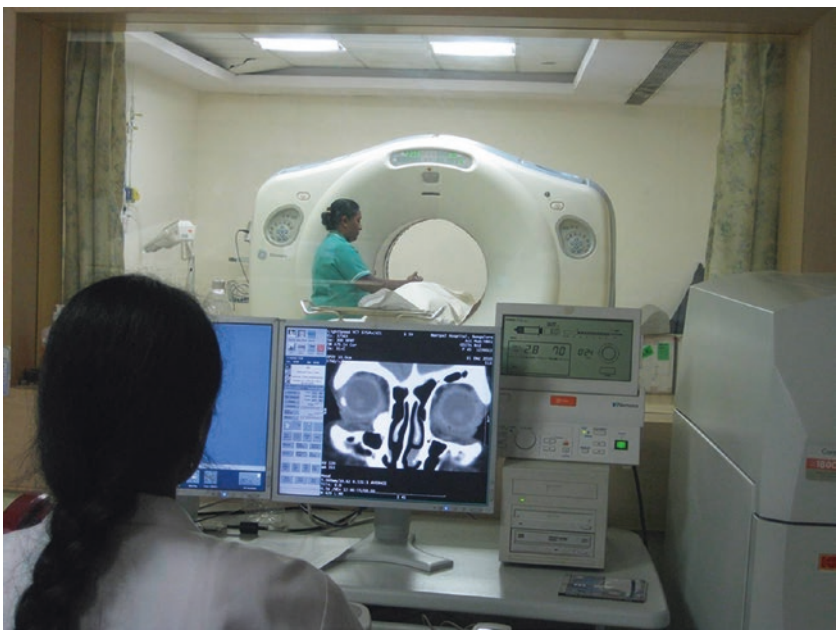


Fig. 11.13 A CT-DCG procedure in action

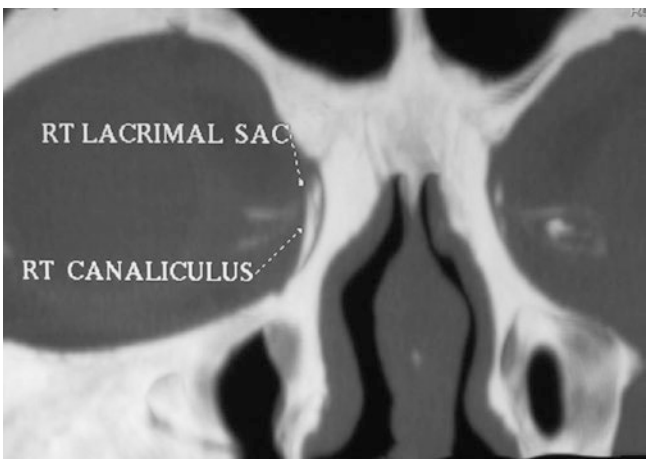


Fig. 11.14 CT-DCG, coronal image showing the dye within the canaliculi and lacrimal sac

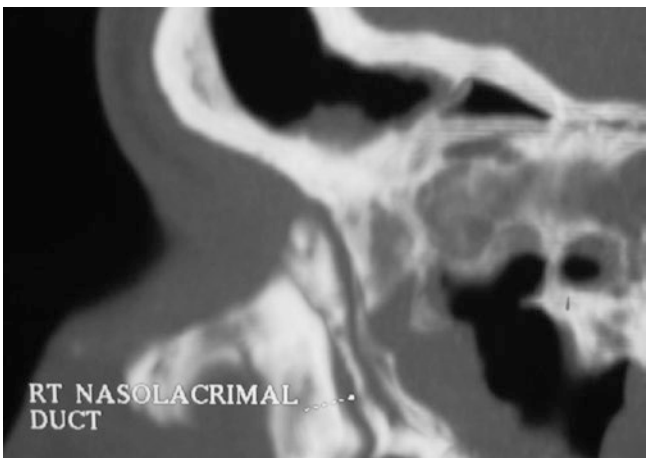


Fig. 11.15 CT-DCG, sagittal reconstruction showing the sac emptying into the nasolacrimal duct

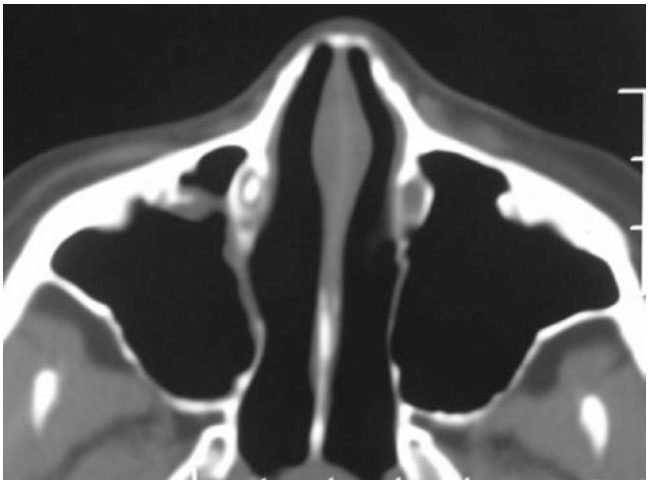


Fig. 11.16 CT-DCG, axial image, showing presence of dye in the right nasolacrimal duct, while it is absent on the left side, indicating obstruction

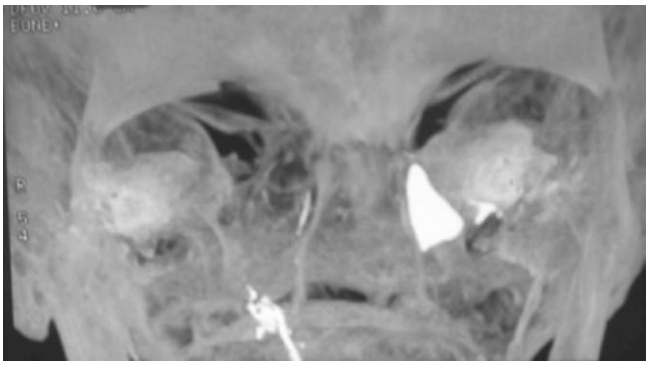


Fig. 11.17 Virtual rendered image showing pooling of dye on the left side indicating an obstruction. Note the dye in the right nasal cavity indicating a patent right system

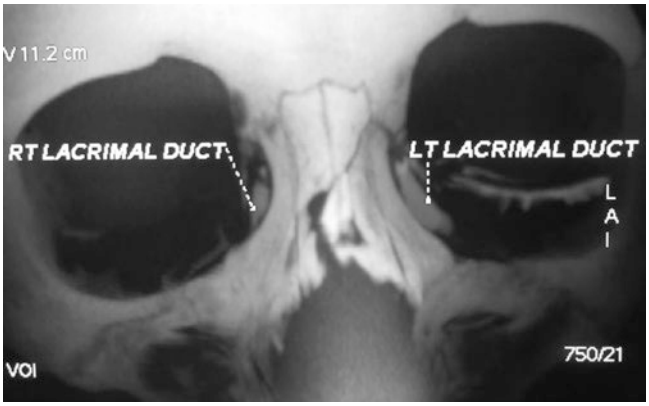


Fig. 11.18 CT-DCG in a trauma setting showing accumulation of the dye in the left lacrimal sac indicating an obstruction below in a case of naso-orbito-ethmoid fractures

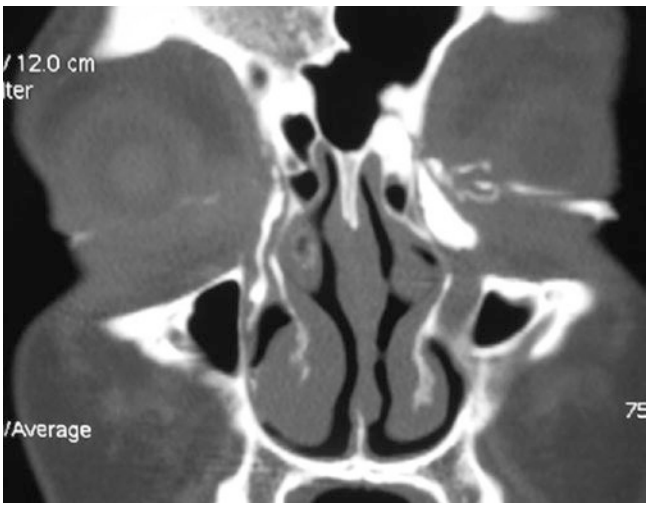


Fig. 11.19 CT-DCG of the same patient as in Fig. 11.17, showing a patent right system and an obstructed left lacrimal system

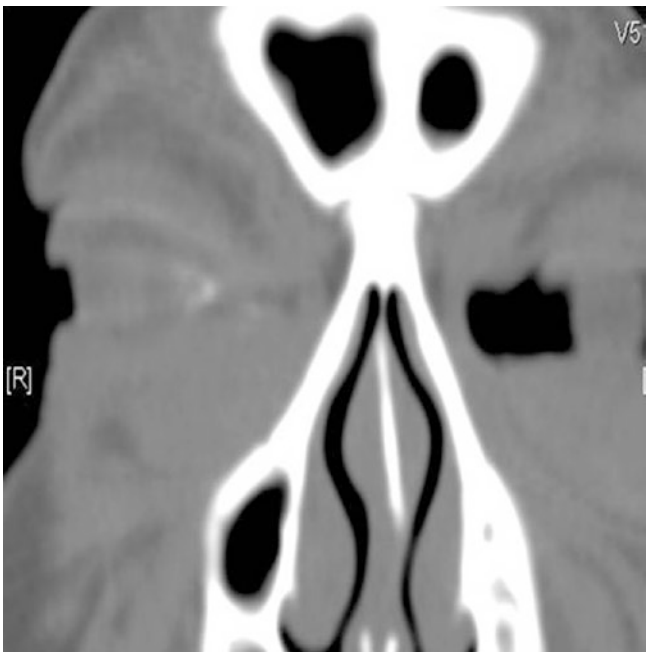


Fig. 11.20 CT-DCG, coronal image, showing a mass in the inferomedial orbit. Note the presence of dye in the canaliculi

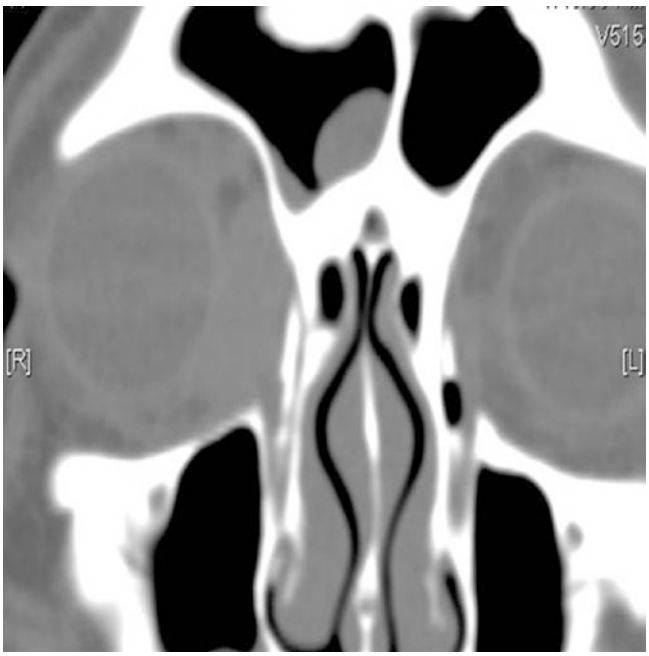


Fig. 11.21 CT-DCG, coronal image of the same patient as in Fig. 11.19, showing the lacrimal sac and nasolacrimal filling, indicating that the mass is not arising from lacrimal sac

Optical Coherence Tomography of the Lacrimal System

12

Swati Singh and Mohammad Javed Ali

Introduction

Optical coherence tomography or OCT has revolutionized the ophthalmology practice since 1991 primarily for retinal imaging. It was employed in imaging anterior segment for the first time by Izatt in 1994 [1–4]. It is an evolving technology with a shift from conventional time domain to spectral domain (SD) and latest addition of ultra high-speed intuitive swept source technology (SS-OCT). Apart from its routine use for corneal and anterior chamber angle imaging, anterior segment OCT (ASOCT) has been used for non-contact meibography, evaluating tear film height in monitoring effectiveness of a dacryocystorhinostomy surgery, evaluating early-phase tear clearance and in dermatology for skin lesions with depth penetration of up to 1.6 mm [5–8].

Implications of imaging punctum and proximal lacrimal system lie in diagnosing and managing punctal stenosis, punctal cysts, and use of punctal plugs in dry eye which are affected by punctum size, shape, and function [9, 10]. Multiple options exist today for proximal lacrimal system imaging (Table 12.1). Lacrimal punctum imaging has been traditionally performed with slit lamp cameras using Ramsden eyepiece which enhances magnification but suffers from interobserver variations and lack of an objective measurement tool [11]. Ultrasonic biomicroscopy of proximal canaliculus has been demonstrated by Hurwitz et al. [12] by distension of canaliculus with a viscoelastic (Table 12.2). However, a routinely used objective technique for assessing punctum morphology was lacking at that time. An ideal imaging technique should be non-contact, non-invasive, high resolution with deeper penetration of 5–6 mm and an objective measurement tool for punctal size with high reliability, reproducibility, and least interobserver variation. Wawrzynski et al. [13] demonstrated for the first time in vivo high-resolution spectral domain-OCT (SD-OCT) images of normal punctum and vertical canaliculus and found the modality to be ideally suited for imaging the proximal lacrimal system (Fig. 12.1).

Table 12.1 Existing techniques of measuring punctum size and their potential drawbacks

Technique	Limitations
Probing	Distorts/dilates punctum
Slit lamp photography	Subjective, interobserver variation
Ultrasonic biomicroscopy	Invasive, needs coupling medium
Optical coherence tomography	Limited depth

Table 12.2 Characteristics of optical coherence tomography (OCT) and ultrasonic biomicroscopy (UBM)

Characteristics	OCT	UBM
Source used	Diode light	Sound
Resolution (in μm)	3–20	50
Contact with eyelid	No	Yes
Coupling medium	No	Yes
Acquisition time (in s)	0.1–1.13	~60, skill dependent
Depth penetration (in mm)	3–6	4–5
Longest scan (in mm)	16 * 6	5 * 5

Principle

OCT works on the principle of low-coherence interferometry, wherein light is sent along two optical paths, one being the sample path (into the eye) and the other the reference path of the interferometer [14]. The light source is an 840 nm super luminescent light-emitting diode (SLD). Light returning from the sample and reference paths is combined by the detector, which is a spectrometer in newer generation OCT's. The spectrometer resolves the interference signals by means of a Fourier transformation. In Fourier

S. Singh, M.D.
Ophthalmic Plastics Surgery, Lala Jagannath Eye Institute, Ambala, India

M. Javed Ali, F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_12

Table 12.3 Various commercially available and commonly used OCT machines

	ASOCT, Visante	RTVue (Optovue)	Topcon 3D 2000 (Topcon)	Spectralis (Heidelberg)	DRI OCT (Topcon)
Theory	Time domain	Fourier domain	Fourier domain	Fourier domain	Swept source
Wavelength used (in nm)	1310	840	840	840	1050
Transverse resolution (in μm)	30	8	20	14	20
Axial resolution (in μm)	18	5	5	7	1
Depth penetration (in mm)	4–6	3	3	3	4
Speed (scans per s)	2000	26,000	50,000	40,000	100,000
3D imaging	No	Yes	Yes	Yes	Yes
Additional features	–	En face	En face	En face, EDI	En face

spectral domain, reference arm remains fixed, making it possible to acquire OCT image data about 70 times faster than conventional (time domain) OCT. The vast increase in scan speed makes it possible for FD-OCT to acquire three-dimensional data sets. Recently "swept source" OCT has been introduced, with a longer wavelength of 1050 nm for greater tissue penetration giving a more detailed image [15, 16]. Parametric details of various commercially available OCT are given in Table 12.3.

Technique

Patient is positioned keeping their chin on the OCT chin-rest and their forehead against the upper support. With the eyes open, the lower eyelid margin is gently everted using a cotton bud placed below the punctum just enough to get the punctum into a plane perpendicular to the light source (Figs. 12.2 and 12.3). The long axis of scan is aligned approximately parallel to the lid margin, and line scan is captured. For time-domain ASOCT machine, no additional lens is required. For RTVue® (Optovue Inc., Fremont, CA, USA), a corneal adaptor module 6 mm line scan is used. Heidelberg Spectralis OCT® (Heidelberg Engineering, Germany) uses an "Anterior Segment Module" (ASM) which has a lens and an add-on software along with enhanced depth imaging protocol. Topcon 3D OCT 2000® (Topcon Medical Systems, NJ, USA) utilizes anterior segment setting with its add-on lens for imaging. Volumetric studies can also be carried out.

Normal Proximal Lacrimal System

Depending upon the resolution of the machine used and type of scan acquired, different kinds of images can be obtained. Lacrimal punctum is visualized as an opening or discontinuity along the lid margin with continuity into an underlying vertical canaliculus (Fig. 12.1). Reported literature states the inability to capture vertical canaliculus in 55% of the cases by Timlin et al. [19], although the rest of the other studies have reported 100% acquisition rate. Values from published studies on lacrimal parameters have been summarized in Table 12.4 [13, 17–19].

Qualitative Assessment

The medial wall of punctum has a rounded curve in contrast to almost vertically straight lateral wall. Tapering of these walls can be seen in V-shaped manner or abruptly. Dilatation of lateral wall of punctum was seen in 3/40 puncta by Timlin et al. [19] which was hypothesized to be ampullary region. Greater insights into the surface morphology of the external and internal punctum can be captured on 3D en face imaging (Fig. 12.4).

Layers in lacrimal punctum: All images irrespective of the machine have showed a hyper-reflective layer sandwiched between two comparatively hypo-reflective layers. Kakizaki et al. [20] in their cadaveric studies have demonstrated histologically, a characteristic presence of dense fibrous tissue in continuity with tarsal plate in and around the punctum. Vertical canaliculus is surrounded by muscle of Riolan all around along with dense fibrous tissue. Hyper-reflective layer seen in middle on OCT appears corresponding to the dense fibrous tissue, superficial layer corresponding to epithelium and the lower most to muscle of Riolan (Fig. 12.5). Scanning electronic microscopic study by Ali et al. [21] has shown a slightly thickened elevated mucosa at the junction between punctum and vertical canaliculus (Fig. 12.6). This mucosal elevation could be due to dense fibrous band encircling the punctum which is visible as a hyper-reflective layer on OCT. Internal lacrimal punctum is not an established structure, but evidence on optical biopsy and similar evidence on microscopy makes its existence a potential possibility. High-resolution 3D (Fig. 12.7) and en face (Fig. 12.4) images provide punctal topography and an overview of the punctum and proximal vertical canaliculus. The en face technique along with 3D images gives layer-by-layer sectioning of the tissues and hence provides a better understanding of the area of interest.

Table 12.4 Summary of published articles on OCT of proximal lacrimal system

Study	Wayrzinski et al. (2014)	Kamal et al. (2015)	Allam et al. (2015)	Timlin et al. (2016)	Sung et al. (2016)
Healthy subjects (eyes)	18(36)	52(103)	76(147)	20(40)	38(76)
Machine used	RTVue model-RT100 (Optovue)	RTVue scanner with 3D (Optovue)	Topcon 3D OCT 2000	Heidelberg Spectralis	Heidelberg Spectralis
Parameters (in μm)					
ELP	247 ± 78	215 ± 73	412 ± 163	646 ± 150	614.6 ± 195.6
ILP	110 ± 67	125 ± 61	234 ± 139	50 ± 104	NA
VCL/VCH	753 ± 216	890 ± 155	252 ± 127	544 ± 327	546 ± 270

ELP external lacrimal punctal diameter, *ILP* internal lacrimal punctal diameter, *VCL/VCH* vertical canalicular length/height, *NA* not available

Major Quantitative Assessments (Fig. 12.1)

1. *External lacrimal punctal diameter (ELP)*
This is measured as a line connecting the points where medial and lateral punctal walls meet with the surface of the lid margin. Variation across published studies can be observed due to lack of fixed point of reference for measurement. Drawing a tangent along the highest points on medial and lateral ends as suggested by Timlin et al. [19] could lead to overestimation of values. Timlin reported mean ELP to be 646 μm which is almost 2–3 times compared to other studies. Punctal size has been documented as 0.2–0.3 mm across published anatomical studies and same can be observed clinically on slit lamp biomicroscopy.

2. Internal lacrimal punctum diameter (ILP)
This parameter has been reported only by Timlin et al. [19] where width was measured at 500 μm from the surface corresponding to the lower border of the lower most reflective layer. Mean ILP was 50 ± 104 μm; however, it was 0 in 55% (22/40) of the cases as puncta was closed at this depth. This non visualization of canaliculus could be due to undue lid stretching or collapsed canalicular walls when eyelid is open. ILP could be the transition point between punctum and vertical canaliculus which can be taken as a reference starting point to measure vertical canalicular length.

3. Vertical canalicular length/height (VCL/VCH)
It is measured as a perpendicular from the line across the external lacrimal punctum up to the visible depth of canaliculus. This measurement questions the existing concept of vertical canaliculus to be 2 mm long as was documented in cadaveric studies. The maximum recorded VCL across published literature was 1308 μm which is far less than the widely reported depth of 2 mm [22]. This disagreement can be explained on the basis of three points. One, it could be due to the orbicularis muscle tone which could influence the in vivo measurements of the VCH as compared to cadaveric dissection. Secondly, the effect of scattering of light by collagen bundles in the skin, thereby limiting penetration. Finally, it could result from everting and stretching of lower eyelid could also have altered the measurement. Nonetheless, vertical canalicular length as being 2 mm is no longer sacrosanct, and its accuracy has been questioned.

4. Mid-canalicular diameter (MCD)
The mid-canalicular diameter (MCD) is measured midway between the punctum and the visible lower end of vertical canaliculus, and its mean ± SD recorded was 125.04 ± 60.69 μm (range, 31–333).

OCT as a Diagnostic Modality

1. ***Incomplete Punctal Canalization (IPC)*:** Typical FD-OCT features described for IPC include a hyper-reflective membrane covering the punctal surface with distinctly identifiable and normal lumen of the vertical canaliculus beneath [23, 24]. (Fig. 12.8) Membranotomy, is the preferred modality of managing IPC with very high success rates where normal appearing wide punctum can be seen on OCT (Fig. 12.9).
2. ***Punctal stenosis*:** Punctal stenosis is characterized by near total or complete closure at the level of internal punctum with no visualization of underlying canaliculus [25]. However, enhanced depth imaging has shown a visible canaliculus in some cases which needs to be validated in a larger population (Fig. 12.10).
3. ***Canaliculops*:** Canaliculops is a noninflammatory ectasia of canalicular wall which results in cyst formation near medial canthus [26]. FD-OCT demonstrates a dilated canaliculus with empty lumen surrounded by a well-defined cyst wall (Fig. 12.11). Differentiating it from other lesions like punctal keratinizing cyst and conjunctival cyst becomes important as simple excision would result in iatrogenic canalicular wall trauma.
4. ***Punctal keratinizing cyst*:** Typical FD-OCT features an obliterated punctal opening with a hyper-reflective lesion extending into the vertical canaliculus (Fig. 12.12). Hyper-reflectivity is attributed to the presence of keratin [27].

Future Prospects

OCT of the proximal lacrimal system is likely to significantly add to our existing knowledge. Future endeavors should target upon. Gathering data for normative databases for the various commercial SD-OCT devices should be completed and incorporated within the software. This would facilitate comparisons between a given patient's parameters and that of the healthy population of a similar age, gender, and ethnicity. Utilization of ultrahigh-speed swept source technology for punctal imaging with the highest possible resolution would provide further detailed information. Developing an OCT where lid eversion is not needed would provide real-time and accurate anatomical results.

References

1. Huang D, Swanson EA, Lin CP, et al. Optical coherence tomography. Science. 1991;254:1178–81.
2. Izatt JA, Hee MR, Swanson EA, et al. Micrometer-scale resolution imaging of the anterior eye in vivo with optical coherence tomography. Arch Ophthalmol. 1994;112:1584–9.
3. Drexler W, Fujimoto JG. State-of-the-art retinal optical coherence tomography. Prog Retin Eye Res. 2008;27:45–88.
4. Fujimoto JG, Pitris C, Boppart SA, et al. Optical coherence tomography: an emerging technology for biomedical imaging and optical biopsy. Neoplasia. 2000;2:9–25.
5. Yoo YS, Na KS, Byun YS, et al. Examination of gland dropout detected on infrared meibography by using optical coherence tomography meibography. Ocul Surf. 2017;15:130–8.
6. Boone MA, Norrenberg S, Jemec GB, et al. Imaging of basal cell carcinoma by high- definition optical coherence tomography: histo-morphological correlation. A pilot study. Br J Dermatol. 2012;167:856–64.
7. Fujimoto M, Ogino K, Miyazaki C, et al. Evaluation of dacryocystorhinostomy using optical coherence tomography and rebamipide ophthalmic suspension. Clin Ophthalmol. 2014;8:1441–5.
8. Zheng X, Kamao T, Yamaguchi M, et al. New method for evaluation of early phase tear clearance by anterior segment optical coherence tomography. Acta Ophthalmol. 2014;92:e105–11.
9. Kashkouli MB, Murthy BBR, Astbury N. Acquired external punctal stenosis: etiology and associated findings. Am J Ophthalmol. 2003;136:1079–84.
10. Ibramhim OM, Dogru M, Kojima T, et al. OCT assessment of tear meniscus after punctal occlusion in dry eye disease. Optom Vis Sci 2012;89:E770–6.
11. Soiberman U, Kakizaki H, Selva D, et al. Punctal stenosis: definition, diagnosis, and treatment. Clin Ophthalmol. 2012;6:1011–8.
12. Hurwitz JJ, Pavlin CJ, Hassan A. Proximal canalicular imaging utilizing ultrasound biomicroscopy. A normal canaliculi. Orbit. 1998;17:27–30.
13. Wawrzynski JR, Smith J, Sharma A, et al. Optical coherence tomography imaging of the proximal lacrimal system. Orbit. 2014;33:428–32.
14. Wong IY, Koizumi H, Lai WW. Enhanced depth imaging optical coherence tomography. Ophthalmic Surg Lasers Imaging 2011;42(Suppl):S75–84.
15. Lavinsky F, Lavinsky D. Novel perspectives on swept-source optical coherence tomography. Int J Retina Vitreous. 2016;2:25–35.
16. Liu B, Brezinski ME. Theoretical and practical considerations on detection performance of time domain, Fourier domain, and swept source optical coherence tomography. J Biomed Opt. 2007;12:044007.
17. Kamal S, Ali MJ, Ali MH, et al. Fourier domain optical coherence tomography with 3D and En Face imaging of the punctum and vertical canaliculus. A step towards establishing a normative database. Ophthal Plast Reconstr Surg. 2016;32:170–3.
18. Allam RS, Ahmed RA. Evaluation of the lower punctum parameters and morphology using spectral domain anterior segment optical coherence tomography. J Ophthalmol 2015;2015:591845.
19. Timlin HM, Keane PA, Day AC, et al. Characterization of the lacrimal punctum using spectral domain anterior segment optical coherence tomography: an exploratory study. Acta Ophthalmol. 2016;94:154–9.
20. Kakizaki H, Takahashi Y, Iwaki M, et al. Punctal and canalicular anatomy: implications for canalicular occlusion in severe dry eye. Am J Ophthalmol. 2012;153:229–37.
21. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of the external and internal surfaces of normal adult lacrimal drainage system. Ophthal Plast Reconstr Surg. 2015;31:414–7.
22. Dutton JJ. The lacrimal systems. In: Dutton J, editor. Atlas of clinical and surgical orbital anatomy. Philadelphia: WB Saunders; 1994. p. 140–2.
23. Kamal S, Ali MJ, Naik MN. Incomplete punctal canalization: report of Fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2015;31:251–2.
24. Singh S, Ali MJ, Naik MN. Familial incomplete punctal canalization: clinical and Fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2016 (Epub).
25. Timlin HM, Keane PA, Rose GE, et al. Characterizing the occluded lacrimal punctum using anterior segment optical coherence tomography. Ophthal Plast Reconstr Surg. 2016 (Epub).
26. Singh S, Ali MJ, Naik MN. Imaging the canaliculops with ultrasound biomicroscopy and anterior segment ocular coherence tomography. Ophthal Plast Reconstr Surg. 2017 (Epub).
27. Kamal S, Ali MJ, Naik MN. Punctal keratinizing cyst: report in a pediatric patient with Fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2015;31:161–3.

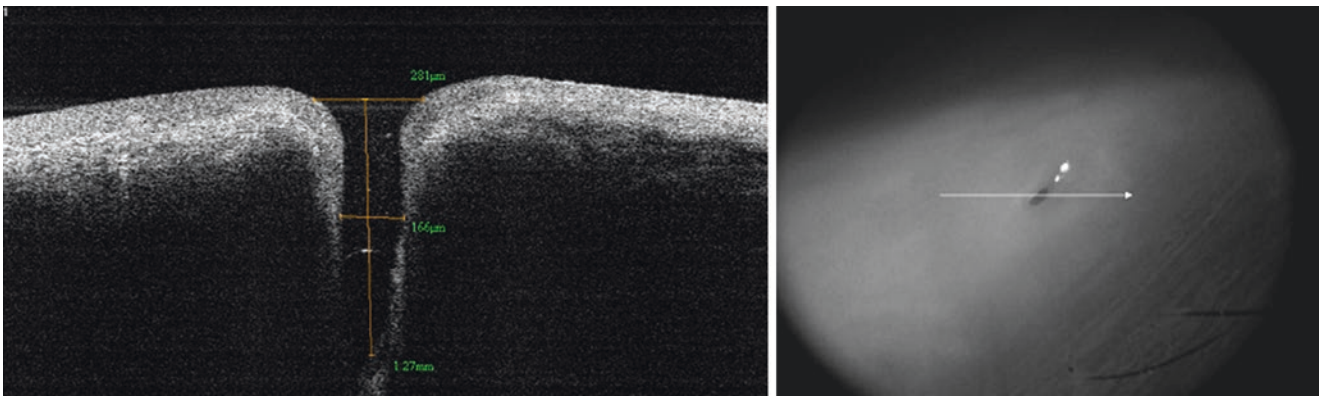


Fig. 12.1 Fourier domain OCT image showing a cross-sectional view of the punctum and the vertical canaliculus in a normal subject. The maximum punctum diameter, mid-canalicular diameter, and the vertical canalicular height have been measured (Courtesy: Kamal et al., Ophthal Plast Reconstr Surg 2016;32:170–173)

Fig. 12.2 A subject undergoing an OCT examination of the proximal lacrimal system

Fig. 12.3 Technique of gentle eversion without pressure enough to get the punctum perpendicular to the rays of light

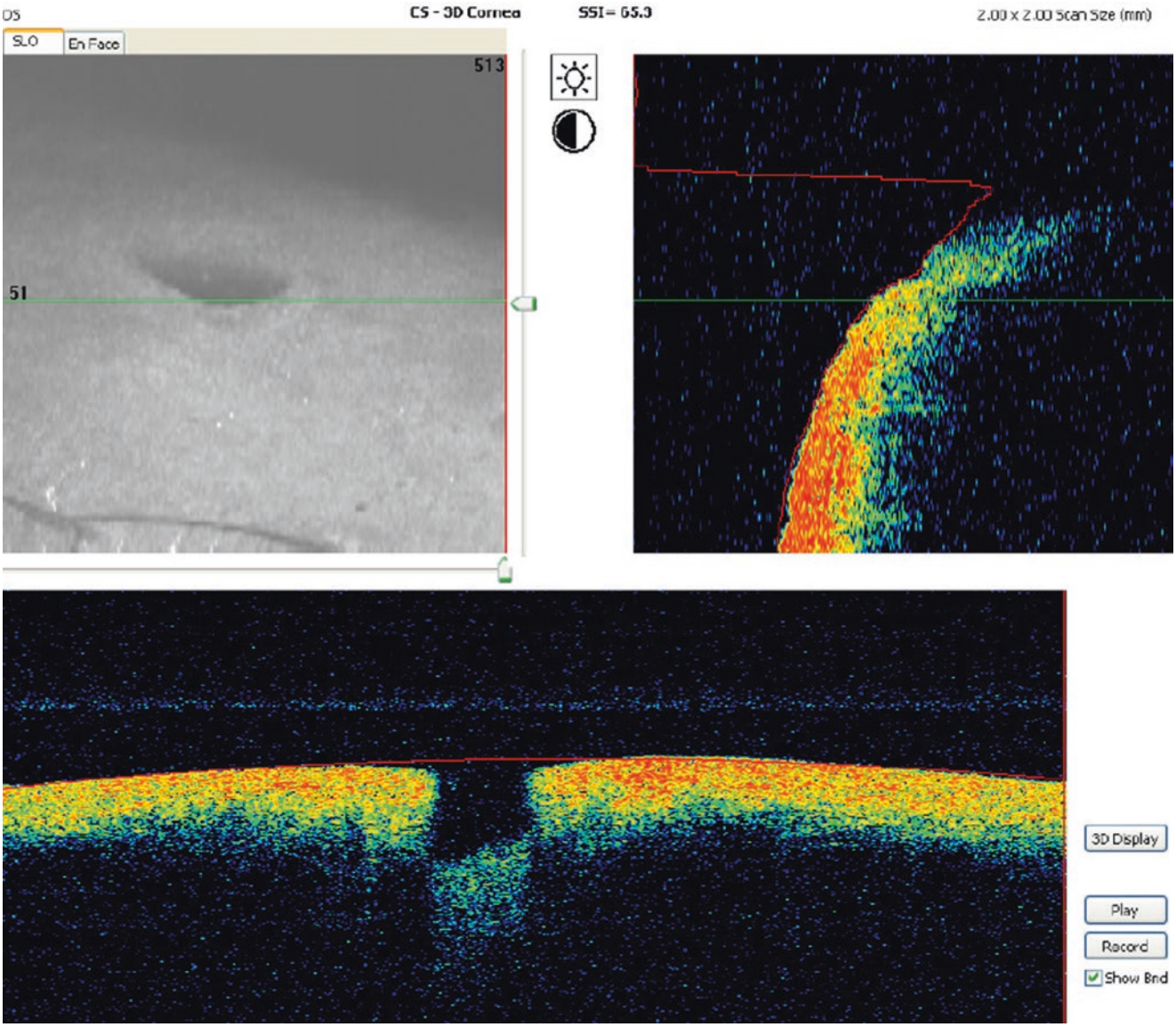


Fig. 12.4 En face imaging capturing the details of the punctal surface and internal punctum

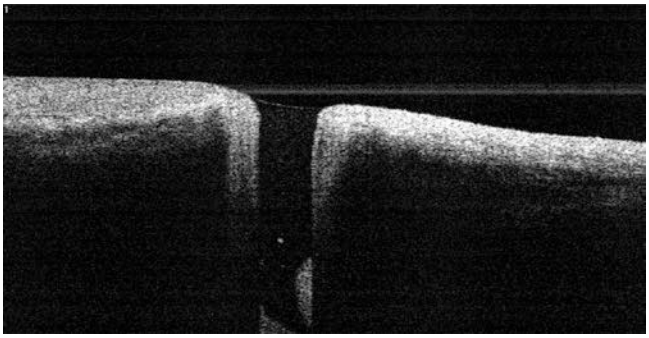


Fig. 12.5 Various reflectivities from different tissue layers of the punctal and peripunctal areas

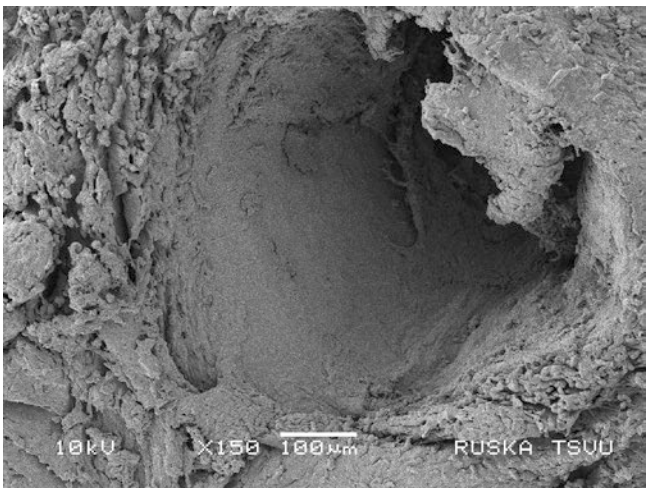


Fig. 12.6 Scanning electron microscopic (SEM) image of the punctum. Note the end on view into the lumen and the raised junctional area between the inner punctum and the beginning of the vertical canaliculus (Courtesy: Ali et al. Ophthal Plast Reconstr Surg 2015;31:414–417)

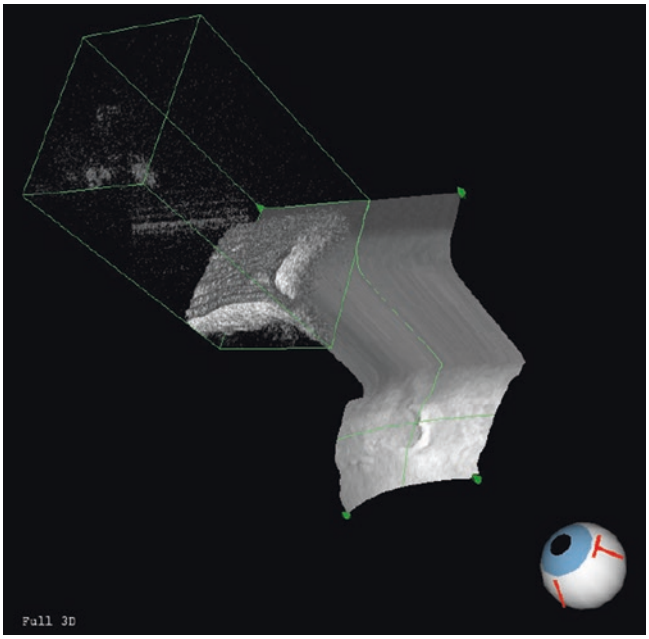


Fig. 12.7 Three-dimensional (3D) imaging of the punctum and vertical canaliculus

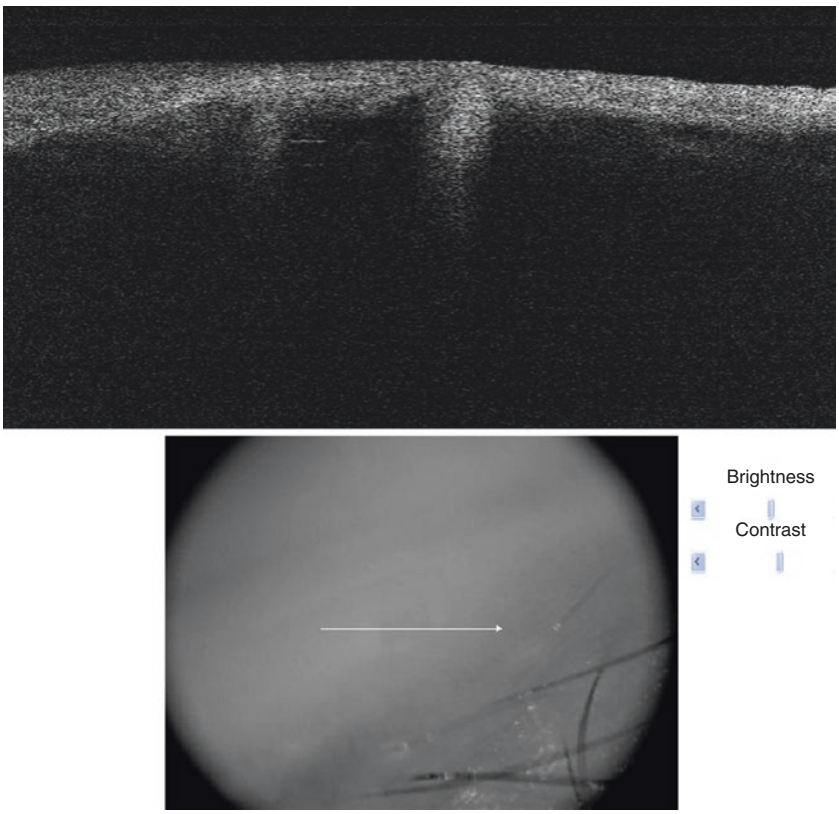


Fig. 12.8 A case of incomplete punctal canalization of external membrane variety

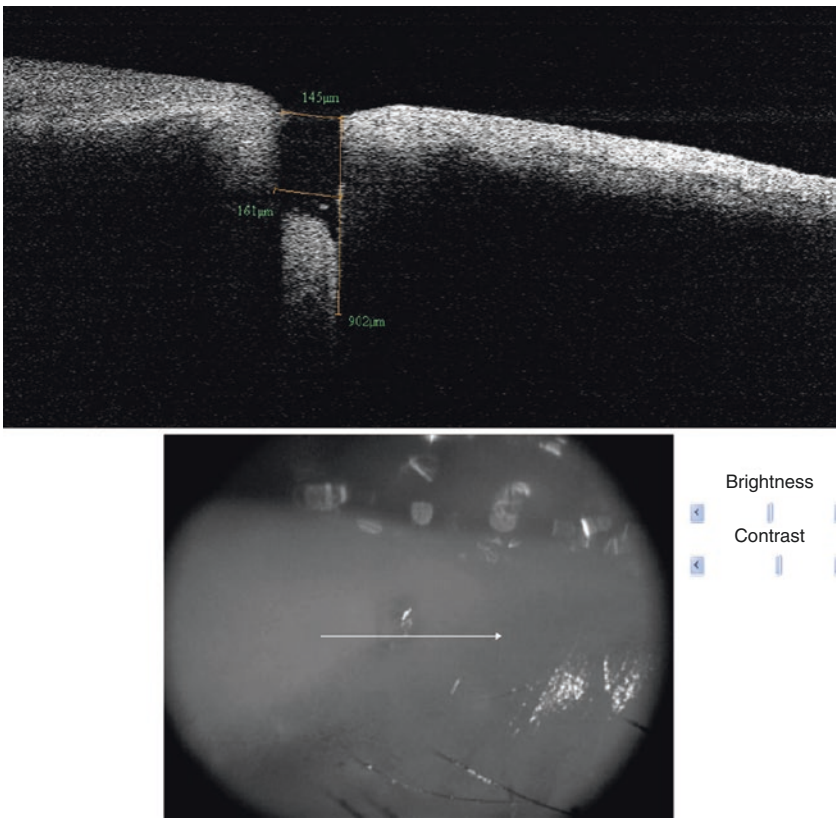


Fig. 12.9 Same patient as in Fig. 12.8, following a membranotomy and restoration of the normal proximal lacrimal drainage anatomy

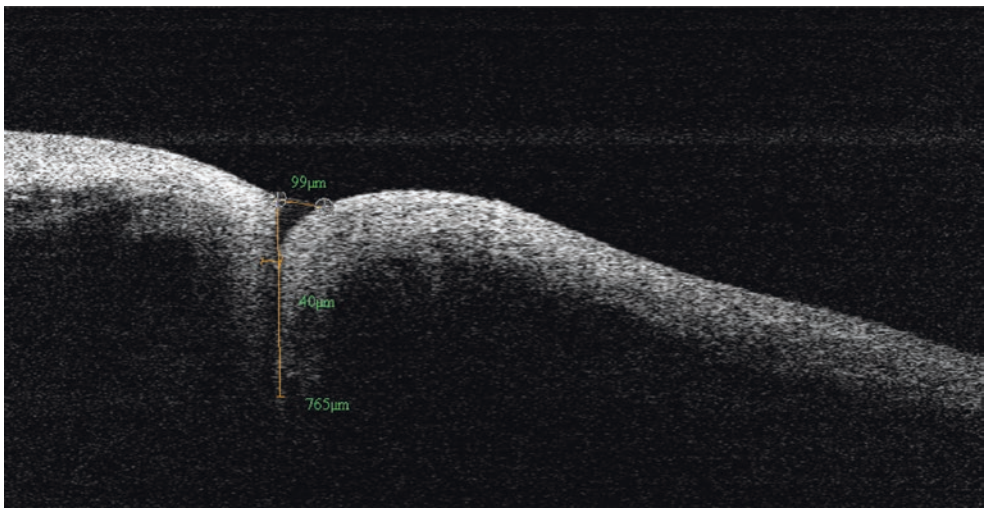


Fig. 12.10 OCT of a proximal lacrimal system in a case of punctal stenosis

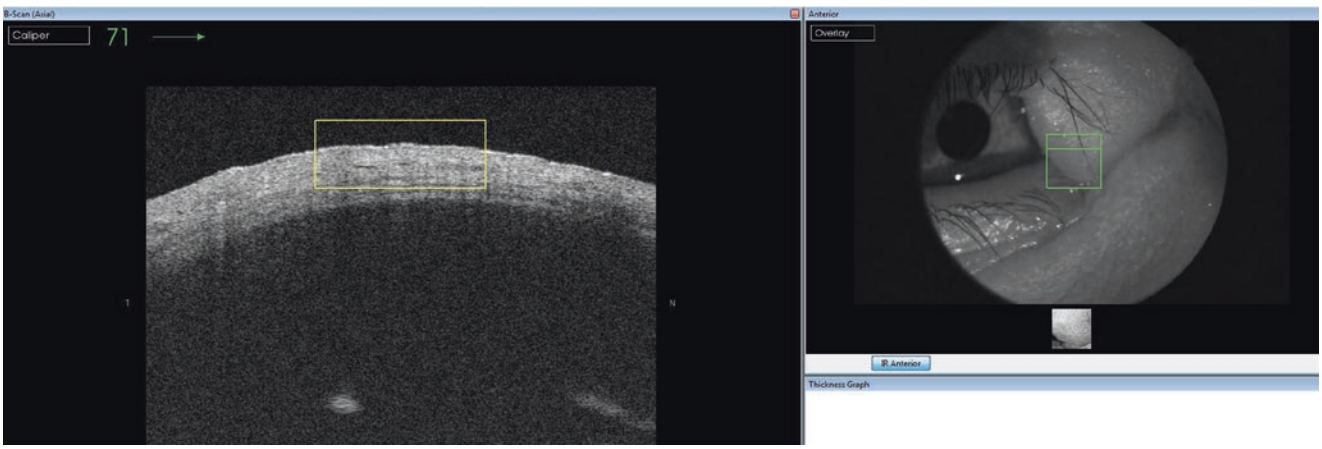


Fig. 12.11 OCT of a case of canaliculops. The thickness of the canaliculops prevents a complete imaging of both the ends

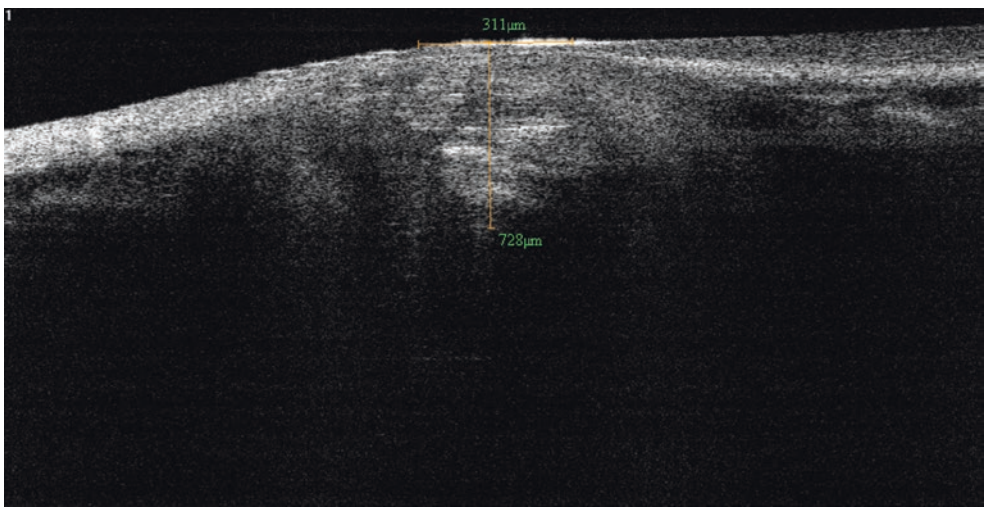


Fig. 12.12 OCT in a case of punctal keratinizing cyst. Note the hyper-reflective areas just beneath the punctal membrane, representing the accumulated keratin

Disorders of the Upper Lacrimal System

13

Mohammad Javed Ali

Introduction

Proximal lacrimal outflow disorders are sparsely documented in the literature [1–9]. Disorders of the upper lacrimal system pose much more challenges in terms of management as compared to the lower system. These disorders can be broadly classified as congenital or acquired. In order to simplify this topic, we will broadly discuss it under the following three headings:

(a) Disorders of the puncta
(b) Disorders of the canaliculi
(c) Lacrimal fistula

Before we dwell into the details of each of the disorders, a thorough knowledge and understanding of upper lacrimal system embryology is of imperative value. The embryonic origin of lacrimal passages is along the line of the cleft between the lateral nasal process and the maxillary process of the embryonic face (Fig. 13.1) [6]. After the cleft obliterates, a solid epithelial rod appears in the embryo of 9.5 mm length and then completely separates from the surface in an embryo of 15 mm. The canaliculi are formed by budding of the upper end of this solid cord in an embryo of 18–24 mm (Fig. 13.2) [9]. The process of canalization begins in a 35 mm embryo by the disintegration or apoptosis of the central cells (Fig. 13.3). The entire canaliculus is canalized except near the puncta which opens onto the lid surface when the embryo is 130 mm, before the separation of the eyelids at seventh month of intrauterine life [3, 4, 6, 9].

M. Javed Ali, M.S., F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Disorders of the Punctum

Punctum is the entrance to the lacrimal outflow system, hence is of sacrosanct value in terms of disease recognition and its subsequent management. The spectrum of punctal disorders is wide and varies from a mild stenosis to punctal agenesis. Table 13.1 outlines the proposed classification of punctal disorders, which we believe will help in better understanding and building standardized protocols. Certain disorders like punctal and canalicular trauma would be discussed in chapter "Lacrimal System Trauma" and canaliculitis in the chapter "Infections of the Lacrimal System."

Punctal Agenesis

Proximal lacrimal outflow dysgenesis involving the punctum and canaliculus is sparsely documented entity in the literature [1–12]. The term punctal atresia has been used interchangeably with punctal agenesis as well as for a spectrum of punctal disorders varying from a fine membrane in the punctum to its absence itself [1–11]. It is important therefore to clearly differentiate punctal agenesis from other congenital punctal disorders.

Table 13.1 Proposed broad classification of punctal disorders

A. Primary punctal disorders
1. Punctal agenesis
2. Incomplete punctal canalization
3. Punctal stenosis
4. Supernumerary puncta
5. Ectopic punctum
B. Secondary punctal disorders
1. Peri-punctal disorders
2. Punctal trauma
3. Punctal ectropion
4. Iatrogenic punctal disorders
5. Contiguous punctal involvement in ocular and systemic disorders

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_13

The basic etiopathogenesis of punctal agenesis is likely to be failure of canaliculi outbudding from the upper end of the solid lacrimal cord in an embryo of 18–24 mm (Fig. 13.2) [9]. It is very rare to have intact canaliculi with a punctal agenesis [13, 14]. Welham and Hughes reported 89% ($n = 19$) of the patients with punctal agenesis to have concomitant canalicular agenesis [15].

The diagnosis of punctal agenesis should include a careful history and examination. History of epiphora and other symptoms may be variable depending upon the agenesis of single or both puncta of the eye. Patients with single punctum missing may have mild epiphora. Severe epiphora usually indicates an associated nasolacrimal duct obstruction. Associated redness and discharge is also seen. In contrast, patients with both puncta missing have universal epiphora but are usually not very symptomatic and do not have redness or discharge. Lyons et al. [3] in his series reported 78% of the eyes with single punctum missing ($n = 41$) presented with epiphora and 22% presented with medial canthal swelling and features of dacryocystitis. As against this, 100% of the eyes with both punctum missing ($n = 53$) presented with epiphora, but none had any discharge or dacryocystitis. Clinical examination by slit lamp would show absence of the punctal papilla, absence of any transilluminant membrane, absence of any dimple in the area of punctum, and occasionally presence of eyelashes medial to the punctum in the pars lacrimalis area of eyelids (Figs. 13.4 and 13.5).

Punctal agenesis has important associated ocular and systemic associations. Lyons et al. [3] found 23% of their cases ($n = 57$) to have ocular abnormalities like lacrimal fistula, blepharitis, distichiasis, eyelid tags, absence of caruncle, and divergent strabismus. Punctal agenesis has well-known association with systemic syndromes like ectodermal dysplasia [1, 6], Hay-Wells [1] and Levy-Hollister syndromes [8], and multiple other craniofacial syndromes. In addition it has been found that in patients with both puncta missing showed intraoperative anatomical variations like aplasia of lacrimal crests, sac hypoplasia, and large anterior ethmoidal air cells [3].

Management of punctal agenesis is challenging. Patients who have a single punctum missing and are asymptomatic may be observed without any intervention. However, probing is warranted in those who have associated nasolacrimal duct and most would do well. Failure of probing is an indication for a dacryocystorhinostomy with a mini-monoka tube. Lyons et al. [3] performed probing in 24% ($n = 41$) of the eyes with a single punctum missing, DCR in 31%, and CDCR with Lester-Jones tubes in 17% of patients in his series. Patients with both punctum missing but with minimal symptoms can be observed. For those with severe symptoms, we prefer to manage using an endoscopic placement of Lester-Jones tube (Fig. 13.6) or Gladstone-Putterman tube without an actual dacryocystorhinostomy (Fig. 13.7) [16]. However there are many techniques described for Jones tube insertion in these patients, and individual surgeon preferences are based on what suits them best [17–21]. We do not advocate any retrograde approach or cutting down of the canaliculus or canaliculostomy, since these are cumbersome procedures and the results in the literature are not very encouraging [3, 13, 14].

Incomplete Punctal Canalization (IPC)

Incomplete punctal canalization is a term that refers to a form of punctal dysgenesis with membranes. The term was first described by Ali et al. [22], who studied 55 such dysgenetic puncta. The pathogenesis of punctal membranes is unknown but is believed to either represent failed dehiscence of epithelium overlying the normally formed canaliculi or failure of canalization of the most proximal part of lacrimal apparatus. This dysgenesis is not found to have any systemic association although associated lacrimal system anomalies like canalicular stenosis and congenital nasolacrimal duct obstruction are reported [22]. Patients typically present in the first decade with symptoms of epiphora since birth or infancy. Clinical examination reveals punctal membranes which could be external or internal. The external membrane (EM) variety, which is also called IPC-EM, typically covers the external surface of the puncta and hides it beneath, giving a false impression of punctal agenesis (Fig. 13.8). The internal membrane (IM) variety, which is also called IPC-IM, typically demonstrates blurred punctal margins but, just at the entry into the puncta, covers it entirely with a membrane. The membranes usually appear translucent (Fig. 13.9). Clinical diagnosis is based on high degree of suspicion; slight avascular dimple at the site of puncta and the membrane tends to stand out as a translucent structure from the surroundings if indirect illumination is used with the help of slit lamp and a thin slit beam is placed perpendicular and adjacent to the punctum.

Ali et al. [22] found that external membranes (EM) over the puncta were noted in 86.4% and internal punctal membranes (IM) in 13.6% of their patients. The punctal membranes on histopathological examination uniformly were fibrovascular membranes without any signs of inflammation.

Management of IPC is usually simple. A membranotomy using a slow taper punctum dilator is almost always helpful. Once the membrane is overcome, the surgeon would find a normal punctum beneath, and usually the canaliculus and the rest of the lacrimal outflow are found to be normal (Fig. 13.10). Intubation is helpful for the rarely associated canalicular stenosis; however, the authors do not advocate the use of routine intubation following membranotomy, since the diameter of the punctum is fairly large following the procedure and does not tend toward restenosis later on. With a simple

membranotomy and occasional adjunctive procedures, the anatomical patency was found to be 100%, and the relief from symptoms was seen in 91% (20/22) of the patients [22].

Punctal Stenosis

Punctal stenosis is not an uncommon disorder of the punctum. It is an important cause of epiphora and accounted for 8% of all patients presenting with epiphora in a tertiary care oculoplastics practice [23]. Table 13.2 enlists the frequent causes of punctal stenosis [2, 12, 24–26]. The pathogenesis is still elusive, but it is important to remember in this regard that punctum being the entry point for tears is exposed to all the possible soluble irritants that an ocular surface encounters. The widely believed hypothesis that has been supported by histological studies [27] is a common mechanism involving inflammation leading to fibrosis and subsequent stenosis.

In order to facilitate uniform protocols of management, Kashkouli [12, 25] proposed a grading system for the puncta based on its size and shape. Table 13.3 enlists the different grades of punctal stenosis as published by Kashkouli with slight modifications, which the author believes are important. Figure 13.11 represents a normal round punctum, whereas Figs. 13.12 and 13.13 represent punctal stenosis.

There are no uniform acceptable guidelines for the management of punctal stenosis. Several modalities described in the literature include punctal dilatation, one-snip punctoplasty, two-snip punctoplasty, three-snip punctoplasty, rectangular three-snip punctoplasty, four-snip punctoplasty, punctal punching with Kelly's or Riess punch, punctoplasty with mitomycin C and inserting perforated punctal plugs, and self-retaining bicanalicular stents or mini-monoka [28–34]. It is important to note that there is increasing evidence in the literature about the benefits of mini-monoka as a non-invasive modality of managing punctal stenosis, and the author anticipates this to be one of the most acceptable modalities in the near future. Mathew et al. [28] reported punctal dilatation and placement of mini-monoka without any surgical snips as a simple yet effective procedure. Hussain et al. [29] in a very large series of 123 eyes showed mini-monokas to be effective in relieving epiphora in 82% of the eyes at 6 weeks. Konuk O et al. [30] showed a long-term success rate of 84% with the use of perforated punctal plugs in their series of 44 procedures with a follow-up of 19 ± 13.4 months.

Table 13.2 Common causes of punctal stenosis

1. Involutional or age related
2. Conjunctivitis (HSV, HPV, chlamydial)
3. Eyelid infections
4. Topical medications toxicity (timolol, latanoprost)
5. Systemic medications (5-fluorouracil, paclitaxel)
6. Lid malpositions
7. Trauma (thermal)
8. Chronic cicatricial disorders (Steven-Johnson syndrome)
9. Peri-punctal tumors
10. Systemic disorders (porphyrias, acrodermatitis)
11. Radiotherapy

Table 13.3 Grades of punctal stenosis

Grade 0–punctal agenesis
Grade 1–incomplete punctal canalization (IPC-EM and IPC-IM)
Grade 2–recognizable but less than normal
Grade 3–normal, round punctum (admits 26G cannula)
Grade 4–slit punctum <2 mm in size

Punctoplasty

The earliest description of one-snip punctoplasty was by Bowman in 1853, later modified by Jones in 1962 [24, 25]. One-snip punctoplasty involves a single vertical cut on the conjunctival side of the punctum and vertical canaliculus till the ampulla (Fig. 13.14). Kashkouli et al. [4] combined a 2 mm horizontal one snip starting from the ampulla, parallel to lid margin, with additional mini-monoka insertion, and reported a 77.4% success (n = 53) at a mean follow-up of 18.5 months. In two-snip punctoplasty, after the vertical cut like one-snip procedure, the second snip starts from the end of first incision as a 2 mm horizontal cut and involves the ampulla (Fig. 13.15). Two-snip procedures are not very popular.

Three-snip procedures were described by Thomas in 1951. The modern three-snip punctoplasty can be triangular or rectangular in shape. The triangular three snip is a more traditional way which is like a two snip with an additional excision of the base (Fig. 13.16). This means that there is one cut in the vertical canaliculus, one cut in the horizontal canaliculus, and one cut at the base. In contrast to this, the rectangular three-snip procedure has two vertical cuts on either side of the vertical canaliculus with one cut at the base. Cesar and McNab [24] documented a success rate of 92% with a three-snip procedure (n = 53). Chak et al. [32] compared 49 triangular three snips with 59 rectangular three-snip procedures and found that the recurrence rates were not significantly different between both the groups. However, postoperatively, the patients who underwent triangular three snips were more symptomatic (16.9%) compared to those with rectangular three snips (10.2%). This can be partly explained because of lack of cut in the horizontal canaliculus with rectangular three snips, hence avoiding greater injury to the lacrimal pump.

Cicatrization following punctoplasty due to wound healing is a major cause of restenosis, which is much more

difficult to manage then the primary stenosis (Fig. 13.17). Fraser and colleagues [35] advocated the use of re-dilatation with punctum dilator for early cicatrization following a three-snip punctoplasty. However, the study was retrospective and a clear benefit was not demonstrated. Ma'luf et al. [34] compared two groups of patients undergoing punctoplasty with and without the use of adjunctive mitomycin C (0.5 mg/ml). They found that the restenosis and cicatrization were seen in 19% ($n = 26$) of patients where MMC was not used as compared to none ($n = 25$) in cases where MMC was used ($p < 0.02$).

Peri-punctal Disorders

Peri-punctal disorders refer to those which involve the periphery of punctal rim and vicinity or encircle it all around. Numerous lesions can have a peri-punctal location like a peri-punctal granuloma secondary to a foreign body or stent (Fig. 13.18), nevus (Fig. 13.19), papilloma, hemangioma, basal cell carcinoma (Fig. 13.20), neurofibroma, and peri-punctal abscess (Fig. 13.21). The management of these lesions can be very challenging since excision can potentially result in trauma to the puncta and proximal canaliculus. Lesions that are benign and not showing a growth may be observed. Nevi may have to be followed up closely specially in elderly patients. A simple clinical tip would be to assess the patency of the puncta with a probe. Obstruction in a previously patent puncta should be viewed with a high suspicion. Occasionally hemangiomas may have a similar lesion, and careful use of steroids or propranolol (if associated with extensive hemangioma) may be helpful in preserving the punctal integrity. All lesions where excision becomes mandatory, all attempts must be made for preserving as much as canaliculi as possible as well as stenting the passages for lacrimal reconstruction.

Disorders of the Canaliculi

There are wide varieties of congenital and acquired canalicular disorders. These include canalicular wall dysgenesis, canaliculitis, and post-traumatic canalicular fistulas. The latter two will be discussed in the chapters on lacrimal infections and trauma, respectively.

Canalicular Wall Dysgenesis (CWD)

Proximal lacrimal outflow dysgenesis involving the punctum and canaliculus is sparsely documented entity in the literature [1–9]. Ali et al. [36] introduced the term canalicular wall dysgenesis and its eight subtypes of aplasia and hypoplasia. The same group also introduced an arbitrary division of a canaliculus into four walls, namely, roof, floor, anterior wall, and posterior wall toward the conjunctiva (Fig. 13.22). Roof is that wall of the canaliculus which is near and parallel to the lid margin, and posterior wall is parallel to the palpebral conjunctiva.

The etiopathogenesis of canalicular wall dysgenesis is unknown, but three possibilities have been proposed. One, it could represent dysregulation of mesenchymal condensation around the canalicular primordium and its contiguity with the subadjacent mesenchyme of the surface ectoderm during Carnegie stage 19 of embryonic development. Second, when the canaliculi are well differentiated but without a lumen (Carnegie stage 22), the cells in the center of the future lumen are loosely arranged as compared to dense and tight arrangement near the walls. Changes in this arrangement can lead to focal or diffuse wall dysgenesis. Third, during the early fetal weeks (10–12 weeks of gestation), the canalicular epithelium interacts and becomes contiguous with the conjunctival epithelium. Interference with this mechanism or dehiscence of the epithelium overlying the maturing canaliculi could result in wall dysgenesis. Future well-planned embryonic morphogenetic studies using embryonic specimens are needed to verify these possibilities.

The diagnosis of single canalicular wall dysgenesis (SCWD) is made on slit lamp biomicroscopy. The term isolated refers to involvement of a single wall of the canaliculus. The typical finding in cases of aplasia, which is called single canalicular wall aplasia (SCWA), includes an obvious defect in the canalicular wall, which is a complete dehiscence (Fig. 13.23). This defect can be further classified as focal if it involves a part of the canaliculi (Fig. 13.23) or diffuse if the defect extends along the entire length of the canaliculi. This canalicular wall dehiscence may mimic a post-traumatic slit canaliculus. The points in favor of SCWA would be negative history, larger dehiscence with smoother walls, and no other obvious signs of associated trauma. If the roof is aplastic, one would notice the whitish mucosal lining of the canaliculi on the remaining three walls by slit lamp biomicroscopy with high magnification (Fig. 13.23). The other variant of SCWD is hypoplasia, which is called single canalicular wall hypoplasia (SCWH), requires a high degree of suspicion for the clinical diagnosis. The most obvious finding in SCWH is thinning of the wall, most noticeable if we place a probe in the canaliculus (Fig. 13.24). The surface of the probe becomes more obvious and is easily visualized in the areas of hypoplasia. A comparison with a probe in normal canaliculi helps us understand this difference. Unlike aplasia, the mucosal lining of the remaining walls cannot be easily noticed in hypoplasia because there is just a thinning of a wall and no defect. As for SCWA, the hypoplastic component can be focal or diffuse (Fig. 13.24).

When more than one wall of the canaliculus is affected, the term multiple canalicular wall dysgenesis (MCWD) is

Table 13.4 Proposed classification of canalicular wall dysgenesis (CWD)

Canalicular wall dysgenesis: proposed classification
A. Single canalicular wall dysgenesis (SCWD)
1. Single canalicular wall hypoplasia (SCWH)
(a) Focal
(b) Diffuse
2. Single canalicular wall aplasia (SCWA)
(a) Focal
(b) Diffuse
B. Multiple canalicular wall dysgenesis (MCWD)
1. Multiple canalicular wall hypoplasia (MCWH)
(a) Focal
(b) Diffuse
2. Multiple canalicular wall aplasia (MCWA)
(a) Focal
(b) Diffuse

used and is further classified into aplastic and hypoplastic components (Table 13.4). The diagnosis of multiple canalicular wall aplasia (MCWA) and hypoplasia (MCWH) would follow similar principles with subtle differences. In cases of MCWA, apart from the obvious defect as noted in isolated walls, one would notice the whitish mucosal lining of the canaliculi only on the remaining one or two walls by slit lamp biomicroscopy with high magnification (Fig. 13.25, left panel). However, MCWH may pose diagnostic challenges, and the clinical feature that gives a clue to anterior or posterior wall involvement would be increasing circumference of the probe that becomes noticeable in front or behind the roof and wall assessment by a "probe tilt test" (Fig. 13.25, right panel). In this test, under biomicroscopic guidance, once the probe is gently advanced into the canaliculus in the area of dysgenesis, a gentle tilt is attempted toward the roof of the canaliculus. This tilt along with the presence of probe helps the examiner to assess the thinning and status of both the anterior and posterior walls (Fig. 13.25, right panel). However, the floor assessment is difficult with this test. Multiple canalicular wall dysgenesis can further be subclassified as focal or diffuse based on the extent of canalicular wall involvement.

In their study, Ali et al. [36] found that SCWD involving only the roof was the most common feature noted in 71.4%, and about 28.5% patients had three wall involvements. Canalicular wall hypoplasia was most common and seen in 57.1%, whereas canalicular wall aplasia was noted in 42.8%. Associated lacrimal anomalies were seen in all patients and included supernumerary puncta, incomplete punctal canalization of the external membrane variety (IPC-EM), punctal stenosis, congenital nasolacrimal duct obstruction (CNLDO), and punctal agenesis. Systemic anomalies were noted in 28.5% (2/7) of the patients and included right hemiparesis with left cerebral hypoplasia and delayed milestones.

Dysgenetic canaliculi may have long-term profound effect in terms of its clinical and psychosocial implications. All these patients present with epiphora, where complete cure is desired but a challenging goal. Almost all patients have associated lacrimal system anomalies, which, if addressed effectively, will go a long way in helping improve the overall quality of life. Accordingly, ipsilateral punctal stenosis, punctal agenesis, CNLDO, and IPC-EM when addressed appropriately result in satisfied patients and parents. It is also prudent to keep few points in mind while irrigating or treating associated lacrimal anomalies in cases of canalicular wall dysgenesis especially hypoplasia. During irrigation or probing, be very gentle and mindful of the canaliculus anatomy and course. Any quick or aggressive misdirection may lead to rupture of the thinned walls and worsen the epiphora. This care is especially required when rotating the probe 90° for probing the nasolacrimal duct. On the other hand, in aplasia, there is a propensity to engage the edge of the residual wall during irrigation or probing, leading to an extended tear. The baseline is that CWD merits careful evaluation and even more careful interventions.

Lacrimal Fistula

Lacrimal fistula is an accessory or an anlage duct communicating with the skin on one side and the canaliculus, lacrimal sac, or nasolacrimal duct on the other [37–40]. The incidence of congenital lacrimal fistulae has been reported to be 1 in 2000, but this could be a referral bias [3]. These result from abnormal embryological development at the optic end of the naso-optic fissure, whereby there are additional outbudding from the embryonic lacrimal epithelial cord in an embryo of 18–24 mm (Fig. 13.2) [6, 37]. The external opening can be on the skin below the punctum, lid margin, or medial end of lower lid crease. Almost all of these are external, but occasionally an internal fistula may be present between the lacrimal system and the nasal cavity and fortunately do not cause any obstructions!

The embryonic etiopathogenesis is unclear even after three centuries following its first description by Rasor in 1675 [41]. Jones and Wobig [42] proposed that lacrimal fistulae develop secondary to failure of lacrimal anlage to involute and its subsequent canalization. Others have implicated amniotic bands or inflammation as the causes, but these theories have not gained wider acceptance. Harman [43] proposed that lacrimal fistulae represent rudimentary lacrimal sinus. Welham and Donald [38] proposed the more accepted theory of fistula being an extra canaliculus based on their histopathological analysis. Another interesting dimension to this is the reports of lacrimal fistula presenting in an autosomal dominant inheritance pattern in up to four generations, its presence in twins, in first cousins, and its association with fistulas elsewhere in the body [38, 40, 42].

Lacrimal fistulas can be congenital or acquired following trauma or surgical interventions. There might be associated epiphora or discharge from the fistula (Fig. 13.26). Occasionally the surrounding skin may get excoriated. Congenital fistula is usually small with a well-defined opening, classically present 1–2 mms inferomedial to medial canthus (Fig. 13.27). In contrast the acquired fistulas may be irregular, large with surrounding scarring, and without any probable location (Fig. 13.28). A lacrimal probe can be passed through the fistula to assess its depth and possible internal communicating structure (Fig. 13.28). Few decades earlier, a radiological test called the three-point test was popular to differentiate congenital and acquired varieties, whereby three lacrimal probes are passed (one from upper and lower punctum each and one from the fistula) and assessed. All the three probes would meet in a congenital but not in acquired fistulae. However, the procedure is cumbersome with unspecified benefits.

In a large clinic-pathologic study of 22 surgical patients of lacrimal fistula, Welham and Donald found [38] that 15 of the 22 originated from the common canaliculus and four from the lacrimal sac giving an impetus to the theory of lacrimal fistula being an extra canaliculus.

The management of lacrimal fistulae is case dependent. All patients should undergo lacrimal system irrigation to assess the patency of the lacrimal system. In cases of associated congenital nasolacrimal duct obstruction, the patient should undergo a probing along with a simple excision of the fistulous tract (fistulectomy). We recommend the closed excision technique of fistulectomy as described by Sullivan et al. [40] and found it to be very useful in preventing recurrences. In this technique, a Bowman's probe is placed in the fistula track to assess its extent. With the probe in place, an elliptical incision is taken in the skin around the fistula. The fistulous tract is then traced to its origin by gentle dissection. A 8-0 Vicryl is placed and tightened in a purse-string manner at the base of the fistula followed by excision of the tract. The skin is closed vertically with 6-0 Vicryl sutures.

In patients with failed probing or in adults, fistulectomy can be performed along with a dacryocystorhinostomy with or without intubation (based on canalicular manipulation) for associated nasolacrimal duct obstructions. In light of the published literature, we do not advocate repeated probings or cautery of the fistula, since this may potentially damage the normal underlying canaliculus.

Updates (2015–2016)

Etiopathogenesis of Punctal Stenosis

Inflammation and fibrosis have long been implicated as a common pathogenic mechanism in punctal stenosis. Conjunctival biopsies have been shown to be good proxies for studying presumed idiopathic punctal stenosis [44]. Nearly half of the patients in one such study showed underlying immunological disorders like lichen planus [44]. Direct histopathological studies of the punctal tissues in stenosis have shown subepithelial fibrosis with predominant lymphocytic infiltration by CD45 and CD3 cells [45]. Electron microscopy has shown blunted microvilli, inter- and intracellular edema, irregular deposition of collagen, and activated fibroblasts with typical lymphocytes in their vicinity [45]. These studies open up more avenues for better understanding of the etiopathogenesis of punctal stenosis.

Balloon IPC and FD-OCT

Since the description of two types of incomplete punctal canalization, another variant which is called the balloon type has been described [46]. The punctal membrane was dome shaped with its slopes being contiguous with the tarsal conjunctiva. Membranotomy was successful in the management, and no associated lacrimal anomalies were noted. It is presumed that this dome-shaped membrane could represent one of the terminal stages in the embryological development of the puncta. The Fourier domain OCT in IPC shows an obliterated punctal opening with a hyper-reflective surface [47]. Visualization of the proximal portions of vertical canaliculus gives a clue to the underlying patent lumen. It has also been noted that IPC is the causative etiology in almost 20% of patients who masquerade as CNLDO [48].

Punctal Keratinizing Cyst

Punctal keratinizing cyst is an extremely rare keratin piling ectasia [49–51]. This usually presents with an obliterated punctum with a dome-shaped translucent covering with underlying whitish discoloration representing the keratin (Fig. 13.29) [50]. FD-OCT shows a cystic globular obliteration of the punctal orifice with dense multilayered hyperreflectivity in the area of vertical canaliculus (Fig. 13.30) [51]. Excision of the membrane with evacuation of the keratin is usually curative. Histopathological analysis has shown the cyst wall to be crenated and lined by stratified squamous epithelium with numerous elongated needlelike keratin arranged in multilayered wavy patterns.

Punctoplasty Updates

In the last 2 years, there have been reports of high success with the regular three-snip punctoplasty [52]. However, the need for lesser-invasive modalities is being increasingly propagated. Four-snip rectangular punctoplasty, which is less invasive than

a three snip, has shown good results in only ¾ of the patients in a large series [53]. On the other hand, results with Kelly's punch has shown high success rates in long term (mean = 34 months) [54]. The high incidence of functional epiphora following punctoplasty cannot be ignored [53], and non-incisional measures like punctal dilatation and monoka stents should be evaluated more carefully for long-term outcomes.

Canaliculops

Canaliculops or canaliculocele is a term used for a noninfectious and noninflammatory distention of a localized segment of the canaliculus with accumulation of serous fluid within the lumen [55–58]. It is an uncommon disorder and equally involves the upper and lower lids without a clear-cut gender predilection. Predisposing factors include trauma, surgeries, or past infections. The lesion usually presents as a painless, translucent, and slow-growing medial eyelid swelling (Fig. 13.31). Rarely it may be associated with a punctal agenesis [57]. Ultrasound biomicroscopy and OCT have been reported to be useful adjuncts in the diagnosis (Fig. 13.32) [58]. Careful excision of the lesion with maintenance of the canalicular pathway with temporary intubation is usually curative. Histopathological analysis is crucial for the definite diagnosis. The cyst wall is lined by canalicular epithelium; however, the characteristic feature is superficial epithelial layer staining by cytokeratin 7 or CK7 [56–58].

Congenital Lacrimal Fistula and Histopathology

Congenital lacrimal fistulae are probably the foremost lacrimal anomaly that is associated with multiple craniofacial syndromes and non-syndromic systemic entities [59]. Isolated congenital lacrimal fistulas have shown good outcomes with fistulectomy alone without any DCR [60]. Histopathological analyses of the fistulae have demonstrated hypertrophy of the stratified squamous lining with subepithelial infiltration of mixed (CD3+, CD5+, and CD30+) lymphocytes. It is believed that histological examination also has an adjunctive value in determining the embryological origin [61].

References

1. Ahn Yuen SJ, Oley C, Sullivan TJ. Lacrimal outflow dysgenesis. Ophthalmology. 2004;111:1782–190.
2. Cahill KV, Burns JA. Management of epiphora in the presence of congenital punctal and canalicular atresia. Ophthal Plast Reconstr Surg. 1991;7:167–72.
3. Lyons CJ, Rosser PM, Welham RAN. The management of punctal agenesis. Ophthalmology. 1993;100:1851–5.
4. Buerger DG, Schaefer AJ, Campbell CB, et al. Congenital lacrimal disorders. In: Nesi F, Levine MR, editors. Smith's ophthalmic plastics and reconstructive surgery. Maryland Heights, Missouri: Mosby; 1998. p. 649–60.
5. Kirk RC. Developmental anomalies of the lacrimal passages. A review of the literature and presentation of three unusual cases. Am J Ophthalmol. 1956;42:227–32.
6. Duke-Elder S. Development of ocular adnexa. In: Duke-Elder S, editor. System of ophthalmology, vol. 1. Maryland Heights, Missouri: CV Mosby; 1938. p. 364–5.
7. Viers ER. Disorders of the nasolacrimal apparatus in infants and children. J Pediatr Ophthalmol. 1966;3:32.
8. Katowitz WR, Katowitz JA. Congenital etiologies of lacrimal system obstructions. In 'The lacrimal system'. Cohen AJ, Mercandetti M, Brazzo BG (eds). Springer:New York ; Berlin 2006, pp 35–42.
9. Whitnall SE. The lacrimal apparatus. In: Whitnall SE, editor. The anatomy of the human orbit and accessory organs of vision. Oxford: Oxford Univ Press; 1921. p. 223–52.
10. Olver J. Pediatric lacrimal surgery. In: Olver J, editor. Colour atlas of lacrimal surgery. Oxford; Boston: Butterworth-Heinemann; 2002. p. 69–89.
11. Kashkouli MB. Assessment and management of proximal and incomplete symptomatic obstruction of the lacrimal system. Middle East Afr J Ophthalmol. 2012;19:60–9.
12. Kashkouli MB, Beigi B, Murthy R, et al. Acquired external punctal stenosis. Etiology and associated findings. Am J Ophthalmol. 2003;136:1079–84.
13. Beard C. Congenital and hereditary abnormalities of the eyelids, lacrimal system and orbit. In: Symposium on surgical and medical management of congenital anomalies of the eye, Trans New Orleans Acad Ophthalmol. St Louis: CV Mosby; 1968. p. 412.
14. Putterman AM. Treatment of epiphora with absent lacrimal puncta. Arch Ophthalmol. 1973;89:125–7.
15. Welham RA, Hughes SM. Lacrimal surgery in children. Am J Ophthalmol. 1985;99:27–34.
16. Ali MJ, Honavar SG, Naik MN. Endoscopically guided minimally invasive bypass tube intubation without DCR: evaluation of drainage and objective outcomes assessment. Minim Invasive Ther Allied Technol. 2013;22:104–9.
17. Klapper SR, Jordan DR. Jones tube insertion in children with canalicular agenesis. Ophthalmic Surg Lasers. 1999;30:495–8.
18. Boerner M, Seiff SR, Arroyo J. Congenital absence of lacrimal puncta. Ophthalmic Surg. 1995;26:53–6.
19. Henderson PN. A modified trephining technique for the insertion of Jones tube. Arch Ophthalmol. 1985;103:1582–5.
20. Rose GE, Welham RAN. Jones lacrimal canalicular bypass tubes: twenty five years experience. Eye. 1991;5:13–9.
21. Gladstone GJ, Putterman AM. A modified glass tube for conjunctivodacryocystorhinostomy. Arch Ophthalmol. 1985;103:1229–30.
22. Ali MJ, Mohapatra S, Mulay K, et al. Incomplete punctal canalization: the external and internal punctal membranes. Outcomes of membranotomy and adjunctive procedures. Br J Ophthalmol. 2013;97:92–5.
23. Mainville N, Jordan DR. Etiology of tearing: a retrospective analysis of referrals to a tertiary care oculoplastics practice. Ophthal Plast Reconstr Surg. 2011;27:155–7.
24. Caesar RH, McNab AA. A brief history of punctoplasty: the three snip revisited. Eye. 2005;19:16–8.
25. Kashkouli MB, Beigi B, Astbury N. Acquired external punctal stenosis: surgical management and long-term follow up. Orbit. 2005;24:73–8.
26. Hurwitz JJ. Diseases of the punctum. In: Hurwitz JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 149–53.
27. Port AD, Chen YT, Lelli GJ. Histopathological changes in punctal stenosis. Ophthal Plast Reconstr Surg. 2013;29:201–4.
28. Mathew RG, Olver JM. Mini-monoka made easy: a simple technique for mini-monoka insertion in acquired punctal stenosis. Ophthal Plast Reconstr Surg. 2011;27:293–4.

29. Hussain RN KH, McMullan T. Use of mini- monoka stents for punctal and canalicular stenosis. Br J Ophthalmol. 2012;96:671–3.
30. Konuk O, Urgancioglu B, Unal M. Long term success rates of perforated punctal plugs in the management of acquired punctal stenosis. Ophthal Plast Reconstr Surg. 2008;24:399–402.
31. Chalvatzis NT, Tzamalis AK, Mavrikakis I, et al. Self-retaining bicanaliculus stents as an adjunct to 3-snip punctoplasty in the management of upper lacrimal duct stenosis. A comparison to standard 3 snip procedures. Ophthal Plast Reconstr Surg. 2013;29:123–7.
32. Chak M, Irvine F. Rectangular 3 snip punctoplasty outcomes: preservation of lacrimal pump in punctoplasty surgery. Ophthal Plast Reconstr Surg. 2009;25:134–5.
33. Kim SE, Lee SJ, Lee SY, et al. Outcomes of 4-snip punctoplasty for severe punctal stenosis: measurement of tear meniscus height by optical coherence tomography. Am J Ophthalmol. 2012;153:769–73.
34. Ma'luf RN, Hamush NG, Awwad ST, et al. Mitomycin C as adjunct therapy in correcting punctal stenosis. Ophthal Plast Reconstr Surg. 2002;18:285–8.
35. Fraser CE, Petrakos P, Lelli GJ Jr. Adjunctive re-dilatation for early cicatrization after punctoplasty. Orbit. 2012;31:313–5.
36. Ali MJ, Naik MN. Canalicular wall dysgenesis: the clinical profile of canalicular hypoplasia and aplasia, associated systemic and lacrimal anomalies and clinical implications. Ophthal Plast Reconstr Surg. 2013;29:464–8.
37. Hurwitz JJ. Embryology of the lacrimal drainage system. In: Hurwitz JJ, editor. The lacrimal system. Philadelphia: Lippincott-Raven; 1996. p. 9–13.
38. Welham RAN, Bergin DJ. Congenital lacrimal fistulas. Arch Ophthalmol. 1985;103:545–8.
39. Francois J, Bacskulin J. External congenital fistulae of the lacrimal sac. Ophthalmologica. 1969;159:249–61.
40. Sullivan TJ, Clarke MP, Morin JD, et al. The surgical management of congenital lacrimal fistulae. Austr NZ J Opthalmol. 1992;20:109–14.
41. Rasor C, cited by Schirmer R. Graefe-Saemisch Handbuch der Augenheilkunde. Leipzig, Germany, Engelmann. 1877, Vol 8, pp 1–58.
42. Jones LT, Wobig JL. Survey of the eyelids and lacrimal system. Birmingham: Aesculapius Publishing Co; 1976. p. 167–73.
43. Harman NB. A minimal form of fissura facialis. Trans Ophthal Soc UK. 1903;23:256–60.
44. Reddy AK, Baker MS, Maltry AC, et al. Immunopathology and histopathology of conjunctival biopsies in patients with presumed idiopathic punctal stenosis. Br J Ophthalmol. 2017;101:213–7.
45. Ali MJ, Mishra DK, Baig F, et al. Punctal stenosis: histopathology, immunology and electron microscopic features- a step towards unraveling the mysterious etiopathogenesis. Ophthal Plast Reconstr Surg. 2015;31:98–102.
46. Ali MJ, Naik MN. Incomplete punctal canalization–a balloon variant of the external membrane: a case report. J Med Case Rep. 2014;8:120–2.
47. Kamal S, Ali MJ, Naik MN. Incomplete punctal canalization: report of fourier domain optical coherence tomography features. Ophthal Plast Reconstr Surg. 2015;31:251–2.
48. Kamal S, Ali MJ, Gupta A, et al. Lacrimal and nasal masquerades of congenital nasolacrimal duct obstructions: etiology, management and outcomes. Int Ophthalmol. 2015;35:807–10.
49. Yonekawa Y, Jakobiec FA, Zakka FR, et al. Keratinizing cyst of the lacrimal punctum. Cornea. 2013;32:883–5.
50. Ali MJ, Naik MN, Kaliki S, et al. Punctal keratinizing cyst: a clinicopathological correlation of an exceptionally rare lacrimal disorder. Ophthal Plast Reconstr Surg. 2015;31:e66–8.
51. Kamal S, Ali MJ, Naik MN. Punctal keratinizing cyst: report in a pediatric patient with fourier domain ocular coherence tomography features. Ophthal Plast Reconstr Surg. 2015;21:161–3.
52. Murdock J, Lee WW, Zatezalo CC, et al. Three-snip punctoplasty outcome rates and follow up treatments. Orbit. 2015;34:160–3.
53. Ali MJ, Ayyar A, Naik MN. Outcomes of rectangular 3-snip punctoplasty in acquired punctal stenosis: is there a need to be minimally invasive? Eye (Lond). 2015;29:515–8.
54. Wong ES, Li EY, Yuen HK. Long-term outcomes of punch punctoplasty with Kelly punch and review of literature. Eye (Lond). 2016;31(4):560–5. (Epub)
55. Sacks E, Jakobiec FA, Dodick J. Canaliculops. Ophthalmology. 1987;94:78–81.
56. Yoon MK, Jakobiec FA, Mendoza PR. Canaliculops: clinicopathologic features and treatment with marsupialization. Am J Ophthalmol. 2013;156:1062–8.
57. Ali MJ, Saha D, Mishra DK, et al. Canaliculops associated with punctal agenesis: a clinicopathological correlation and review of literature. Ophthal Plast Reconstr Surg. 2015;31:e108–11.
58. Singh S, Ali MJ, Peguda HK, et al. Imaging the canaliculops with ultrasound biomicroscopy and anterior segment ocular coherence tomography. Ophthal Plast Reconstr Surg. 2017;33:e143–4; (Epub)
59. Chaung JQ, Sundar G, Ali MJ. Congenital lacrimal fistula: a major review. Orbit. 2016;35:212–20.
60. Al-Salem K, Gibson A, Dolman PJ. Management of congenital lacrimal (anlage) fistula. Br J Ophthalmol. 2014;98:1435–6.
61. Ali MJ, Mishra DK, Naik MN. Histopathology and immunophenotyping of congenital lacrimal (anlage) fistulae. Ophthal Plast Reconstr Surg. 2016;32:17–9.

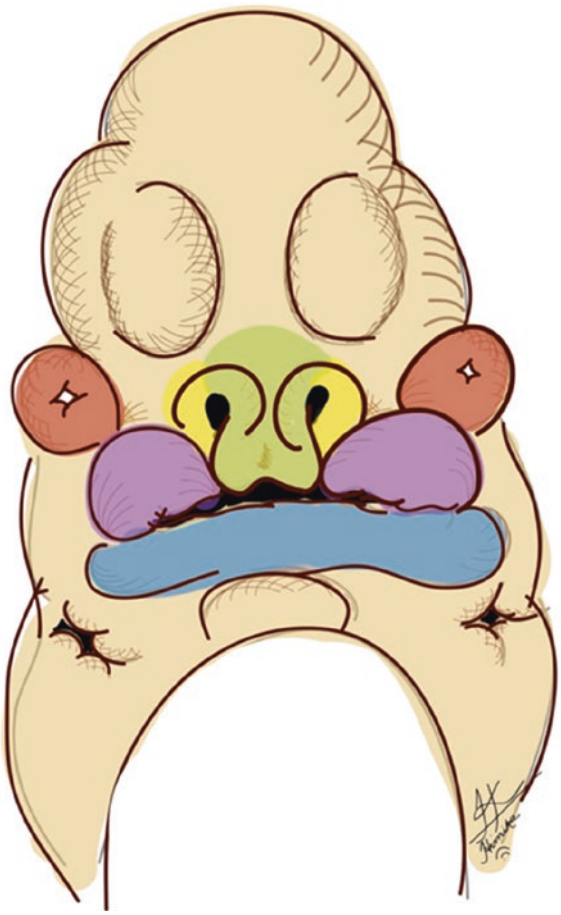


Fig. 13.1 Schematic diagram showing the development of lacrimal system between the maxillary and fronto-nasal process (Photo courtesy: Dr. Himika Gupta)

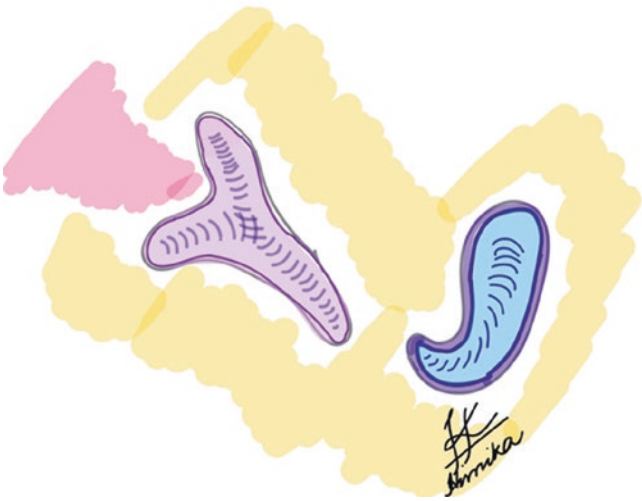


Fig. 13.2 Schematic diagram showing the outbudding of solid canaliculi from the lacrimal rod (Photo courtesy: Dr. Himika Gupta)

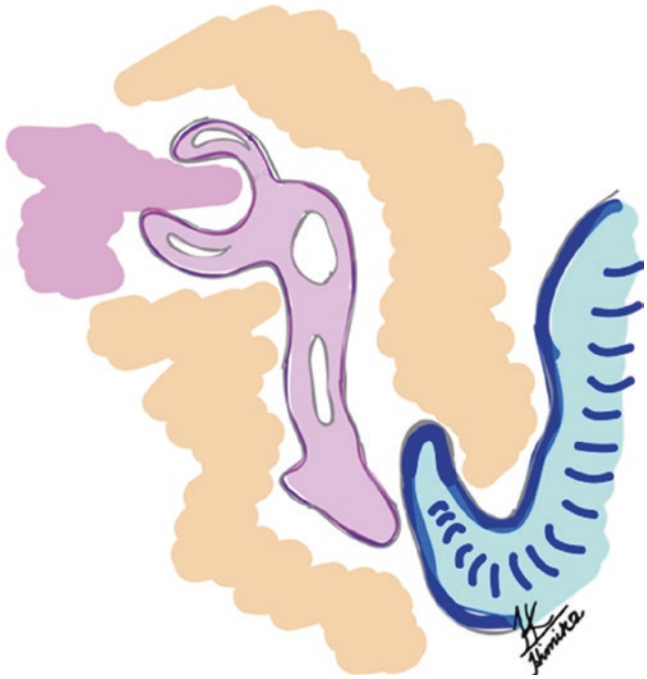


Fig. 13.3 Schematic diagram showing the process of canalization (Photo courtesy: Dr. Himika Gupta)

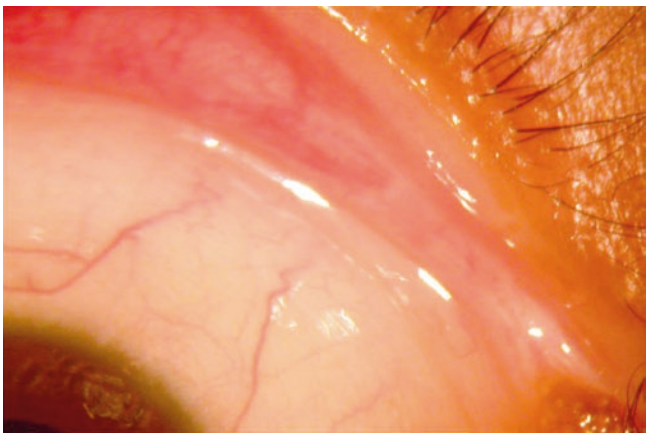


Fig. 13.4 Clinical photograph showing a lower punctum agenesis. Note the cilia in the pars lacrimalis portion of the eyelid

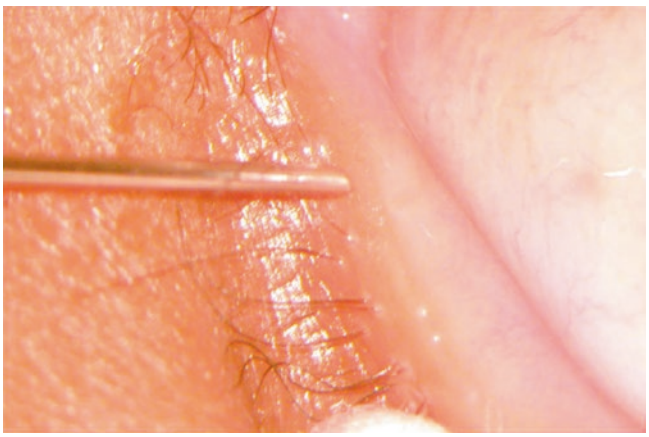


Fig. 13.5 Upper punctal agenesis. Note the absence of punctal papilla

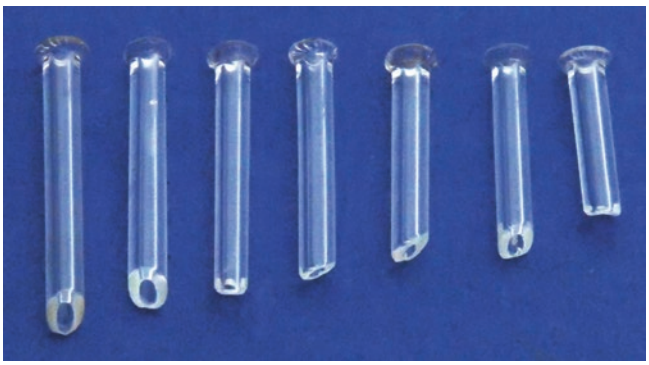


Fig. 13.6 Lester-Jones tubes

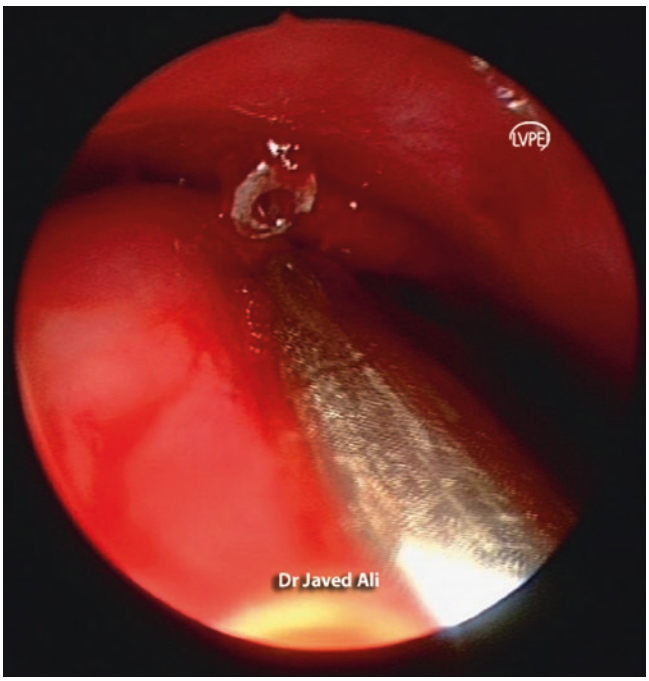


Fig. 13.7 Endoscopic view following CDCR with Lester-Jones tube

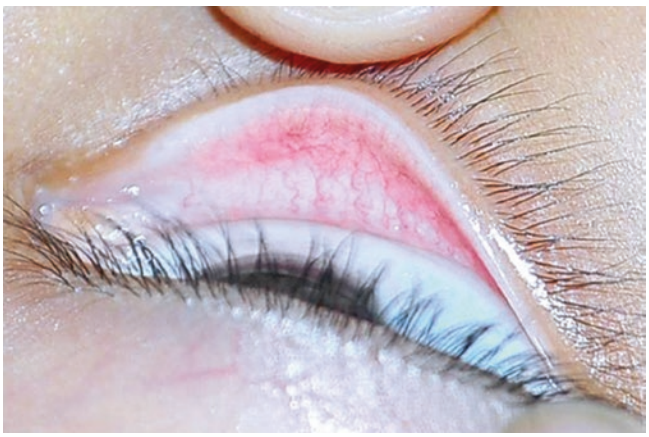


Fig. 13.8 Clinical photograph showing IPC-EM variety. Note how closely it mimics punctal agenesis

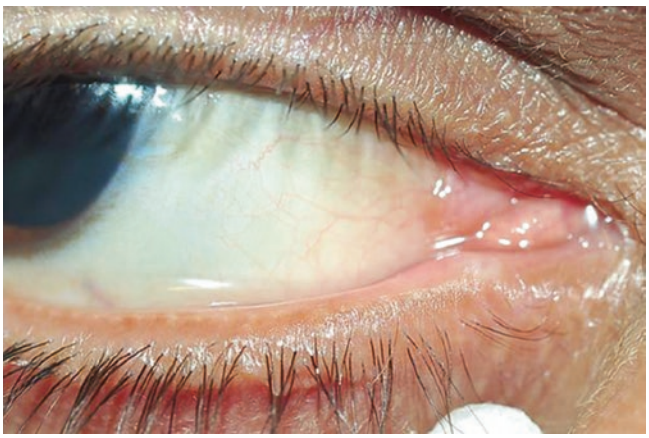


Fig. 13.9 IPC-IM variety. Note that the blurred punctal margins can still be made out

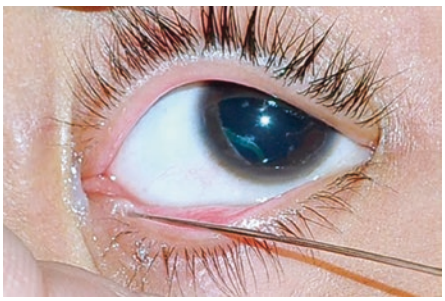


Fig. 13.10 IPC—following membranotomy, the canaliculus was found to be normal

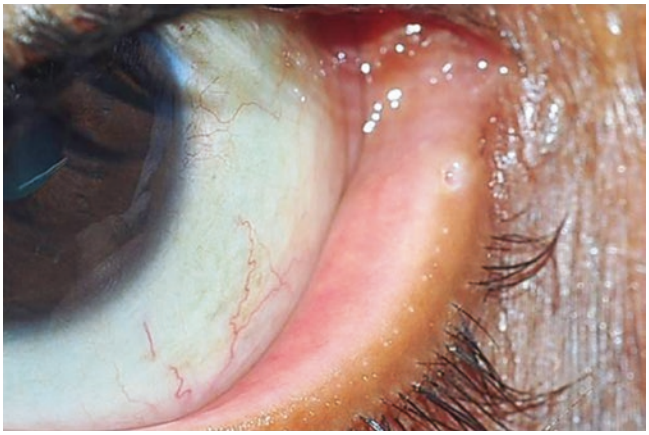


Fig. 13.11 A normal round punctum

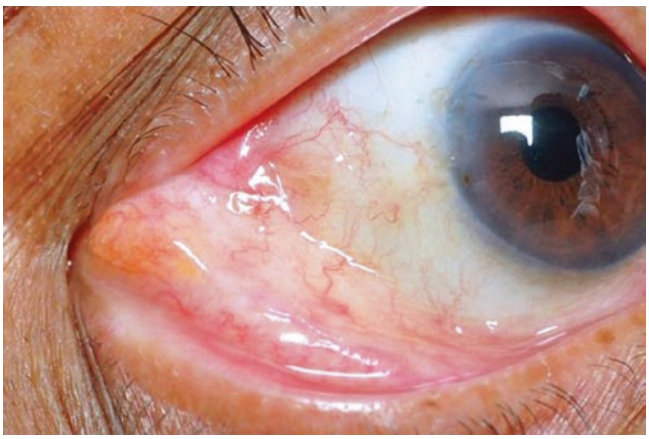


Fig. 13.12 Clinical photograph showing lower punctal stenosis

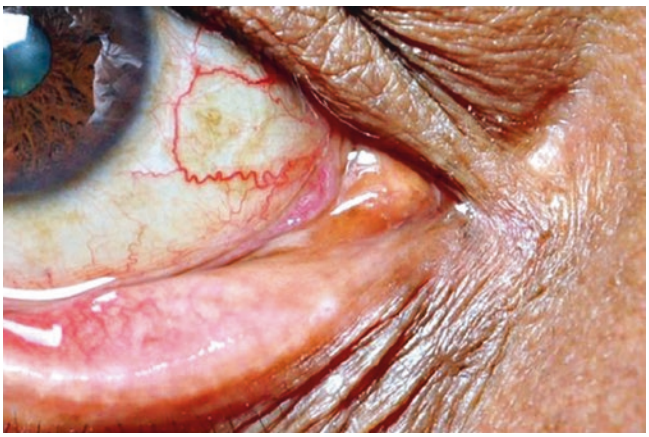


Fig. 13.13 Grade 2 punctal stenosis

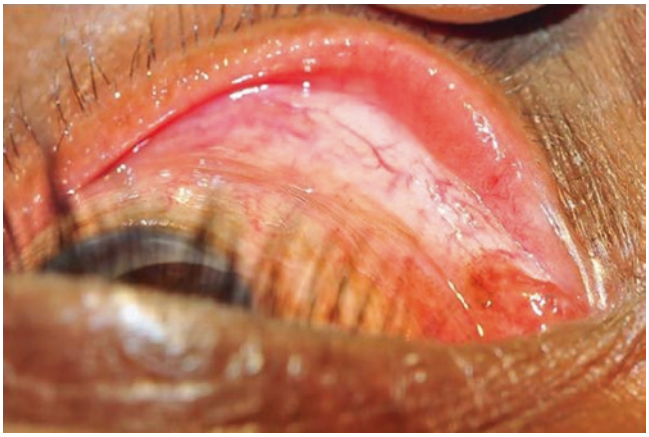


Fig. 13.14 One-snip punctoplasty

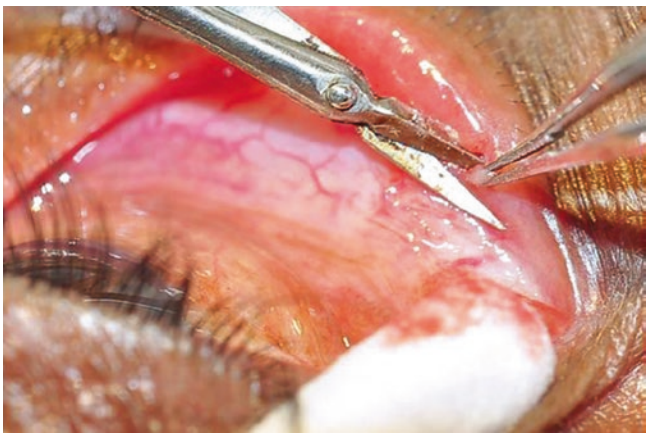


Fig. 13.15 The second snip in punctoplasty

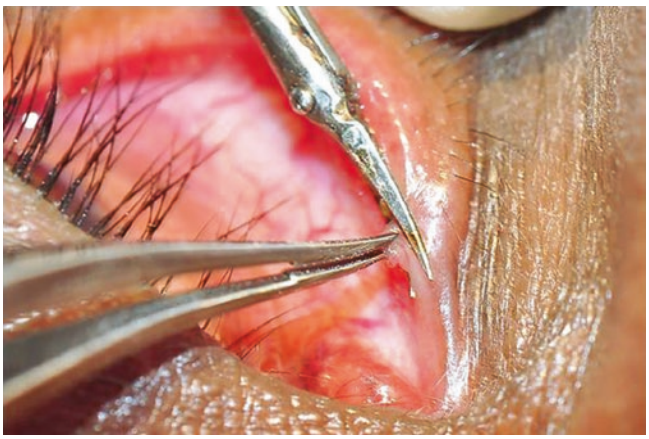


Fig. 13.16 The third snip in punctoplasty

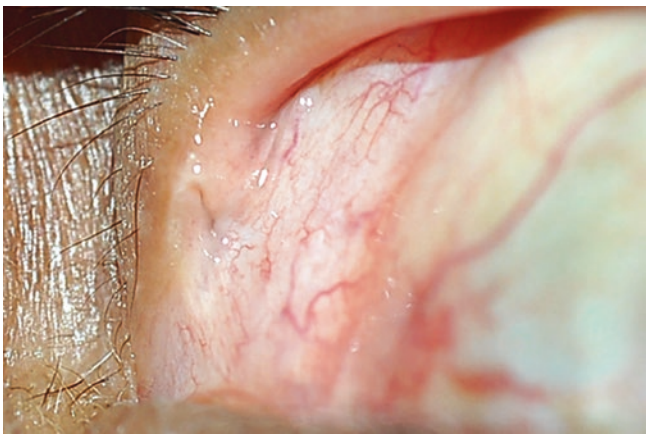


Fig. 13.17 Cicatrization following punctoplasty

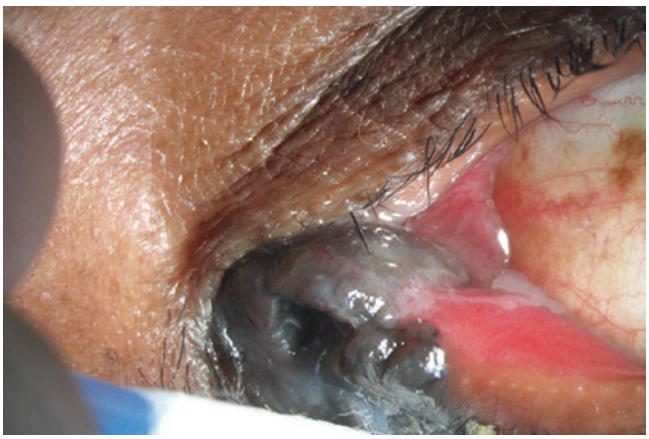


Fig. 13.20 Peri-punctal basal cell carcinoma

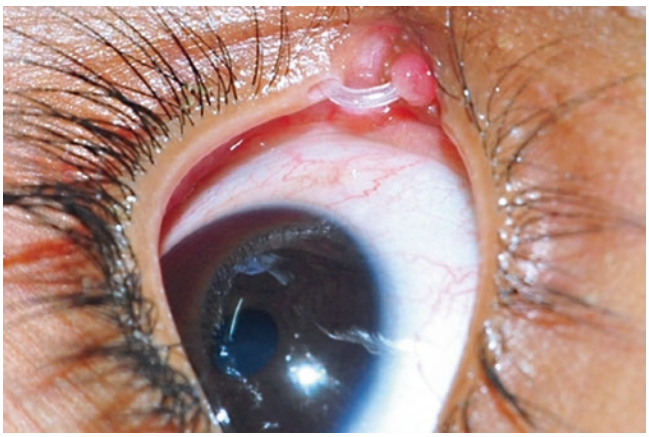


Fig. 13.18 Peri-punctal granuloma

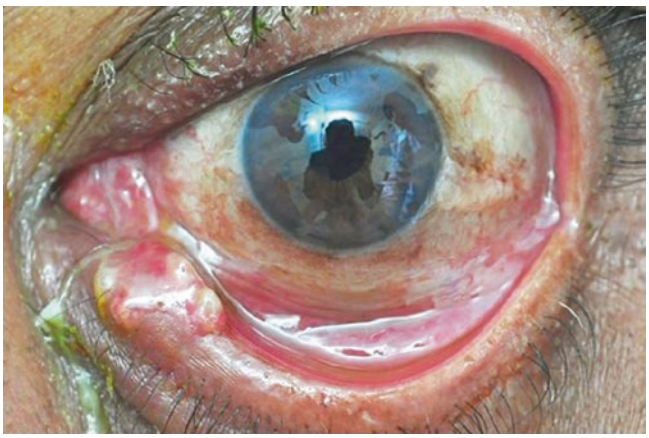


Fig. 13.21 Peri-punctal abscess

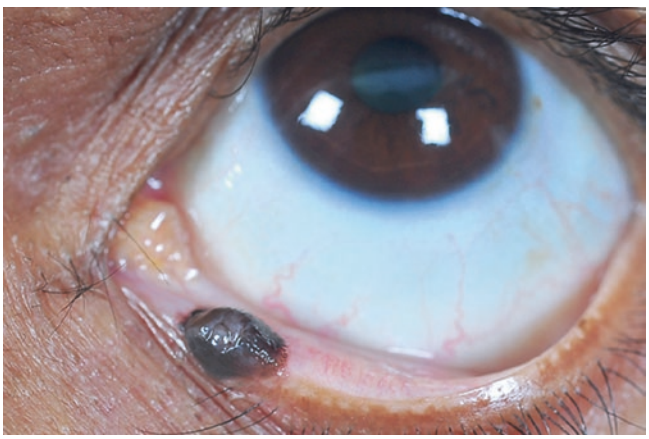


Fig. 13.19 Peri-punctal nevus

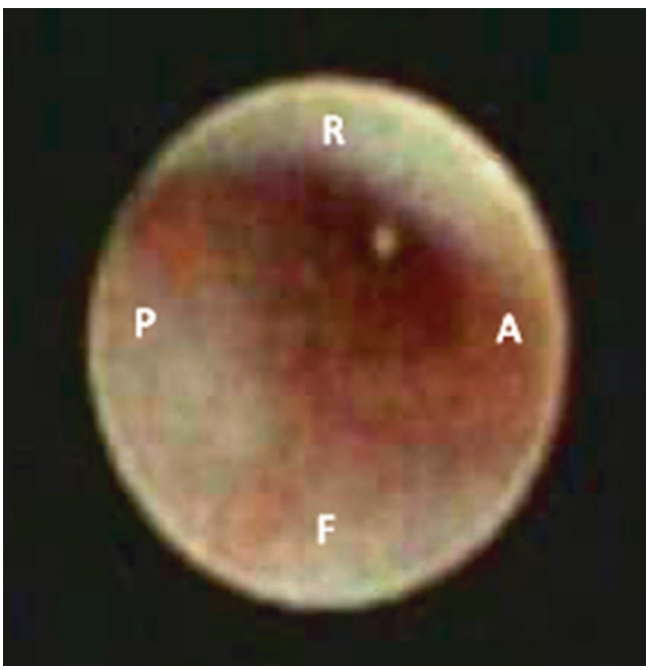


Fig. 13.22 Arbitrary division of canaliculus into four walls, a dacryo-endoscopic view

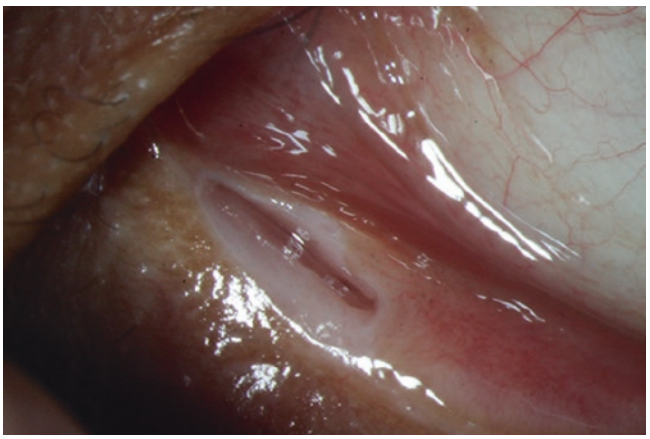


Fig. 13.23 Single canalicular wall aplasia

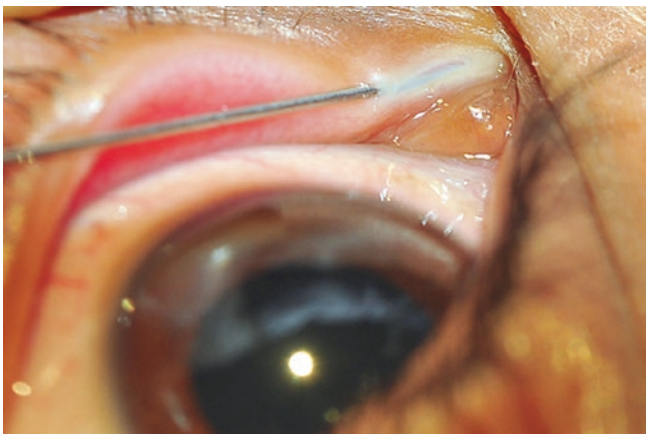


Fig. 13.24 Single canalicular wall hypoplasia

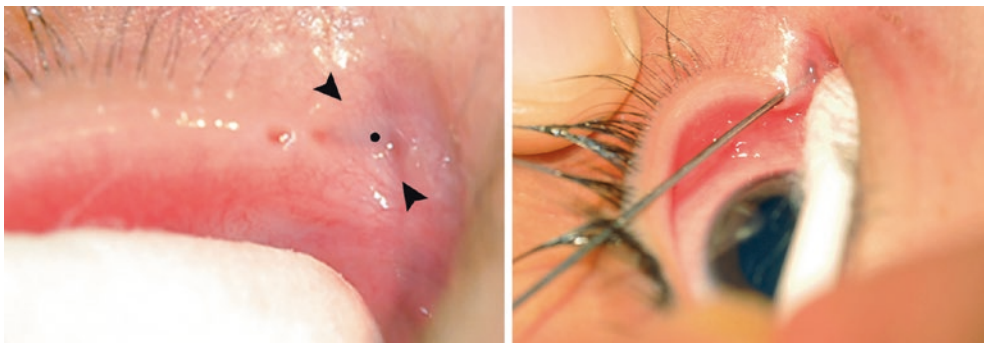


Fig. 13.25 Multiple canalicular wall aplasia (*left panel*) and multiple canalicular wall hypoplasia (*right panel*)

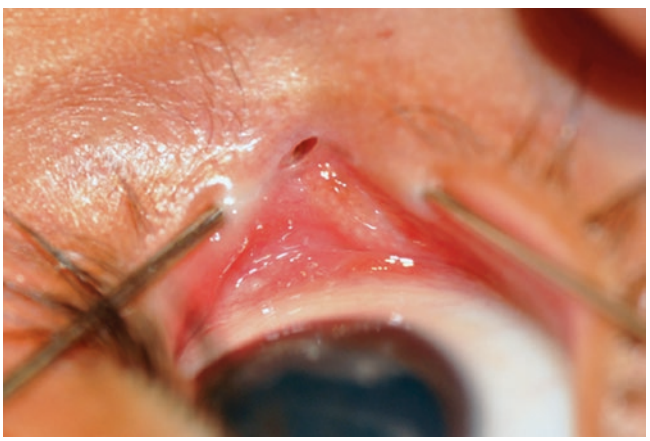


Fig. 13.26 Congenital lacrimal fistula with epiphora

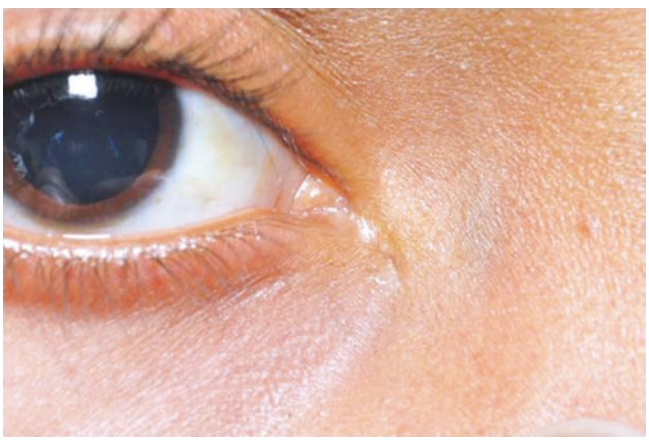


Fig. 13.27 Congenital lacrimal fistula

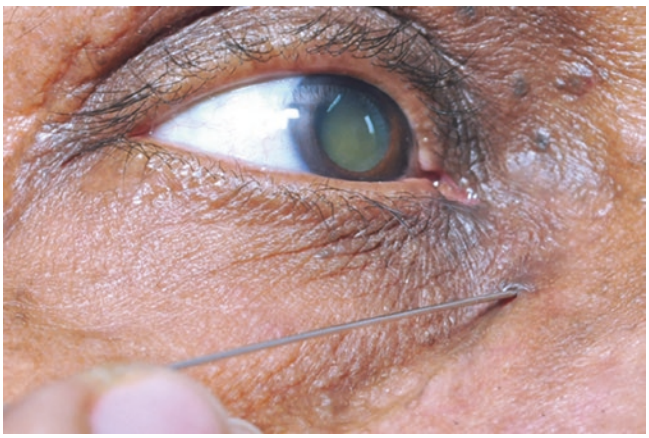


Fig. 13.28 An acquired lacrimal fistula

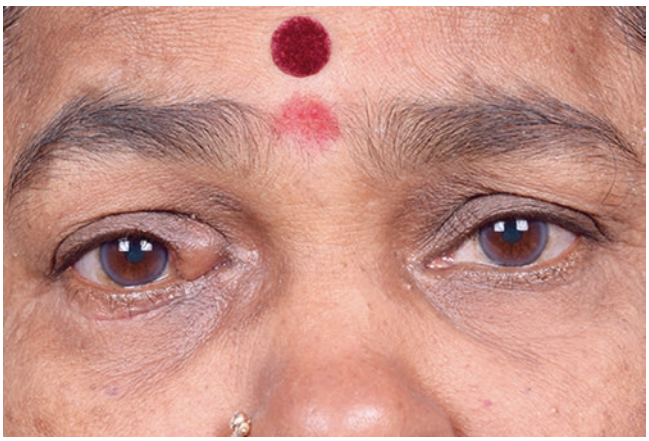


Fig. 13.31 A right upper lid canaliculops presenting as a medial eyelid mass

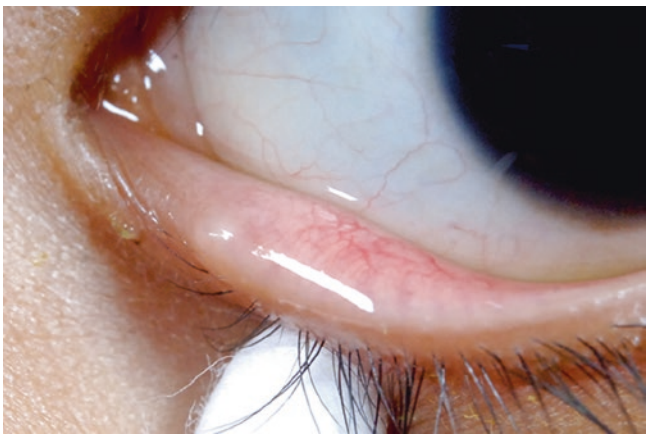


Fig. 13.29 Punctal keratinizing cyst. Note the whitish discoloration

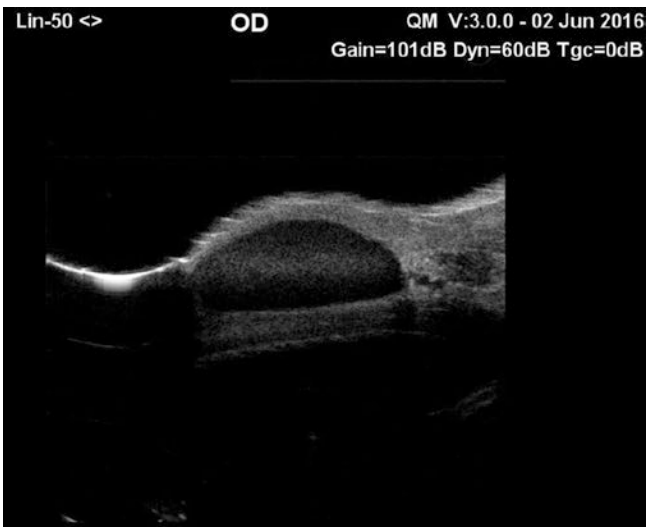


Fig. 13.32 Ultrasound biomicroscopy of a canaliculops. Note the well-defined and dilated cavity and the adjacent small normal canalicular lumen

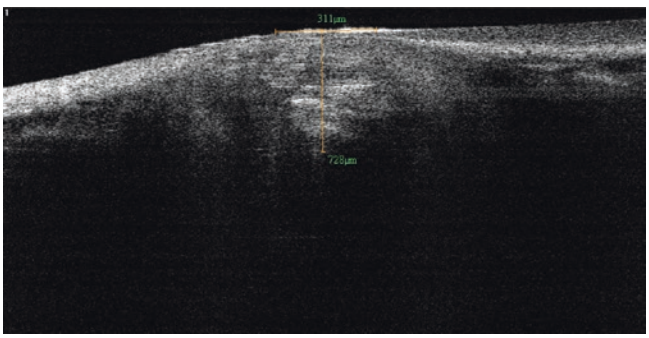


Fig. 13.30 FD-OCT of a punctal keratinizing cyst

Congenital Nasolacrimal Duct Obstructions

14

Saurabh Kamal, Mohammad Javed Ali, and Vinod Gauba

Introduction

Congenital nasolacrimal duct obstruction (CNLDO) is a common cause of epiphora in children with incidence of symptoms ranging from 1.2 to 30% [1, 2]. However, the incidence of anatomic nasolacrimal duct obstruction seen in stillborn is much higher at around 73%. It is believed that respiratory efforts, crying, and sucking create negative pressure within nose which helps to break the membrane present at nasolacrimal duct (NLD) opening. This spontaneous perforation usually occurs by 3–4 weeks of age, but if it fails, manifestations of CNLDO are seen [3]. Management of CNLDO is principally guided by natural history of disease and high spontaneous remission rate by 1 year of age [2]. The standard of care now for non-resolving cases is endoscopic-assisted probing with or without intubation. There is an increasing role of dacryoendoscopy and simultaneous correction of associated intranasal abnormalities [4, 5].

Embryology

There are 23 Carnegie stages which cover the 8 weeks postovulation stage of human embryo [6]. Each stage characterizes the morphological development of embryo. Development of lacrimal excretory system begins at Carnegie stage 16 when lacrimal groove is formed between maxillary and external nasal processes which thicken to form lacrimal lamina. At Carnegie stage 18, lacrimal lamina bifurcates at extreme medial end to form primordium of lacrimal canaliculi (Fig. 14.1) [6]. At Carnegie stage 19, lacrimal lamina separates from surface ectoderm to form lacrimal cord, the medial end of which bifurcates to form two canaliculus. At Carnegie stage 23, medial end of lacrimal cord differentiates into canaliculi, and other end continues caudal and lateral to inferior meatal lamina (thickened epithelium of inferior and lateral part of nasal cavity). At 10 weeks of fetal stage, three significant changes occur: first is the appearance of lumen in lacrimal system, epithelium of canaliculi makes contact with the epithelium of conjunctiva and forms continuous lamina, and third cavitations start near the caudal end of lacrimal cord and inferior meatal lamina (Fig. 14.2). At seventh month puncta open when two eyelids start to separate. At caudal end where lacrimal cord and inferior meatal lamina are present, apoptosis of cells to form a luminal passage occurs but varies from sixth-month intrauterine to several weeks or months after the birth [7].

Therefore development of lacrimal sac and nasolacrimal duct occurs earlier than canaliculi, but the caudal end of nasolacrimal duct is last to canalize [7]. This explains why pathology in CNLDO is mostly present at distal end, where the NLD normally opens into the inferior meatus (Fig. 14.3).

CNLDO: Types and Variations

A number of variations of CNLDO were described way back in 1976 by Jones and Wobig [8]. These variations are seen in the lower end of NLD, and the most common one described is the duct that fails to open through the nasal mucosa and stops at the vault of anterior end of the inferior nasal meatus (Fig. 14.4a). The other variations include NLD extending lateral to nasal mucosa, extending up to floor, complete absence of duct or impacted anterior end of inferior turbinate, etc. (Fig. 14.4b–f).

Kushner first described the types of CNLDO into simple and complex based on intraoperative findings during probing [9]. In cases of simple obstruction, there is lack of resistance in passing probe through the NLD until a point of membranous obstruction which can be perforated. Simple obstruction also

S. Kamal, M.D.
Ophthalmic Plastics Surgery, EyeHub, Faridabad, India

M. Javed Ali, F.R.C.S (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

V. Gauba, F.R.C.S.
Ophthalmic Plastics Surgery, Imperial Healthcare Institute, Dubai, UAE

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_14

includes cases of canalicular valves, where resistance is encountered while bypassing them although there may not be true obstruction. Complicated obstruction can be those associated with any of the variations described earlier like a buried probe, bony obstruction, nondevelopment of nasolacrimal duct, and NLD opening into inferior turbinate and anlages.

Clinical Features

The characteristic triad includes watering, discharge, and matting of eyelashes. In 95% of cases, onset of epiphora is within first month of age [2]. Condition can be unilateral or bilateral. Symptoms may worsen with occurrence of upper respiratory tract infection. Other signs include increased tear meniscus height, positive fluorescein dye disappearance test (FDDT), and regurgitation on pressure over lacrimal sac (ROPLAS). Spectrum of presentation can rarely include acute dacryocystitis, dacryocele, mucopyocele, preseptal, and orbital cellulitis (Fig. 14.5a–f**).**

Dacryocystocele or simply dacryoceles are bluish cystic lacrimal sac swelling typically present below the medial canthal tendon, filled with secretions from epithelial lining and tears (Figs. 14.5b and 14.6). It is uncommon manifestation of CNLDO occurring in 1 in 3900 live births [8]. Nasolacrimal duct obstruction when combined with either functional obstruction of proximal lacrimal system or common canaliculus leads to accumulation of secretions in the lacrimal sac. This leads to distortion of common canaliculus and creates a ball-valve mechanism at valve of Rosenmuller which allow ingress of tears into the sac but interferes with egress [10]. Dacryocystocele can be bilateral in 25% cases and can complicate into superadded infection and respiratory distress [5, 11]. Associated intranasal cyst (Fig. 14.7) can be small or large (if >50% of nasal cavity) and, if large, can cause respiratory insufficiency because neonates are nasal breathers. This can potentially be life threatening in cases of bilateral pathology [11]. Infection can lead to preseptal cellulitis, orbital cellulitis, and sepsis and therefore indicating an early management of this condition. In the absence of intranasal cysts, dacryocele can be managed conservatively, and success rate achieved with sac compression alone was 76% in one of the series [12]. In non-resolving cases and with associated intranasal cyst, it is preferable to marsupialize the intranasal cyst early. Ali et al. [13] defined and classified the intranasal cysts as small and large based on endoscopic features and described a new technique of cruciate marsupialization for large intranasal cysts with good outcomes.

Lacrimal fistula (anlage duct) is seen in 1 in 2000 births [14]. It can cause epiphora (seen from fistulous opening), discharge, dermatitis, and ascending infection causing acute or chronic dacryocystitis (Figs. 14.5f and 14.8). There are many theories postulating its formation; most accepted one is that lacrimal fistula is an aberrant canaliculus which often originates from common canaliculus or canaliculus and lined by nonkeratinized stratified squamous epithelium resembling canaliculus [14, 15]. Other associated lacrimal anomalies include CNLDO, absent canaliculus, supernumerary/absent punctum, and total agenesis of lacrimal system [16]. A careful fistulectomy is performed when lacrimal system is patent, but in cases of associated CNLDO, the authors prefer probing first and to wait for 6 months for spontaneous closure of fistula secondary to no flow. However if fistula persists, a fistulectomy can be performed.

Syndromes and Craniofacial Abnormalities Associated with CNLDO

Syndromic associations include Down's syndrome (Trisomy 21), Crouzon syndrome, Treacher Collins syndrome, Klinefelter's syndrome, and Rubinstein-Taybi syndrome [14]. Associated craniofacial abnormalities include cleft lip/palate, facial cleft, hypertelorism, bifid uvula, hemifacial microsomia, preauricular skin appendages, deformed external ears, and laryngeal stenosis (Fig. 14.9) [16]. Tables 14.1 and 14.2 enlist the syndromic and non-syndromic systemic associations of CNLDO.

Table 14.1 Syndromic associations of CNLDO

1. Down syndrome
2. Ectrodactyly ectodermal dysplasia clefting (EEC) syndrome
3. Treacher Collins syndrome
4. Rubinstein-Taybi syndrome
5. Hay-Wells syndrome
6. Lacrimo-auriculo-dento-digital (LADD) syndrome
7. ADULT syndrome
8. Limb mammary syndrome
9. Rapp-Hodgkin syndrome
10. Apert syndrome
11. Saethre-Chotzen syndrome
12. Cornelia de Lange syndrome
13. Crouzon syndrome
14. Congenital arhinia microphthalmia syndrome
15. Blepharophimosis syndrome
16. Congenital rubella syndrome
17. VACTERL association
18. Branchio-oculofacial syndromes
19. Fraser syndrome
20. Johanson-Blizzard syndrome

Table 14.2 Non-syndromic systemic associations of CNLDO

1. Facial clefting; Tessier types 3 and 4
2. Craniometaphyseal dysplasia
3. Craniodiaphyseal dysplasia
4. Bifid uvula
5. Coloboma auris
6. Accessory auricle
7. Choanal atresia
8. Laryngeal stenosis
9. Non-syndromic dysmorphisms
10. Meningocele
11. Hydroencephalocele
12. Corpus callosum agenesis
13. Maxillary hypoplasia
14. Hypertelorisms
15. Hemifacial microsomias
16. Anophthalmos
17. Phocomelia
18. Uterine didelphys
19. Pyloric stenosis
20. Motor delays

Natural History

A thorough knowledge and understanding of natural history of CNLDO is a must for making a decision regarding the management as well as explaining prognosis to the parents. In the landmark study by MacEwen and Young published in 1991, a large cohort of 1019 eyes of infants were observed to determine the incidence and natural history of epiphora during first year of life [2]. In 95% of cases, onset of epiphora was within the first month of age and thereafter 3% in second month and less than 1% in third and fourth month of age. Spontaneous resolution was observed throughout the year from first month, and by 1 year of age, overall spontaneous resolution rate was 96%. They also provided the probability of spontaneous resolution, i.e., percentage of infants at each month, who, upon follow-up, resolved before age 12 months. Table 14.3 reflects the rounded-up figures making it easy to remember. This study provided the evidence that the probing should ideally be delayed until 1 year of age but did not provide the optimum age at which probing should be considered.

In subsequent study by same researchers on CNLDO during second year of life, it was noted that at 15 months of age, probing is superior to "no treatment" with statistical difference, but at age of 24 months, there was no statistical difference between the two groups (74% resolution in probing group versus 60% in observation group) [17]. Spontaneous resolution remains a common occurrence during second year of life with about 50% rate (among the residuals) between 13 and 18 months and 23% between 19 and 24 months of age. Appropriate time of probing recommended was 18 months of age if there were no signs of resolution.

Table 14.3 Predicting the probability of spontaneous resolution of CLNDO by 1 year of age at various months of presentation [2] (numbers rounded for easy memory!)

Age	Spontaneous resolution probability
1 month	95%
2 months	95%
3 months	90%
4 months	85%
5 months	80%
6 months	75%
7 months	65%
8 months	50%
9 months	35%
10 months	25%
11 months	5%
12 months	0%

The Pediatric Eye Disease Investigator Group (PEDIG) studied the resolution of CNLDO with 6 months of observation for infants presenting between 6 and <10 months old [18]. In this age group, more than half of the eyes (~66%) resolved.

Treatment

The most common outcome of CNLDO is the spontaneous resolution without the surgical intervention. Topical antibiotics are needed when there is purulent discharge and conjunctivitis or associated acute dacryocystitis. However, some surgeons prefer antibiotics more so for their additional anti-inflammatory actions as well. Various treatment options in CNLDO are conservative with compression over lacrimal sac area, probing, intubation, balloon catheter dilation, endoscopic-assisted correction of associated nasal abnormalities, and, as a last resort for recalcitrant cases, an endoscopic or external dacryocystorhinostomy (DCR).

Conservative with Compression over Lacrimal Sac Area

Hydrostatic pressure over lacrimal sac area was described by Criggler in 1923. The aim was to increase the intraluminal pressure and direct it downward (by compressing the common canaliculus) to rupture the membrane (Hasner valve) at lower end of NLD (Fig. 14.10a, b). The success rate observed in various studies ranged from 30 to 93% [16] being maximum when performed early in life as compared to older age group. Other factors for success include a correct technique of sac compression and compliance. It appears that sac

compression essentially causes earlier resolution of CNDLO symptoms when compared to natural history. In clinics, the correct method of sac compression should be demonstrated to the parents or caregivers and encouraged to perform the technique under clinician supervision. Depending upon the treating physician, sac compression can be continued till age of 9–12 months, and if symptoms persist, probing is advised.

Method of Sac Compression

Parents should be instructed to wash hands and use index finger of the contralateral hand for sac compression. Pressure should be directly applied over lacrimal sac area, just on the inside of anterior lacrimal crest, below the medial canthal tendon, and without compressing the bone or eye. Downward movements on the lateral wall of the nose are not required. Usual frequency advised is ten times/session with four sessions per day (Fig. 14.10a, b).

Probing: Early Office-Based Versus Late Probing Under General Anesthesia

Probing is indicated if symptoms and signs of CNLDO persist despite lacrimal sac compression. Age at which probing is indicated is debated in literature but is usually after 6 months of age [19]. Early probing usually done between 6 and 9 months of age is an office procedure practiced by some which avoids general anesthesia and is done under topical anesthesia and restraint. Late probing after 9–12 months of age is done under general anesthesia and is technically easier. Adopting early office probing would result in probing approximately two-thirds of infants in whom obstruction would have spontaneously resolve on follow-up of 6 months [20]. Early probing for 6 to <10 months of age group has success rate of 92% compared to 82% with late probing when done after 6 months of observation [20].

PEDIG concluded that although CNLDO resolves spontaneously in two-thirds of cases presenting between 6 and <10 months of age group, early office-based probing is an effective and cost saving when compared to late probing with added advantage of 3 months of fewer symptoms. But the treatment decision rests entirely upon parent and physician weighing the risk-benefit ratio. The authors of this chapter prefer to avoid office-based probing because it causes undue stress on infants and parents. A more controlled irrigation and probing under general anesthesia also allows a more detailed evaluation of lacrimal system as well as diagnosing and treating suspected nasal pathology with an aid of endoscope. The authors usually perform probing for unresolved cases beyond 12 months of age. However, early probing is performed in cases of sac dilatation, mucocele, dacryoceles, acute dacryocystitis, or when there is a need for early intervention in associated ocular comorbidities like congenital glaucoma.

Technique of Probing

Probing is a technique of passing a predetermined diameter rigid probe into the lacrimal system with an aim of overcoming the obstruction at the lower end of nasolacrimal duct. The instrumentation is simple (Fig. 14.11). It is preferred to pass the probe through upper punctum because it is more in continuation with the lacrimal sac and gives an easier entry and a less traumatic 90° turn. Nasal mucosa is decongested with 0.025% oxymetazoline. Upper punctum is first gently dilated with Nettleship punctum dilator (Fig. 14.12). Although the choice of probe depends on the surgeon, a general guideline is useful (Table 14.4). It is also important to know what kind of probe is being used, Bowman's or Clarke's or any other, since they may vary in diameter although the number may be same (Table 14.5). A smear of lubrication onto the probe in form of ointment or jelly helps being less traumatic (Fig. 14.13). Probe of appropriate size is then passed gently, first directed along vertical canaliculus and then bending it gently at ampulla, without any force and then along the horizontal canaliculus with simultaneous outward stretching of upper lid (Fig. 14.14). Once the probe enters the sac and touches its medial wall, a hard stop is felt. The probe is then withdrawn by 1 mm and then gently turned 90° to lie flat on the forehead in line with trochlea (Fig. 14.15). The probe is then gently advanced into the lacrimal sac and nasolacrimal duct. It is important to know that the NLD in most course downward, backward, and laterally. No undue movements or force should be applied to avoid any false passage. Membranous obstruction at lower end of nasolacrimal duct

Table 14.4 Broad guidelines used by authors' for choosing the size of probe

Age	Bowman's probe size
Neonate	# 00
Infants	# 0
1–4 years	# 1
>4 years	# 1 or # 2

Table 14.5 Comparison of Bowman and Clarke's probes with respect to size number and diameter

Bowman's size	Bowman's diameter	Clarke's size	Clarke's diameter
# 0000	0.7 mm	# 00	0.6 mm
# 000	0.8 mm	# 0	0.7 mm
# 00	0.9 mm	# 1	0.8 mm
# 0	1 mm	# 2	0.9 mm
# 1	1.1 mm	# 3	1.0 mm
# 2	1.2 mm	# 4	1.1 mm

can be overcome with a very gentle give way of resistance without application of much force. Probe should be pushed just for few millimeters further so as to avoid injury to the floor of the nose and subsequently palate. The presence of probe at NLD opening can be confirmed by metal to metal touch by placing spatula in inferior meatus at NLD opening. However, these blind maneuvers can be traumatic and do not rule out possibility of a false passage. Patency can also be confirmed with irrigation using fluoroscein-stained saline. However, the authors routinely perform an endoscopic-guided probing in all their patients (Fig. 14.16).

Probing in Older Age Group

Probing can also be used as a primary treatment for children <36 months of age, where success rate of 78–93% can be achieved [21, 22]. For older children success rate is even less [22, 23]. Studies on older children between 25 and 60 months have shown failure rates as high as 28%. The prevalence of complex obstruction in children between 49 and 60 months was 43% with a success rate of only 33% on probing.

Factors Affecting the Success of Probing

Various studies have reported the factors affecting the outcome of probing. Those associated with higher failure rate include age >36 months, bilateral affection, failed conservative treatment, failed earlier probing, dilated lacrimal sac, intraoperative firm obstruction, inability to past 0000 probe, proximal obstructions, and physiologic causes [4, 20, 22].

Balloon Catheter Dilation (BCD)

BCD or balloon dacryoplasty is usually indicated for cases with previous failed probing, but some surgeons also use it as a primary modality. When used as primary treatment, success rate achieved for age 12–24 months is 82% and for age 24–48 months was 75% [24]. Other indications include previous failed probing, failed intubation, complex CNLDO, CNLDO with syndromic association, and older age group [25].

Technique of BCD

The usual balloon size used is 2 mm for children <30 months age and 3 mm for >30 months age [25]. Nasal mucosa is decongested. Upper punctum is dilated and probing is performed to confirm the type of block. Obstruction is overcome and probe is confirmed in inferior meatus. Desired size balloon is lubricated with viscoelastic and passed in lacrimal system. There are two markings on balloon: 10 and 15 mm. Balloon catheter is passed till 15 mm mark reaches punctum. Two cycles of balloon inflation and deflation are performed: first cycle of 8 atmosphere pressure for 90 s and second cycle of 8 atmosphere for 60 s (Fig. 14.17). Probe is then withdrawn till 10 mm mark, and similar two cycles are repeated to dilate the proximal NLD. Patency is confirmed with fluoroscein-stained saline (detailed technique and outcomes can be read in chapter on balloon dacryoplasty).

Silicon Intubation (SI)

SI is indicated for cases with previous failed probing and complex CNLDO and can also be used as primary treatment modality. When used as primary treatment, success rate reported for age <12 months is 95%, for 12–24 months is 92%, and for 24–45 months is 84% [26]. Results with monocanalicular intubation (with mini-monoka) and bicanalicular SI are comparable. Advantage of monocanalicular stent is the easy removal under topical anesthesia in clinic without the need of sedation or general anesthesia. Common monocanalicular stent used is either mini-monoka or monoka-Crawford and that for bicanalicular is Crawford silicone stent (Figs. 14.18, 14.19, and 14.20).

Timing of SI removal in CNLDO is controversial. While the PEDIG study aimed to retain the SI for period of 2–5 months, other studies have noted higher success rate with early (6 weeks) as well as late (≥6 months) removal of stent [26].

Complications are rare but can occur and include epistaxis, inferior turbinate and floor injury, punctal cheesewiring, corneal abrasion, migration of tube, and pyogenic granuloma.

Persistent CNLDO (Failed Probing)

Persistent CNLDO is defined as recurrence of symptoms of CNLDO after primary probing usually occurring within 6 weeks. Apart from the various factors associated with increased failure (as stated above), complex CNLDO comprises the bulk of this category. Frequency of complex CNLDO cases increases with increasing age with 2.2–3.6% incidence in <24 months age but 20–57% incidence in age group 24–60 months [27].

All cases of persistent CNLDO should have a careful nasal examination to rule out nasal causes. Other causes of persistent symptoms include punctal stenosis, canalicular obstruction, upper nasolacrimal duct obstruction, and physiological obstruction [4]. Their recognition is important during repeat procedure and should be appropriately addressed.

Options for treatment include repeat probing with intubation, balloon catheter dilation, or intubation alone. PEDIG investigated these treatment modalities and noted success

rate of 56% for repeat probing, 77% for BCD, and 84% for intubation [28, 29]. But these studies excluded the patients of Down's syndrome and other syndromic associations, where the success can be still lower.

Nasal Endoscopy

Recently there has been increasing use of endoscopic-assisted probing for CNLDO. Endoscopy allows direct visualization of probe and inferior nasolacrimal duct opening, avoids false passage, helps detect false passage if any (Fig. 14.21), directs visualization of fluoroscein during fluoroscein endoscopic dye test (FEDT), aids in diagnosing NLD variations, performs inferior turbinate medialization, and most importantly recognizes and treats intranasal abnormalities. The endoscopy is especially useful for cases with complex and persistent CNLDO. Intranasal abnormalities include nasal cyst in cases of dacryocele (Fig. 14.7), distal NLD cyst in cases of long-standing mucocele, and buried probe (Fig. 14.22) [5].

Inferior Turbinate (IT) Medialization

We prefer the term medialization to infracture, since we do not advocate it. Medialization is only for a better view in a more lateralized IT. Historical teaching to perform it in cases where it is impacted around the opening of NLD does not appear to hold more ground today, since IT impactions are exceptionally rare as in lateral nasal wall dysgenesis. Commonly, the lateralized ITs are more often labeled as impacted. Endoscopic guidance gives a better control, allows direct visualization of inferior meatus, and avoids damage to the intrameatal portion of NLD (Fig. 14.23) [12].

Dacryoendoscopy

Dacryoendoscopy is a procedure utilizing microendoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [30, 31]. It is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders thus having many diagnostic and therapeutic implications. It is a very useful tool to assess the NLD in children with persistent CNLDO. Accurate assessment on the type of inflammation, locations of fibrotic tissues (Fig. 14.24), and recanalization of NLD can be performed. Although it appears to be a very promising diagnostic modality, therapeutic uses in management for complex CNLDO are not yet fully known. For details of this technique and indications, please refer to chapters on dacryoendoscopy and NLD recanalization.

Dacryocystorhinostomy (DCR)

DCR is indicated in persistent CNLDO cases which fail to resolve with repeated probing/BCD/intubation and endoscopic evaluation and treatment of nasal abnormality. Both external and endoscopic approaches are feasible and have good success rate. Endoscopic DCR may be difficult for the beginners because of variable anatomy and narrow confines, but success rate can be comparable to external approach [32].

Update (2015–2016)

CNLDO Meta-analysis

A recent systematic review and quantitative meta-analysis of randomized controlled trials for CNLDO have revealed interesting observations [33]. There was no difference noted between the outcomes of early probing (around 6 months age) versus routine probing (around 1 year age). Balloon dilatation and intubation offered similar success rates. Between monocanalicular and bicanalicular intubations, neither the outcomes differed nor the dislocation rates [33]. In essence this means that with regard to use of intubation or its types, balloons, and timing of probing, the surgeon can decide based on his comfort, parental discussion, and the overall risk-benefit ratios.

Amblyopia and CNLDO

There is an increasing evidence of associated refractive errors and amblyogenic risk factors in patients with CNLDO. This prevalence of risk factors can be as high as 25% [34, 35]. Unilateral CNLDO were found to have higher anisometropia and hence higher risk of developing amblyopia as compared to the bilateral cases [36, 37]. The degree of anisometropia was found to increase with age, and this led few authors to propose an earlier intervention [37, 38]. However, there are conflicting reports with regards to this with a study reporting that those CNLDO that resolve early and spontaneously have higher rates of anisometropia than those with late spontaneous resolution or surgical intervention [39]. On the other hand, failed probing was also reported to have a higher degree of anisometropia, giving impetus to the theory of structural alterations as a cause of refractive errors in CNLDO [40]. The general consensus currently is to comprehensively examine all children with CNLDO and intervene as needed with regard to correction of refractive errors and prevention of subsequent amblyopia.

Buried Probe

Buried probe is a variant of complex CNLDO and is more commonly noted in older children [41, 42]. This is an endoscopic diagnosis and is defined "as a condition when the entire nasolacrimal duct remains submucosally in the lateral wall of the nose up to the floor without any opening into the inferior meatus" [42]. It accounted for 10% of complex CNLDOs. The probe in these patients passes smoothly up to the floor without coming out in the inferior meatus (Figs. 14.4b and 14.22). In such a case, the entire length of the probe movement in the lateral wall of the inferior meatus should be assessed to find out the thinnest mucosal point. This can be noted by the maximum light reflectance from the probe at the thinnest point. The probe is then gently tilted to come out from this point into the inferior meatus. The outcomes are good with an anatomical success rate of around 90% [42]. This again emphasizes the fact that endoscopic guidance is mandatory for a good evaluation and management of CNLDO.

Masquerades of CNLDO

Various lacrimal and nasal conditions can masquerade as a CNLDO, and this need to be kept in mind. The common masquerades in a large series were noted to be incomplete punctal canalization, functional epiphora, and punctal agenesis [43]. Rarely glial heterotopia or ectopic brain has masqueraded as a congenital dacryocele [44]. Table 14.6 lists the masquerades of CNLDO.

Bony NLD Parameters in CNLDO

Many parameters of the bony NLD have been well studied in adults. Zhang et al. [45] studied 18 infants with unilateral CNLDO and compared the parameters on the diseased and healthy sides. The anteroposterior diameters, the transverse diameters, and the area of bony NLD were larger on the diseased side as compared to the healthy sides. This can partly be explained secondary to dilated soft tissue NLD with higher luminal pressures, which may lead to expansion of the moldable pediatric bony NLD.

Table 14.6 Masquerades of CNLDO

1. Incomplete punctal canalization (IPC)
2. Pediatric functional epiphora
3. Punctal agenesis
4. Allergic rhinitis
5. Monocanalicular obstructions
6. Pre-saccal stenosis
7. Punctal stenosis
8. Canalicular wall dysgenesis
9. Lateral nasal wall dysplasia
10. Glial heterotopia

Updates on Dacryoceles

Prenatal detection of a dacryoceles on USG is not a routine, and very interesting information has come up in the literature [46–48]. The incidence of dacryoceles among routine obstetric USG was 0.43%. No gender predilection was apparent. The highest detections were around 27 weeks of gestational age and reduced at term. Most were unilateral with mean maximum diameter of 7 mm. About 76% of them had a spontaneous resolution at birth [46]. These newer findings reflect that although uncommon, dacryoceles usually resolve spontaneously. Prenatal detections can help in better management in persistent cases and hence reduce the morbidity.

Owing to awareness and better diagnosis at birth, many reports of fetal distress due to large intranasal cysts and their management with immediate surgical marsupialization and nasal mask continuous positive airway pressures were reported [49–51]. Bilateral dacryocystoceles have also been reported in a set of monozygotic twins [52], and similar such earlier reports [53, 54] in siblings have put up a strong case for a possible genetic basis.

Orbital and periorbital extension of dacryoceles is a rare complication and can occur when there are anatomical variations in lacrimal sac fossa that result in less posterior resistance and orbital extension of the rapidly expanding dacryoceles [55]. A transconjunctival orbitotomy and marsupialization of the cysts along with a nasolacrimal intubation have been found to be curative for this rare complication [55].

Caesarian Section and CNLDO

There is building evidence on the association of Caesarean sections (CS) with CNLDO. The prevalence of CNLDO has been higher in children born with CS. The relative risk has been estimated to be 1.7-fold more with CS [56]. Another report has shown a very high statistically significant association ($P = 0.00004$) [57]. It is believed that normal labor induces multiple mechanical alterations, and numerous collagenolytic enzymes in the amniotic fluid and disturbance of this normal mechanism may influence canalization of the nasolacrimal duct.

Genetics of CNLDO

Certain genetic disorders with widespread or frequent association with lacrimal anomalies can be explored further to

assess any common links. Foster et al. [58] reported four siblings with isolated CNLDO (autosomal recessive inheritance) having mutations in IGSF3 gene (immunoglobulin superfamily member 3). The gene TP63 (tumor protein 63) plays a crucial role in ectodermal, orofacial, and limb development [59]. Hence, disorders of this gene result in a wide variety of syndromes with multiple lacrimal anomalies. Notable among these are the EEC syndrome, LMS syndrome, Rapp-Hodgkin syndrome, and ADULT syndrome [60]. Mutations of FGF10 (fibroblast growth factor 10) and its receptors FGFR2 and 3 (fibroblast growth factor receptors) can influence the development of the lacrimal drainage system [60]. Classical examples of these mutations are LADD and ALSG syndromes. Jadico et al. [61] found that 60% of patients with a mutation in TWIST gene in patients with Saethre-Chotzen syndrome had NLDO. All these point toward increasing evidence of genetic basis of congenital nasolacrimal duct obstruction at least in some cases.

Conclusion

Congenital nasolacrimal duct obstruction is a common cause of epiphora in children. Most of the cases either resolve spontaneously or can be managed conservatively with lacrimal sac compression. Persistent, complex CNDLO and older age children would usually require intubation or balloon catheter dilation and endoscopy to rule out intranasal abnormalities. Cases of dacryocele should be managed early with endoscopic approach when associated with intranasal cyst. With the advent of dacryroendoscopic guided probing, fewer numbers of children would need a dacryocystorhinostomy.

References

1. Geurry D, Kendig EL. Congenital impatency on the naso-lacrimal duct. Arch Ophthalmol. 1948;39:193–204.
2. Macewen CJ, Young JDH. Epiphora during the first year of life. Eye. 1991;5:596–600.
3. Cassady JV. Developmental anatomy of nasolacrimal duct. Arch Ophthalmol. 1952;47:141–58.
4. Wallace EJ, Cox A, White P, et al. Endoscopic-assisted probing for congenital nasolacrimal duct obstruction. Eye. 2006;20:998–1003.
5. Lueder GT. Endoscopic treatment of intranasal abnormalities associated with nasolacrimal duct obstruction. J AAPOS. 2004;8:128–32.
6. dela Cuadra-Blanco C, Peces-Pena MD, Janez-Escalada L, et al. Morphogenesis of the human excretory lacrimal system. J Anat. 2006;209:127–35.
7. Takahashi Y, Matsuda H, Nakamura Y, et al. Dacryoendoscopic findings of lacrimal passage with congenital punctal atresia. Orbit. 2013;32:338–40.
8. Jones LT, Wobig JL. Surgery of the eyelids and lacrimal system. Birmingham, Alabama: Aesculapius; 1976. p. 162–4.
9. Kushner BJ. The management of nasolacrimal duct obstruction in children aged between 18 months and 4 years. JAAPOS. 1998;2:57–60.
10. Perry LJ, Jakobiec FA, Zakka FR, et al. Giant dacryocystomucopyocele in an adult: a review of lacrimal sac enlargements with clinical and histopathologic differential diagnoses. Surv Ophthalmol. 2012;57:474–85.
11. Paysee EA, Coats DK, Bernstein JM, et al. Management and complications of congenital dacryocele with concurrent intranasal mucocele. JAAPOS. 2000;4:46–53.
12. MacEwen CJ, Young JD, Barras CW, et al. Value of nasal endoscopy and probing in the diagnosis and management of children with congenital epiphora. Br J Ophthalmol. 2001;85:314–8.
13. Ali MJ, Psaltis AJ, Brunworth J, et al. Congenital dacryocele with large intranasal cysts. Efficacy of cruciate marsupialization, adjunctive procedures and outcomes. Ophthal Plast Reconstr Surg. 2014;30:346–51.
14. Francois J, Bacskulin J. External congenital fistulae of the lacrimal sac. Ophthalmologica. 1969;9:249–61.
15. Welham RAN, Bergin DJ. Congenital lacrimal fistulas. Arch Ophthalmol. 1985;103:545–8.
16. Freitag SK, Woog JJ. Congenital nasolacrimal duct obstruction. Ophthal Clin N Am. 2000;13:705–18.
17. Young JD, MacEwen CJ, Ogston SA. Congenital nasolacrimal duct obstruction in the second year of life: a multicentre trial of management. Eye. 1996;10:485–91.
18. Paediatric Eye Disease Investigator Group. Resolution of congenital nasolacrimal duct obstruction with nonsurgical management. Arch Ophthalmol. 2012;130:730–4.
19. Schnall BM. Paediatric nasolacrimal duct obstruction. Curr Opin Ophthalmol. 2013;24:421–4.
20. Paediatric Eye Disease Investigator Group. A randomized trial comparing the cost-effectiveness of two approaches for treating unilateral nasolacrimal duct obstruction. Arch Ophthalmol. 2012;130:1525–33.
21. PEDIG. Primary treatment of nasolacrimal duct obstruction with probing in children less than four years. Ophthalmology. 2008;115:577–84.
22. Honavar SG, Prakash VE, Rao GN. Outcome of probing for congenital nasolacrimal duct obstruction in older children. Am J Ophthalmol. 2000;130:42–8.
23. Maheshwari R. Success rate and causes of failure for late probing for congenital nasolacrimal duct obstruction. J Pediatr Ophthalmol Strabismus. 2008;45:168–71.
24. Paediatric Eye Disease Investigator Group. Primary treatment of nasolacrimal duct obstruction with balloon catheter dilation in children less than four years old. JAAPOS. 2008;12:451–5.
25. Ali MJ, Naik MN, Honavar SG. Balloon dacryoplasty: ushering the new and routine era in minimally invasive lacrimal surgeries. Int Ophthalmol. 2013;33:203–10.
26. Paediatric Eye Disease Investigator Group. Primary treatment of nasolacrimal duct obstruction with nasolacrimal duct intubation in children less than four years old. JAAPOS. 2008;12:445–50.
27. Kashkouli MB, Beigi B, Parvaresh MM, et al. Late and very late initial probing for congenital nasolacrimal duct obstruction: what is the cause of failure? Br J Ophthalmol. 2003;87:1151–3.
28. Paediatric Eye Disease Investigator Group. Repeat probing for treatment of persistent nasolacrimal duct obstruction. JAAPOS. 2009;13:306–7.
29. Repka MX, Chandler DL, Holmes JM, Paediatric Eye Disease Investigator Group, et al. Balloon catheter dilation and nasolacrimal duct intubation for treatment of nasolacrimal duct obstruction after failed probing. Arch Ophthalmol. 2009;127:633–9.
30. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal

dacryorhinotomy: part II. Inferior meatal dacryorhinotomy. Am J Ophthalmol. 2005;140:1070–4.
31. Emmerich KH, Steinhauer J, Meyer-Rüsenberg HW, et al. Dacryoendoscopy–current status. Ophthalmologe. 1998;95:820–2.
32. Leibovitch I, Selva D, Tsirbas A, et al. Paediatric endoscopic endonasal dacryocystorhinostomy in congenital nasolacrimal duct obstruction. Graefes Arch Clin Exp Ophthalmol. 2006;244:1250–4.
33. Lin AE, Chan YC, Lin MY, et al. Comparison of treatment for congenital nasolacrimal duct obstruction: a systematic review and meta-analysis. Can J Ophthalmol. 2016;51:34–40.
34. Matta NS, Singman NL, Silbert DI. Prevalence of amblyopia risk factors in congenital nasolacrimal duct obstruction. J AAPOS. 2010;14:386–8.
35. Ramkumar VA, Agarkar S, Mukherjee B. Nasolacrimal duct obstruction: does it really increase the risk of amblyopia in children. Indian J Ophthalmol. 2016;64:496–9.
36. Siddiqui SN, Mansoor H, Asif M, et al. Comparison of anisometropia and refractive status in children with unilateral and bilateral congenital nasolacrimal duct obstruction. J Pediatr Ophthalmol Strabismus. 2016;53:168–72.
37. Bagheri A, Safapoor S, Yazdani S, et al. Refractive status in children with unilateral congenital nasolacrimal duct obstruction. J Ophthalmic Vis Res. 2012;7:310–5.
38. Kim JW, Lee H, Chang M, et al. Amblyopia risk factors in children with congenital nasolacrimal duct obstruction. J Craniofac Surg. 2013;24:1123–5.
39. Son MK, Hodge DO, Mohney BG. Timing of congenital dacryostenosis resolution and the development of anisometropia. Br J Ophthalmol. 2014;98:1112–5.
40. Eshraghi B, Akbari MR, Fard MA, et al. The prevalence of amblyogenic factors in children with persistent congenital nasolacrimal duct obstruction. Graefes Arch Clin Exp Ophthalmol. 2014;252:1847–52.
41. Ali MJ, Kamal S, Gupta A, et al. Simple vs complex congenital nasolacrimal duct obstruction: etiology, management and outcomes. Int Forum Allergy Rhinol. 2015;5:174–7.
42. Gupta A, Kamal S, Javed Ali M, et al. Buried probe in complex congenital nasolacrimal duct obstruction: clinical profiles and outcomes. Ophthal Plast Reconstr Surg. 2015;31:318–20.
43. Kamal S, Ali MJ, Gupta A, et al. Lacrimal and nasal masquerades of congenital nasolacrimal duct obstruction: etiology, management and outcomes. Int Ophthalmol. 2015;35:807–10.
44. Ali MJ, Kamal S, Vemuganti GK, et al. Glial heterotropia or ectopic brain masquerading as a congenital dacryocystocele. Ophthal Plast Reconstr Surg. 2015;31:e26–8.
45. Zhang C, Wu Q, Cui Y, et al. Anatomy of nasolacrimal canal in congenital nasolacrimal duct obstruction–18 cases retrospective study. Acta Ophthalmol. 2015;93:e404–5.
46. Kim YH, Lee YJ, Song MJ, et al. Dacryocystocele on prenatal ultrasonography: diagnosis and postnatal outcomes. Ultrasonography. 2015;34:51–7.
47. Machado MA, Abreu Junior LD, Silva JA, et al. Congenital dacryocystocele: diagnosis using ante and post-natal ultrasonography. Arq Bras Oftalmol. 2014;77:261–3.
48. Li SL, Luo GY, Tian XX, et al. Prenatal diagnosis and perinatal outcome of congenital dacryocystocele: a large case series. Prenat Diagn. 2015;35:103–7.
49. Kim H, Park J, Jang J, et al. Urgent bilateral endoscopic marsupialization for respiratory distress due to bilateral dacryocystitis in a newborn. J Craniofac Surg. 2014;25:e292–3.
50. Durmaz A, Yildizoglu U, Arslan F, et al. Bilateral dacyrocystocele with an intranasal cyst as the cause of respiratory distress in a newborn. B-ENT. 2016;12:23–7.
51. Kuboi T, Okazaki K, Kusaka T, et al. Congenital dacryocystocele controlled by nCPAP via nasal mask in a neonate. Pediatr Int. 2015;57:475–7.
52. Barham HP, Wudel JM, Enzenauer RW, et al. Congenital nasolacrimal duct cyst/dacyrocystocele: an argument for a genetic basis. Allergy Rhinol. 2012;3:e46–9.
53. Plaza G, Nogueira A, Gonzalez R, et al. Surgical treatment of familial dacryocystocele and lacrimal puncta agenesis. Ophthal Plast Reconstr Surg. 2009;25:52–3.
54. Wang JC, Cunningham MJ. Congenital dacryocystocele: is there a familial predisposition? Int J Pediatr Otorhinolaryngol. 2011;75:430–2.
55. Bernardini FP, Cetinkaya A, Capris P, et al. Orbital and periorbital extension of congenital dacryocystoceles: suggested mechanism and management. Ophthal Plast Reconstr Surg. 2016;32:e101–4.
56. Spaniol K, Stupp T, Melcher C, et al. Association between CNLDO and delivery by cesarian section. Am J Perinatol. 2015;32:271–6.
57. Kuhli-Hattenbach C, Luchtenberg M, Hoffman C, et al. Increase prevalence of dacryostenosis following cesarian sections. Ophthalmologe. 2016;113:675–83.
58. Foster J 2nd, Kapoor S, Diaz-Horta O. Identification of an IGSF3 mutation in a family with congenital nasolacrimal duct obstruction. Clin Genet. 2014;86:589–91.
59. Brunner HG, Hamel BC, van Bokhoven H. The p63 gene in EEC and other syndromes. J Med Genet. 2002;39:377–81.
60. Allen RC. Hereditary disorders affecting the lacrimal system. Curr Opin Ophthalmol. 2014;25:424–31.
61. Jadico SK, Huebner A, McDonald-McGinn DM, et al. Ocular phenotype correlations in patients with TWIST versus FGFR3 genetic mutations. J AAPOS. 2006;10:435–44.

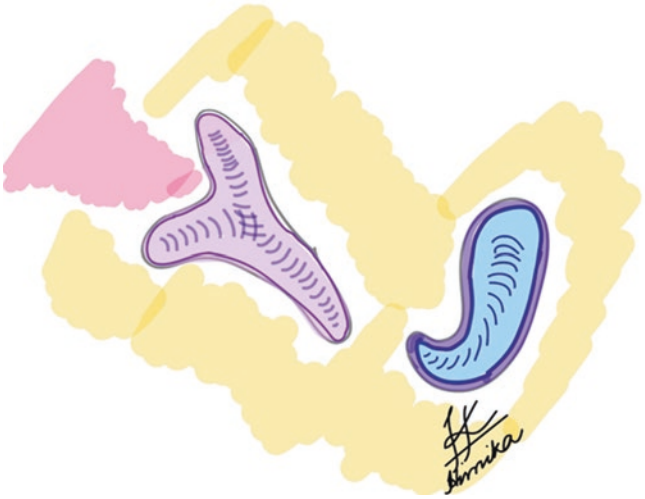


Fig. 14.1 Schematic diagram showing the outbudding of solid canaliculi from the lacrimal cord (Photo courtesy: Dr. Himika Gupta)

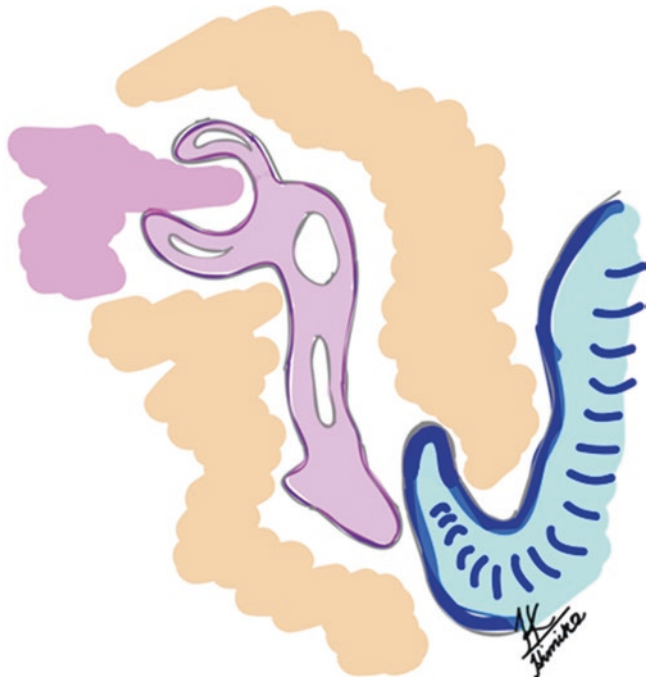


Fig. 14.2 Schematic diagram showing the process of canalization (Photo courtesy: Dr. Himika Gupta)

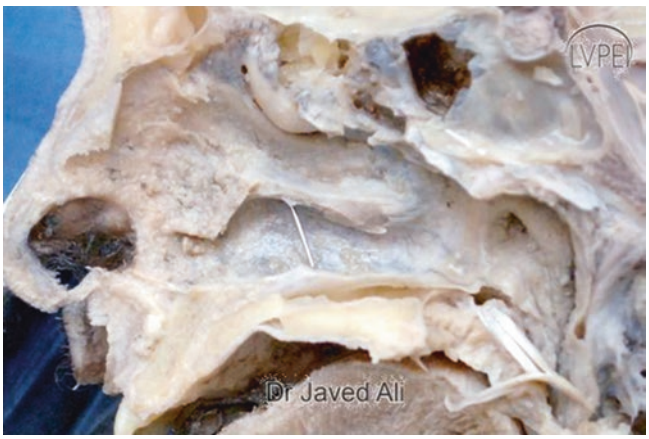


Fig. 14.3 Cadaver midsaggital head section showing the lateral wall and the probe entry into the inferior meatus

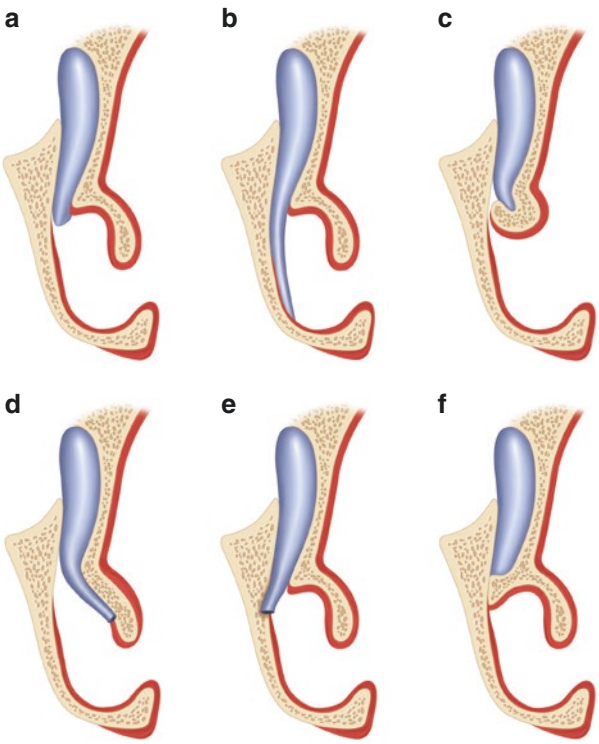


Fig. 14.4 Schematic diagram showing various CNDLO variations: Nasolacrimal duct (NLD) entering at vault of inferior meatus (**a**). NLD extending up to floor lying lateral to nasal mucosa or a buried probe (**b**). NLD obstruction caused by impacted anterior end of inferior turbinate (**c**). NLD ending in anterior end of inferior turbinate (**d**). NLD ending blindly into the maxillary wall (**e**). Complete absence of NLD (**f**) (*blue*: lacrimal sac and NLD, *yellow*: lateral wall of nose, *orange*: inferior turbinate)

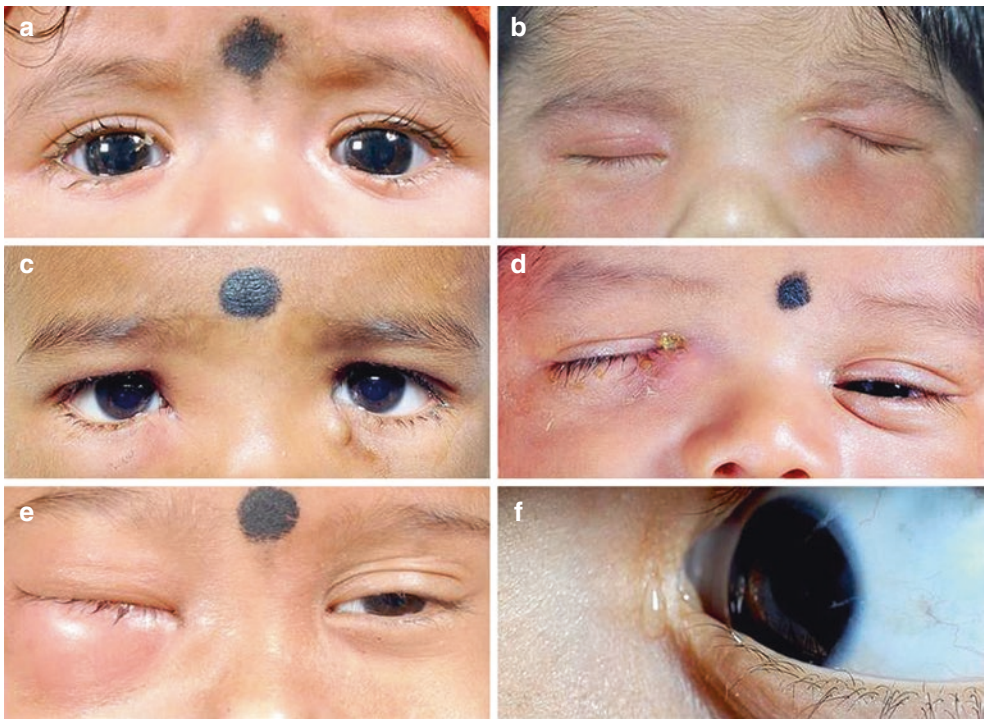


Fig. 14.5 Clinical spectrum of CNLDO: Typical manifestation with increased tear meniscus, discharge, and matting of eyelashes (**a**). Left dacryocele (**b**). Bilateral CNLDO presenting with right-sided acute dacryocystitis and left side mucocele (**c**). Superadded infection of right-sided dacryocele (**d**). Infected dacryocele complicating into orbital cellulitis (**e**). Congenital lacrimal fistula at typical location near medial canthus (**f**)

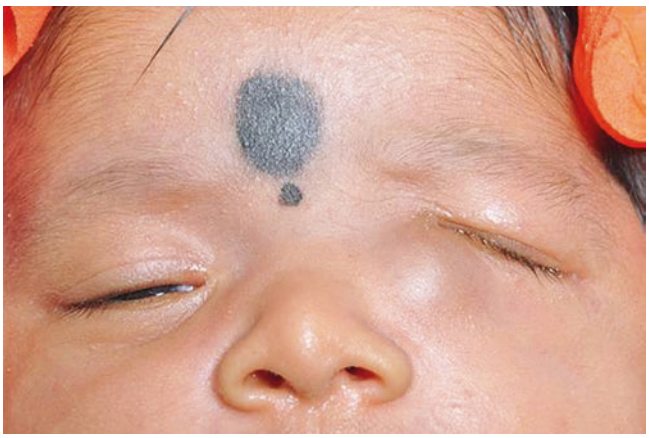


Fig. 14.6 Left congenital dacryocele

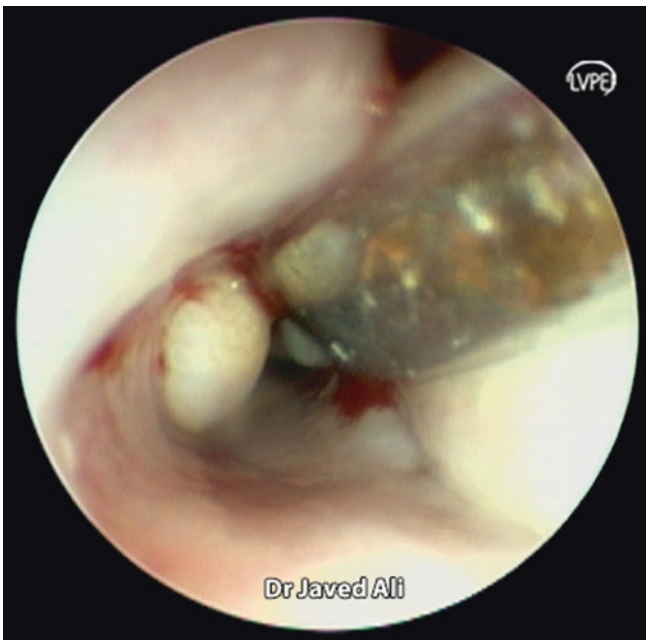


Fig. 14.7 Endoscopic view of a intranasal cyst

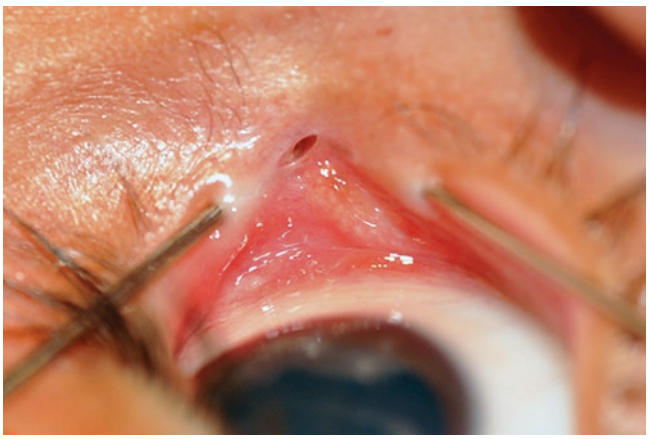


Fig. 14.8 Lacrimal fistula

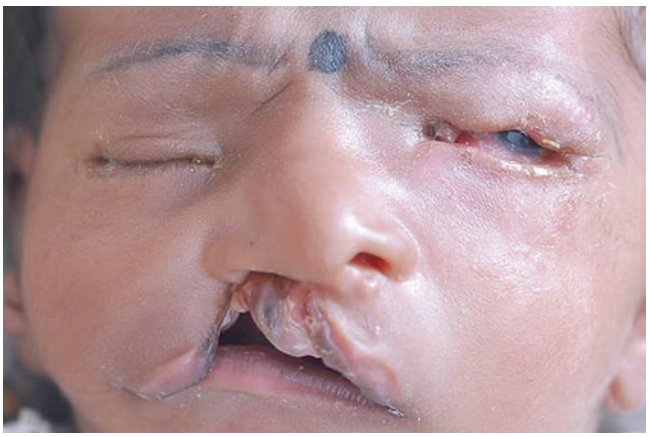


Fig. 14.9 Syndromic association with CNLDO

Fig. 14.10 (**a**) Technique of Criggler's lacrimal sac compression. (**b**) Closer view of the exact technique

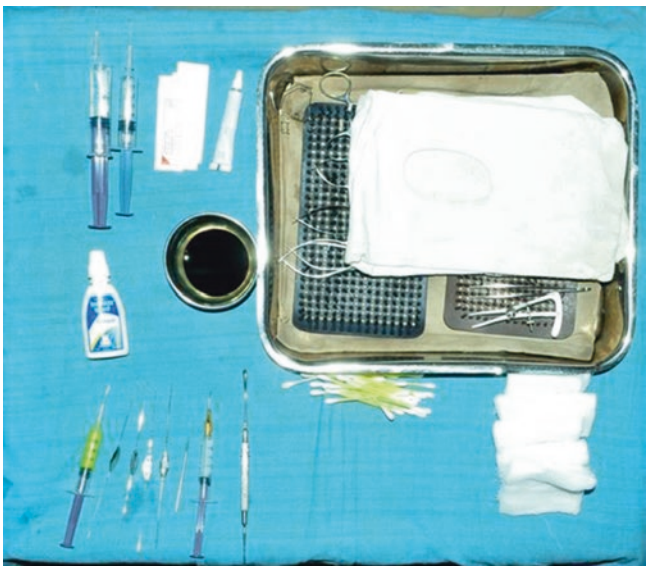


Fig. 14.11 Instrumentation for a probing

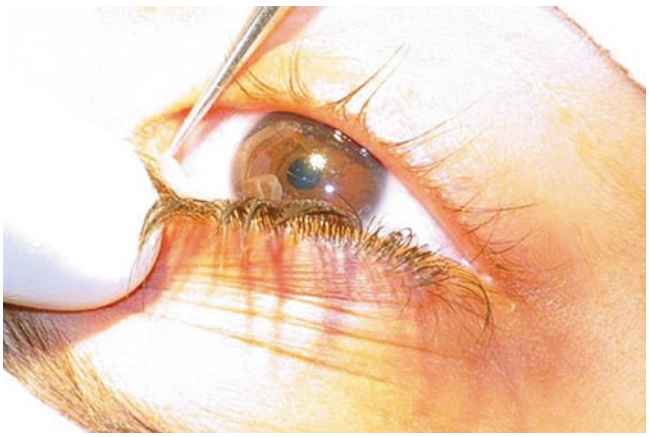


Fig. 14.12 Punctal dilatation

Fig. 14.13 Probe smeared with ointment for lubrication

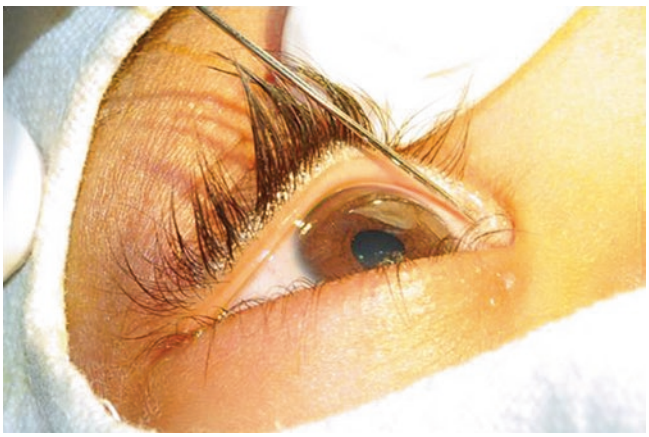


Fig. 14.14 Probe in upper canaliculus on an outstretched eyelid

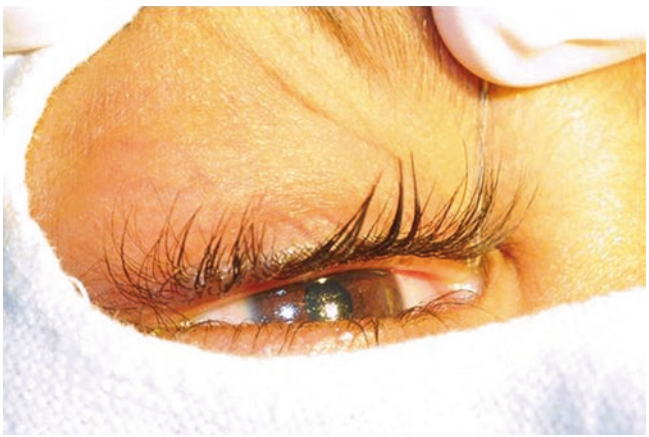


Fig. 14.15 Probe vertically oriented and flat on trochlea

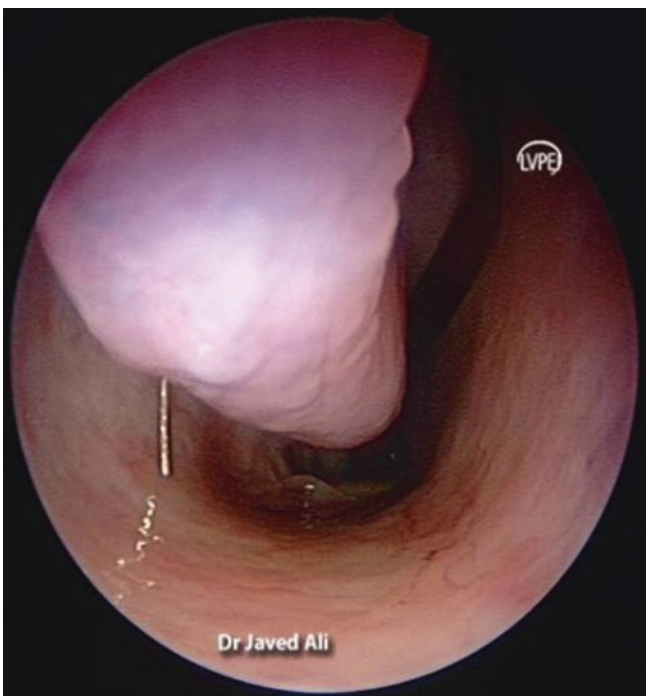


Fig. 14.16 Endoscopic view of the probe in inferior meatus

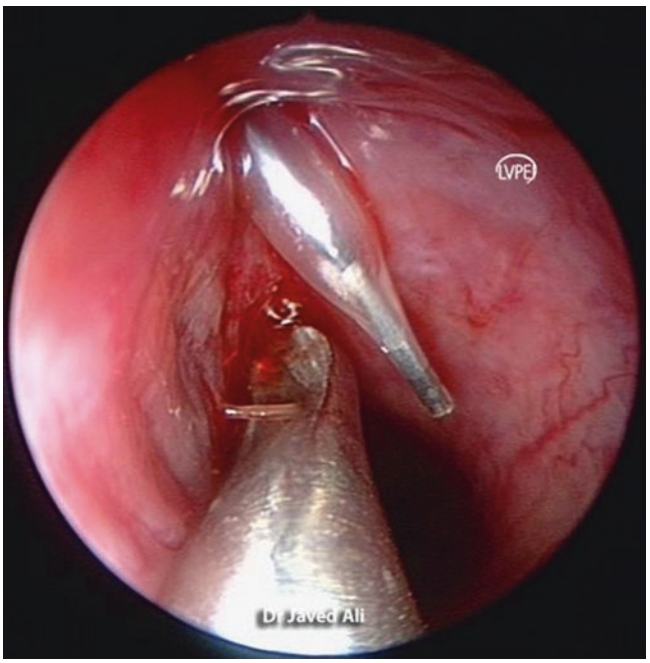


Fig. 14.17 Endoscopic view of balloon dilatation of NLD

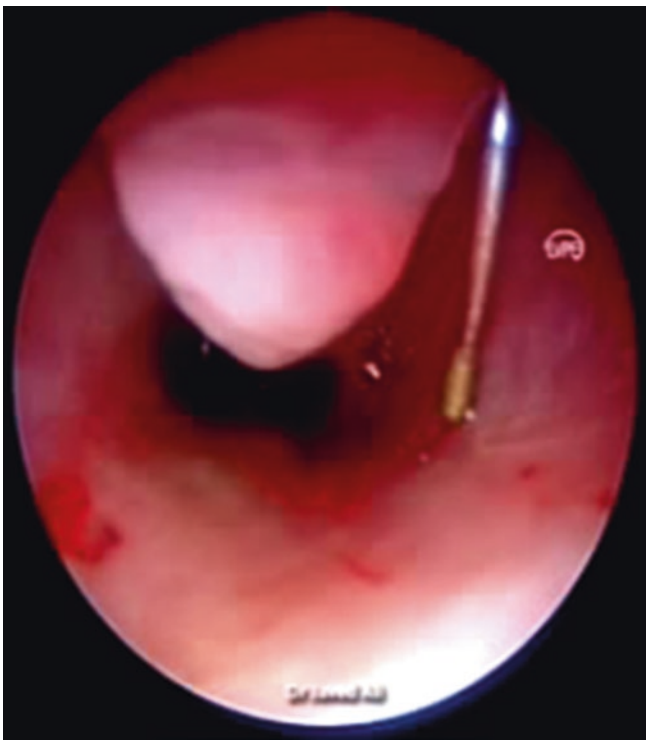


Fig. 14.19 Crawford bodkin in inferior meatus before retrieval

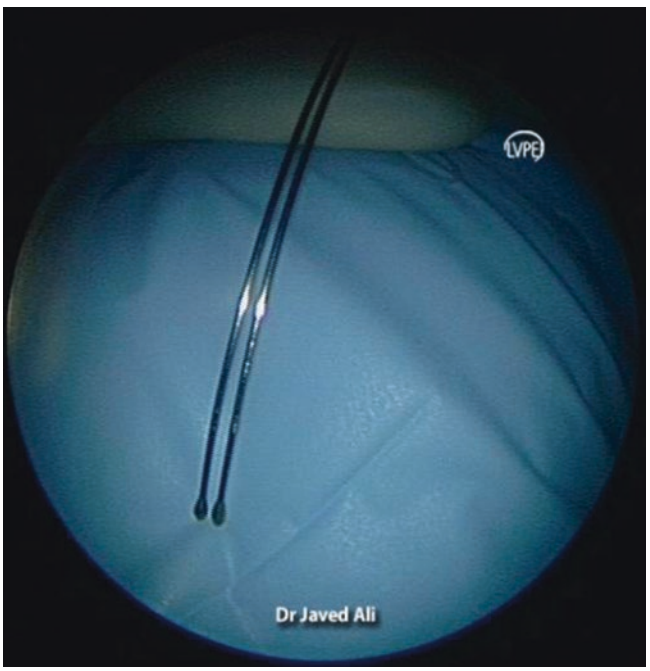


Fig. 14.18 Crawford bicanalicular intubation

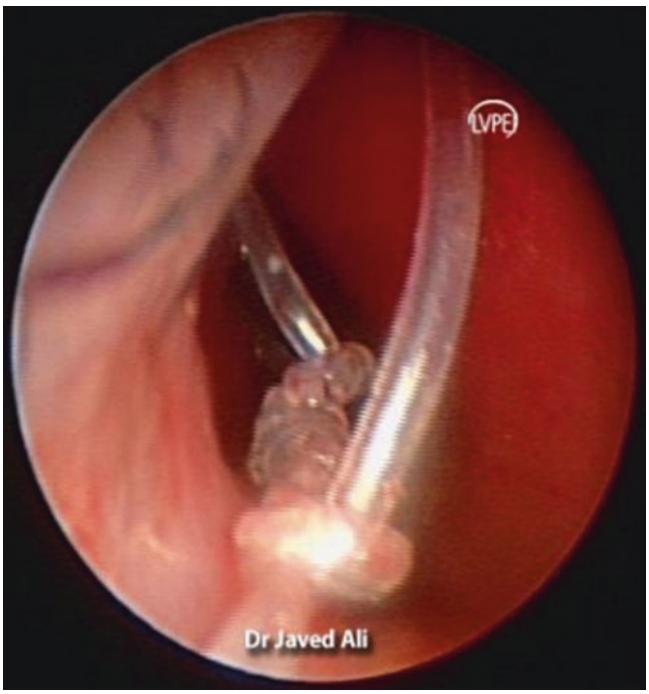


Fig. 14.20 Silicone tube secured in inferior meatus

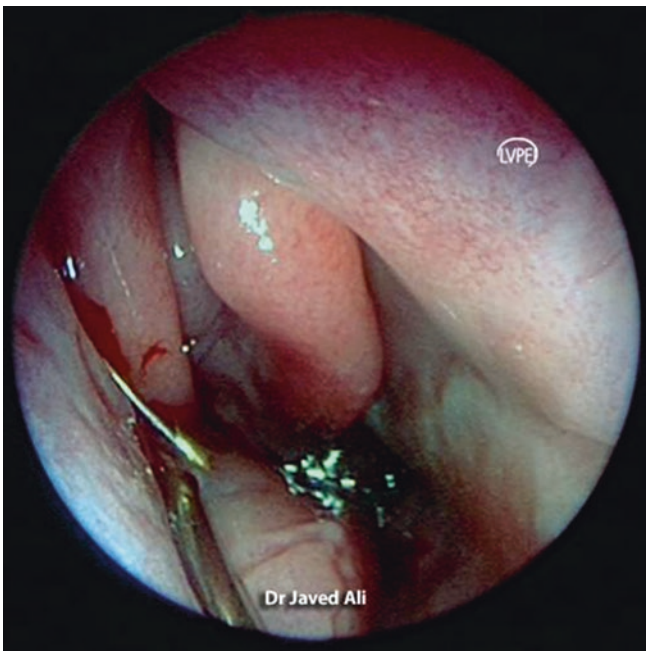


Fig. 14.21 Endoscopic view of a false passage

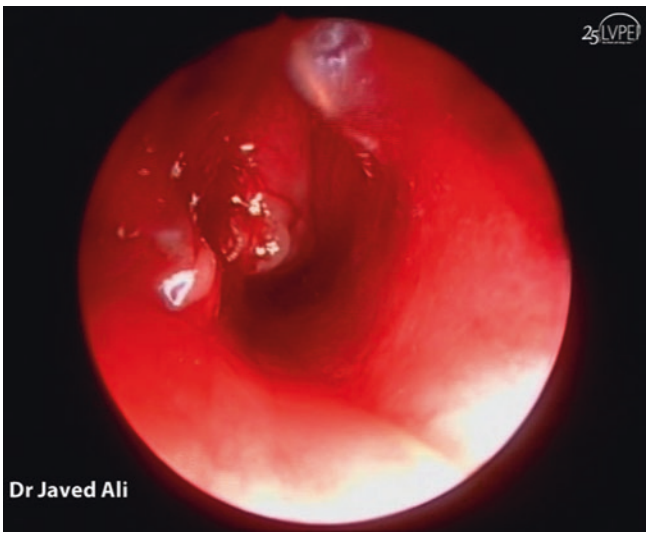


Fig. 14.22 Buried probe

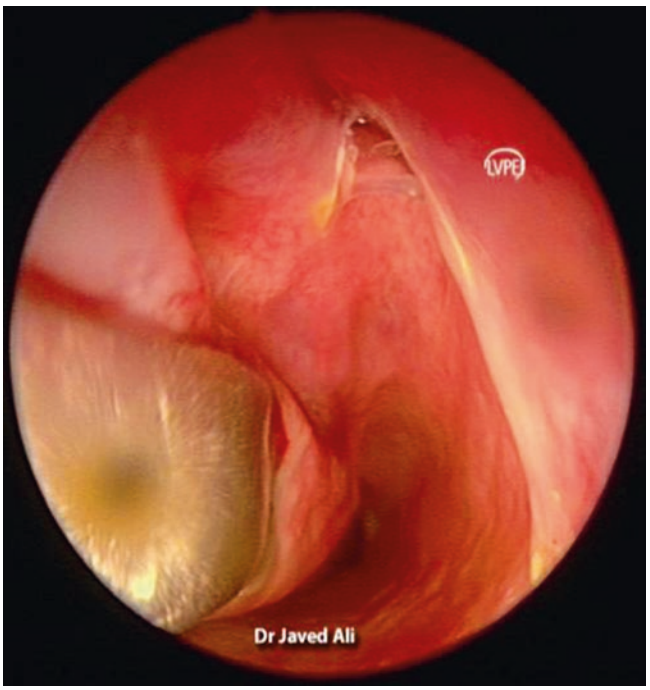


Fig. 14.23 Inferior turbinate medialization

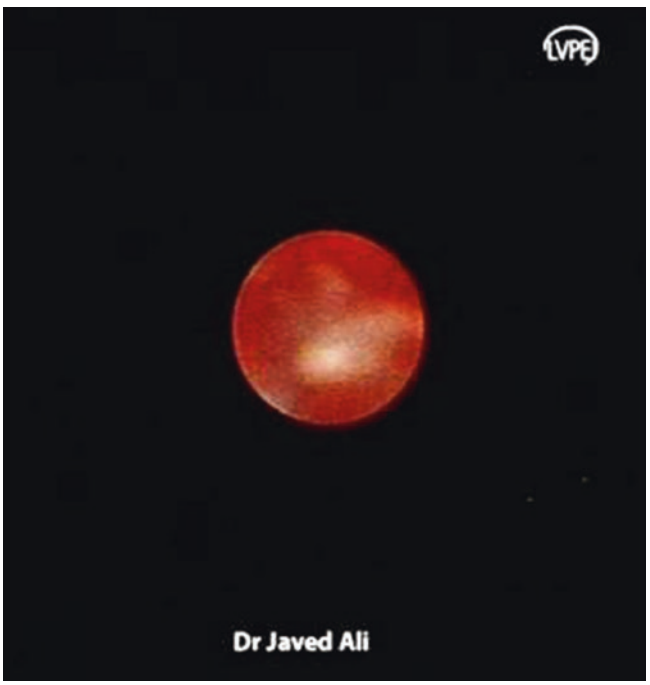


Fig. 14.24 Dacryoendoscopic photo showing focal thick fibrotic tissue in NLD

15 Primary Acquired Nasolacrimal Duct Obstruction (PANDO) and Secondary Acquired Lacrimal Duct Obstructions (SALDO)

Saurabh Kamal and Mohammad Javed Ali

Introduction

Epiphora resulting from nasolacrimal duct obstruction (NLDO) is common and accounts for about one-third of cases [1]. Symptomatic acquired NLDO has average annual incidence rate of 30.47 per 100,000 [2]. It is commonly encountered in ophthalmic clinics especially ophthalmic plastics and dacryology clinics. NLDO can be classified as either primary acquired nasolacrimal duct obstruction (PANDO) when it is idiopathic or secondary acquired lacrimal duct obstructions (SALDO) when it is secondary to various etiologies [3, 4]. The term PANDO was coined by Linberg and McCormick in 1986 [4]. They described a usual onset of epiphora after the age of 40 years, female preponderance, and subsequent development of associated symptoms and signs of chronic or acute dacryocystitis, which constitutes the clinical syndrome of primary acquired nasolacrimal duct obstruction (PANDO) [4].

Pathophysiology of PANDO

The epithelial lining of lacrimal sac and nasolacrimal duct (NLD) is formed by pseudostratified columnar epithelium with intraepithelial goblet cells. Beneath the epithelium there is loose connective tissue containing many lymphocytes and a rich vascular plexus called cavernous body which is presumed to regulate the tear outflow [5].

The first landmark study on the pathophysiology of PANDO was published in 1986 by Linberg and McCormick who described a surgical technique of performing biopsy from nasolacrimal duct (NLD) to elucidate the disease pathology [4]. They biopsied NLD during routine external dacryocystorhinostomy (DCR) in 16 patients. They observed narrowing of the NLD lumen with inflammatory infiltrates, edema and dense fibrosis of periductal tissues, and prominent vascular plexus with intimal proliferation and muscular hypertrophy. They classified NLD specimens into three types: active inflammatory, intermediate, and fibrotic. Early in the course of disease, they noted the presence of active inflammation and infiltrate which antedates the onset of infection leading to stenosis of NLD. These cases have epiphora but there is absence of mucopurulent reflux on pressure over lacrimal sac and irrigation of lacrimal system is patent. This stage is followed by the fibrotic stage where initially there is focal resolution of inflammatory process with patchy replacement of the duct by fibrosis, and over years (>2 years) there is complete fibrous obliteration of duct. Their findings provided the basis that probing or stenting in cases of PANDO is unlikely to produce a patent duct except for partial obstructions, where stents may apparently maintain the tract and prevent complete obstruction of NLD [4].

Further insight into pathophysiology of PANDO was given by Paulsen et al. [5] who postulated the pathogenic concept of PANDO and role of ectopic nasal epithelial cells in NLD. Their findings suggest that either descending or ascending inflammation from nose results initially in malfunctioning of cavernous body, reactive hyperemia, edema of mucous membrane, and temporary occlusion of NLD. This results in repeated attacks of dacryocystitis with permanent structural changes setting in such as loss of goblet cells, epithelial damage and fibrosis of helical connective tissues, and loss of specialized blood vessels of cavernous body [6]. These changes are thought to affect the tear outflow mechanism and starting up a vicious cycle [7]. In addition they explained that the obstruction initially results from edema of mucous membrane, and later with advanced structural changes, there is loss of functioning segment and tear transport.

There is increased number of pathogenic microbes which can be seen in obstructed lacrimal duct. Whether these

S. Kamal, M.D.
Ophthalmic Plastics Surgery, EyeHub, Faridabad, India

M. Javed Ali, F.R.C.S (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_15

organisms are primarily the cause of inflammation or secondarily colonize the duct remains obscure [6, 8].

The current focus is on understanding the mucosa associated lymphoid tissue (MALT) associated with lacrimal sac and duct. Lacrimal drainage-associated lymphoid tissue (LDALT) and tear duct-related lymphoid tissue (TALT) have been identified and studied recently [9, 10]. These lymphoid tissues are thought to modulate immune responses, and their derangements can have possible implications on etiopathogenesis of PANDO. Changes that have been noted in LDALT in cases of dacryocystitis include: diffuse infiltrate lymphoid pattern (81%), distinct lymphoid follicles (28%), increase in the goblet cells (82%), dilated lymphatics (94%), proliferating blood vessels (99%), thickened epithelium (54.5%), and stromal fibrosis (88%) [9]. TALT has been observed to be absent in cases of NLDO, probably related to the fact that lack of antigen exposure in obstructed duct or replacement of lymphoid tissue by scarring [10]. Alternatively, it can be thought that the presence of TALT may have protective effect against the development of lacrimal duct stenosis [9].

PANDO: Predisposing and Associated Factors

(a) *Age*: PANDO occurs more frequently in middle-aged and elderly population and is usually noted in age group above 40 years [4, 11, 12].
(b) *Race and sex*: Increase prevalence is noted in females and whites. This can be explained due to longer and narrower canal in them as compared to males and blacks [11, 12]. However, whether this NLD canal size difference really contributes to PANDO is not established.
(c) *Previous infections*: History of previous infectious conjunctivitis or rhinitis (non-specific, viral, or bacterial) before the onset of NLDO has been noted to be a predisposing factor [13].
(d) Swimming pool exposure could be associated with development of PANDO. Chlorinated compound can cause inflammation, oxidative stress, and hyperpermeability in respiratory mucosa and nasolacrimal duct [13]. However, this is at present a belief and not satisfactorily established.
(e) Other associations noted with PANDO are ischemic heart disease, glaucoma, allergic conjunctivitis, dry eye, antiglaucoma medication (timolol maleate), and allergic rhinitis [14]. A relationship between gasteroesophageal reflux disease and rhinopharyngitis and rhinosinusitis has been noted, and some also believe that it can cause direct and indirect (autonomic nervous system) hyperemia and edema of NLD [15].
(f) Nasal factors noted to be associated with PANDO are concha bullosa, inferior turbinate hypertrophy, osteomeatal complex disease, and maxillary sinusitis [4].

Clinical Spectrum

A detailed history and examination in most of the cases can distinguish PANDO from SALDO. History should elicit secondary causes like trauma, sinus disease, sinus surgery, systemic diseases such as tuberculosis and sarcoidosis. History of previous acute dacryocystitis should be recorded. Classically the lacrimal sac swelling/mucocele (in PANDO) is noted below the medial palpebral ligament (MPL). Symptoms of nasolacrimal duct obstruction may include epiphora, discharge, irritation, and blurred vision due to tear accumulation in conjunctival cul-de-sac. Lacrimal pump function abnormality which can be age related or associated with facial nerve palsy should be kept in mind. A detailed comprehensive evaluation as described earlier in "Evaluation of Epiphora" must be carried out.

Obstruction of nasolacrimal duct can be associated with chronic or acute dacryocystitis, lacrimal mucocele, fistula, lacrimal abscess, and even may complicate into orbital cellulitis and cavernous sinus thrombosis. The stasis of tear and secretions within the sac can lead to buildup of bacterial load which causes chronic dacryocystitis. Chronic dacryocystitis can be classified into three types: catarrhal dacryocystitis, lacrimal mucocele, and chronic suppurative form [16]. Catarrhal dacryocystitis is characterized by constant and persistent epiphora and angular conjunctivitis. Lacrimal mucocele is a cystic swelling which results from the accumulation of secretions which causes dilation of sac and collapse of valve of Rosenmuller. This creates a ball-valve mechanism which initially allows ingress of fluid but limits egress of fluid leading to formation of lacrimal mucocele [17]. Absence of reflux of discharge from sac in to conjunctival fornix can decrease conjunctival irritation and thus epiphora. The clinical picture in chronic suppurative dacryocystitis consists of increase epiphora, discharge, and formation of pyocele (inflamed sac filled with pus) [16].

Acute inflammation can result leading to acute dacryocystitis. Acute dacryocystitis [18] is defined as "A medical urgency which is clinically characterized by rapid onset of pain, erythema and swelling, classically below the medial canthal tendon with or without pre-existing epiphora mainly resulting from the acute infection of the lacrimal sac and perisac tissues." Clinical presentation includes swelling, pain, and erythema over lacrimal sac area. Complications seen in advanced cases can be orbital cellulitis, orbital abscess, superior ophthalmic vein thrombosis, cavernous sinus thrombosis, meningitis, and visual loss. But these complications are rare due to various barriers such as orbital septum, medial canthal tendon, Horner's muscle, and Jones muscle [18]. Causes of non-resolving acute dacryocystitis and progression to lacrimal sac abscess include virulent organism, antibiotic resistance, and persistent inflammation [18]. About 2% of cases have no response to medication, and in 6% of cases there may

be relapse of acute dacryocystitis. Lacrimal abscess can be a presenting feature in one-fourth of acute dacryocystitis cases, and cutaneous fistula formation is noted in about 6% of cases secondary to spontaneous rupture or after incision and drainage [18]. Most common microorganisms isolated in such cases are gram-positive cocci (*S.aureus, S.pneumoniae*) followed by gram-negative bacilli (*H.influenzae*) [19].

Indications for Treatment

Indications for treatment of PANDO vary and depend upon patient symptoms, their motivation, stage of dacryocystitis, and also the need for an intraocular surgery in some patients. Acute dacryocystitis is an emergency and requires immediate medical or surgical treatment. Treatment for chronic dacryocystitis is usually elective, but early surgical intervention may be needed for cases with ophthalmic infections and/or those requiring ocular surgery.

Patient-related factors which determine the need for surgery are impact on quality of life due to blurred vision, irritation or skin eczema, social embarrassment due to epiphora, [20] frequency of dapping, and presence of discharge or matting of eyelashes in the morning.

Management

The medical management of acute infections has been described in the chapter on "Lacrimal infections." The various surgical modalities, minimally invasive therapies, and various approaches in literature for both partial and complete PANDO have been described subsequently in this text individually and in great detail.

SALDO

Secondary acquired lacrimal duct obstructions or SALDO is a term described by Bartley in 1992 to define all the secondary causes of lacrimal obstructions [3]. It essentially means that the specific cause of obstructions could be zeroed in on, and therapies targeting the cause may result in relief from obstructions. Bartley et al. [21, 22] classified five categories of secondary obstructions, namely, infectious, inflammatory, traumatic, mechanical, and neoplastic with numerous etiologies for each category.

(a) Infectious SALDO

The infections can involve any site of lacrimal system and may present as punctal abscess, canaliculitis, dacryocystitis, and isolated NLD infections. Etiological factors can be bacterial, viral, fungal, or rarely parasitic (Figs. 15.1, 15.2, and 15.3). Treatment is based upon the location and organism involved. Chapter on "Lacrimal infections" provides illustrated details on this subject.

(b) Inflammatory SALDO

Inflammatory SALDO can include endogenous etiologies like Stevens-Johnson syndrome, cicatricial pemphigoid, sarcoidosis, and Wegener's granulomatosis (Figs. 15.4 and 15.5). Exogenous etiologies include burns, allergies, the use of eye drops like antiviral, radiotherapy, and certain chemotherapeutic agents like 5-fluorouracil and paclitaxel (Figs. 15.6 and 15.7). All the etiologies whether endogenous or exogenous result in response by lacrimal tissues by progressive fibrosis and ultimately result in an obstruction. Instituting measures early on in the inflammatory phase by removing or minimizing the inciting agent, topical and systemic steroids, and recanalization procedures in later phases helps in reducing the morbidity associated with epiphora.

(c) Traumatic SALDO

Traumatic SALDO is a distinct entity that includes iatrogenic and accidental trauma. Iatrogenic etiologies include probing, intubation, punctal plugs, and sinus surgeries (Figs. 15.8 and 15.9). Accidental traumas involve SALDO secondary to either a soft tissue trauma or a bony trauma. Among the soft tissue injuries, canalicular tears are the most common (Figs. 15.10 and 15.11), and among the bony injuries, a specific naso-orbito-ethmoid fractures are known to cause nasolacrimal entrapment and damage (Figs. 15.12 and 15.13) [23]. The specifics of diagnosis and treatment are mentioned in detail in the chapter "Lacrimal trauma."

(d) Mechanical SALDO

The term mechanical refers to a lacrimal passage physically obstructed anywhere along its entire course by specific agents. These could be endogenous factors like dacryoliths (Fig. 15.14) and migrated punctal plugs or exogenous factors like conjunctivochalasis (Fig. 15.15), sinus mucocele (Fig. 15.16), or caruncular masses (Fig. 15.17). Treatment consists of removing the inciting agent like punctal plugs and excision of caruncular mass or redundant conjunctiva.

(e) Neoplastic SALDO

SALDO can occur from primary neoplasms arising from the lacrimal system like papillomas, squamous cell carcinomas, lymphoma, and melanoma (Figs. 15.18 and 15.19). Lacrimal obstructions can also occur as a result of secondary involvement by many tumors that may develop in adjacent tissues, for example, basal cell carcinoma, squamous cell carcinoma, adenoid cystic carcinoma, leukemia, and lymphomas (Figs. 15.20 and 15.21). Rarely SALDO can result from metastasis from breast carcinoma, malignant melanoma, and prostate carcinoma. The chapter on "lacrimal tumors" in this text enlists all the malignancies and modes of their management.

Updates (2015–2016)

Radiological Assessment of NLD and PANDO

Bony nasolacrimal duct (NLD) parameters and their ethnic and gender variations have been a subject of debate as to their role in etiopathogenesis of PANDO. More recent literature has presented conflicting opinions on this subject. Estes et al. [24] observed no significant difference in volume of bony NLD between subjects (cases with PANDO) and controls, based on 3D computed tomography (CT). However, this report did not compare the volume between affected and normal sides of patients. Bulbul et al. [25] used multi-detector CT and compared affected side of PANDO with normal side in same patient and also to those of controls. Interestingly, in cases with unilateral PANDO, both the sides had a narrow transverse diameter compared to controls; however, no statistical difference was observed between PANDO and non-PANDO sites of same subjects. Authors concluded that a narrow bony NLD is not the sole etiological factor for PANDO. Another report observed the angle between inferior turbinate and upper part of medial wall of the maxillary sinus with PANDO to be narrow on the diseased side as compared to the normal side [26]. A Japanese group observed two types of bony NLD on CT scans: funnel and hourglass shapes [27]. It was noted that PANDO cases usually had a funnel-type NLD. These patients had a shorter distance from the entrance to the narrowest diameter of the bony NLD. Czyz and colleagues [28] did not find any evidence for linking NLD diameter or area with PANDO; however, they found that those at risk for PANDO like females and elderly had decreased aeration of the NLD, and this could possibly be one of the factors to play a role in etiopathogenesis. Summarizing all the results, there is no concrete evidence as of now to link the NLD diameters with causation of PANDO.

Microbiology of PANDO

Microbiological profiles of dacryocystitis have evinced strong interest not only from a clinical standpoint but also from their possible etiological roles in PANDO. The production of antimicrobial peptides like the human beta-defensins by the lacrimal system can be influenced by the local microflora and hence may be an important player in the initial stages of infection-inflammation [29]. A recent report from Thailand has shown that most samples of lacrimal sac contents from PANDO were culture-positive in the absence of any clinical infections. A wide variety of bacteria could be isolated and were responsive to ciprofloxacin [30]. However, the exact role of microbial flora in the causation of PANDO is uncertain.

PANDO and Paranasal Abnormalities

Sino-nasal diseases have long been implicated to be causative factors for PANDO and the widespread presumption being ascending infection of inflammation of the nasolacrimal ducts. However, recent reports and certain well thought of studies provide contrary evidence [29, 31]. When diseased and non-diseased sides of PANDO patients and controls were evaluated for paranasal abnormalities; no associations were found [31]. Summarizing the evidence as of now, it is unlikely that this may be a causative factor in routine PANDO patients.

PANDO and Aquaporin Expressions

Aquaporins are a family of ten or more proteins (AQ1–AQ10) which significantly contributes in the water transport mechanisms of the nasolacrimal ducts [32]. They have been demonstrated earlier as well, but a recent study found that their levels are higher in PANDO [33]. In addition, functional obstructions were found to have statistically significant higher expression levels as compared to PANDO cases [33]. However, it is important to note that this significance was seen only on immunohistochemistry and not on western blot analysis. Nonetheless, it would be interesting to explore whether this increased expression was a result of PANDO or vice versa.

Systemic and Local Associations of SALDO

Numerous systemic and local associations have already been elucidated in the chapter. Recently Sobel et al. [34] looked at these factors separately in patients undergoing unilateral versus bilateral lacrimal surgery. Of interest was a rise in the incidence of autoimmune disorders and malignancies in bilateral surgeries [34]. Although chronic leukemias have usually been implicated in metastatic infiltrative SALDO, it is interesting to note that acute dacryocystitis can be the first presentation of malignancy itself [35]. Another major contributor in causation of both unilateral and bilateral SALDO was the use of radioactive iodine [34], and this will be discussed in the next subheading.

I-131 and SALDO

Radioactive iodine or I-131 is being increasingly used for thyroid malignancies and certain cases of Grave's disease. I-131 as a causative factor for NLDO has been increasingly getting attention [34]. It is believed that I-131 causes radiotoxicity of the lacrimal sac and nasolacrimal ducts, mediated

by the Na^+-I^- symporter protein present in the lacrimal drainage system [36]. The incidence has been reported to be 2.2–18% in the literature and is frequently seen in patients who get a dose of more than 150 millicurie [37]. Although DCR gives good outcomes in these cases, the issue is with diagnosis, which is often missed. Recently screening protocols have been proposed, and the physicians involved in care can follow these to help earlier detection, better management, and reduced morbidities [37].

References

1. Sibley D, Norris JH, Malhotra R. Management and outcomes of patients with epiphora referred to a specialist ophthalmic plastic unit. Clin Experiment Ophthalmol. 2013;41:231–8.
2. Woog JJ. The incidence of symptomatic acquired lacrimal outflow obstruction among residents of Olmsted County, Minnesota, 1976–2000 (an American ophthalmological society thesis). Trans Am Ophthalmol Soc. 2007;105:649–66.
3. Bartley GB. Acquired lacrimal drainage obstruction: an etiologic classification system, case reports, and a review of the literature. Part 1. Ophthal Plast Reconstr Surg. 1992;8:237–42.
4. Linberg JV, McCormick SA. Primary acquired nasolacrimal duct obstruction. A clinicopathologic report and biopsy technique. Ophthalmology. 1986;93:1055–63.
5. Paulsen FP, Thale AB, Hallmann UJ, et al. The cavernous body of the human efferent tear ducts: function in tear outflow mechanism. Invest Ophthalmol Vis Sci. 2000;41:965–70.
6. Paulsen FP, Thale AB, Maune S, et al. New insights into the pathophysiology of primary acquired dacryostenosis. Ophthalmology. 2001;108:2329–36.
7. Perra MT, Serra A, Sirigu P, et al. A histochemical and immunohistochemical study of certain defence mechanisms in the human lacrimal sac epithelium. Arch Histol Cytol. 1995;58:517–22.
8. Blicker JA, Buffam FV. Lacrimal sac, conjunctival, and nasal culture results in dacryocystorhinostomy patients. Ophthal Plast Reconstr Surg. 1993;9:43–6.
9. Ali MJ, Mulay K, Pujari A, et al. Derangements of lacrimal drainage-associated lymphoid tissue (LDALT) in human chronic dacryocystitis. Ocul Immunol Inflamm. 2013;21:417–23.
10. Paulsen FP, Schaudig U, Maune S, et al. Loss of tear duct-associated lymphoid tissue in association with the scarring of symptomatic dacryostenosis. Ophthalmology. 2003;110:85–92.
11. Janssen AG, Mansour K, Bos JJ, et al. Diameter of the bony lacrimal canal: normal values and values related to nasolacrimal duct obstruction: assessment with CT. Am J Neuroradiol. 2001;22:845–50.
12. Shigeta K, Takegoshi H, Kikuchi S. Sex and age differences in the bony nasolacrimal canal: anatomical study. Arch Ophthalmol. 2007;125:1677–81.
13. Ohtomo K, Ueta T, Toyama T, et al. Predisposing factors for primary acquired nasolacrimal duct obstruction. Graefes Arch Clin Exp Ophthalmol. 2013;251:1835–9.
14. Nemet AY, Vinker S. Associated morbidity of nasolacrimal duct obstruction-a large community based case-control study. Graefes Arch Clin Exp Ophthalmol. 2014;252:125–30.
15. Owji N, Bagher Abtahi SM. Does gastroesophageal reflux contribute to development of acquired nasolacrimal duct obstruction? Med Hypotheses. 2010;74:455–6.
16. Duke-Elder WS. Diseases of lacrimal passages. In: Text book of ophthalmology. St. Louis: C.V. Mosby; 1952. p. 5279–366.
17. Perry LJ, Jakobiec FA, Zakka FR, et al. Giant dacryocystomucopyocele in an adult: a review of lacrimal sac enlargements with clinical and histopathologic differential diagnoses. Surv Ophthalmol. 2012;57:474–85.
18. Ali MJ, Joshi SD, Naik MN, et al. Clinical profile and management outcome of acute dacryocystitis: two decades of experience in tertiary eye care centre. Semin Ophthalmol. 2015;30:118–23.
19. Ali MJ, Motukupally SR, Joshi SD, et al. The microbiological profile of lacrimal abscess: two decades of experience from a tertiary eye care center. J Ophthalmic Inflamm Infect. 2013;3:57–61.
20. Jutley G, Karim R, Joharatnam N, et al. Patient satisfaction following endoscopic endonasal dacryocystorhinostomy: a quality of life study. Eye. 2013;27:1084–9.
21. Bartley GB. Acquired lacrimal drainage obstruction: an etiologic classification system, case reports and a review of literature. Part 2. Ophthal Plast Reconstr Surg. 1992;8:243–9.
22. Bartley GB. Acquired lacrimal drainage obstruction: an etiologic classification system, case reports and a review of literature. Part 3. Ophthal Plast Reconstr Surg. 1993;9:11–26.
23. Ali MJ, Gupta H, Honavar SG, et al. Acquired nasolacrimal duct obstructions secondary to naso-orbito-ethmoidal fractures: patterns and outcomes. Ophthal Plast Reconstr Surg. 2012;28:242–5.
24. Estes JL, Tsiouris AJ, Christos PJ, et al. Three-dimensional volumetric assessment of the nasolacrimal duct in patients with obstruction. Ophthal Plast Reconstr Surg. 2015;31:211–4.
25. Bulbul E, Yazici A, Yanik B, et al. Morphometric evaluation of bony nasolacrimal canal in a caucasian population with primary acquired nasolacrimal duct obstruction: a multi-detector computed tomography study. Korean J Radiol. 2016;17:271–6.
26. Gul A, Aslan K, Karli R, et al. A possible cause of nasolacrimal duct obstruction: narrow angle between inferior turbinate and upper part of the medial wall of the maxillary sinus. Curr Eye Res. 2016;41:729–33.
27. Takahashi Y, Nakata A, Miyazaki H, et al. Comparison of bony nasolacrimal canal narrowing with or without primary acquired nasolacrimal duct obstruction in Japanese population. Ophthal Plast Reconstr Surg. 2014;30:434–8.
28. Czyz CN, Bacon TS, Stacey AW, et al. Nasolacrimal system aeration on computed tomographic imaging: sex and age variations. Ophthal Plast Reconstr Surg. 2016;32:11–6.
29. Paulsen F. The human nasolacrimal ducts. Adv Anat Embryol Cell Biol. 2003;170:1–106.
30. Pornpanich K, Luemsamran P, Leelaporn A, et al. Microbiology of primary acquired nasolacrimal duct obstruction: simple epiphora, acute dacryocystitis and chronic dacryocystitis. Clin Ophthalmol. 2016;10:337–42.
31. Yazici H, Bulbul E, Yazici A, et al. Primary acquired nasolacrimal duct obstruction: is it really related to paranasal abnormalities? Surg Radiol Anat. 2015;37:579–84.
32. Jaeger K, Reh D, Gebhardt M, et al. Expression profile of aquaporins in human nasolacrimal duct epithelium. Curr Eye Res. 2010;35:267–73.
33. Park J, Kim J, Kim M, et al. Aquaporin expression in the lacrimal sac of patients with primary and functional nasolacrimal duct obstruction. Br J Ophthalmol. 2016;101(4):519–24. (Epub)
34. Sobel KR, Carter KD, Allen RC. Bilateral lacrimal drainage obstruction and its association with secondary causes. Ophthal Plast Reconstr Surg. 2014;30:152–6.
35. Mishra DK, Ali MJ, Bhargava A, et al. Acute dacryocystitis as a presenting sign of chronic lymphocytic leukemia. Clin Exp Ophthalmol. 2016;44:67–9.
36. Ali MJ, Vyakaranam AR, Rao GE, et al. Iodine-131 therapy and lacrimal drainage system toxicity. Nasal localization studies using whole body nuclear scintigraphy and SPECT-CT. Ophthal Plast Reconstr Surg. 2017;33:13–6.
37. Ali MJ. Iodine-131 therapy and nasolacrimal duct obstructions: what we know and what we need to know. Ophthal Plast Reconstr Surg. 2016;32:243–8.

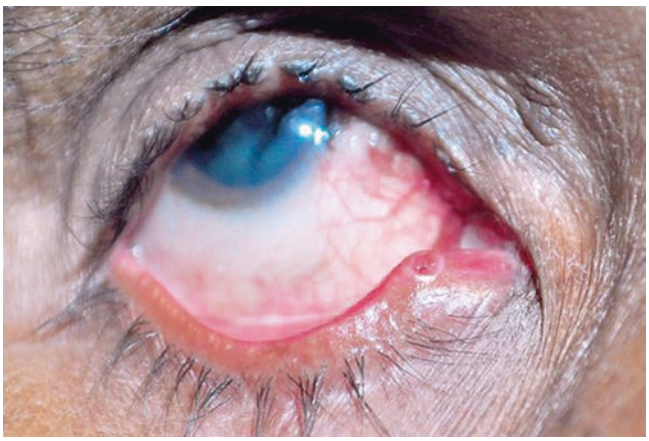


Fig. 15.1 Infective canaliculitis: an example of an infectious SALDO

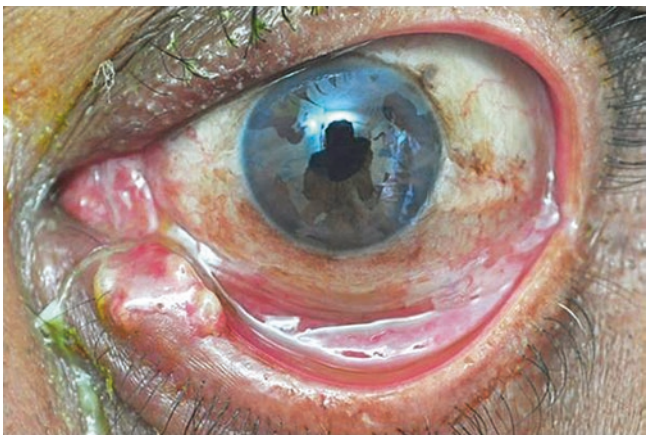


Fig. 15.2 Punctal and canalicular abscess

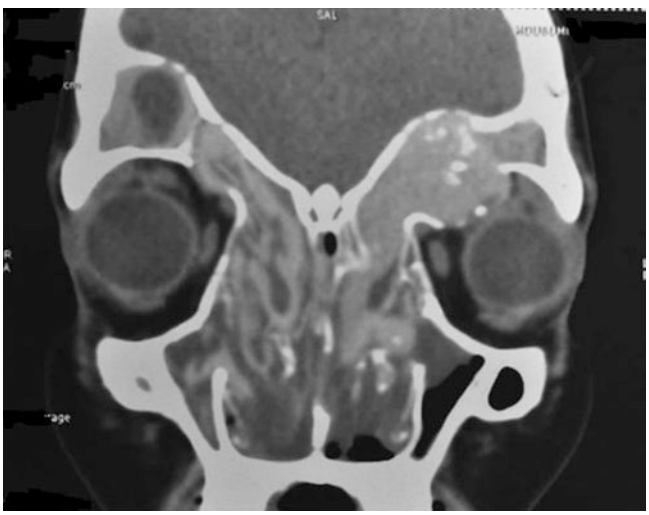


Fig. 15.3 CT scan, coronal plane showing extensive pan-sinus and lacrimal involvement by aspergillosis

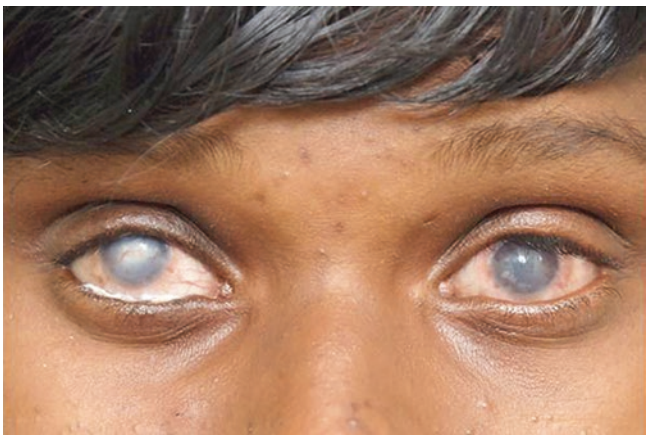


Fig. 15.4 Stevens-Johnson syndrome: an example of inflammatory SALDO

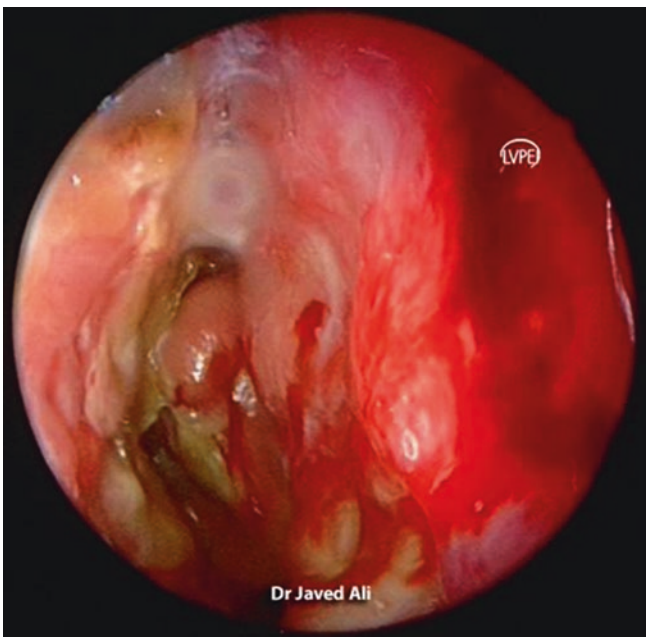


Fig. 15.5 Endoscopic view of a nasal cavity extensively involved with Wegener's granulomatosis

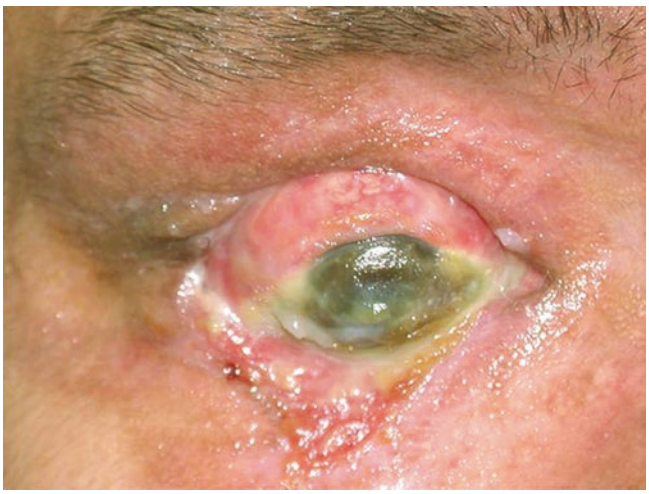


Fig. 15.6 Loss of eyelids and proximal lacrimal system in a case of chemical burns

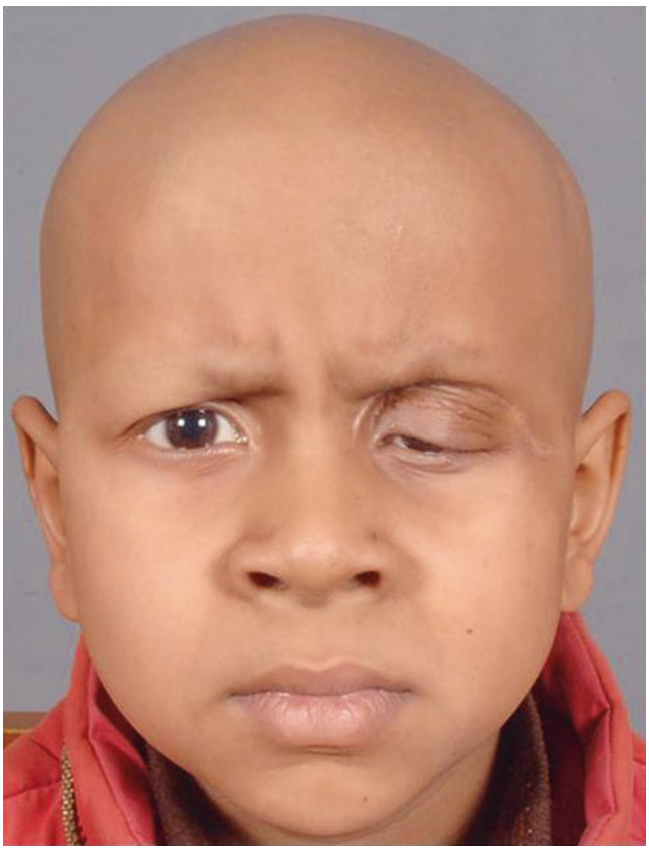


Fig. 15.7 Radiotherapy-induced SALDO

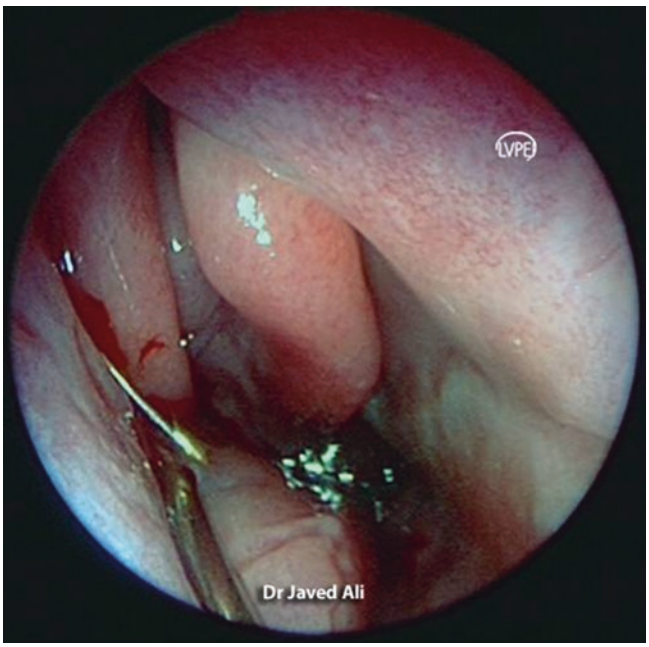


Fig. 15.8 Endoscopic photograph of an iatrogenic SALDO caused by producing a false passage during probing

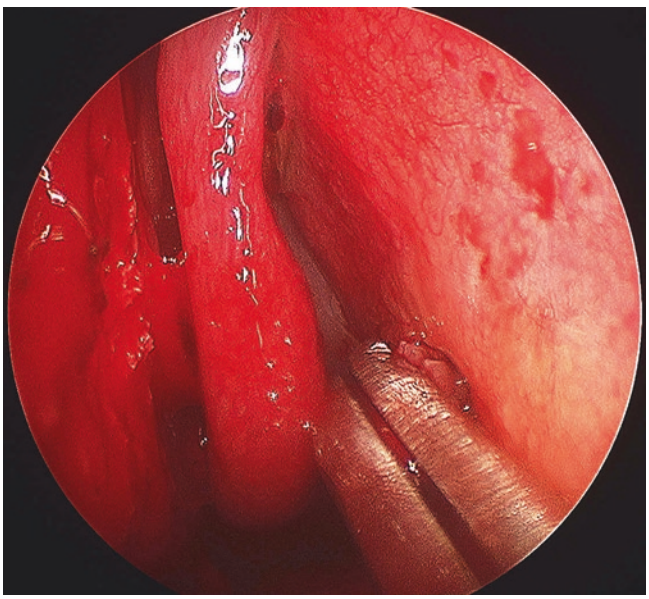


Fig. 15.9 Endoscopic photograph showing horizontal uncinectomy during a sinus surgery. This step has the potential for causing a traumatic SALDO involving the nasolacrimal duct

Fig. 15.10 A lower lid canalicular tear

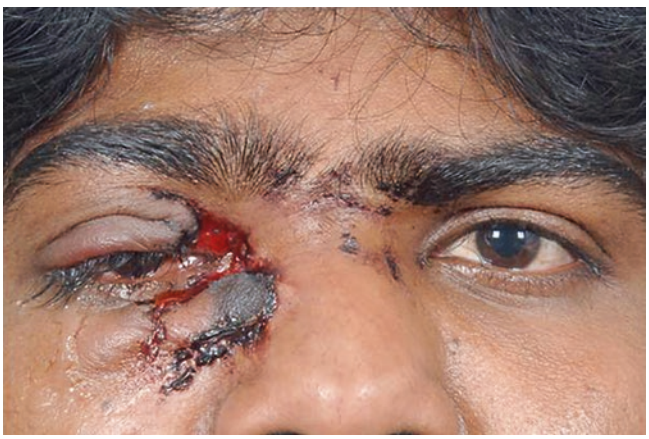


Fig. 15.11 Extensive periocular lacerations involving the lacrimal system

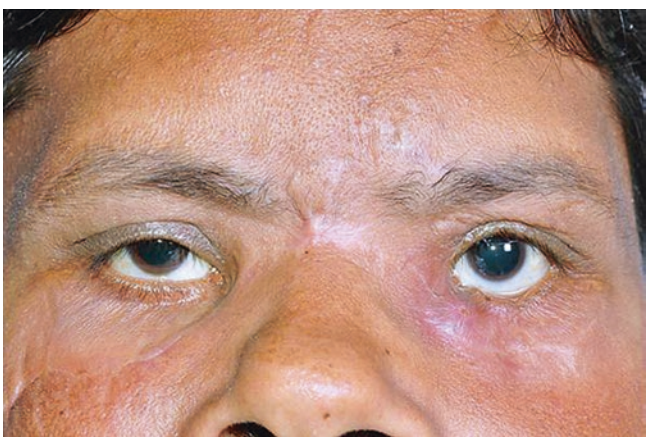


Fig. 15.12 Left acute dacryocystitis with a fistula in a case of naso-orbito-ethmoid fracture. Note the past scars of maxillofacial repair

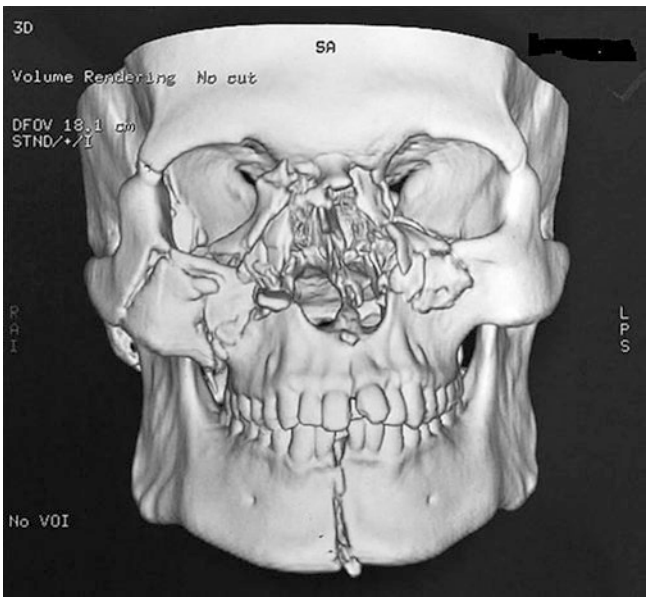


Fig. 15.13 3D reconstructed, volume-rendered CT scan of facial skeleton showing an extensive NOE fracture along with bony lacrimal involvement

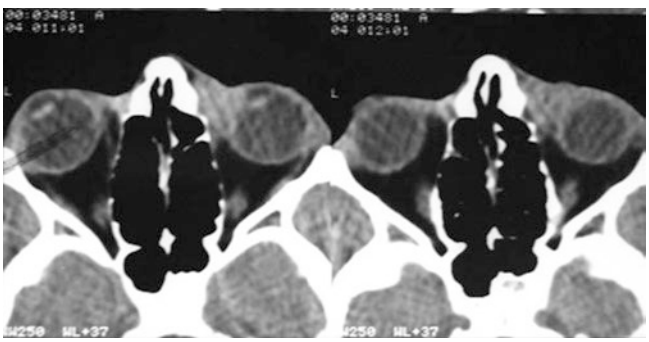


Fig. 15.14 CT scan axial image showing left lacrimal sac enlargement with dacryolithiasis

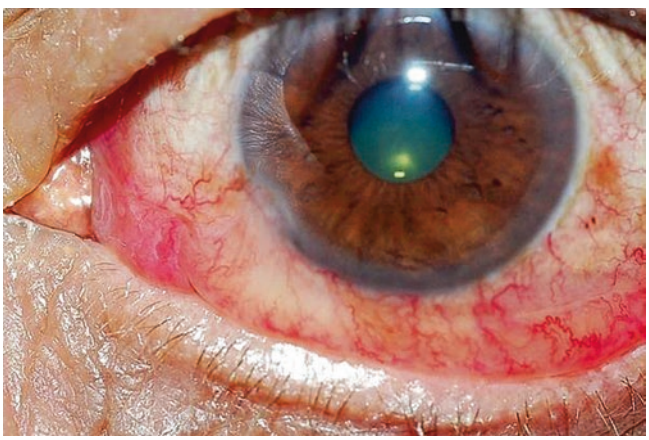


Fig. 15.15 Mechanical SALDO caused by redundant and inflamed conjunctiva obstructing the punctum

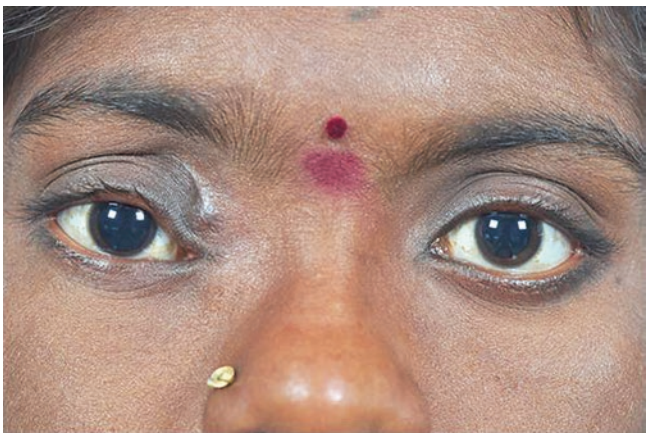


Fig. 15.16 Mechanical SALDO caused by an ethmoid mucocele. Note the unilateral telecanthus

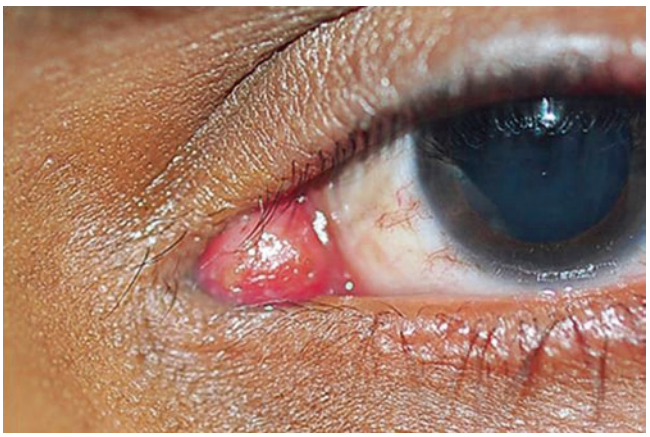


Fig. 15.17 Mechanical SALDO secondary to punctal obstruction by a caruncular mass

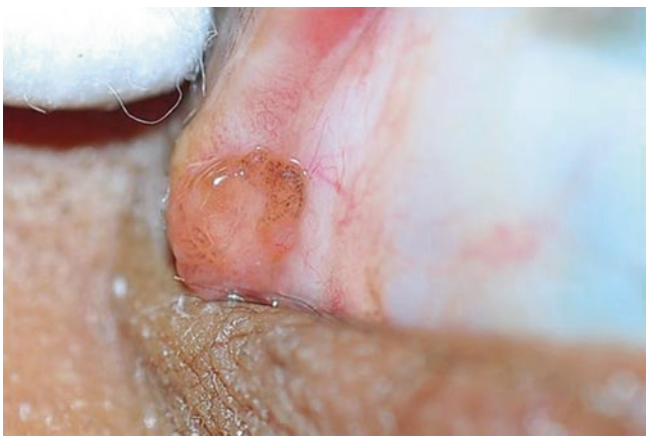


Fig. 15.18 Papilloma involving the proximal lacrimal system

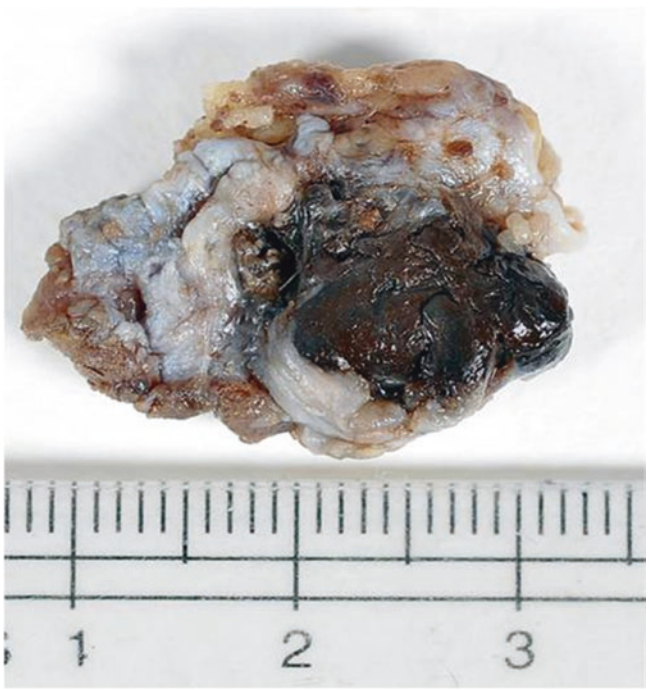


Fig. 15.19 Malignant melanoma of the lacrimal sac following an extended dacryocystectomy

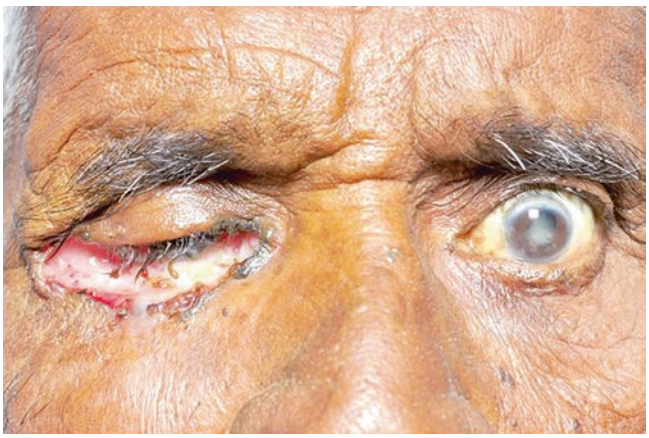


Fig. 15.20 Neoplastic SALDO secondary to a basal cell carcinoma

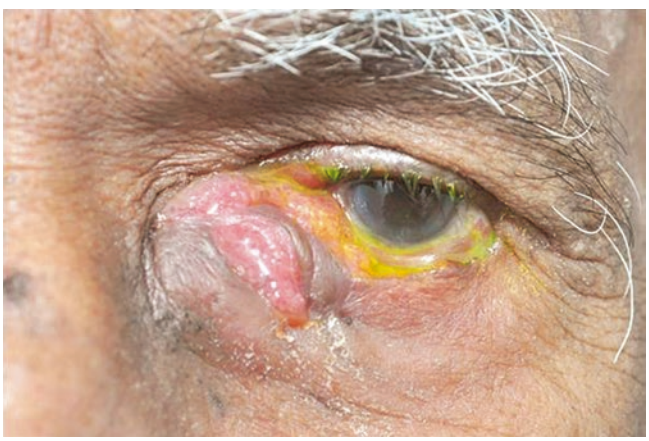


Fig. 15.21 Neoplastic SALDO secondary to a squamous cell carcinoma

Functional Obstructions of the Lacrimal System

16

Mohammad Javed Ali

Introduction

Functional obstructions of lacrimal drainage systems are an under diagnosed entity. Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description. Nomenclature has been confusing since functional issues of lacrimal system have been poorly defined. Terms used include functional block, physiologic dysfunction, and functional acquired epiphora; however, the commonest terminology used is functional nasolacrimal duct obstruction (FNLDO) [1–5]. Few authors have defined FNLDO to also include partial obstructions [5] but would be misleading since that would be an anatomical issue rather than a functional one. Functional epiphora can be an alternate and probably a better term [1]. It is of utmost importance to rule out other causes of epiphora before labeling a case as functional. Functional issues can be of the upper or lower lacrimal system. Altered outflow dynamics without anatomical narrowing in the upper system is known to occur in older patients (mean age 57–64 years) with a high incidence of bilaterality (86%) [6, 7]. These findings in upper system dysfunctions support the theory of decreasing efficiency of lacrimal pump secondary to weakening of the orbicularis oculi with increasing age as suggested by Jones in 1957 [8] and later supported by Worst in 1971 [9]. In addition, the lower system dysfunctions occur more frequently in younger patients. The current chapter aims to describe the clinical examinations, investigations, management, and outcomes of functional epiphora.

M. Javed Ali, F.R.C.S
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Clinical Examination

A careful history of epiphora with emphasis on preceding and subsequent events must be noted. Relevant ocular history, periocular surgical events, and drug (chemotherapy) history are important. Functional epiphora is a diagnosis of exclusion, and hence a careful slit lamp examination should be performed to rule out a number of potential causes of epiphora like ocular surface disorders, lacrimal gland hypersecretion, eyelid malpositions, eyelid laxities, puncta-globe incongruities, punctal stenosis, conjunctivochalasis, dry eyes, and lagophthalmos. Clinical examination should be tailored toward suspects like tear break-up time and Schirmer's test for dry eyes and hypersecretion. Nasal endoscopy can occasionally reveal nasal causes of functional epiphora like rhinitis (Fig. 16.1) [10].

Irrigation and probing should be carefully performed as elucidated in chapter on evaluation of epiphora, to be very sure that there is no anatomical problem (Figs. 16.2 and 16.3). Functional dye disappearance test (FDDT) is also very reliable adjunctive clinical test (Fig. 16.4) to support the diagnosis and must be performed as part of standard protocol in all cases of functional epiphora (please refer to chapter on evaluation of epiphora) [11, 12]. A survey conducted in southwest United Kingdom to study the assessment practice by ophthalmologists in cases of FNLDO showed gross variations. Only 41% used FDDT as an assessment tool and only 51% performed irrigation themselves. They concluded that incomplete assessments result in inadequate management and recommended FDDT in all patients, irrigation by experienced staff, and additional use of radiological investigations [12].

Investigations

Dacryocystography (DCG) has been used to exclude areas of narrowing or stenosis, and if the lacrimal system is patent, dacryoscintigraphy (DCS) is used to define the level of outflow delay [1, 13]. Wearne et al. [14] studied the feasibil-

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_16

ity of DCG and DCS in patients with FNLDO and showed that when used together, they have a high sensitivity of 98%. Montanara et al. [3] described outflow difficulties of contrast medium without anatomical narrowing as characteristic features on DCG. Hurwitz et al. [6] divided the functional abnormalities radiologically at two levels: upper part (orbicularis-puncta-canaliculi) and lower part (sac-duct-inferior meatus). Chan et al. [1] further refined these as those with pre-sac and post-sac delay. Francis et al. [15] showed increased tear meniscus height in FNLDO using videoreflective dacryomeniscometry but found no statistical difference when compared with PANDO, making it a nonspecific diagnostic tool.

The author of this chapter believes that with the advent of dacryoendoscopy, it would be easier to identify any anatomical narrowing or stenosis and hence exclude many cases that were earlier labeled as FNLDO. Since the management does not differ markedly, exclusion of anatomical abnormalities with demonstrable patent lacrimal passage should be sufficient for a diagnosis in a routine practice.

Management

The management of functional epiphora is controversial, and no consensus has evolved over the last six decades since its first description in 1955 [2]. One of the fundamental reasons for this is the variations in terminologies, exclusion criteria, and management. Do these patients really need treatment? Evidence suggests in the affirmative. Cheung et al. [7] conducted a detailed study on 33 FNLDO patients and studied their symptoms in relation to the vision, reading, driving, moods, work, and embarrassment. All these parameters were affected specifically vision, reading, and embarrassment, resulting in lower quality of life. Overall symptom scores significantly reduced after dacryocystorhinostomy (DCR) from a mean preoperative score of 3.50 (SD = 2.07) to 2.0 (SD = 1.65) in the postoperative period ($p < 0.05$).

Lacrimal pump failures with severe symptoms can be candidates for a conjunctivo-dacryocystorhinostomy or CDCR with Jones tubes [16]. These tubes have also shown to benefit persistent epiphora following a patent DCR [16, 17]. There is an increasing evidence of benefits of silicone intubation (SI) in FNLDO patients [4, 18, 19]. Moscato et al. [4] studied 44 eyes of 30 patients diagnosed as FNLDO, who underwent SI for a mean duration of 4 (±4.1) months. They were followed for a mean of 2.6 (±2.0) years from the time of intubation. The overall success for resolution of symptoms was seen in 77%. Extrapolating the data showed success at 50% between 5 and 6 years. They concluded that SI has good long-term success in cases of FNLDO.

Multiple mechanisms have been postulated to explain the benefit seen with SI in FNLDO [4, 20, 21]. Stent placement increases the volume and hence reduces resistance to outflow. Poiseuille's law states that resistance to flow is inversely proportional to fourth power of the radius. Hence the stents, by increasing the diameter of the lumen, reduce resistance to flow (Fig. 16.5). In addition Moscato et al. [4] proposed the river bed phenomenon where an increased outflow following reduced resistance helps to maintain the enlarged passage. In addition, the stents may straighten up acute curves impeding outflow as well as help tear outflow by capillary action.

There is good evidence in literature that supports the beneficial effects of DCR in FNLDO patients. Both external DCR (Ex-DCR) and endoscopic DCR (En-DCR) have shown good results. However, these results should be interpreted with caution since few studies did not take into account strict criteria, not to include NLD stenosis, but did demonstrate preoperative patency. The success rates in those with strict criteria ranged from 54 to 84% [17, 22] and in those without from 50 to 94% [23–26]. Cho et al. [27] performed a comparative trial between SI (n = 108), En-DCR (n = 32), and Ex-DCR (n = 13) in FNLDO patients. At 6 months' follow-up, complete resolution of symptoms was achieved in 68.5% of SI, 81.3% of En-DCR, and 53.9% of Ex-DCR. However, these results need to be interpreted with caution because of grossly variable number in each group and variable SI duration and SI confounding effects in DCRs.

Updates (2015–2016)

Punctal Pipette Function

Lacrimal pump, gravity, capillary action, and pressure gradient between the ocular surface and intracanalicular areas have all been proposed as mechanisms that help in tear flow from the cul-de-sac into the lacrimal system [28–30]. Beigi et al. [31] studied the dynamics of the punctal and peripunctal area during active tear drainage. They universally noted a superomedial movement of the inferior punctum toward the medial canthus along with posterior rotation and medially directed protrusion of the punctum. They called this a pipetting action and the loss of this synchronized action can potentially result in a functional epiphora.

Management Updates

There has been more support for the use of stents for primary FNLDO and functional failures after a DCR surgery. Good success rates of up to 75% have been reported with primary intubation [32]. Functional failure after a DCR surgery is uncommon, and more than half of the patients tend to do well with silicone intubation alone [33]. Good outcomes (90%) have been reported with CDCR and Jones tubes in

refractory functional cases after a DCR [33]. Although endoscopic DCR is a preferred modality for operating FNLDO, refractory to intubation, the results of external DCR have also been reported to be good (around 77%) [34].

Orbicularis tightening is a commonly practiced surgery in cases of FNLDO with lid laxity. Salour et al. [35] have shown its efficacy in relieving epiphora in up to 80% (n = 12) of primary FNLDO patients, while others have shown the efficacy to be around 50% in post-DCR functional failures [33].

There is a report of the use of microdrill dacryoplasty for the management of FNLDO with good success rates [36]. However, the author of this chapter believes that any demonstrable anatomical abnormality (which has been managed by microdrill dacryoplasty in this instance) rules out the diagnosis of a pure FNLDO.

Pediatric functional epiphora is not common but has been documented in 14.1% (13/92) among cases that masqueraded as a CNLDO [37]. Numerous etiologies like inefficient lacrimal pump, nasal mucosal edema, and altered flow dynamics have been proposed. The success rates with silicone intubation have been reported to be above 60%, but long-term results are not known [37].

FNLDO and Basic Sciences

Electron microscopic and histological studies have shown presence of helically arranged fibrillar structures around the lacrimal sac which has a tendency to passively "wrung out" during sac distension, thereby altering the pressure dynamics and facilitating tear flow [38]. In addition, malfunctions of the cavernous body of blood vessels in the substantia propria of lacrimal sac and nasolacrimal duct are increasingly being implicated in functional epiphora [39, 40].

Certain segments of the lacrimal drainage can be nonfunctional in facilitating tear flow. In this regard, it has been postulated that downregulation of trefoil family factor (TFF) peptides and mucins on the luminal surfaces of lacrimal sac and nasolacrimal ducts could contribute to dysfunctional flow of tears [41]. Recently aquaporins, which significantly contribute in the water transport mechanisms of the nasolacrimal ducts, have been implicated in FNLDO. Functional obstructions were found to have statistically significant higher aquaporin expression levels as compared to PANDO cases [42]. Further evaluation and understanding of these pathways could potentially pave way for targeted therapies.

Conclusion

Functional epiphora is a distinct entity with characteristic clinical features, specific investigative modalities for diagnosis, and decent outcomes upon management. However gold-standard diagnostic criteria are unknown, and further work needs to focus on understanding the functional dynamics at cellular level and also standardization of nomenclatures for a better understanding that would then translate to better patient management.

References

1. Chan W, Malhotra R, Kakizaki H, et al. Perspective: what does the term functional mean in the context of epiphora? Clin Experiment Ophthalmol. 2012;40:749–54.
2. Domerest BH, Milder B. Dacryocystography. The pathologic lacrimal apparatus. AMA Arch Ophthalmol. 1955;54:410–21.
3. Montanara A, Ciabattoni P, Rizzo P. Stenoses and functional disorders of the lacrimal drainage apparatus. Radiological examination. Surv Ophthalmol. 1979;23:249–58.
4. Moscato EE, Dolmetsch AM, Silkiss RZ, Seiff SR. Silicone intubation for the treatment of epiphora in adults with presumed functional nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2012;28:35–9.
5. Conway ST. Evaluation and management of "functional" nasolacrimal blockage: results of a survey of the American society of ophthalmic plastic and reconstructive surgery. Ophthal Plast Reconstr Surg. 1994;10:185–7.
6. Hurwitz JJ, Welham RAN. Radiography in functional lacrimal testing. Br J Ophthalmol. 1975;59:323–31.
7. Cheung LM, Francis IC, Stapleton F, et al. Symptoms assessment in patients with functional and primary acquired nasolacrimal duct obstruction before and after a successful dacryocystorhinostomy surgery: a prospective study. Br J Ophthalmol. 2007;91:1671–4.
8. Jones LT. Epiphora. II. Its relation to the anatomic structures and surgery of the medial canthal region. Am J Ophthalmol. 1957;43:203–12.
9. Worst JGF. In: Veirs ER, editor. The lacrimal system. St Louis: Mosby; 1971. p. 98.
10. McNeill EJ, Kubba H, Bearn MA, et al. The management of rhinitis in patients with functional epiphora: a randomized controlled crossover trial. Am J Rhinol. 2005;19:588–90.
11. Kashkouli MB, Mirzajani H, Jamshidian-Tehrani M, et al. Reliability of fluorescein dye disappearance test in assessment of adults with nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2013;29:167–9.
12. Cuthbertson FM, Webber S. Assessment of functional nasolacrimal duct obstruction–a survey of ophthalmologists in the southwest. Eye (Lond). 2004;18:20–3.
13. Chung YA, Yoo IR, Oum JS, et al. The clinical value of dacryoscintigraphy in the selection of surgical approach for patients with functional lacrimal duct obstruction. Ann Nucl Med. 2005;19:479–83.
14. Wearne MJ, Pitts J, Frank J, et al. Comparison of dacryocystography and lacrimal scintigraphy in the diagnosis of functional nasolacrimal duct obstruction. Br J Ophthalmol. 1999;83:1032–5.
15. Francis IC, Chan DG, Papalkar D, et al. Videoreflective dacryomeniscometry in normal adults and in patients with functional or primary acquired nasolacrimal duct obstruction. Am J Ophthalmol. 2005;139:493–7.
16. Athanasiov PA, Madge S, Kakizaki H, et al. A review of bypass tubes for proximal lacrimal drainage obstruction. Surv Ophthalmol. 2011;56:252–66.
17. Peter NM, Pearson AR. External dacryocystorhinostomy for the treatment of epiphora in patients with patent but non-functioning lacrimal systems. Br J Ophthalmol. 2010;94:233–5.
18. Fulcher T, O'Connor M, Moriarty P. Nasolacrimal intubation in adults. Br J Ophthalmol. 1998;82:1039–41.

19. Connell PP, Fulcher TP, Chacko E, et al. Long term follow up of nasolacrimal intubation in adults. Br J Ophthalmol. 2006;90:435–6.
20. Tucker SM, Linberg JV. Measurement of the resistance to fluid flow. Ophthalmology. 1995;102:1639–45.
21. Demirci H, Elner VM. Double silicone intubation for management of partial lacrimal system obstruction. Ophthalmology. 2008;115:383–5.
22. Wormald PJ, Tsirbas A. Investigation and endoscopic treatment for functional and anatomical obstruction of the nasolacrimal duct system. Clin Otolaryngol Allied Sci. 2004;29:352–6.
23. Sahlin S, Rose GE. Lacrimal drainage capacity and symptomatic improvement after dacryocystorhinostomy in adult presenting with patent lacrimal drainage systems. Orbit. 2001;20:173–9.
24. Brewis C, Yung M, Merkonidis C, et al. Endoscopic dacryocystorhinostomy in functional lacrimal obstruction. J Laryngol Otol. 2008;122:921–3.
25. O'Donnell B, Shah R. Dacryocystorhinostomy for epiphora in the presence of a patent lacrimal system. Clin Experiment Ophthalmol. 2001;29:27–9.
26. Delaney YM, Khooshabeh R. External dacryocystorhinostomy for treatment of acquired partial nasolacrimal duct obstruction in adults. Br J Ophthalmol. 2002;86:533–5.
27. Cho WK, Paik JS, Yang SW. Surgical success rate comparison in functional nasolacrimal duct obstruction: simple lacrimal stent versus endoscopic versus external dacryocystorhinostomy. Eur Arch Otorhinolaryngol. 2013;270:535–40.
28. Jones LT. Practical fundamental anatomy and physiology of the eye. Trans Am Acad Ophthalmol Otolaryngol. 1958;62:669–78.
29. Murube del Castillo J. On gravity as one of the impelling forces of lacrimal flow. Japan: Ashavi Evening News; 1978. p. 51–9.
30. Hurwitz JJ, Maisey MN, Welham RAN. Quantitative lacrimal scintillography. Method and physiological application. Br J Ophthalmol. 1975;59:308–12.
31. Beigi B, Gupta D, Luo YH, et al. Punctal function in lacrimal drainage: the pipette sign and functional ectropion. Clin Exp Optom. 2015;98:366–9.
32. Tong NX, Zhao YY, Jin XM. Use of Crawford intubation for symptomatic epiphora without nasolacrimal duct obstruction. Int J Ophthalmol. 2016;9:282–5.
33. Shams PN, Chen PG, Wormald PJ, et al. Management of functional epiphora in patients with an anatomically patent dacryocystorhinostomy. JAMA Ophthalmol. 2014;132:1127–32.
34. Simsek I, Kiziloglu OY, Ziylan S. External dacryocystorhinostomy for the treatment of functional nasolacrimal duct obstruction. Turk J Ophthalmol. 2015;45:208–12.
35. Salour H, Khosravifard K, Bagheri A, et al. Efficacy of tightening of orbicularis muscle in patients with functional nasolacrimal duct obstruction. Orbit. 2016;35:11–5.
36. Stemplewitz B, Amin S, Emmerich KH, et al. Minimally invasive lacrimal duct surgery with a multimodal concept for functional lacrimal stenosis. Klin Monatsbl Augenheilkd. 2015;232:44–50.
37. Kamal S, Ali MJ, Gupta A, et al. Lacrimal and nasal masquerades of congenital nasolacrimal duct obstructions: etiology, management and outcomes. Int Ophthalmol. 2015;35:807–10.
38. Thale A, Paulsen F, Rochels R, et al. Functional anatomy of the human efferent tear ducts: a new theory of tear outflow mechanism. Graefes Arch Clin Exp Ophthalmol. 1998;236:674–8.
39. Ayub A, Thale AB, Hedderick J, et al. The cavernous bodies of the human efferent tear ducts contributes to regulation of tear outflow. Invest Ophthalmol Vis Sci. 2003;44:4900–7.
40. Paulsen F, Hallmann U, Paulsen J, et al. Innervation of the cavernous body of the human efferent tear ducts. J Anat. 2000;197:177–87.
41. Paulsen FP, Berry MS. Mucins and TFF peptides of the tear film and lacrimal apparatus. Prog Histochem Cytochem. 2006;41:1–53.
42. Park J, Kim J, Kim M, et al. Aquaporin expression in the lacrimal sac of patients with primary and functional nasolacrimal duct obstruction. Br J Ophthalmol. 2016;101(4):519–24. (Epub)

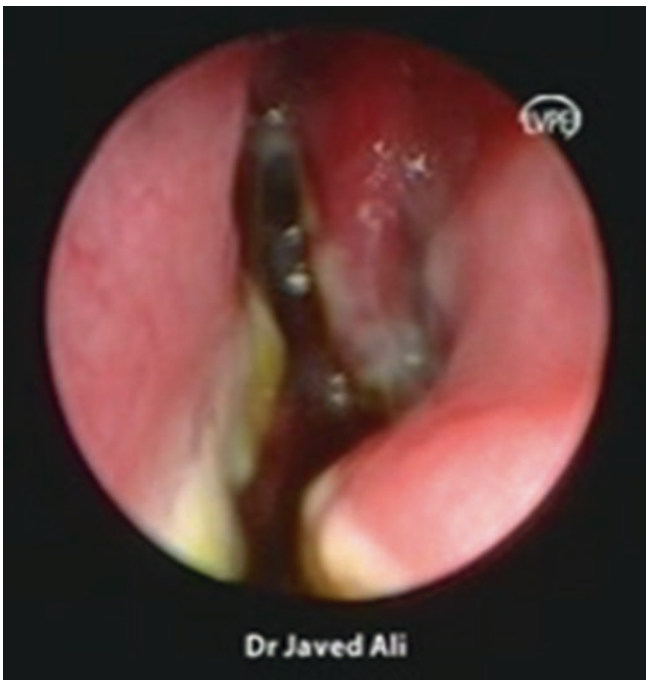


Fig. 16.1 Endoscopic view in acute rhinitis

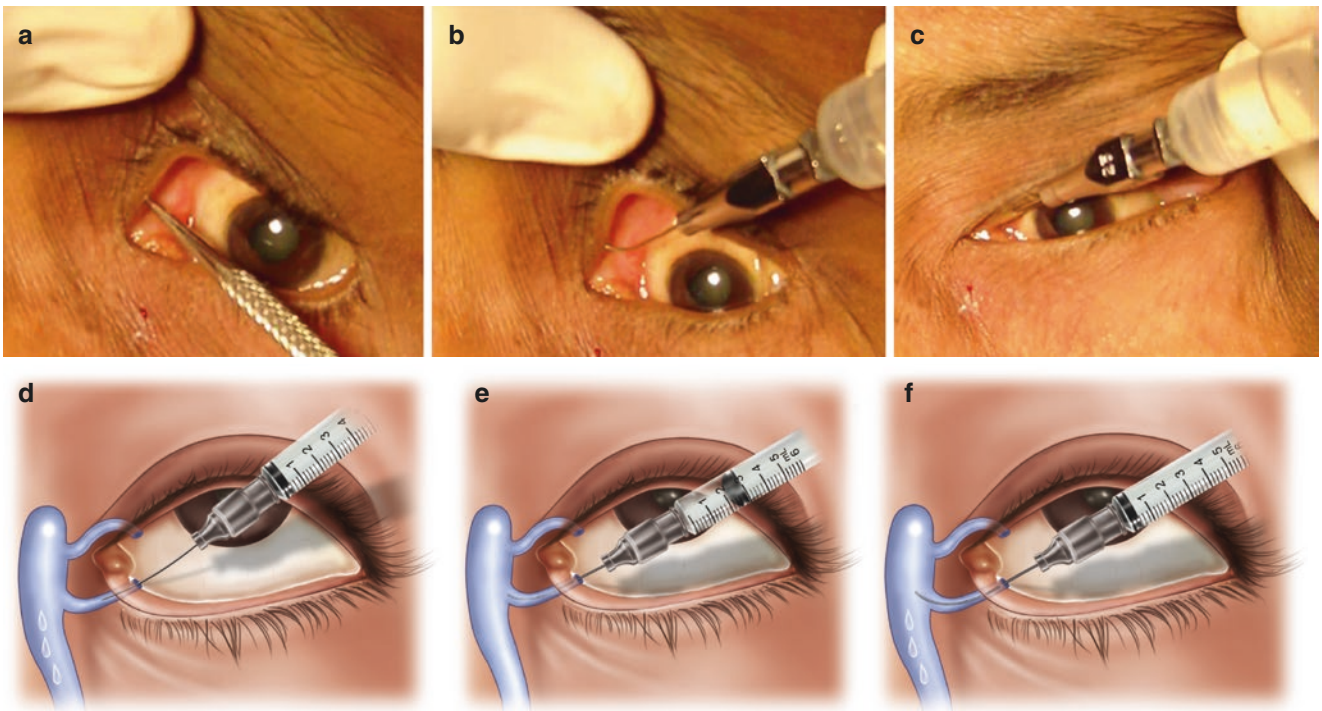


Fig. 16.2 Technique of irrigation (Photo courtesy Dr. Sima Das)

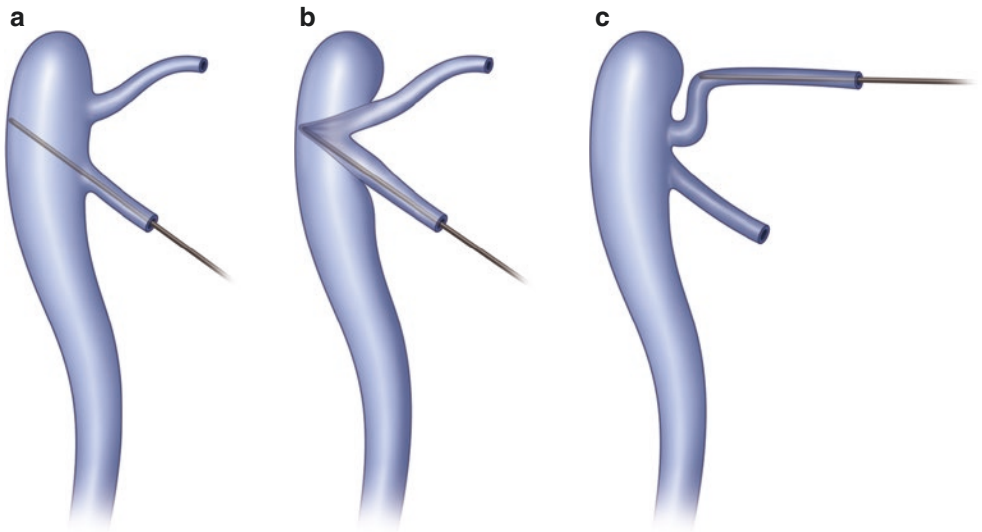


Fig. 16.3 Technique of probing (Photo courtesy Dr. Sima Das)

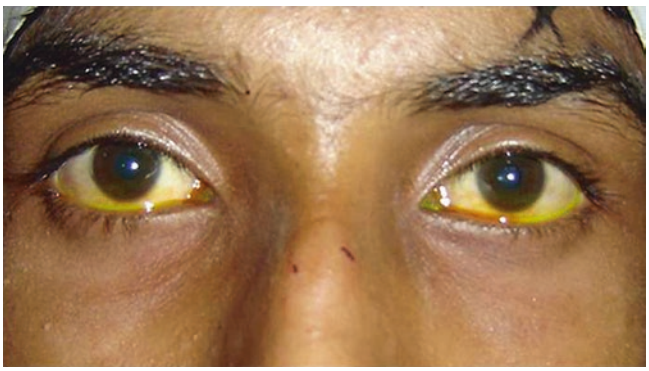


Fig. 16.4 Bilaterally retained dye in FDDT (Photo courtesy Dr. Sima Das)

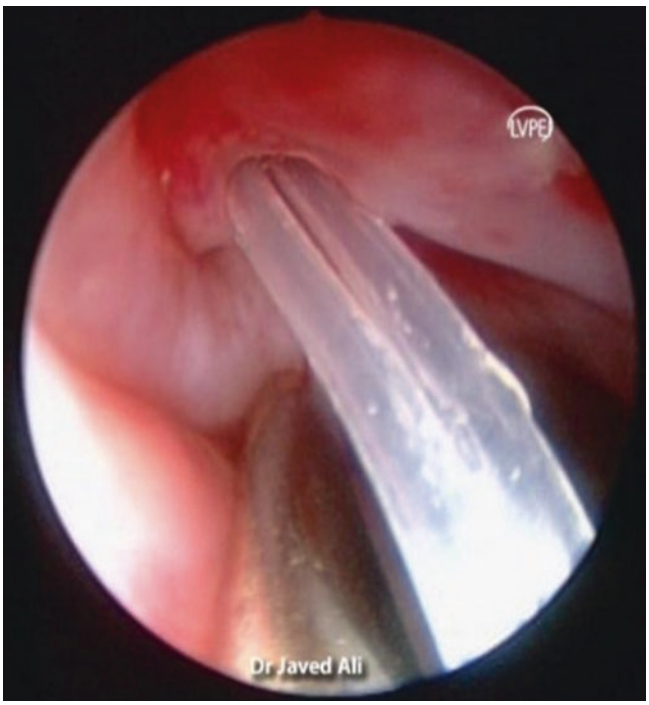


Fig. 16.5 Endoscopic view of silicone tube dilating the nasolacrimal duct

Infections of the Lacrimal Drainage System

17

Aditi Pujari and Mohammad Javed Ali

The canaliculi and the lacrimal sac are those segments of lacrimal drainage system, which are prone for infections. In this chapter we would focus on infective canaliculitis and dacryocystitis.

Canaliculitis

It is an infection of the canalicular part of lacrimal drainage system (Fig. 17.1) [1].

Epidemiology

It accounts for only 2% of all patients with lacrimal diseases [2]. Canaliculitis affects the lower eyelid more than the upper eyelid and women more than men [3]. This female preponderance is thought to be partly due to physiological or hormonal changes during menopause, which may cause decreased tear production and reduced protection against infections [4]. Furthermore, makeup and cosmetics may occlude the canaliculus and promote bacterial growth, predisposing to canaliculitis [5].

Etiology

Most of the cases are idiopathic in nature. Few rare predisposing factors include diverticulum or obstruction of the canaliculus which promote anaerobic bacterial growth secondary to stasis of tear and use of cosmetics.

Microbiological Profile

Most published case series report *Actinomyces* and *Nocardia* species, prominent among them being *Actinomyces israelii* (Fig. 17.2) and *Nocardia asteroides* as the common pathogenic organisms [6–16]. There are only isolated case reports of canaliculitis due to other various organisms like *Mycobacterium chelonae, Lactococcus lactis, Eikenella corrodens, Enterobacter cloacae, Fusobacterium*, *Kocuria rosea*, viruses like *Herpes simplex*, and fungal organisms like *Pityrosporum pachydermatis and Candida albicans* [17–25]. However, in one of the largest studies in literature from the author's institution, the culture positive rates were 91% with *Staphylococcus* species being the most common isolate (39%) (Fig. 17.3) followed by *Streptococcus* species (29%) and *Actinomyces* (10%) [3].

Clinical Presentation

Common presenting symptoms include epiphora, swelling of the eyelid, pain, or redness (Fig. 17.1). Kaliki et al. [3] in a very large series showed epiphora as the commonest symptom (85%) followed by swelling of the canalicular portion of the eyelid (32%) and pain in 27% of the cases. Rarely patient may even be asymptomatic [3].

On clinical examination, typical signs of canaliculitis include thickening of canalicular portion of eyelid margin (72%), expressible punctal discharge (36%), and pouting erythematous punctum (34%) (Fig. 17.1), or rarely a firm, non-tender nodule in punctal and canalicular region [3].

Diagnosis

Although canalicular imaging by dacryocystography and ultrasound biomicroscopy has been described for diagnosis and documentation of canaliculitis, a thorough clinical examination is sufficient for the diagnosis in most cases [26, 27].

A. Pujari, M.D.
Ophthalmic Plastics Surgery, Sunayn Oculoplasty Center, Kolhapur, India

M. Javed Ali, F.R.C.S (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_17

The rarity of this disease may be attributed to the high rate of missed and delayed diagnosis. Furthermore, it may have atypical presentations, leading to additional difficulties in diagnosis [4, 28–30]. Canaliculitis can be misdiagnosed as chronic conjunctivitis, chalazion, hordeolum internum, or chronic dacryocystitis, causing a further delay in the initiation of effective treatment [3, 4, 31–33].

Management

Various modalities of treatment have been described for canaliculitis [2–33]. Conservative measures include oral and topical antibiotics, punctal dilatation, and canalicular expression or canalicular irrigation with antibiotics [6–8]. Surgical measures include punctoplasty and canalicular curettage, canaliculotomy with canalicular curettage, or canaliculotomy [2, 3, 10–33].

However, with any of the modality of treatment, it is important to send the material for a meticulous microbiological examination.

Conservative Medical Therapy

Initially, punctal dilatation with expression of canalicular discharge is performed under strict aseptic precautions under topical anesthesia. After instilling a drop of 0.5% proparacaine hydrochloride in the conjunctival cul-de-sac, dilatation of the punctum is performed with Nettleship punctum dilator and manual expression of canalicular contents by a milking movement toward the punctum (Fig. 17.4). Mechanical expression is repeated (Fig. 17.5) until no further contents are expressed. The expressed contents are collected on a sterile cotton-tipped applicator and sent for microbiological workup. Broad spectrum antibiotics can be started as dictated by regional isolates and their sensitivity, followed by specific antibiotics guided by patient-specific isolates. Conservative treatment in one of the largest series has shown to be effective in 59% of the patients with a high rate or recurrence [3].

Surgical Treatment

Surgical modalities include punctoplasty alone or in conjunction with canalicular curettage, performed under strict aseptic precautions, under local infiltrative anesthesia with 2% lignocaine hydrochloride. A 3-snip punctoplasty or the surgeon-preferred punctoplasty is performed with a small, straight Vannas scissors (Figs. 17.6 and 17.7). To this, a small canaliculotomy can be added (Fig. 17.8), and a 1-mm chalazion curette is used to curette out the granular material, concretions, or mucoid debris (Figs. 17.9 and 17.10). It is a good practice to evaluate walls of the ampulla, since concretions have a tendency to stack up and accumulate there (Fig. 17.11). The curettage is repeated until there are no further contents (Fig. 17.12). It is of utmost importance to avoid any damage to canalicular mucosa during this procedure. The curetted material is collected on a sterile surface (Fig. 17.13) or cotton-tipped applicator and sent for microbiological culture and sensitivity.

Following any of the two interventions, the patient is prescribed a broad-spectrum antibiotic eye drop (e.g., 0.3% ciprofloxacin 4 times per day) and is subsequently altered according to the results of the microbiology culture and sensitivity report.

Conservative treatment with topical antibiotics is associated with a high recurrence rate in as high as 41% [3, 4]. Canalicular curettage after canaliculotomy or punctoplasty carries a high resolution rate and is the procedure of choice [2–4, 10, 31, 33]. Occasionally a repeat procedure may be required to manage recurrences. However, canaliculotomy can result in canalicular luminal narrowing or scarring, lacrimal pump dysfunction, and canalicular fistula formation [6, 31, 33]. In contrast, curettage through the punctum is a less invasive procedure and preserves the lacrimal pump function [31, 33].

In conclusion, a high index of suspicion is needed for the diagnosis of canaliculitis. The microbiological profile of canaliculitis seems to be evolving with *Staphylococcus* emerging as the most common isolated species in Southeast Asia. Punctal dilatation with canalicular expression, though effective in few patients, is more commonly associated with persistence of the disease. Punctoplasty with canalicular curettage is more efficacious with high success rates. In recurrent and persistent cases, conservative treatment is best avoided, and canalicular curettage should be done in all such cases to achieve a complete resolution.

Acute Dacryocystitis

Dacryocystitis is inflammation of the lacrimal sac which can be chronic or can present as an acute condition due to secondary infection of the stagnant tear secretions [34, 35]. Dacryocystitis is generally due to obstruction of the nasolacrimal duct, which can be congenital or acquired. However, it is uncommon to have acute dacryocystitis associated with congenital nasolacrimal duct obstructions. Rarely a dacryocystocele may be the presenting feature. Details of these infections have been dealt with in the chapter "Congenital Nasolacrimal Duct Obstruction." In this section, we shall discuss acute infective dacryocystitis.

Definition

Acute dacryocystitis can be defined as "a medical urgency which is clinically characterized by rapid onset of pain, ery-

thema and swelling, classically below the medial canthal tendon with or without preexisting epiphora mainly resulting from the acute infection of the lacrimal sac and perisac tissues" [34] (Fig. 17.14).

Epidemiology

Epidemiology of acute dacryocystitis is not very well known. It constitutes 2.4% of all lacrimal disorders with a female preponderance (2:1), usually noted in third to fifth decade, although it can affect at any age and is predominantly unilateral (91.6%) [34].

Microbiological Profile

Although many microbiological studies are available for chronic dacryocystitis, very few looked at the acute ones [36–38]. The microbiologic spectrum of acute dacryocystitis in 21 patients found gram-positive organisms to be the most common with *Staphylococcus aureus* as the most common organism isolated from cultures [36]. In contrast Razavi et al. [37] concluded that there are significant differences in the isolates between acute and chronic dacryocystitis, although the study did not show much difference and the sample size of acute cases was only 12 patients. In the largest study on microbiological profile of lacrimal abscess (n = 100) [38], gram-positive cocci (GPC) were the most common isolates (56%) followed by gram-negative bacilli (GNB) (30%) (Figs. 17.15 and 17.16) and gram-positive bacilli (3%). Among the gram-positive cocci, the commonest isolates were *Staphylococcus aureus*, *Streptococcus pneumoniae*, and *Streptococcus pyogenes*. *Haemophilus influenzae*, *Escherichia coli*, and *Pseudomonas aeruginosa* were the common gram-negative bacilli [38]. Occasionally rare organisms like *Cardiobacterium hominis* had been implicated in the pathogenesis of acute dacryocystitis [39].

Clinical Presentation

There is a varied spectrum of its clinical presentations ranging from tenderness and erythema of the overlying tissues to a frank lacrimal abscess [34–45]. Generally, patients present with pain and swelling in the lacrimal sac area with a tender induration below the medial canthal tendon, epiphora with or without a palpable distended lacrimal sac, and regurgitation of purulent material from the puncta (Fig. 17.14) [34–45]. In the largest series on acute dacryocystitis (n = 347), swelling in the lacrimal sac region was noted in 84% with 83% of patients complaining of pain. Erythema and redness were noted in 48%, discharge in 40%, lacrimal abscess in 23% (Fig. 17.17), orbital cellulitis (Fig. 17.18) in 3%, and constitutional symptoms like fever in 6% of patients [34]. Occasionally lacrimal fistula may be the presenting feature secondary to spontaneous drainage of lacrimal abscess (Fig. 17.19) [34].

Orbital cellulitis following acute dacryocystitis is not common owing to numerous barriers that limit spread of an infection like the orbital septum, medial canthal ligaments, Horner's muscle, and Jones muscle [34, 44]. Breach of these barriers would provide the infection an unhindered access to the orbital tissues.

More advanced presentations in the form of orbital cellulitis with orbital abscess (Fig. 17.20), necrotizing fasciitis, superior ophthalmic vein thrombosis, cavernous sinus thrombosis, meningitis, and total vision loss have also been reported [34, 41–45].

Management

Conservative Medical Therapy

Acute dacryocystitis is a very painful condition which resolves slowly with systemic antibiotics [34–45]. *Conservative management* includes warm compresses, systemic antibiotics, and anti-inflammatory drugs. In a large series (n = 347), only 4% required an inpatient management and rest were treated on a day care basis [34]. All attempts should be made to control the acute attack medically. Gram-positive isolates from Southeast Asia were susceptible to penicillins and cephalosporins, while most of the gram-negative isolates to quinolones [38]. Appropriate antibiotic should be chosen based on the common regional isolates and their sensitivity profiles. The mean time to resolution is around 7–10 days and 6% relapsed before a definite surgical therapy could be performed, mostly due to delays in seeking treatment or long waiting periods [34, 38].

Causes of non-resolving acute dacryocystitis:

- Progression to lacrimal sac abscess
- Virulent organism
- Antibiotic resistance
- Persistent aggressive inflammation

Disadvantages of continuous conservative management in suboptimal response:

- Prolonged/recurrent infection leading to orbital cellulitis, cavernous sinus thrombosis
- Adverse effect of antibiotic due to prolong and repeated usage
- Cutaneous scar/fistula, most commonly in patients with spontaneous rupture of abscess.
- Failure of surgery due to scarring and granulation in sac

Surgical Management

The surgical modalities include drainage of lacrimal or orbital abscess and dacryocystorhinostomy (DCR) after resolution of acute infection [34–45].

The results of external DCR are quite good at when done by an appropriate method. In the largest reported DCRs following resolution of acute attack ($n = 264$), 70% required bicanalicular intubation [34]. At 1-year follow-up after removal of stents, anatomical success was achieved in 94.3% and functional success in 93.5% of the patients. Of the 15 failures, who underwent a revision external DCR with MMC and intubation, 73% reported anatomical success [34]. Endoscopic dacryocystorhinostomy in acute dacryocystitis is gaining wider acceptance as a promising modality of management [46, 47]. It can be a good option not only following resolution of acute phase but could have potential use in an acute clinical setting of cases which either do not resolve or show suboptimal response following medical management.

Updates (2015–2016)

Dacryoendoscopy Features of Acute Canaliculitis

Dacryoendoscopy has a potential to provide newer insights into the pathophysiology of canaliculitis. Features in acute canaliculitis include widespread mucosal edema of horizontal and vertical canaliculus, concretions and submucosal hemorrhages, and patchy fibrosis [48]. Two distinct types of concretions were noted. The well-defined ones are smaller in size with clear borders and have a tendency to be located in the central and pericentral areas of the lumen. The ill-defined ones were large with fluffy borders, situated more toward the wall with blood clots separating them from the luminal areas [48].

Vertical Canaliculotomy

The regular treatment by punctoplasty and horizontal canaliculotomy and curettage may cause canalicular strictures, scarring, or loss of tear drainage function [49]. Perumal et al. [50] have shown good outcomes when canaliculitis was initially managed by conservative therapies followed by a 2-mm vertical canaliculotomy and retrograde expression of the canalicular contents. The author of this chapter also believes in the need for being minimally invasive to avoid the potential of functional epiphora.

Updated Canaliculitis Profiles

The incidence of canaliculitis was found to be 1.4% of all the ophthalmic plastic cases presenting at a tertiary eye care [51]. Snip punctoplasty with curettage was found to be very effective [51–53]; however, around 9% of patients had postoperative epiphora [51]. Geographical variations in organisms isolated vary quite a bit with studies from Asia showing *Streptococcus* as a common organism [51], whereas those from the USA showing a mixture of filamentous and nonfilamentous bacteria in all isolates from concretions [53]. This again emphasizes the need for physicians to treat canaliculitis based on their regional isolates and their susceptibility.

Punctal Plugs and Canaliculitis

There has been a surge in reports implicating punctal plugs in etiology of canaliculitis [54–56]. SmartPlug^{R} appears to be the most common variety [54, 56]. The onset of canaliculitis is usually delayed and the mean duration from insertion to development of canaliculitis ranges from 4.7 to 4.5 years [54, 56]. Commonest organisms isolated include *Pseudomonas aeruginosa* and *Actinomycetes*. Fortunately most canaliculitis resolve by removal of the plug without any recurrences.

Unusual Organisms Causing Canaliculitis

Few newer organisms have been isolated from canaliculitis patients and this trend reflect increasing trends toward microbiological examination in every case and also better diagnostic modalities. *Aggregatibacter aphrophilus* has been isolated from a case of chronic canaliculitis [57]. The diagnosis was helped by fluorescence in situ hybridization (FISH), and the organism was sensitive to amoxicillin and ceftriaxone. However, it is important to know that only antibiotics did not help here, and the patient was relieved following a surgical intervention. *Myroides* species which are known to cause infections in immunocompromised states have been isolated from an immunocompetent patient of chronic canaliculitis [58]. The patient responded well to non-incisional curettage and topical moxifloxacin. Similarly there have been reports on *Citrobacter freundii* [59] and non-tubercular *Mycobacteria* [60] being isolated in chronic canaliculitis, and management should be guided by antibiotic sensitivity profiles and surgical intervention if nonresponsive or recurrent.

Pediatric Acute Dacryocystitis (PAD)

Pediatric acute dacryocystitis is now being recognized as a distinctive entity with unique features of its own [61]. Acute dacryocystitis is uncommon in pediatric age groups and occurs commonly as a complication of persistent congenital nasolacrimal duct obstruction. However, the prevalence of PAD rises rapidly in the setting of a dacryocele and ranges from 20 to 75%. The age of onset is usually in the neonatal period with a female preponderance. The commonest organism isolated is *Staphylococcus* although rare organisms like *Pantoea*, *Sporothrix*, and Epstein-Barr virus have also been implicated in causation [61]. Differential diagnosis includes capillary hemangiomas, nasal glioma, encephaloceles, and inflamed dermoid cysts. Management in the form of probing, incision, and drainage and dacryocystorhinostomy have been described, and the choice is decided upon on an individual case basis. Bacteremia can occur even with simple probing in pediatric acute dacryocystitis and this may warrant prophylactic systemic antibiotics [62].

Systemic Associations of Acute Dacryocystitis

An association of infectious mononucleosis with acute dacryocystitis has been reported in pediatric populations. This occurs secondary to Epstein-Barr virus infection [61, 63]. In addition, acute dacryocystitis has been reported to be the first presenting sign of a chronic lymphocytic leukemia [64]. Such a suspicion can be entertained if the severity of leukocytosis does not correlate with that of infection.

Endonasal DCR in Acute Dacryocystitis

Endonasal approach dacryocystorhinostomy is fast evolving as a first-line primary modality of management of acute dacryocystitis [65–69]. Unlike an external DCR, it can be performed safely in an acute infective scenario. The other advantages include reducing the incidence of fistula formation and complications, hastening of recovery, and decreased morbidity because the root cause, nasolacrimal obstruction, is effectively bypassed. The success rates of both endoscopic and non-endoscopic endonasal approaches in acute dacryocystitis and lacrimal abscess are beyond 90%, and these results have been seen to be maintained on long-term follow-ups [65–69]. The current practice of the authors is to administer antibiotics immediate preoperatively, perform the surgery, and continue postoperative antibiotics for 5 days.

References

1. Anand S, Hollingworth K, Kumar V, et al. Canaliculitis: the incidence of long-term epiphora following canaliculotomy. Orbit. 2004;23:19–26.
2. Demant E, Hurwitz JJ. Canaliculitis: review of 12 cases. Can J Ophthalmol. 1980;15:73–5.
3. Kaliki S, Ali MJ, Honavar SG, et al. Primary canaliculitis: clinical features, microbiological profile, and management outcome. Ophthal Plast Reconstr Surg. 2012;28:355–60.
4. Vécsei VP, Huber-Spitzy V, Arocker-Mettinger E, et al. Canaliculitis: difficulties in diagnosis, differential diagnosis and comparison between conservative and surgical treatment. Ophthalmologica. 1994;208:314–7.
5. Brazier JS, Hall V. *Propionibacterium propionicum* and infections of the lacrimal apparatus. Clin Infect Dis. 1993;17:892–3.
6. McKellar MJ, Aburn NS. Cast-forming *Actinomyces israelii* canaliculitis. Aust N Z J Ophthalmol. 1997;25:301–3.
7. Sullivan TJ, Hakin KN, Sathananthan N, et al. Chronic canaliculitis. Aust N Z J Ophthalmol. 1993;21:273–4.
8. Mohan ER, Kabra S, Udhay P, et al. Intracanalicular antibiotics may obviate the need for surgical management of chronic suppurative canaliculitis. Indian J Ophthalmol. 2008;56:338–40.
9. Briscoe D, Edelstein E, Zacharopoulos I, et al. *Actinomyces* canaliculitis: diagnosis of a masquerading disease. Graefes Arch Clin Exp Ophthalmol. 2004;242:682–6.
10. Hussain I, Bonshek RE, Loudon K, et al. Canalicular infection caused by *Actinomyces*. Eye. 1993;7:542–4.
11. Asghar S, Mahmood A, Khan MA. *Nocardia* canaliculitis presenting as pouted punctum. J Coll Physicians Surg Pak. 2008;18:55–7.
12. Bharathi MJ, Ramakrishnan R, Meenakshi R, et al. *Nocardia asteroides* canaliculitis: a case report of uncommon aetiology. Indian J Med Microbiol. 2004;22:123–5.
13. Singh CN, Thakker M, Sires BS. Pyogenic granuloma associated with chronic *Actinomyces* canaliculitis. Ophthal Plast Reconstr Surg. 2006;22:224–45.
14. Eloy P, Brandt H, Nollevaux MC, et al. Solid cast-forming actinomycotic canaliculitis: case report. Rhinology. 2004;42:103–6.
15. Seal DV, McGill J, Flanagan D, et al. Lacrimal canaliculitis due *to Arachnia (Actinomyces) propionica*. Br J Ophthalmol. 1981;65:10–3.
16. Joseph TA, Paniker CK, Kumari S, et al. Actinomycotic lacrimal canaliculitis. Indian J Ophthalmol. 1980;28:157–9.
17. Fowler AM, Dutton JJ, Fowler WC, et al. *Mycobacterium chelonae* canaliculitis associated with SmartPlug use. Ophthal Plast Reconstr Surg. 2008;24:241–3.
18. Leung DY, Kwong YY, Ma CH, et al. Canaliculitis associated with a combined infection of *Lactococcus lactis cremoris* and *Eikenella corrodens*. Jpn J Ophthalmol. 2006;50:284–5.
19. de Koning EW, van Bijsterveld OP. *Herpes simplex virus* canaliculitis. Ophthalmologica. 1983;186:173–6.
20. Jordan DR, Agapitos PJ, McCunn PD. *Eikenella corrodens* canaliculitis. Am J Ophthalmol. 1993;115:823–4.
21. Chumbley LC. Canaliculitis caused by *Enterobacter cloacae*: report of a case. Br J Ophthalmol. 1984;68:364–6.
22. Romano A, Segal E, Blumenthal M. Canaliculitis with isolation of *Pityrosporum pachydermatis*. Br J Ophthalmol. 1978;62:732–4.
23. Newton JC, Tulevech CB. Lacrimal canaliculitis due to *Candida albicans*. Report of a case and a discussion of its significance. Am J Ophthalmol. 1962;53:933–6.
24. Weinberg RJ, Sartoris MJ, Buerger GF Jr, et al. *Fusobacterium* in presumed *Actinomyces* canaliculitis. Am J Ophthalmol. 1977;84:371–4.

25. Ali MJ, Pujari A, Motukupally S, et al. *Kocuria rosea* canaliculitis: a clinicomicrobiological correlation. Ophthal Plast Reconstr Surg. 2014;30:e139–40.
26. Sathananthan N, Sullivan TJ, Rose GE, et al. Intubation dacryocystography in patients with a clinical diagnosis of chronic canaliculitis ("*streptothrix*"). Br J Radiol. 1993;66:389–93.
27. Hurwitz JJ, Pavlin CJ. Proximal canalicular imaging utilizing ultrasound biomicroscopy B: Canaliculitis. Orbit. 1998;17:31–6.
28. Moscato EE, Sires BS. Atypical canaliculitis. Ophthal Plast Reconstr Surg. 2008;24:54–5.
29. Charles NC, Lisman RD, Mittal KR. Carcinoma of the lacrimal canaliculus masquerading as canaliculitis. Arch Ophthalmol. 2006;124:414–6.
30. Fulmer NL, Neal JG, Bussard GM, et al. Lacrimal canaliculitis. Am J Emerg Med. 1999;17:385–6.
31. Pavilack MA, Frueh BR. Through curettage in the treatment of chronic canaliculitis. Arch Ophthalmol. 1992;110:200–2.
32. Lin SC, Kao SC, Tsai CC, et al. Clinical characteristics and factors associated the outcome of lacrimal canaliculitis. Acta Ophthalmol. 2011;89:759–63.
33. Lee MJ, Choung HK, Kim NJ, et al. One-snip punctoplasty and canalicular curettage through the punctum: a minimally invasive surgical procedure for primary canaliculitis. Ophthalmology. 2009;116:2027–30.e2.
34. Ali MJ, Joshi DS, Naik MN, et al. Clinical profile and management outcome of acute dacryocystitis: two decades of experience in a tertiary eye care center. Semin Ophthalmol. 2015;30:118–23.
35. Cahill KV, Burns JA. Management of acute dacryocystitis in adults. Ophthal Plast Reconstr Surg. 1993;9:38–42.
36. Mills DM, Bodman MG, Meyer DR, et al. The microbiologic spectrum of acute dacryocystitis. A national study of acute versus chronic infection. Ophthal Plast Reconstr Surg. 2007;23:302–6.
37. Razavi ME, Ansari-Astaneh MR, Farzadnia M, et al. Bacteriological evaluation of adult dacryocystitis in Iran. Orbit. 2010;29:286–90.
38. Ali MJ, Motukupally SR, Joshi SD, et al. The microbiological profile of lacrimal abscess: two decades of experience from a tertiary eye care center. J Ophthalmic Inflamm Infect. 2013;3:57–61.
39. Manderwad GP, Kodiganti M, Ali MJ. *Cardiobacterium hominis*-induced acute dacryocystitis and lacrimal abscess. Indian J Ophthalmol. 2014;62:495–7.
40. Huber-Spitzy V, Steinkogler FJ, Huber E, et al. Acute dacryocystitis: microbiology and conservative therapy. Acta Ophthalmol. 1992;70:745–9.
41. Kikkawa DO, Heinz GW, Martin RT, et al. Orbital cellulitis and abscess secondary to dacryocystitis. Arch Ophthalmol. 2002;120:1096–9.
42. Warrak E, Khoury P. Orbital abscess secondary t 243 o acute dacryocystitis. Can J Ophthalmol. 1996;31:201–2.
43. Mauriello JA, Wasserman BA. Acute dacryocystitis: an unusual case of life threatening orbital intraconal abscess with frozen globe. Ophthal Plast Reconstr Surg. 1996;12:294–5.
44. Maheshwari R, Maheshwari S, Shah T. Acute dacryocystitis causing orbital cellulitis and abscess. Orbit. 2009;28:196–9.
45. Schmitt NJ, Beatty RL, Kennerdell JS. Superior ophthalmic vein thrombosis in a patient with dacryocystitis induced orbital cellulitis. Ophthal Plast Reconstr Surg. 2005;21:387–9.
46. Wu W, Yan W, MacCallum JK, et al. Primary treatment of acute dacryocystitis by endoscopic dacryocystorhinostomy with silicone intubation guided by a soft probe. Ophthalmology. 2009;116:116–22.
47. Lee TS, Woog JJ. Endonasal dacryocystorhinostomy in 261 the primary treatment of acute dacryocystitis with abscess formation. Ophthal Plast Reconstr Surg. 2001;17:180–3.
48. Ali MJ, Alam SM, Naik MN. Dacryoendoscopic features in a case of canaliculitis with concretions. Ophthal Plast Reconstr Surg. 2017;33(3):228–9. (Epub)
49. Anand S, Hollingworth K, Kumar V, et al. Canaliculitis: the incidence of long-term epiphora following canaliculotomy. Orbit. 2004;12:19–26.
50. Perumal B, Meyer DR. Vertical canaliculotomy with retrograde expression of concretions for the treatment of canaliculitis. Ophthal Plast Reconstr Surg. 2015;31:119–21.
51. Kim UR, Wadwekar B, Prajna L. Primary canaliculitis: the incidence, clinical features, outcome, and long-term epiphora after snip-punctoplasty and curettage. Saudi J Ophthalmol. 2015;29:274–7.
52. Zhang Q, Xu B, Li XX, et al. Clinical characteristics, treatment patterns, and outcomes of primary canaliculitis among patients in Beijing. China Biomed Res Int. 2015;2015:904756.
53. Perumal B, Carlson JA, Meyer DR. A pathological analysis of canaliculitis concretions: more than just Actinomycetes. Scientifica. 2016;2016:6313070.
54. Huang YY, Yu WK, Tsai CC, et al. Clinical features, microbiological profiles and treatment outcome of lacrimal plug-related canaliculitis compared to those of primary canaliculitis. Br J Ophthalmol. 2016;100:1285–9.
55. Foveau P, George JL, Cloche V, et al. Actinomyces canaliculitis as a complication of silicone lacrimal punctal plug. J Fr Ophthalmol. 2015;38:e51–3.
56. Klein-Theyer A, Boldin I, Rabensteiner DF, et al. Prevalence of canaliculitis after Smartplug insertion during long-term follow up. Br J Ophthalmol. 2015;99:1134–6.
57. Boulze-Pankert M, Roux C, Nkamga VD, et al. *Aggregatibacter aphrophilus* chronic lacrimal canaliculitis: a case report. BMC Ophthalmol. 2016;106(16):132–4.
58. Ali MJ, Joseph J, Sharma S, et al. Canaliculitis with isolation of *Myroides* species. Ophthal Plast Reconstr Surg. 2015;33(3S Suppl 1):S24–5. (Epub)
59. Rocke J, Roydhouse T, Spencer T. Canaliculitis caused by *Citrobacter freundii*. Clin Exp Ophthalmol. 2016;44:856–8.
60. Chu HS, Chang SC, Shen EP, et al. Nontuberculous mycobacterial ocular infections- comparing the clinical and microbiological characteristics between *Mycobacterium abscessus* and *Mycobacterium massiliense*. PLoS One. 2015;10:e0116236.
61. Ali MJ. Pediatric acute dacryocystitis. Ophthal Plast Reconstr Surg. 2015;31:341–7.
62. Ganguly A, Ali MJ, Padmaja K, et al. Bacteremia following nasolacrimal duct probing: is there a role of pre-operative antibiotic prophylaxis? Ophthal Plast Reconstr Surg. 2016;32:90–2.
63. Martin G, Pon A, Robert M, et al. Acute dacryocystitis and infectious mononucleosis: an association not to be missed. J Fr Ophthalmol. 2015;38:e245–6.
64. Mishra DK, Ali MJ, Bhargava A, et al. Acute dacryocystitis as a presenting sign of chronic lymphocytic leukemia. Clin Exp Ophthalmol. 2016;44:67–9.
65. Lombardi D, Mattavelli D, Accorona R, et al. Acute dacryocystitis with empyema of the lacrimal sac. Is immediate endoscopic dacryocystorhinostomy justified? Otolaryngol Head Neck Surg. 2014;150:1071–7.
66. Kamal S, Ali MJ, Pujari A, et al. Primary powered endoscopic dacryocystorhinostomy in the setting of acute dacryocystitis and lacrimal abscess. Ophthal Plast Reconstr Surg. 2015;31:293–5.
67. Chisty N, Singh M, Ali MJ, et al. Long-term outcomes of powered endoscopic dacryocystorhinostomy in acute dacryocystitis. Laryngoscope. 2016;126:551–3.
68. Jain S, Ganguly A, Singh S, et al. Primary non-endoscopic endonasal versus delayed external dacryocystorhinostomy in acute dacryocystitis. Ophthal Plast Reconstr Surg. 2016;33(4):285–8. (Epub)
69. Kamal S, Ali MJ, Nair AG. Outcomes of endoscopic dacryocystorhinostomy: experience of a fellowship trainee at a tertiary care center. Indian J Ophthalmol. 2016;64:648–53.

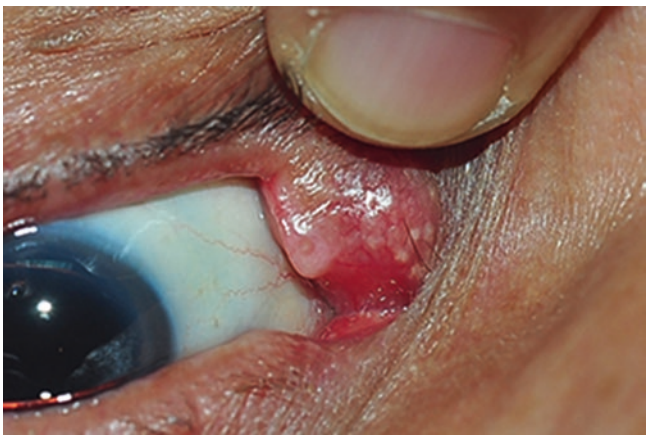


Fig. 17.1 Clinical presentation of canaliculitis

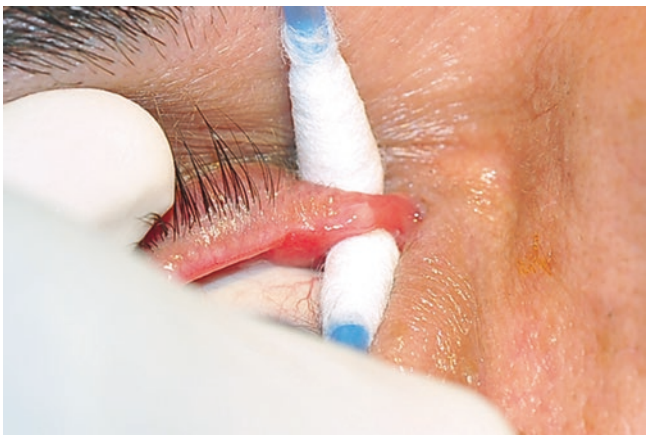


Fig. 17.4 Early phase of milking canalicular contents

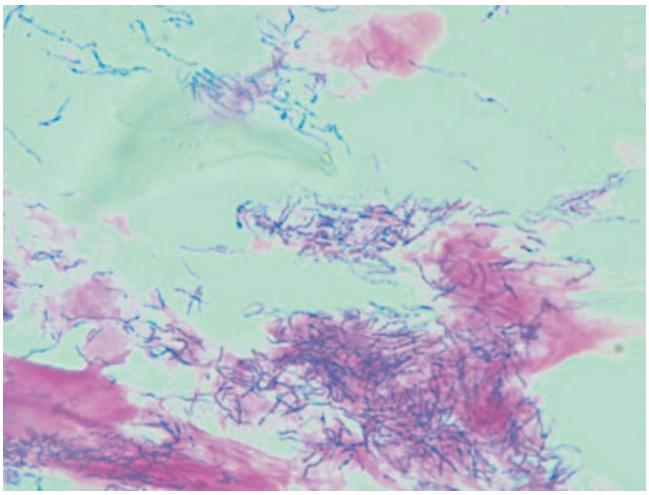


Fig. 17.2 Microbiological smear of *Actinomyces*

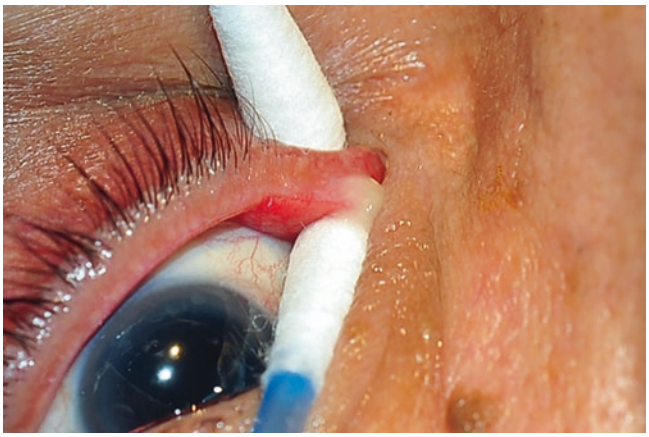


Fig. 17.5 Late phase of canalicular milking

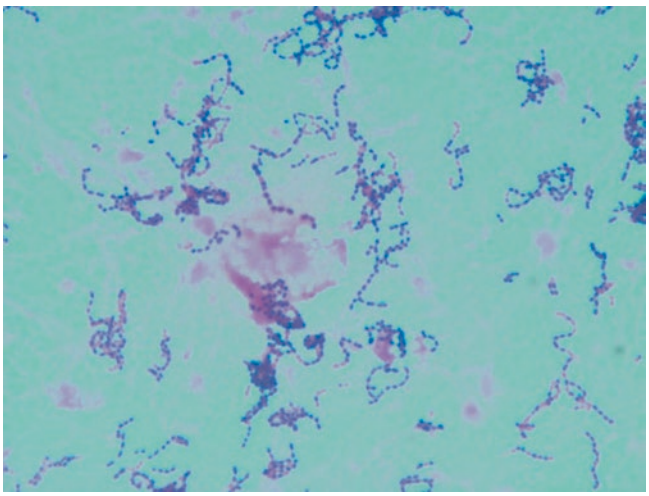


Fig. 17.3 Gram-positive organisms on a smear

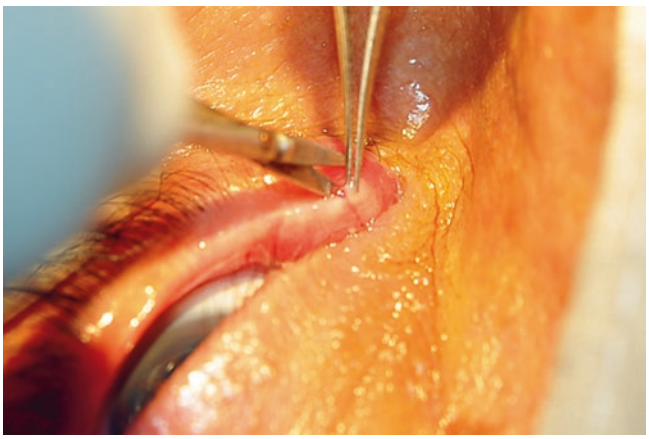


Fig. 17.6 Punctoplasty

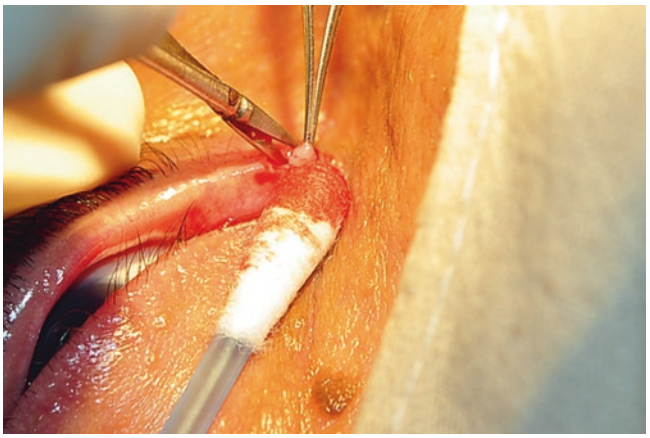


Fig. 17.7 Completed punctoplasty

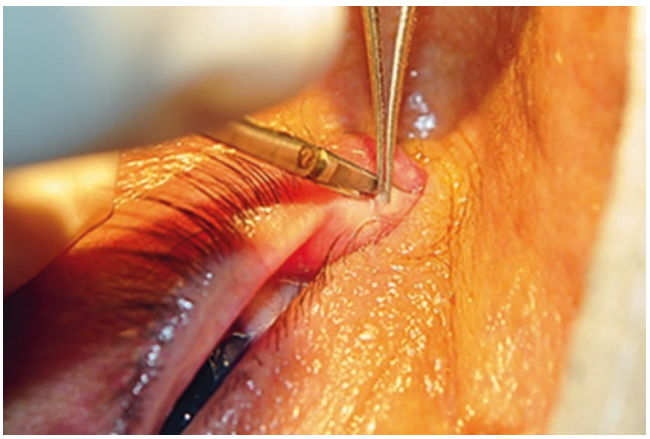


Fig. 17.8 Canaliculotomy

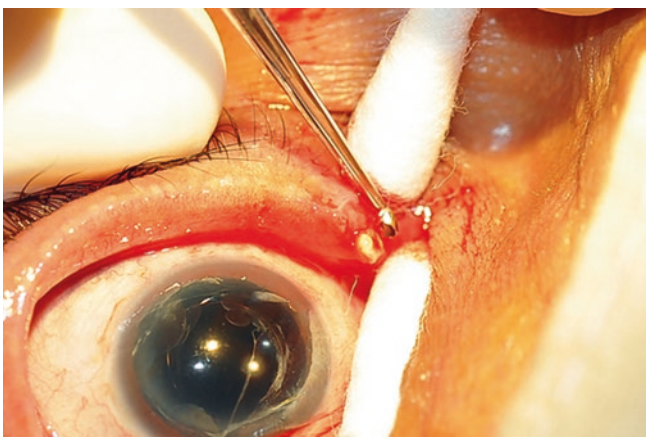


Fig. 17.9 Pouting of concretions following canaliculotomy

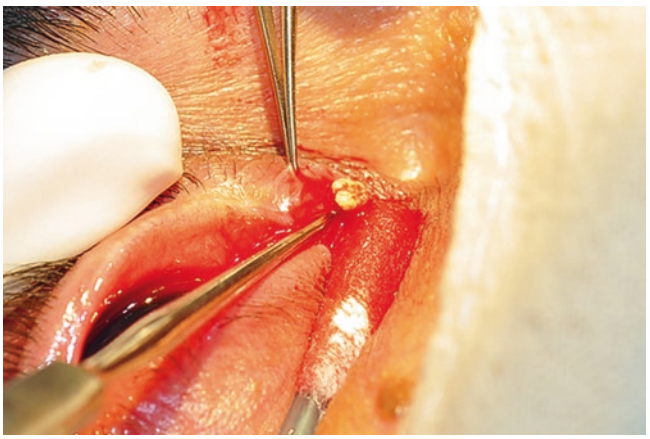


Fig. 17.10 Canalicular curettage

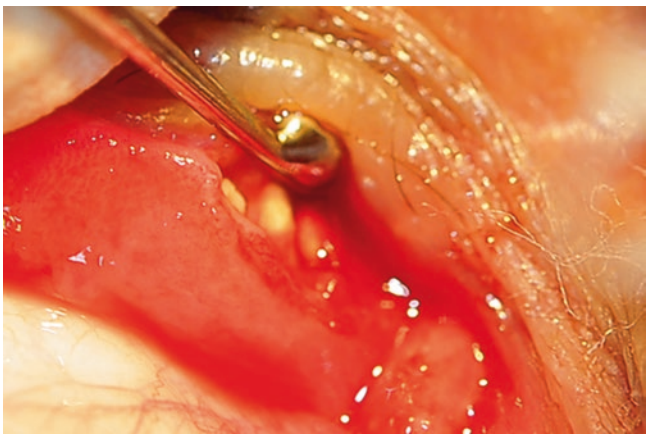


Fig. 17.11 Remnant concretions in ampulla and proximal canalicular floor

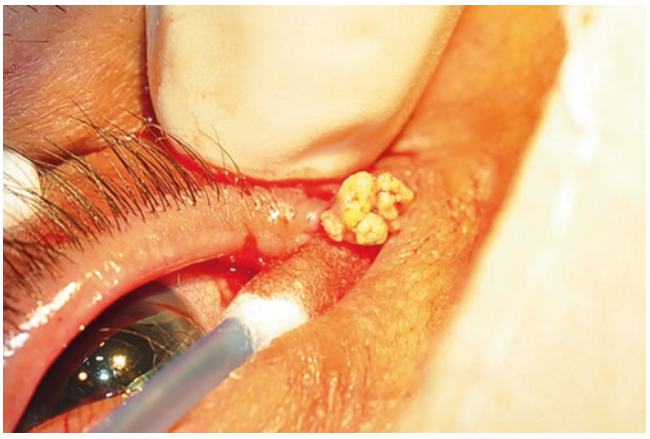


Fig. 17.12 Complete expression of concretions

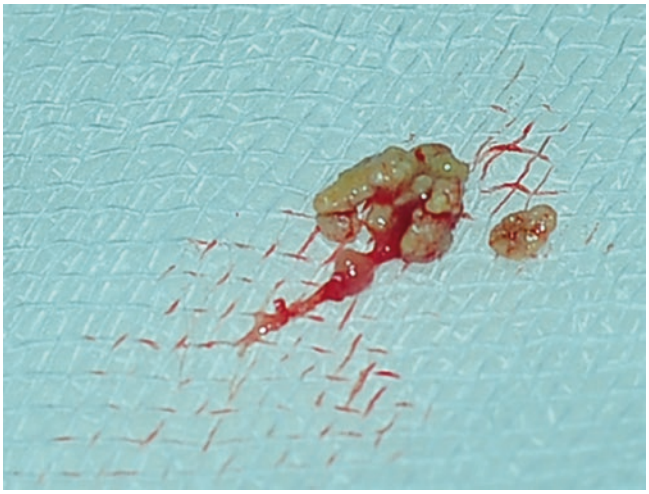


Fig. 17.13 Canalicular concretions on a sterile surface

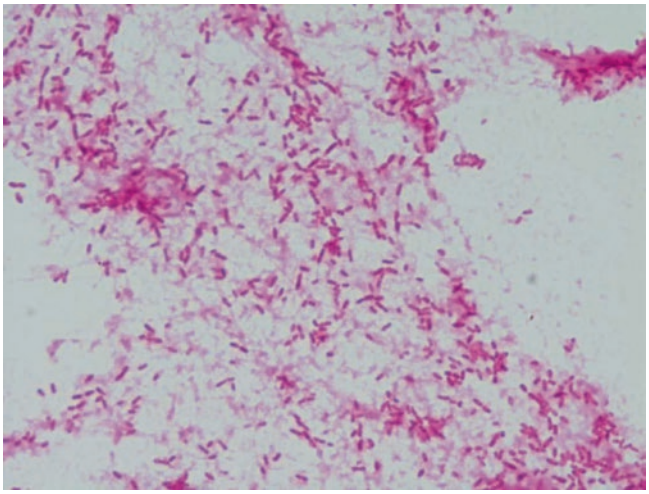


Fig. 17.16 GNB on a smear

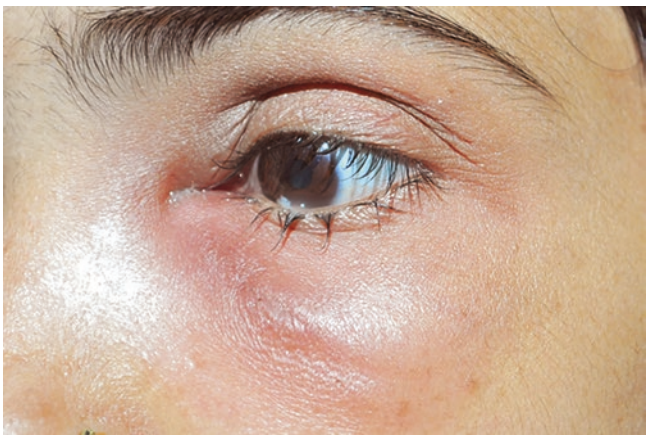


Fig. 17.14 Clinical presentation of acute dacryocystitis

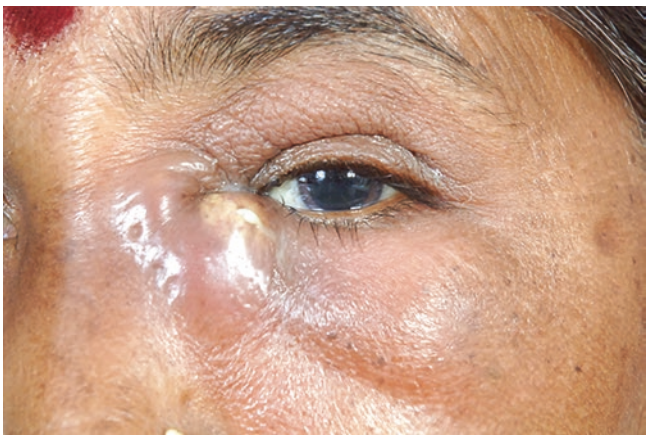


Fig. 17.17 Acute dacryocystitis with lacrimal abscess

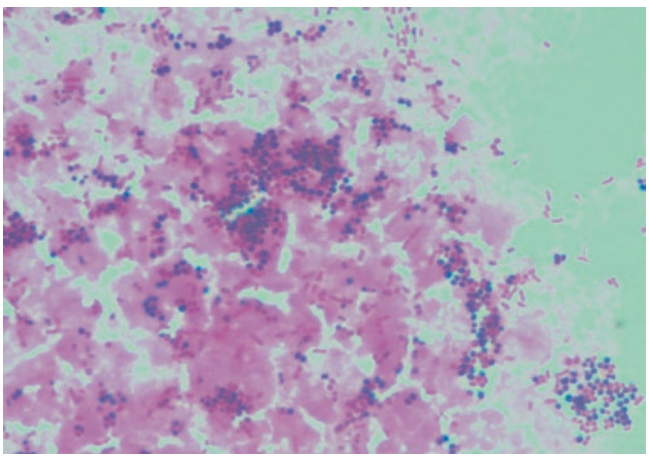


Fig. 17.15 Mixed infection with GPC and GNB

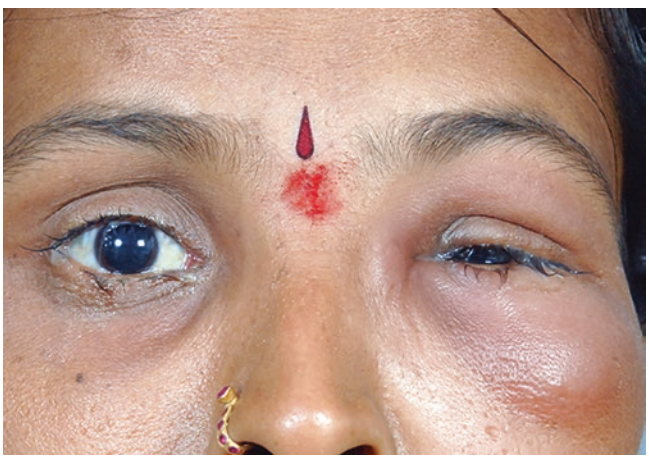


Fig. 17.18 Acute dacryocystitis with orbital cellulitis

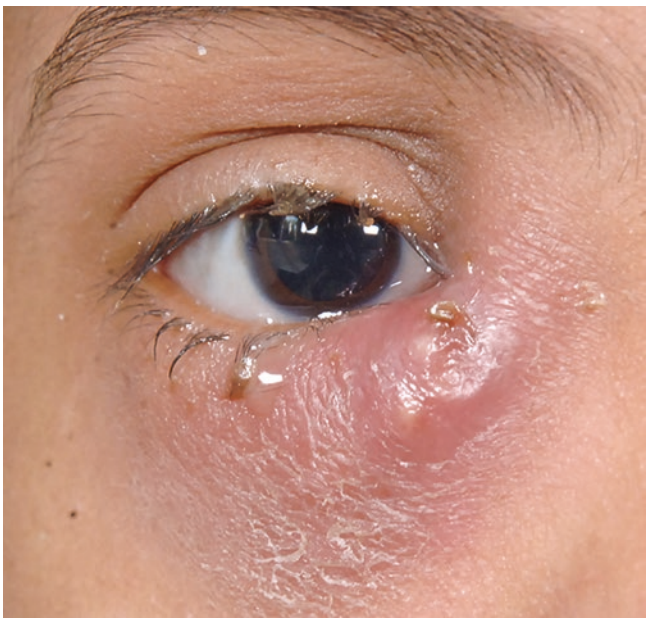


Fig. 17.19 Acute dacryocystitis with lacrimal fistula

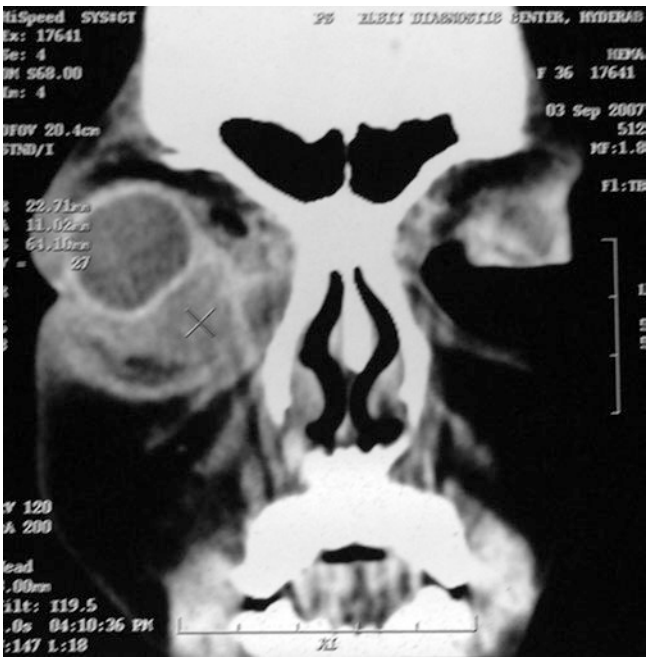


Fig. 17.20 Coronal CT photograph of right orbital abscess associated with acute dacryocystitis

Primary External Dacryocystorhinostomy

18

Mohammad Javed Ali

Introduction

Dacryocystorhinostomy or DCR is among the common oculoplastic surgeries performed for managing epiphora due to nasolacrimal duct obstruction [1, 2]. It is a bypass procedure that creates an anastomosis between the lacrimal sac and the nasal mucosa via a bony ostium. It may be performed through an external skin incision or intranasally with or without endoscopic visualization. This chapter will discuss the indications, goals, and simple techniques for a successful outcome of an external DCR.

Goals

There are two clear goals of a DCR procedure. One is to make a large bony ostium into the nasal cavity and that remains so. Second is to have a mucosal-lined anastomosis. Since both these purposes are equally well served by an external route, it can be one of the approaches with a predictable and a high success rate.

Indications

(a) Persistent congenital nasolacrimal duct obstructions unresponsive to previous therapies
(b) Primary acquired nasolacrimal duct obstructions (PANDO) [3]
(c) Secondary acquired nasolacrimal duct obstructions (SALDO) [4]

M. Javed Ali, F.R.C.S
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

Preoperative Requisites

(a) Confirmation of the diagnosis and clinical findings
(b) Hemoglobin levels
(c) Bleeding and clotting profiles
(d) Blood pressure measurement
(e) Random blood sugars
(f) Additional general anesthesia investigations when required

Steps of the Surgery

Anesthesia

The surgery can be done under general anesthesia or local anesthesia [5]. The latter is the most commonly employed modality. Local anesthesia is given by both infiltration and topical application. For infiltration 2% lignocaine with 0.5% bupivacaine with or without adrenaline is used. Infratrochlear nerve that supplies the lacrimal apparatus is blocked first. The non-dominant hand marks the supraorbital notch and the needle is inserted into the lateral edge of the medial third of the eyebrow and advanced to just medial to medial canthus and 1–2 cc of the drug is injected. The tissues along the anterior lacrimal crest are infiltrated subcutaneously, and the needle enters deeper at about 3 mm medial to medial canthus, and without withdrawing the needle, the drug is injected into deeper tissues up to periosteum both superiorly and inferiorly. A drop of topical proparacaine is placed in conjunctival cul-de-sac for intraoperative comfort. Nasal mucosa is sprayed with 10% lignocaine 1–2 puffs followed by packing with 4% lignocaine and 0.5% xylometazoline. Alternatively topical lignocaine spray along with topical xylometazoline can be used without packing the nasal cavity. The forceps should guide the medicated cottonoid from the external nare superiorly and backward so that it reaches the middle meatus, the site of ostium (Fig. 18.1).

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_18

Incision

Though various incisions have been described, the authors prefer the commonly used curvilinear incision of about 10–12 mm in length, 3–4 mm from the medial canthus along the anterior lacrimal crest (Fig. 18.2).

Sac Dissection

Blunt dissection is carried on to reach the periosteum. A Freer elevator is used to separate the periosteum from the bone and reflect it laterally along with the lacrimal sac to expose the lacrimal fossa. It is preferable to preserve the medial canthal tendon and dissected only when needed (Fig. 18.3).

Bony Ostium Creation

Once the lacrimal fossa is exposed, bone punching should be started at the junction of lamina papyracea of the ethmoid and lacrimal bone. The Kerrison bone punch should be gently inserted between the bone and the nasal mucosa and the ostium sequentially enlarged (Figs. 18.4 and 18.5). The extent of the ostium which the authors follow is:

(a) Anteriorly till the punch cannot be inserted between the bone and the nasal mucosa
(b) Posteriorly till removal of aerated ethmoid
(c) Superiorly till 5 mm above the common canaliculus
(d) Inferiorly till the nasolacrimal duct is de-roofed

Flap Formation

The first step is to create sac flaps. To do this Bowman's probe is passed through the lower punctum and bent in such a way to tent the sac as posterior as possible to create a large anterior and small posterior flap. Alternatively fluorescein-stained viscoelastic can be injected from the upper punctum to dilate the sac and help in creating flaps. Using the probe as guide, an "H"-shaped incision is made with the help of a number 11 or 15 blade right across the sac from the fundus to the nasolacrimal duct. Flaps are raised and the posterior one is cut (Fig. 18.6).

The second step is to fashion nasal mucosal flaps. With the help of number 11 blade, incisions are made in the nasal mucosa along the bony ostium except anteriorly to have a hinged flap. The large anterior flap is raised and the posterior small residual flap is cut (Fig. 18.7). Alternatively both the flaps can be sutured, but no significant difference in the success has been noted in doing this either way [6, 7].

Flap Anastomosis

It is important to appose nasal mucosal and sac flap edge to edge. Excess nasal mucosa can be excised in a controlled manner so as to avoid sagging of the flaps that may compromise the tear drainage later (Fig. 18.8). In case of overriding, nasal mucosal overriding is preferable, or alternatively one can tent the flaps and suture to the overlying orbicularis.

Wound Closure

Once flaps are secured, the orbicularis is sutured back with 6–0 Vicryl followed by skin with 6–0 silk (Fig. 18.9).

Tips for Hemostasis

(a) Good preoperative assessment to rule out bleeding diathesis.
(b) Preoperative blood pressure assessment.
(c) The use of adrenaline or oxymetazoline patties along with local anesthetics provided there are no medical contraindications.
(d) Good nasal decongestion before beginning.
(e) Raising the head end of the table.
(f) Avoid known blood vessels.
(g) Well-powered suction.
(h) Judicious use of cautery.
(i) Keep materials like gel foam or bone wax in the armamentarium.

Adjunctive Measures (Use of Mitomycin C and Intubation)

Mitomycin C in a concentration of 0.02% is used if there are intra-sac synechiae and soft tissue scarring like in failed DCRs and in the presence of a complicated surgery. Intubation is also advisable for similar indications, but in addition it is also used in the presence of canalicular problems and inadequate flaps [8] (Figs. 18.10, 18.11, and 18.12).

Immediate Postoperative Steps

Once wound is closed, reassure the patient that the surgery went fine. Nasal packing is optional. When needed, it is important to note that the purpose of this pack is for hemostasis only, so deeper packing like preoperative one should be avoided for it risks damaging the mucosal flaps. The patient is administered analgesics. Oral antibiotics are optional and can be prescribed based on the surgeon's discretion.

Follow-Up

After the surgery, patient is seen on the first postoperative day. The nasal pack if any is gently removed and hemostasis assessed. The wounds are cleaned with 5% Betadine, and the patient is advised oral antibiotics and analgesics, topical antibiotics and steroids, and nasal decongestants. One week postoperative the sutures are removed, oral medications discontinued, topical steroids tapered, and nasal medications continued for two more weeks. The patient is reviewed at 4 weeks for stent removal, if any.

Complications

Complications following external DCR surgery can be divided as early (1–4 weeks), intermediate (1–3 months), and late (>3 months) [1–3].

Early complications include wound dehiscence (Fig. 18.13), wound infection, tube displacement (Fig. 18.14), excessive rhinostomy crusting (Fig. 18.15), and intranasal synechiae.

Intermediate complications include granulomas at the rhinostomy site, tube displacements, intranasal synechiae, punctal cheese wiring (Fig. 18.16), prominent facial scar, and non-functional DCR.

Late complications include rhinostomy fibrosis, webbed facial scar, medial canthal distortion, and failed DCR.

Outcomes

A successful DCR is one where there is both anatomical and functional patency. The passage should be patent on irrigation and the patient should be free of symptoms. The reported success rates of external DCR in literature vary between 85 and 99% [1–3, 9–11]. These rates were presumed to be much higher as compared to endonasal or transcanalicular, but increasingly literature shows comparable results between both the external and endoscopic approaches [12–15].

Updates (2015–2016)

Technique Modifications and Outcomes

External DCR has undergone little change from the one described by Dupuy-Dutemps in the beginning of the century. The literature of the last 2 years has seen modifications in terms of incisions, flap techniques, and the use of piezo technology. A visible scar following an external DCR has been a much debated issue. There were several reports showing superiority of "V"- or "W"-shaped incisions over the conventional ones [16, 17]. A major review on DCR scars concluded that it still remains a cause of concern from a patient's perspective [18]. It is important to decide on incisions based on the age and ethnicities of patient. Uniform long-term outcome analysis of scars is lacking [18], and it was suggested that the Stony Brook Scar Evaluation Scale [19] may be useful for researchers planning such studies.

Techniques of flap fashioning were modified to form a "U"-shaped nasal mucosal flap that was then sutured to the orbicularis muscle directly with good outcomes in complicated nasolacrimal obstructions [20]. Some others fashioned three flaps (anterior, superior, and inferior) based on the sites of granuloma formation and reported excellent outcomes [21]. The earlier debate on the suturing of only anterior or both anterior and posterior flaps was advanced [22, 23]. There is an increasing evidence now to suggest that it does not matter either ways in terms of outcomes and the decision be based on the surgeon's comfort [22, 23].

The use of ultrasound for bone emulsification is well established in neurosurgery and to some extent in endoscopic DCRs. It was recently reported to have good outcomes in external DCRs as well [24]. Its potential to avoid soft-tissue trauma can be well suited specially for novice surgeons.

Very long-term outcomes (mean 61.7 ± 5.1 months) of external DCR have been reported to be beyond 80% in a large series [25]. Patient-reported outcomes are encouraging with majority of patients expressing high levels of satisfaction following an external DCR [25, 26].

Complications

Temporary lagophthalmos following an external DCR is a known complication which is presumed to occur secondary to damage to the superficial branches of the temporal or zygmomatic nerves. There is an increasing evidence of it occurring in up to 30% of patients who may either present with lagophthalmos or asymmetric blink [27]. It would be interesting to explore why only some develop this complication so that adequate guidelines can be issued on how to avoid this.

Very late complication of an external DCR has been reported in the form of a dacryocystocele after a successful surgery [28]. This was presumed to be a spectrum of the sump syndrome. However it is important to differentiate acquired dacryocystoceles in adults from diverticula [28]. Paranasal sinus mucoceles (fronto-ethmoidal) can present very late after a successful DCR and can be secondary to iatrogenic trauma to the sinus recess or a lateralized middle turbinate obstructing the recess [29]. This can be successfully managed by draining the mucocele and restoring the sinus pathways.

Trainee External DCRs

Recent evidence suggests that inadequate osteotomy and inappropriate location of the ostium were the common reasons of failure when a trainee performs an external DCR as compared to cicatricial obstruction of the ostium for the consultants [30]. However, the trainees here were senior oculoplastic fellows and this may not reflect entirely on the causes in the initial stages of training.

References

1. Tarbet KJ, Custer PL. External dacryocystorhinostomy. Surgical success, patient satisfaction and economic costs. Ophthalmology. 1995;102:1065–70.
2. Welham RA, Henderson PH. Results of dacryocystorhinostomy. Analysis of causes for failures. Trans Ophthalmol Soc UK. 1973;93:601–9.
3. Linberg JV, McCormick SA. Primary acquired nasolacrimal duct obstruction: a clinico-pathological report. Ophthalmology. 1986;93:1055–62.
4. Bartley GB. Acquired lacrimal drainage obstructions: an etiologic classification system, case reports and review of literature. Ophthal Plast Reconstr Surg. 1992;8:237–49.
5. Olver J. External dacryocystorhinostomy. In: Colour atlas of lacrimal surgery. 1st ed. Oxford: Butterworth-Hienemann; 2006.
6. Baldeschi L, Macandie K, Hintschich CR. The length of unsutured mucosal margin in external dacryocystorhinostomy. Am J Ophthalmol. 2004;138:840–4.
7. Turkcu FM, Oner V, Tas M, Alakus F, Iscan Y. Anastomosis of both posterior and anterior flaps or only anterior flaps in external dacryocystorhinostomy. Orbit. 2012;31:383–5.
8. McNab A. Dacryocystorhinostomy. In: Manual of orbital and lacrimal surgery. 2nd ed. Oxford: Butterworth-Hienemann; 1998.
9. Rosen N, Sharir M, Moverman DC, Rosner M. Dacryocystorhinostomy with silicone tubes: evaluation of 253 cases. Ophthalmic Surg. 1989;20:115–9.
10. Dresner SC, Klussman KG, Meyer DR. Outpatient dacryocystorhinostomy. Ophthalmic Surg. 1991;22:222–4.
11. Emmerich KH, Busse H, Meyer-Rusenberg HW. Dacryocystorhinostomia externa. Ophthalmologe. 1994;91:395–8.
12. Cokkeser Y, Evereklioglu C, Er H. Comparative external versus endonasal dacryocystorhinostomy: results in 115 patients. Otolaryngol Head Neck Surg. 2000;123:488–91.
13. Malhotra R, Wright M, Olver JM. A consideration of the time taken to do a dacryocystorhinostomy surgery. Eye. 2003;17:691–6.
14. Dolman PJ. Comparison of external dacyrocystorhinostomy with non-laser endonasal dacryocystorhinostomy. Ophthalmology. 2003; 110:78–84.
15. Hartikainen J, Grenman R, Puukka P, Seppa H. Prospective randomized comparison of external dacyrocystorhinostomy and endonasal laser dacryocystorhinostomy. Ophthalmology. 1998;105:1106–13.
16. Ng DS, Chan E, Yu DK, et al. Aesthetic assessment in periciliary 'V' incisions versus conventional external dacryocystorhinostomy in Asians. Graefes Arch Clin Exp Ophthalmol. 2015;253:1783–90.
17. Dirim B, Sendul SY, Demir M, et al. Comparison of modifications in flap anastomosis patterns and skin incision types for external dacryocystorhinostomy: anterior only flap anastomosis with W skin incision versus anterior and posterior flap anastomosis with linear skin incision. Sci World J. 2015;2015:170841.
18. Ng DS, Chan E. Techniques to minimize skin incision scar for external dacryocystorhinostomy. Orbit. 2015;35:42–5.
19. Singer AJ, Arora B, Dagum A, et al. Development and validation of novel scar evaluation scale. Plast Reconstr Surg. 2007;120:1892–7.
20. Caglar C, Yener HI, Gul A, et al. The modified technique of external dacryocystorhinostomy in the management of complicated nasolacrimal duct obstruction. J Craniofac Surg. 2016;27:416–9.
21. Kakizaki H, Kitaguchi Y, Takahashi Y, et al. Prevention of reobstruction in watery eye treatment: three flap technique in external dacryocystorhinostomy. Graefes Arch Clin Exp Ophthalmol. 2016;254:2455–60.
22. Sharma HR, Sharma AK, Sharma R. Modified external dacryocystorhinostomy in primary acquired nasolacrimal duct obstruction. J Clin Diagn Res. 2015;9:NC01–5.
23. Takahashi Y, Mito H, Kakizaki H. External dacryocystorhinostomy with or without double mucosal flap anastomosis: comparison of surgical outcomes. J Craniofac Surg. 2015;26:1290–3.
24. Czyz CN, Fowler AM, Dutton JJ, et al. Peizosurgery in external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2017;33:69–71.
25. Alnawaiseh M, Mihailovic N, Weineke AC, et al. Long-term results of external dacryocystorhinostomy in the age of transcanalicular microendoscopic techniques. J Ophthalmol. 2016;2016:5918457.
26. Heichel J, Hassan T, Bredehorn-Mayer T, et al. External dacryocystorhinostomy- analysis of patient material of the university hospital Halle from 2000 to 2011. Klin Monatsbl Augenheilkd. 2016;233:29–37.
27. Haefliger O, Meienberg O, Pimentel de Figueiredo AR. Temporary medial upper eyelid lagophthalmos after external dacryocystorhinostomy. Klin Monatsbl Augenheilkd. 2016;233:406–8.
28. Galindo-Ferreriro A, El-Khamary SM, Al-Katan H, et al. Dacryocystocele after successful external dacryocystorhinostomy. A variant of the lacrimal sump syndrome. Ophthal Plast Reconstr Surg. 2016;32:e141–2.
29. DeParis SW, Goldberg AN, Indaram M, et al. Paranasal sinus mucocele as a late complication of dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;33(3S Suppl 1):S23–4. (Epub)
30. Sullivan L, Fearnley T, Al-Maskari A, et al. External dacryocystorhinostomy in consultants and fellows–a comparison of the causes of failure. Hippokratia. 2015;19:216–8.

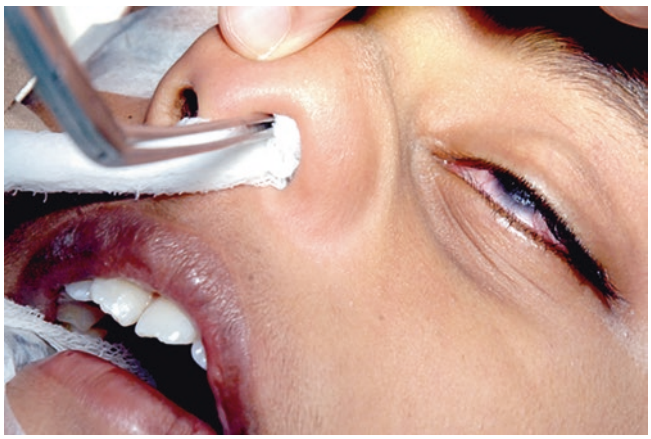


Fig. 18.1 Preoperative nasal packing

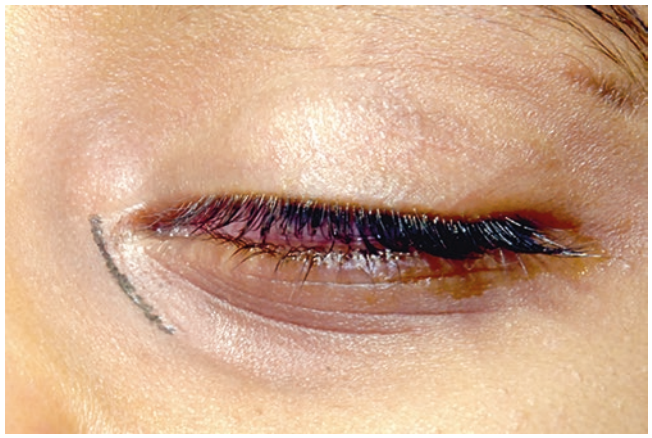


Fig. 18.2 A typical curvilinear incision

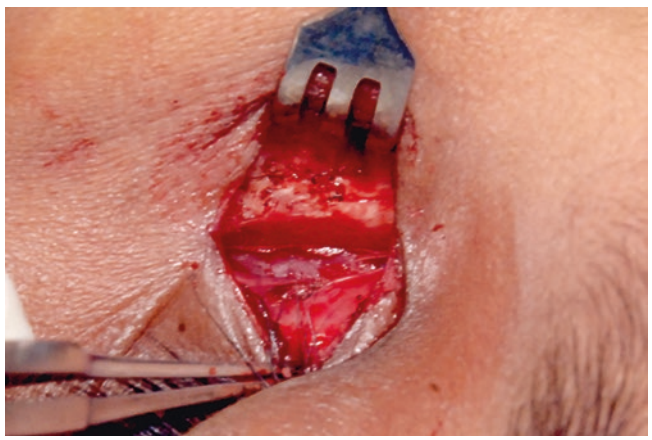


Fig. 18.3 Sac dissected laterally to expose the bony lacrimal fossa

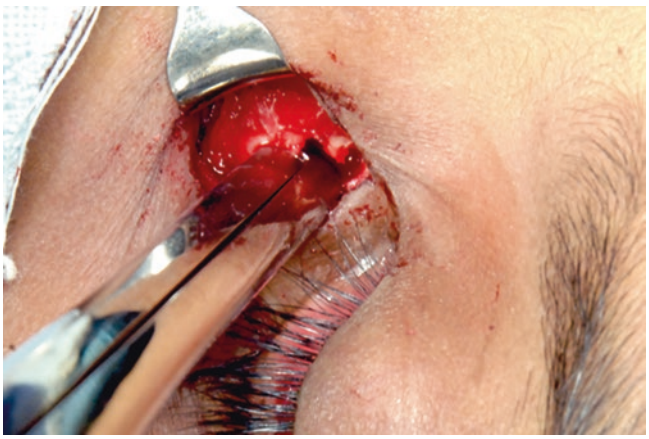


Fig. 18.4 Kerrison punch being used to create a bony ostium

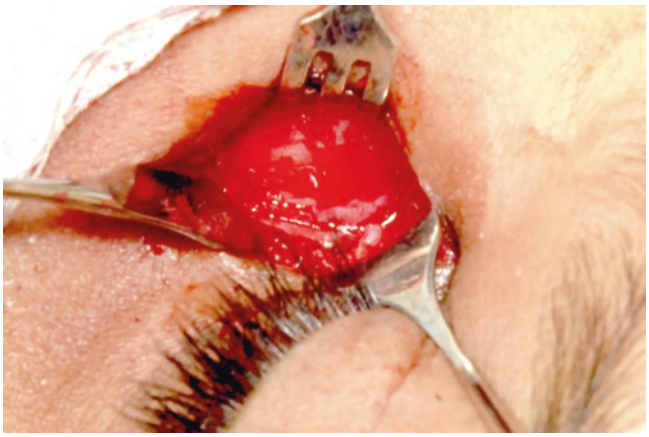


Fig. 18.5 A large bony ostium exposing the nasal mucosa

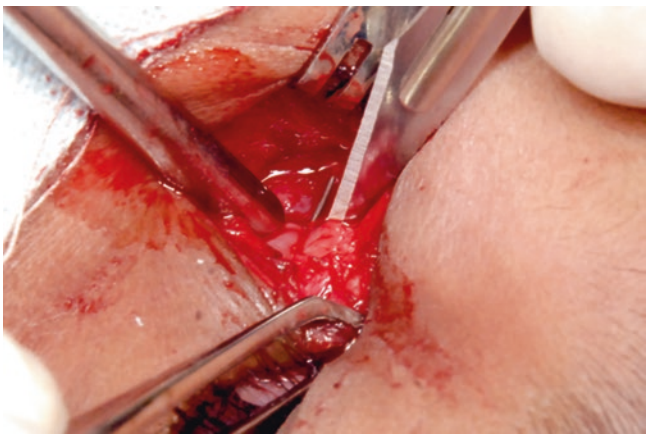


Fig. 18.6 Lacrimal sac incision being taken by an 11 number blade using the probe as a guide

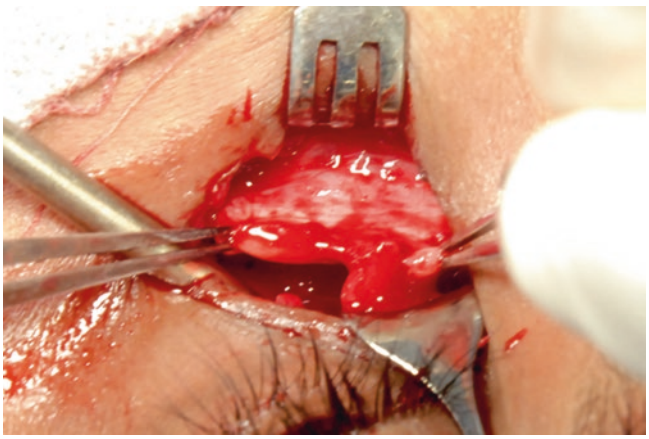


Fig. 18.7 Raising a large nasal mucosal flap

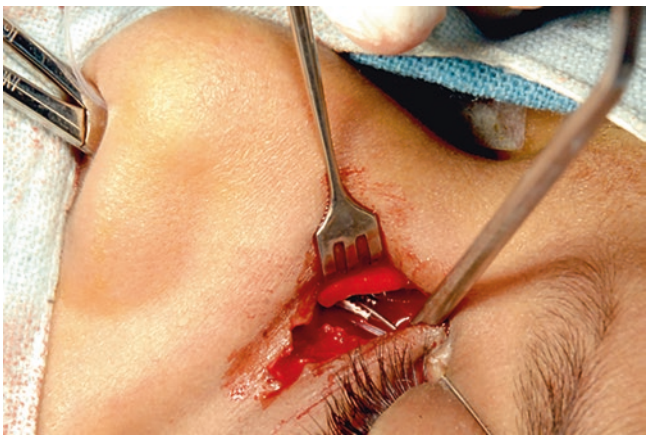


Fig. 18.10 Intubation: upper canaliculi intubated. The bodkins are being retrieved by a transnasal artery forceps

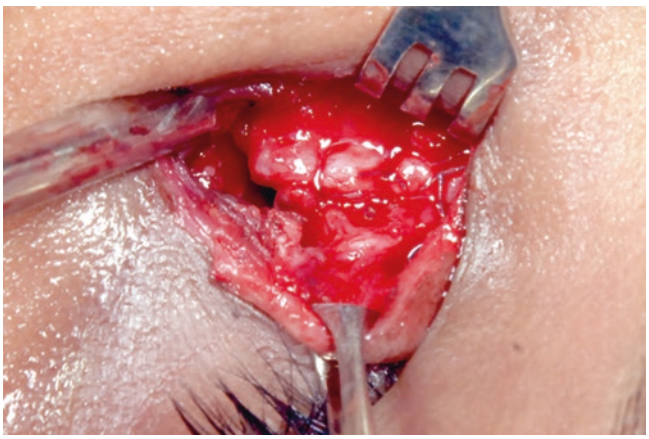


Fig. 18.8 Taut flap anastomosis

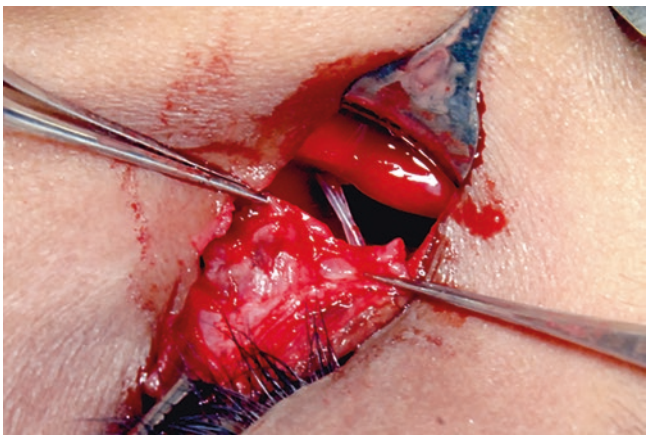


Fig. 18.11 Intubation: tubes in place before flap anastomosis

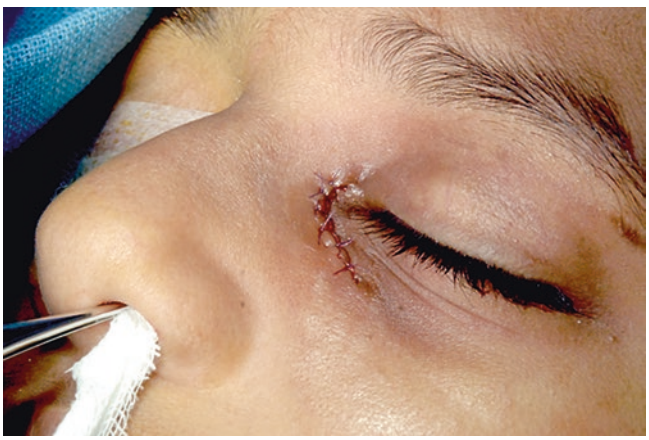


Fig. 18.9 Sutured surgical wound

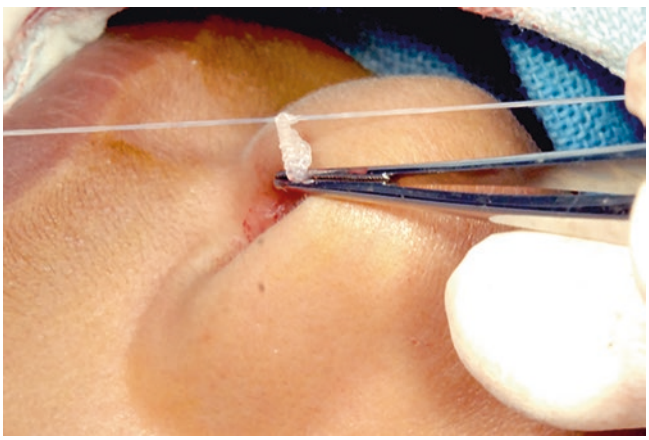


Fig. 18.12 Intubation: tubes being secured in the nose

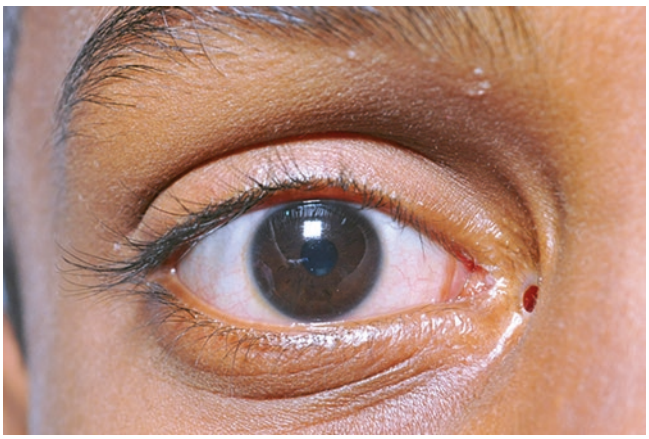


Fig. 18.13 Early wound dehiscence following an external DCR

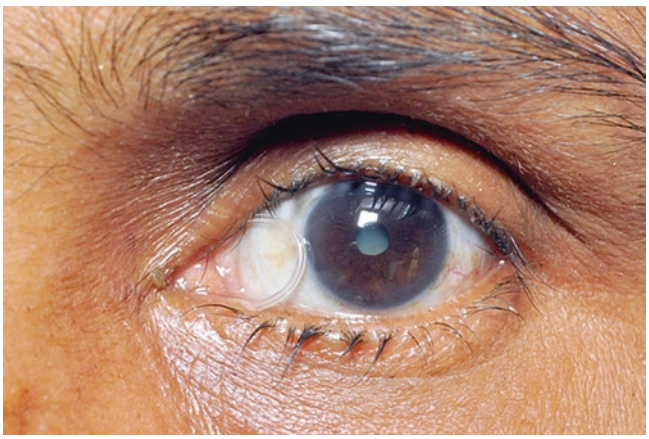


Fig. 18.14 An example of stent prolapsed

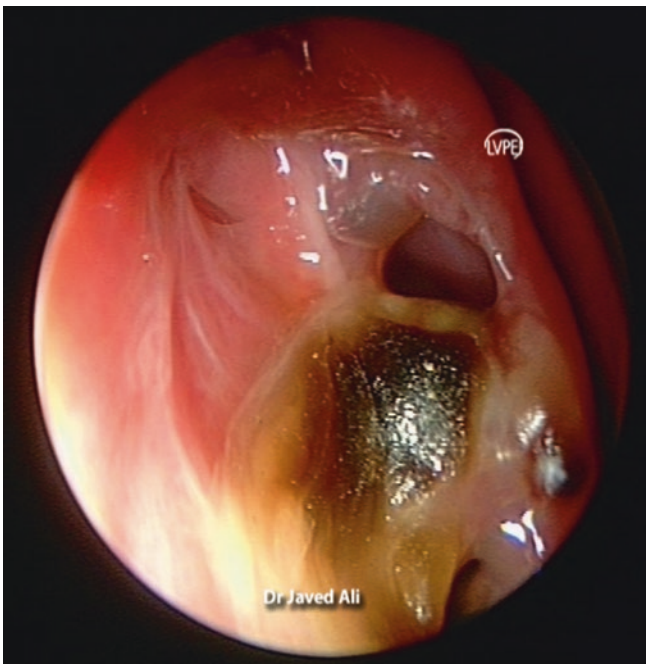


Fig. 18.15 Endoscopic view of rhinostomy scarring

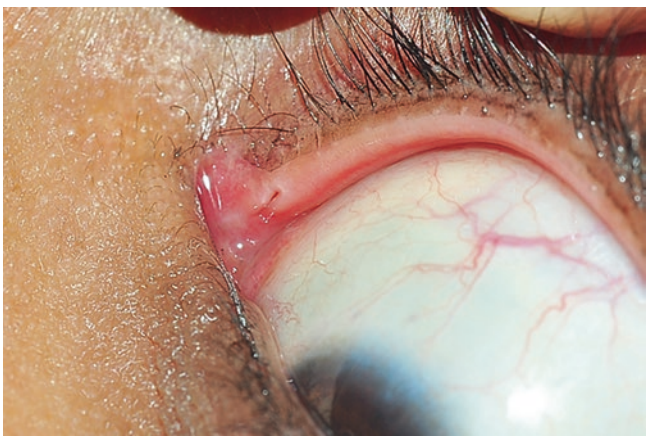


Fig. 18.16 Punctal cheese wiring

Aesthetic External DCR: The Subciliary Approach

19

Milind N. Naik

Introduction

External dacryocystorhinostomy (Ex-DCR) is considered as the gold standard for surgical correction of primary acquired nasolacrimal duct obstruction [1]. It can be performed safely in patients under local anesthesia, with minimal blood loss and economic cost, and has a high success rate of over 90% in most published series [1, 2]. Despite superior success rate, the inevitable downside of Ex-DCR has been an external skin scar, which has led to the evolution of endonasal and several other non-incisional techniques [3–7]. The success rates with endonasal DCR have been reported to range from 59% to 100% in various published series with mechanical endoscopic endonasal DCR being more successful than endolaser DCR [5]. The advantages of endonasal DCR have been reported to be lack of a cutaneous scar, less disruption of medial canthal anatomy or lacrimal pump function, decreased operative time, early postoperative rehabilitation, and the ability to simultaneously treat nasal pathologies [6]. However, the disadvantages of the technique include the need for specialized instruments, increased cost, familiarity with nasal anatomy, difficulty in the treatment of canalicular pathologies, need for an expert assistant, and a steep learning curve [6]. Although there have been promising advances in the field of endocanalicular and endonasal DCR surgery, the high success rate of Ex-DCR continues to be confirmed in the literature [8].

In an attempt to avoid an external incision as well as the endonasal approach, two reports have proposed a transconjunctival approach to DCR surgery [9, 10]. In 2003, Adenis and Robert [9] published a series of 11 patients where DCR performed via a retrocaruncular approach yielded 82% success. Kaynak-Hekimhan and Yilmaz [10] reported a transconjunctival approach to perform scarless DCR in 25 eyes. The authors reported surgical challenges such as orbital fat prolapse and limited access during enlargement of the ostium. The authors needed to convert to external dacryocystorhinostomy in six (34%) patients due to technical difficulties in their initial cases [10].

It is generally agreed that to maximize the success of any DCR, the osteotomy must be large and the sac mucosa should be anastomosed with the nasal mucosa [11–13]. Moreover, published literature recommends flap formation techniques over the endoscopic approaches [14]. An ideal DCR technique, therefore, would be one that allows a large bony ostium and good mucosal anastomosis without an external scar.

Skin Incisions for External DCR

The modified Lynch Incision or the Straight Incision

Since the 1920s when Dupuy-Dutemps and Bourguet [15] published their Ex-DCR technique, the surgery has been performed, with slight variations, with the same type of a linear vertical incision in the nasal skin medial to the angular vein called the straight or the modified Lynch incision (Fig. 19.1).

The Nasojugal or the Angular Incision

This is a curvilinear incision on the anterior lacrimal crest and is known to allow easy access to the lacrimal sac [16] (Fig. 19.2).

Incisions on the Lower Eyelid

Harris et al. [17] in 1989 was the first to demonstrate that external DCR can also be done with a horizontal incision placed on a lower lid crease. This incision extended 10 mm

M.N. Naik, M.D.
Govindram Seksaria Institute of Dacryology,
L. V. Prasad Eye Institute, Hyderabad, India
e-mail: milind@drmilindnaik.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_19

medial to the medial canthus and downward in the first lower eyelid crease. After his first description of this approach in 1989, it was further studied and reported by Putterman [18] in 1994. Putterman also reported a mechanical retraction system. Kim et al. [19] in 2005 used a customized approach where the site of the incision varied. It was either placed in the most prominent wrinkle or in the relaxed skin tension line (4 mm below). Akaishi et al. [20] in 2011 reported good functional and cosmetic outcomes of lower eyelid crease incision. Although there are differences in the location and the extent of incision in all these reports, the common theme is to perform an external dacryocystorhinostomy through an inconspicuous scar. Harris et al. [17] reported their incision to extend 10 mm medial to the medial canthus and downward in the first lower eyelid crease. An actual subciliary incision was only used in children without a prominent eyelid crease. The above studies retrospectively analyzed the scars and reported it to be a cosmetically superior approach. The lower eyelid incision within the relaxed skin tension line as reported by Akaishi et al. [20] most closely resembles our approach of the subciliary incision.

The Subciliary Incision

The eyelid subciliary incision is an established approach for several orbital and eyelid procedures and is known to provide excellent cosmesis [21, 22]. We explored the possibility of a subciliary incision to perform an Ex-DCR and evaluate whether the cosmetic benefits of a subciliary incision can be combined with the high success rate of an Ex-DCR (Fig. 19.3).

Surgical Technique of Subciliary DCR

Surgery is performed under general or local anesthesia as per patient preference. All patients receive local anesthetic infiltration (2% lignocaine admixed with 1:100,000 adrenaline) along the anterior lacrimal crest and the medial half of pretarsal lower eyelid. The nasal cavity is packed with three cotton-tipped applicators soaked with local anesthetic. A 10- to 15-mm subciliary incision is placed along the medial half of lower eyelid, reaching up to the medial canthus (Fig. 19.4a). The incision is placed 1–2 mm below the lash line (subciliary) and not within the eyelid crease. It extends from the punctum medially to mid-pupillary line laterally (Fig. 19.4a). Subcutaneous dissection is then carried out inferomedially, to reach the anterior lacrimal crest (Fig. 19.4b). At the level of the anterior lacrimal crest, the orbicularis fibers are gently separated, to expose the periosteum over the anterior lacrimal crest (Fig. 19.4c). The remainder of the surgical procedure is performed like a standard Ex-DCR, including creation of the ostium (Fig. 19.4d, e) and anterior mucosal flaps (Fig. 19.4f, g). Upon completion of the flap anastomosis (Fig. 19.4h), the orbicularis and skin are apposed with interrupted 6–0 polyglactin sutures (Fig. 19.4i).

Routine postoperative wound care and medications are prescribed. Postoperatively, the patients are examined on day 1, 1 week, 6 weeks, 3 months, and thereafter every 3–6 months. One day, 1 week, and final postoperative photographs of patients undergoing dacryocystorhinostomy through the subciliary approach are shown in Fig. 19.5. One patient underwent a bilateral subciliary DCR with good outcomes (Fig. 19.6).

Outcomes

Our group prospectively studied 17 eyes of 16 patients who underwent a subciliary approach DCR [23, 24]. Anatomical and functional success was noted in all patients. Objective grading of the scar was one of the major outcome measures. The scars were independently graded by another physician as well as subjectively by the patients themselves at different time points, and the grades were defined as follows:

Grade 0: Invisible incision
Grade 1: Minimally visible incision
Grade 2: Moderately visible incision
Grade 3: Very visible incision

At an average follow-up of 29 weeks (range 6–72 weeks), the objective grading reported 47% of the scars to be invisible (grade 0) and 88.2% to have invisible to minimally visible (grade 0–1) scars. The subjective grading by the patient reported 88% of the scars to be invisible (grade 0) and 100% scars to be invisible or minimally visible (grade 0–1). Hence subciliary approach provided excellent cosmetic outcomes while retaining both access and success of an external DCR.

Waly et al. [25] compared vertical incisions with subciliary incisions in 20 patients each and reported cosmetically significant scars in 27.5% of patients with vertical incisions as compared to 5% with a subciliary incision. They advocated the use of a subciliary incision and closure by 6–0 Prolene to obtain favorable aesthetic results.

Limitations

Though promising, this surgical approach needs to be adopted with caution. We believe that certain amount of learning curve is involved to attain good aesthetic outcomes with this approach. The amount of wound retraction needed during ostium creation is certainly more than a standard incision Ex-DCR, and hence gentle tissue handling is required. We did face inadvertent extension (2 mm) of the incision medially in few patients. The subciliary approach is likely to

give good results in the hands of an oculoplastic surgeon who is familiar with subciliary incision for other eyelid or orbital surgeries. A comprehensive ophthalmologist who performs an occasional Ex-DCR may need some formal training to get the best results with this approach.

We did not have any patient with significant eyelid laxity in our series, nor did we include any pediatric patients. We therefore do not know how these eyelids would respond to a subciliary approach in terms of scarring. However, extrapolating from the incisions taken for lower eyelid blepharoplasty, one may assume that extremely lax lower eyelids might be very prone to lower eyelid medial ectropion following a subciliary incision.

Conclusions

There is increasing demand on oculoplastic surgeons from their patients and referring physicians to do endonasal surgery. Young and middle-aged patients are increasingly aware of the endonasal approach and are easily dissuaded by a skin scar. While we wait for endonasal procedures to evolve and achieve comparable success rates, an external approach DCR that can successfully hide the scar is highly desirable. Our technique reports a novel incision approach to Ex-DCR. The subciliary approach was simply an attempt to combine the best of two worlds, namely, endonasal and Ex-DCR.

References

1. Tarbet KJ, Custer PL. External dacryocystorhinostomy. Surgical success, patient satisfaction, and economic cost. Ophthalmology. 1995;102:1065–70.
2. Warren JF, Seiff SR, Kavanagh MC. Long-term results of external dacryocystorhinostomy. Ophthalmic Surg Lasers Imaging. 2005;36:446–50.
3. Watkins LM, Janfaza P, Rubin PA. The evolution of endonasal dacryocystorhinostomy. Surv Ophthalmol. 2003;48:73–84.
4. Goldberg RA. Endonasal dacryocystorhinostomy: is it really less successful? Arch Ophthalmol. 2004;122:108–10.
5. Moore WM, Bentley CR, Olver JM. Functional and anatomic results after two types of endoscopic endonasal dacryocystorhinostomy: surgical and holmium laser. Ophthalmology. 2002;109:1575–82.
6. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report by the American Academy of Ophthalmology. Ophthalmology. 2001;108:2369–77.
7. Javate RM, Campomanes BS Jr, Co ND, et al. The endoscope and the radiofrequency unit in DCR surgery. Ophthal Plast Reconstr Surg. 1995;11:54–8.
8. Duffy MT. Advances in lacrimal surgery. Curr Opin Ophthalmol. 2000;11:352–6.
9. Adenis JP, Robert PY. Retrocaruncular approach to the medial orbit for dacryocystorhinostomy. Graefes Arch Clin Exp Ophthalmol. 2003;241:725–9.
10. Kaynak-Hekimhan P, Yilmaz OF. Transconjunctival dacryocystorhinostomy: scarless surgery without endoscope and laser assistance. Ophthal Plast Reconstr Surg. 2011;27:206–10.
11. Cokkeser Y, Evereklioglu C, Er H. Comparative external versus endoscopic dacryocystorhinostomy: results in 115 patients (130 eyes). Otolaryngol Head Neck Surg. 2000;123:488–91.
12. Sham CL, van Hasselt CA. Endoscopic terminal dacryocystorhinostomy. Laryngoscope. 2000;110:1045–9.
13. Sprekelsen MB, Barberán MT. Endoscopic dacryocystorhinostomy: surgical technique and results. Laryngoscope. 1996;106:187–9.
14. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
15. Dupuy-Dutemps B. Procédé plastique de dacryocysto-rhinostomie et ses résultats. Ann Oculistique. 1921;158:241–61.
16. Linberg JV. Contemporary issues in ophthalmology, vol. 5. New York: Churchill Livingstone; 1988. p. 151–67.
17. Harris GJ, Sakol PJ, Beatty RL. Relaxed skin tension line incision for dacryocystorhinostomy. Am J Ophthalmol. 1989;108:742–3.
18. Putterman AM. Eyelid incision approach to dacryocystorhinostomy facilitated with a mechanical retraction system. Am J Ophthalmol. 1994;118:672–4.
19. Kim JH, Woo KI, Chang HR. Eyelid incision for dacryocystorhinostomy in Asians. Korean J Ophthalmol. 2005;19:243–6.
20. Akaishi PM, Mano JB, Pereira IC, et al. Functional and cosmetic results of a lower eyelid crease approach for external dacryocystorhinostomy. Arq Bras Oftalmol. 2011;74:283–5.
21. Heckler FR, Songcharoen S, Sultani FA. Subciliary incision and skin-muscle eyelid flap for orbital fractures. Ann Plast Surg. 1983;10:309–13.
22. Ben Simon GJ, Molina M, Schwarcz RM, et al. External (subciliary) vs internal (transconjunctival) involutional entropion repair. Am J Ophthalmol. 2005;139:482–7.
23. Dave TV, Javed Ali M, Shravani P, et al. Subciliary incision for an external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2012;28:341–5.
24. Dave TV, Javed Ali M, Shravani P, et al. Reply re: 'Subciliary incision for an external dacryocystorhinostomy'. Ophthal Plast Reconstr Surg. 2013;29:71–2.
25. Waly MA, Shalaby OE, Elbakary MA, et al. The cosmetic outcome of external dacryocystorhinostomy scar and factors affecting it. Indian J Ophthalmol. 2016;64:261–5.

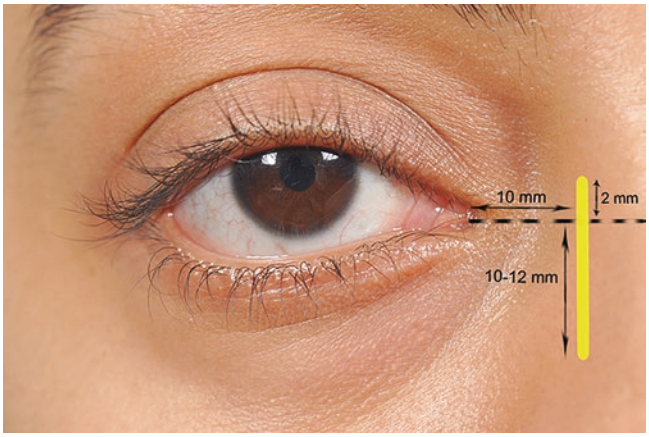


Fig. 19.1 The modified Lynch incision for external dacryocystorhinostomy

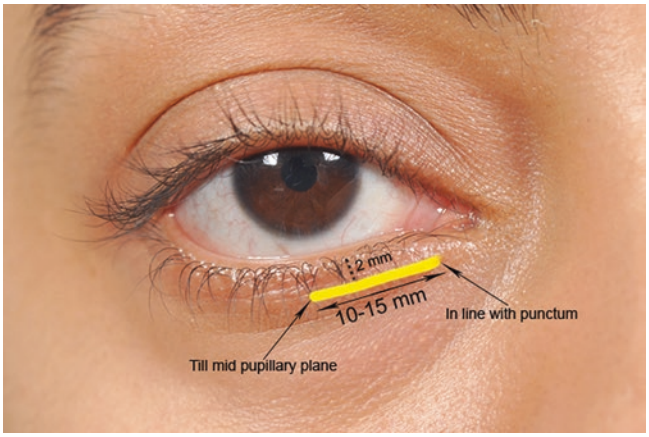


Fig. 19.3 The subciliary incision for external dacryocystorhinostomy

Fig. 19.2 Angular or the nasojugal incision for external dacryocystorhinostomy

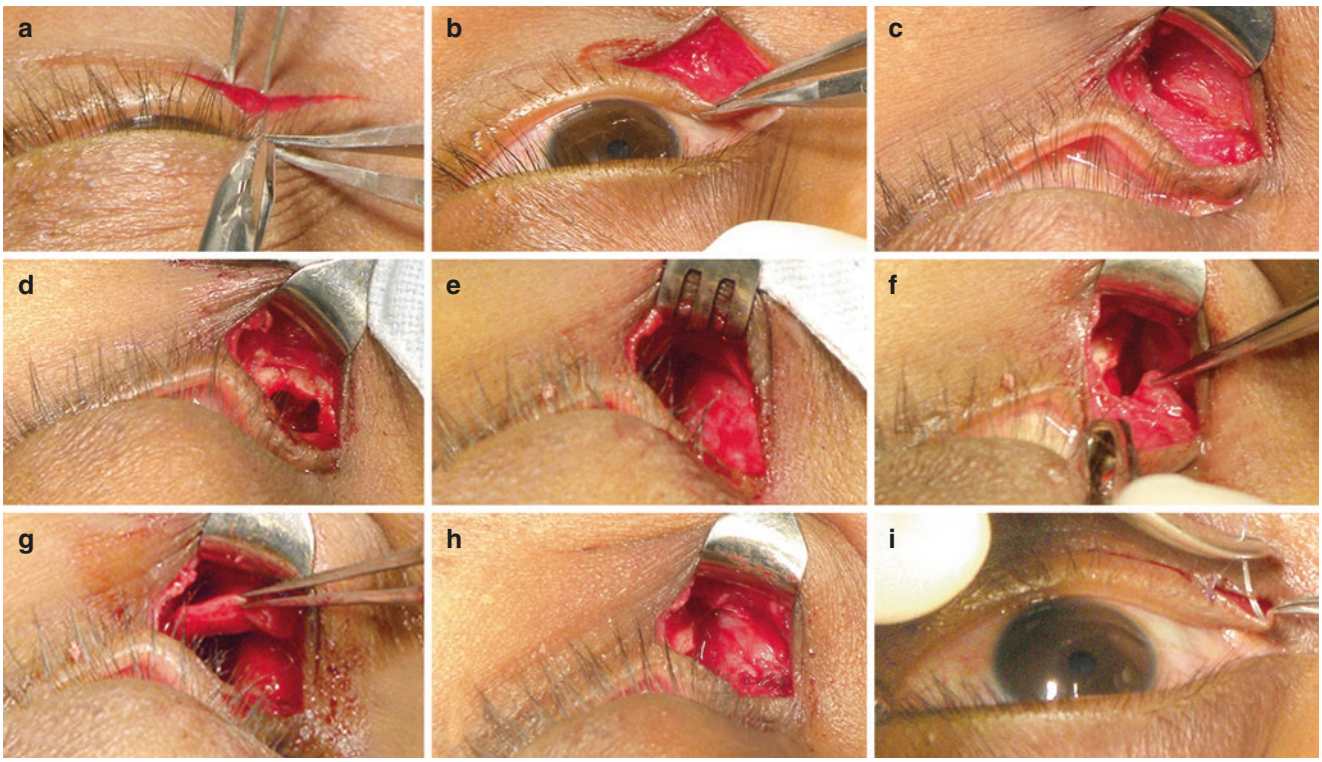


Fig. 19.4 Operative photographs showing the subciliary skin incision (**a**), dissection in the subcutaneous plane to reach the anterior lacrimal crest (**b**), exposing the periosteum over the anterior lacrimal crest (**c**), initiation of the osteotomy after reflecting the sac laterally (**d**), completion of the osteotomy (**e**), construction of the anterior lacrimal sac flap (**f**), construction of the nasal mucosal flap (**g**), suturing the anterior flaps (**h**), skin closure with interrupted 6–0 polyglactin sutures (**i**)

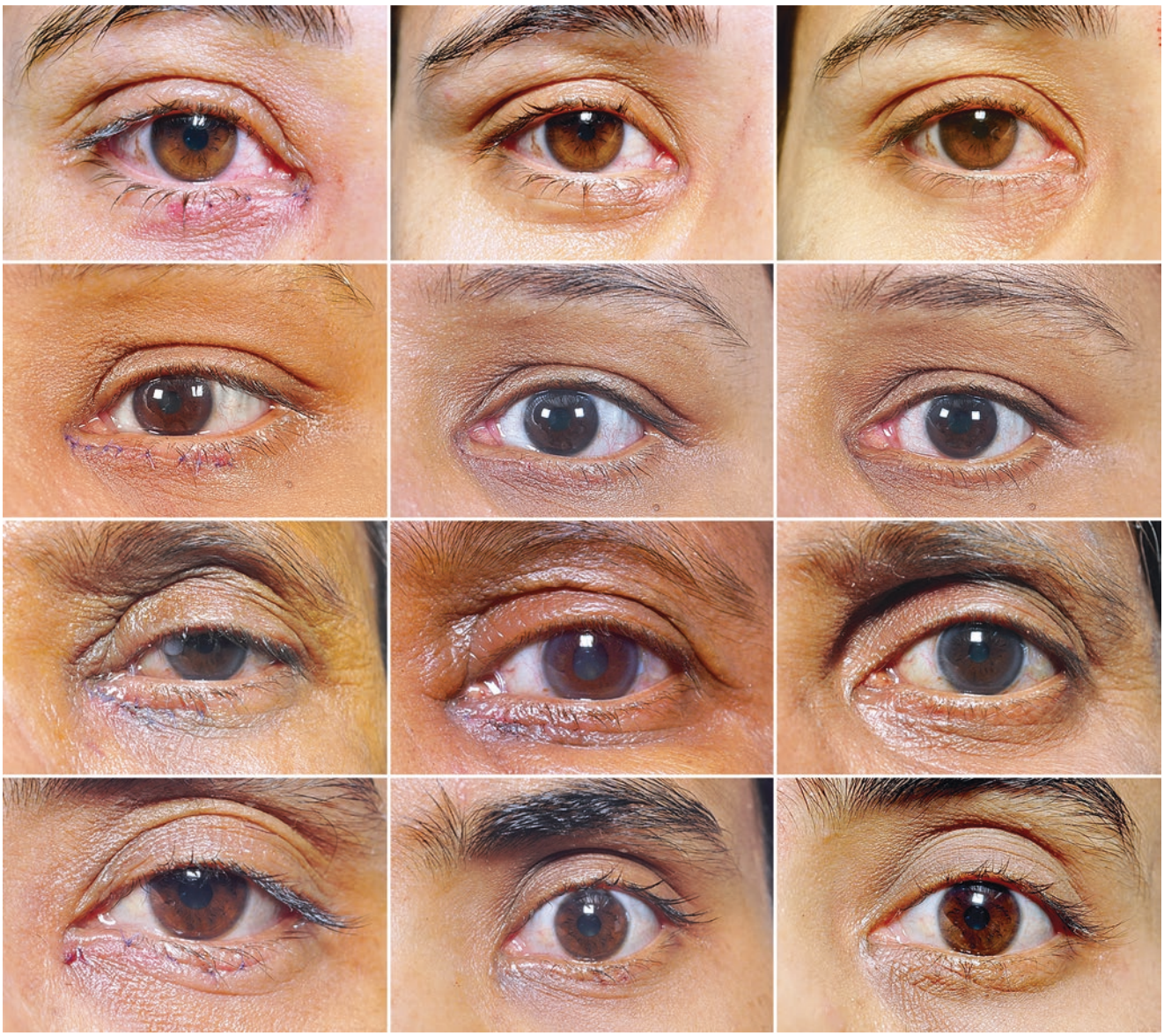


Fig. 19.5 Day 1, week 1, and 6 weeks postoperative photographs of patients undergoing subciliary dacryocystorhinostomy

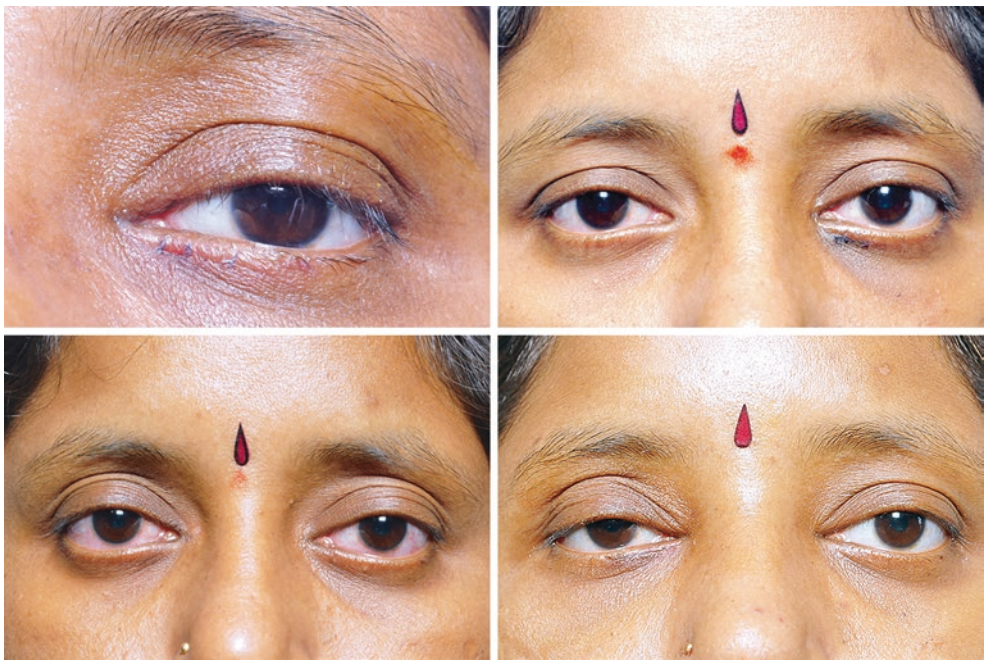


Fig. 19.6 One patient undergoing bilateral subciliary dacryocystorhinostomy (*left* followed by *right*)

Aesthetic External DCR: The Transconjunctival Approach

20

Pelin Kaynak

Introduction

Primary and secondary nasolacrimal duct obstructions are quite frequently encountered in ophthalmology practice. The traditional surgical approach for managing nasolacrimal duct obstruction (NLDO) is an external dacryocystorhinostomy (Ex-DCR), first described by Toti in 1904 [1]. He gained access to the sac and nasal cavity via a skin incision in the medial canthal region. Dupuy-Dutemps and Bourguet later described an Ex-DCR technique where mucosal anastomosis was achieved with suturing of the nasal and saccal flaps [2]. External DCR is still performed in a similar way with minor alterations and high success rates of over 90% [3–9]. However, external DCR leaves a scar in the medial canthal area.

Endonasal techniques with or without the use of lasers and endocanalicular techniques have reported success rates between 60 and 100%. The results of modern endoscopic DCR are comparable to that of external DCR [10–19]. Use of radio-frequency electrodes [20], powered drills [21], adjunct alkylating agents such as mitomycin C [22], and mechanical endoscopic techniques with flaps [23] contributed to the success. Endoscopic procedures avoid the facial scar, but they necessitate additional surgical equipment and visualization systems.

Retrocaruncular DCR is an uncommon DCR approach aiming to avoid the facial scar as in transconjunctival DCR. Adenis et al. [24] published a series of 11 patients in whom the lacrimal fossa was reached by retrocaruncular approach to perform DCR with 82% success. This technique avoids a facial scar but may disfigure the caruncular area [24]. Although familiar area to the ophthalmologist, to reach the sac via caruncle may not be a common experience. Simpler surgical methods and easy-to-insert stents are under investigation for high success scarless DCRs [25, 26].

P. Kaynak, M.D.
Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey
e-mail: pkaynak@gmail.com

Transconjunctival DCR (TC-DCR) performed by the author's group and the results of the first series of 25 patients are encouraging [27]. TC-DCR is a scarless external technique where the lacrimal system patency is reestablished via inferomedial transconjunctival approach. This chapter would discuss surgical techniques, complications, and outcomes of TC-DCR.

Surgical Technique

Transconjunctival DCR is performed using conventional external DCR instruments. Rongeurs and/or drills are usually efficient tools for osteotomy. Headlight and surgical loupes are recommended because of the need for high illumination of the deep surgical area as in external DCR. Microscopes can also be used. Surgery can be done either under local anesthesia with or without sedation or general anesthesia.

Preoperative Preparation

The nose is packed with ribbon gauze soaked with 0.05% xylometazoline and 2% lidocaine with 1:100,000 adrenaline solution for hemostasis and analgesia. The conjunctival incision site and medial canthal area are infiltrated by approximately 1–4 ml, 2% lidocaine with similar adrenaline concentration. A soft contact lens or a lubricated acrylic corneal protector is placed to protect the cornea.

Surgical Steps

Lower eyelid is retracted gently away from the eyeball. Inferomedial vestibular transconjunctival incision of 2–3 cm, similar to medial transconjunctival blepharoplasty incision, is performed starting from a point 4–5 mm below the caruncle (Fig. 20.1). Medial fat pad and inferior oblique muscle are exposed and gently retracted laterally to reach

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_20

the anterior lacrimal crest (Fig. 20.2). Periosteum is incised over the anterior lacrimal crest and reflected medially and laterally. Nasal packing is removed prior to removal of bone. After lacrimal sac is visualized and carefully protected, frontal process of maxilla and lacrimal bone are removed either with drill or rongeurs. Bony rhinostomy site around the suture in the lacrimal fossa, approximately, 10 mm × 10 mm large is created (Fig. 20.3). Attention must be paid not to traumatize the lacrimal sac and nasal mucosa.

Nasal and saccal mucosae are incised to form "H"-shaped flaps, as in external DCR. Full-thickness sac incision and common canalicular patency are checked. The contents of the sac are emptied by irrigation. The nasal and saccal posterior mucosal flaps are best anastomosed with 6-7/0 polyglactin sutures, preferably on a 5/8 curved round needle. When posterior flap apposition is impossible because of either poor manipulation in a deep surgery site or lacerated flaps, it is advisable to excise the remnants of posterior flaps. Bicanalicular silicone intubation can be done prior to the anastomosis of the anterior nasal and saccal flaps (Fig. 20.4). Periosteum is closed in a fashion to suspend the anterior mucosal wall of the anastomosis. Medial conjunctiva is approximated and sutured with 6-0 polyglactin or may be left unsutured if well apposed (Fig. 20.5).

The surgeon may choose to convert the surgery to conventional external DCR with skin approach, whenever an adequate size bony ostium cannot be created. Agger nasi cells may prevent access to the nasal cavity, and care should be taken to avoid any inadvertent entry into other posterior ethmoidal cells.

Postoperative Care

Eye patching for four hours with sterile antibiotic and corticosteroid ointment after surgery is safe and comfortable for the patient. The eyes are opened early on surgery day to check for hemorrhage. It is advised to keep the patient in supine position and apply ice compresses for the first 24 hours. Topical and systemic antibiotics are prescribed for 1 week; nasal and ocular steroids and nasal saline spray are continued for 3 weeks after surgery. Patients are also advised not to blow the nose during the first week.

Figures 20.6, 20.7, and 20.8 show the typical postoperative course of a patient who had transconjunctival DCR for treatment of PANDO. We suggest to follow up the patients on the first day, 1 week, and 1, 3, and 6 months afterward. During the follow-up, the incision site is examined, and the patency of the new rhinostomy is assessed by a dye test or irrigation if required. Silicone tubes are mostly removed at 4 weeks.

Outcomes

The success rate of transconjunctival DCR is over 90% which is comparable to success of external DCR [27]. It is easy to convert the surgery to external DCR when needed. In the author's series of 25 patients, 76% of the eyes could be successfully operated using TC-DCR, and among these, epiphora resolved completely in 94.7% eyes [27]. In the remaining 24%, the DCRs needed to be completed via with cutaneous approach because of fat prolapse hindering adequate osteotomy. Ethmoidal cells were entered in 12.5% of the eyes. Although Becker reported 92.5% success in patients who underwent external DCRs without flaps [7], the general surgical principles advocate the mucosal-lined smooth tract for the long-term patency of the anastomosis and the drainage of tears. High success rate of transconjunctival DCR can also be attributed to the successful flap anastomosis.

Kaynak et al. [28] published long-term results of TC-DCR in 33 eyes of 29 patients. They found that the rate of conversion to external DCR was reduced to 18.2% as compared to 25% in their previous series. This could be attributed to better experience. The mean surgical time was 65 min. The overall success rate was 92.5%. Complications include lower eyelid margin laceration in one eye and conjunctival incision site granulomas in three eyes. Ganguly et al. [29] reported their experiences with TC-DCR in 18 eyes of 17 Indian patients. TC-DCR could be successfully performed in 82% (15/18) of patient. Two patients had to be converted to external DCR, and one underwent a dacryocystectomy. It is interesting to note that none of the patients had any fat disturbance and this could be attributed to the surgeon's experience and meticulous techniques. A questionnaire-based health status evaluation in these patients showed marked improvement in their anxiety/depression after their surgery with the mean overall health score being 88 on a scale of 0–100 (0 to worse and 100 to best). These studies of the recent past report encouraging outcomes for TC-DCR.

Table 20.1 summarizes the advantages of TC-DCR. Surgical difficulties and disadvantages of TC-DCR are listed in Table 20.2.

Limitations

The higher rate of conversion to external DCR (24%) especially during the learning curve appears to be the major disadvantage of TC-DCR technique [27]. It is occasionally difficult to reach the nasal mucosa and suture the flaps in the deep surgical planes. In our series of first 25 cases of transconjunctival DCR, the incidence of converting to cutaneous approach external DCR to complete surgery (technical

Table 20.1 Advantages of TC-DCR

1. Avoids facial scar
2. Minimal trauma to medial canthal structures
3. Preserved lacrimal pump
4. Enables flap anastomosis
5. Surgery with basic DCR equipment
6. No need for endoscopy and laser assistance

Table 20.2 Difficulties and disadvantages of TC-DCR

1. Difficult visualization of deeper planes
2. Difficult access to the sac and lacrimal fossa
3. Tight lower eyelids are prone to injury
4. Manipulation and maneuvering difficulties (ethmoid cell entry, agger nasi cell, orbital fat prolapse)
5. Longer procedure time
6. Variable learning curve

failure) decreased from 38.5% (first 13 eyes) to 8% (last 12 eyes) in the second half of the patient group [29]. In subsequent studies, it was much lower [28, 29]. This result may point toward a learning curve, but the decrease in this conversion as we gain experience is noticeable.

Complications

Orbital fat prolapse was commonly encountered while performing transconjunctival DCR, which is considered to be one of the important reasons for DCR failure according to Welham et al. [7, 30]. In the presence of this complication, manipulation of bony and soft tissues is difficult, and undue trauma to the fat tissue may end up with retroseptal hemorrhage. Fat prolapse, whenever encountered, should be retracted from the site, and the periosteum should be closed meticulously after rhinostomy and flap suturing are completed, to prevent fat tissue incarceration in the rhinostomy site.

Anteriorly located ethmoidal air cells can occasionally confuse the surgeon. Talks and Hopkinson [31] reported that the ostium was opened via the standard lacrimal fissure in only 46% of DCRs. Ethmoidal cells beyond the agger nasi might occasionally be violated. Occasionally ethmoidal sinus entrance might be a hindrance in fashioning the appropriate rhinostomy site in transconjunctival DCR, although it does not mandate conversion to an external DCR.

Eyelid laceration due to excessive traction for better visualization of the surgical site is possible and should be watched for from the beginning and meticulously sutured, if they occur. It would be wise to choose patients with good eyelid elasticity and not to exert too much force for traction to the lower eyelid for surgical site exposure. Figures 20.9 and 20.10 exemplify a patient with a repaired eyelid laceration due to excessive traction during TC-DCR.

Table 20.3 Complications of transconjunctival DCR

1. Retroseptal hemorrhage
2. Orbital fat prolapse
3. Entry to posterior ethmoid cells
4. Inferior oblique muscle injury
5. Granuloma formation at the incision site
6. Eyelid laceration

Children with tight eyelids and patients with broad nose saddles are difficult to operate on and may be considered while selecting patients for surgery. A patient with broad nose can have significant postoperative periocular ecchymoses and subconjunctival hemorrhage caused by the difficult access and manipulation of soft and bony tissues during transconjunctival DCR (Figs. 20.11 and 20.12). Such patients are better candidates for external and/or endoscopic DCR although the surgery was completed via transconjunctival route in this patient.

Possible complications of transconjunctival DCR are listed in Table 20.3.

Comparing Transconjunctival and Retrocaruncular Routes for DCR

Retrocaruncular DCR series of 11 cases, by Adenis et al. [24], is the most similar approach to transconjunctival technique presented in ophthalmology literature. Both surgical techniques avoid facial scarring, minimize trauma to the medial canthal tendon-Horner's muscle complex, allow anastomosis of mucosal flaps, and can be performed with conventional surgical instruments.

The major difference between retrocaruncular approach and the transconjunctival DCR is the site of incision. The incision is hidden in the medial conjunctival fornix in transconjunctival DCR, avoiding the medial canthal scar. The retrocaruncular entry is adjacent to the globe, and the incision is also reported to heal without scarring [24], although the potential for a scar still exists. The medial vestibular transconjunctival incision heals with negligible scarring. In case of a scar or a granuloma formation, it is hidden completely by the lower eyelid.

Another difference between these techniques is the site of the rhinostomy. Adenis et al. [24] created the rhinostomy posterior to the medial canthal ligament, while in TC-DCR, medial canthal ligament makes the superior border of the rhinostomy [24]. More inferior location of the rhinostomy did not decrease the success rate of transconjunctival DCR but is likely to improve the drainage owing to additional factor of

gravity. Less surgical trauma to the tissues around the medial canthal ligament which contributes to the pump mechanism may be another factor of higher success of TC-DCR.

Conclusion

The transconjunctival dacryocystorhinostomy is a useful technique for treating patients with epiphora due to NLDO, with high success rates comparable to external and endoscopic DCR techniques. There are technical difficulties while performing this surgery, but transconjunctival DCR offers the surgeon and the patient a scarless surgery option in the presence of solely the conventional DCR equipment. It does not leave a facial scar and can be performed without endoscope and laser assistance.

References

1. Toti A. Nuovo metodo conservatore di cura radicale delle suporazioni chroniche del sacco lacrimale. Clin Mod Firenze. 1904;10:385–9.
2. Dupuy-Dutemps L, Bourguet J. Procédé plastique de dacryocystorhinostomie et ses resultats. Ann Ocul. 1921;158:241–61.
3. Pico G. A modified technique of external dacryocystorhinostomy. Am J Ophthalmol. 1971;72:679–89.
4. McPherson SD, Egleston D. Dacryocystorhinostomy: a review of 106 patients. Am J Ophthalmol. 1959;47:328–31.
5. Warren JF, Seiff SR, Kavanagh MC. Long term results of external dacryocystorhinostomy. Ophthalmic Surg Lasers Imaging. 2005;36:446–50.
6. Welham RAN, Henderson PH. Results of dacryocystorhinostomy analysis of causes for failure. Trans Ophthalmol Soc UK. 1973;93:601–9.
7. Becker BB. Dacryocystorhinostomy without flaps. Ophthalmic Surg. 1988;19:419–27.
8. Walland MJ, Rose GE. Factors affecting the success rate of open lacrimal surgery. Br J Ophthalmol. 1994;78:888–91.
9. Fayers T, Laverde T, Tay E, et al. Lacrimal surgery success after external dacryocystorhinostomy: functional and anatomical results using strict outcome criteria. Ophthal Plast Reconstr Surg. 2009;25:472–5.
10. Caldwell GW. Two new operations for obstruction of the nasal duct with preservation of the canaliculi, and an incidental description of a new lachrymal probe. NY Med J. 1893;57:581.
11. Steadman MG. Transnasal dacryocystorhinostomy. Otolaryngol Clin N Am. 1985;18:107–11.
12. McDonogh M, Meiring JH. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–7.
13. Lester SE, Robson AK, Bearn M. Endoscopic 'cold steel' versus laser dacryocystorhinostomy: completing the audit cycle. J Laryngol Otol. 2008;122:924–7.
14. Hartikainen J, Jukka A, Matti V, et al. Prospective randomized comparison of endonasal endoscopic dacryocystorhinostomy and external dacryocystorhinostomy. Laryngoscope. 1988;108:1861–6.
15. Bakri SJ, Carney AS, Downes RN, et al. Endonasal laser-assisted dacryocystorhinostomy. Hosp Med. 1998;59:210–5.
16. Massaro BM, Gonnering RS, Harris GJ. Endonasal laser dacryocystorhinostomy. A new approach to nasolacrimal duct obstruction. Arch Ophthalmol. 1990;108:1172–6.
17. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report by the American Academy of Ophthalmology. Ophthalmology. 2001;108:2369–77.
18. Watkins LM, Janfaza P, Rubin PA. The evolution of endonasal dacryocystorhinostomy. Surv Ophthalmol. 2003;48:73–84.
19. Drnovšek-Olup B, Beltram M. Transcanalicular diode laser-assisted dacryocystorhinostomy. Indian J Ophthalmol. 2010;58:213–7.
20. Javate RM, Campornanes BS, Nelson D. The endoscope and the radiofrequency unit in DCR surgery. Ophthalmic Plast Reconstr Surg. 1995;11:54–8.
21. Fayet B, Racy E. Endonasal dacryocystorhinostomy (DCR) with protected drill. J Fr Ophthalmol. 2000;23:321–6.
22. Camara JG, Bengzon AU, Henson RD. The safety and efficacy of mitomycin C in endonasal endoscopic laser-assisted dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2000;16:114–8.
23. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
24. Adenis JP, Robert PY. Retrocaruncular approach to the medial orbit for dacryocystorhinostomy. Graefes Arch Clin Exp Ophthalmol. 2003;241:725–9.
25. Plaza G, Beteré F, Nogueira A. Transcanalicular dacryocystorhinostomy with diode laser: long term results. Ophthal Plast Reconstr Surg. 2007;23:179–82.
26. Ibrahim HA, Noble JL, Batterbury M, Johnson CP, Williams R. Endoscopic-guided trephination dacryocystorhinostomy (Hesham DCR): technique and pilot trial. Ophthalmology. 2001; 108:2337–45.
27. Kaynak-Hekimhan P, Yilmaz OF. Transconjunctival dacryocystorhinostomy: scarless surgery without endoscope and laser assistance. Ophthal Plast Reconstr Surg. 2011;27:206–10.
28. Kaynak P, Ozturker C, Karabulut G, et al. Transconjunctival dacryocystorhinostomy: long-term results. Saudi J Ophthalmol. 2014;28:61–5.
29. Ganguly A, Ramarao K, Mohapatra S, et al. Transconjunctival dacryocystorhinostomy: an aesthetic approach. Indian J Ophthalmol. 2016;64:893–7.
30. Welham RAN, Wulc AE. Management of unsuccessful lacrimal surgery. Br J Ophthalmol. 1987;71:152–7.
31. Talks SJ, Hopkisson B. The frequency of entry into an ethmoidal sinus when performing a dacryocystorhinostomy. Eye. 1996;10:742–3.

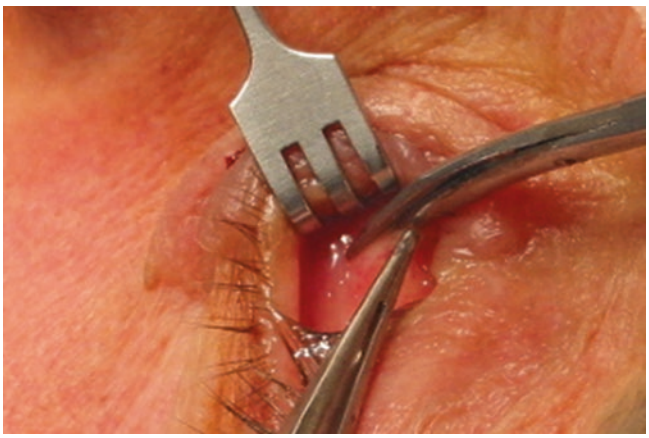


Fig. 20.1 The transconjunctival incision

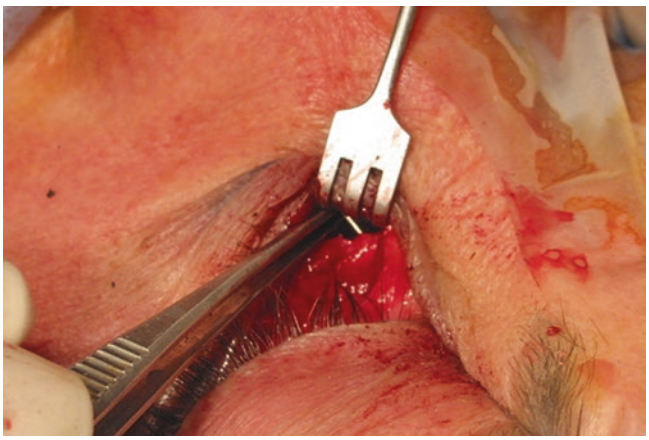


Fig. 20.4 Probe tip in the sac before suturing anterior flaps

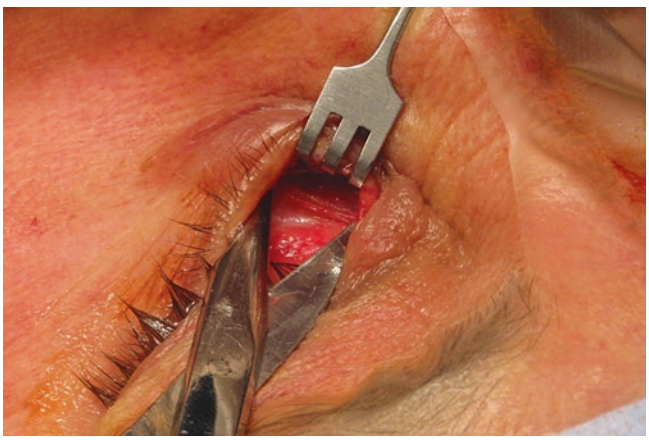


Fig. 20.2 Dissection to access the anterior lacrimal crest

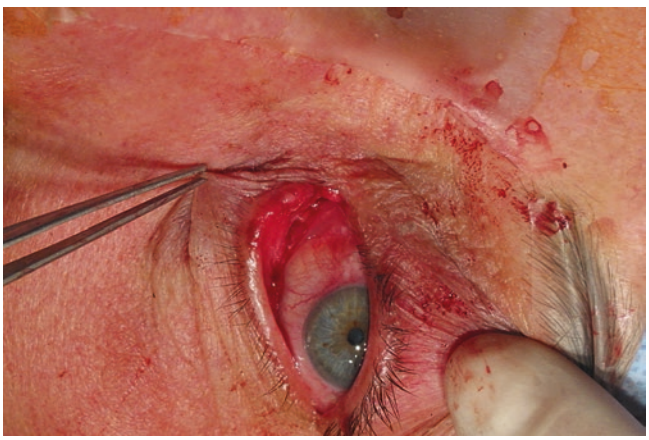


Fig. 20.5 Incision site at the end of surgery

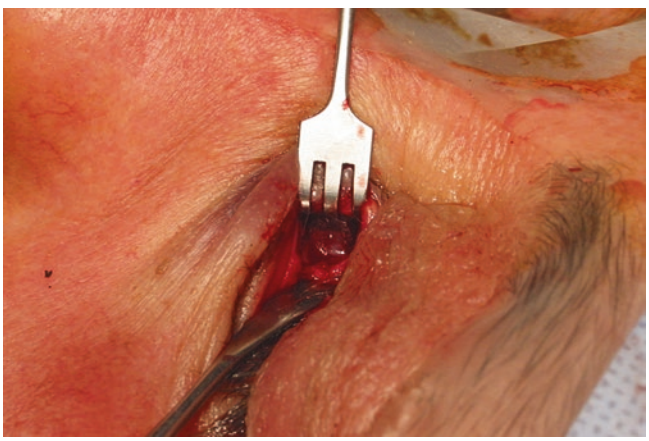


Fig. 20.3 Bony osteotomy

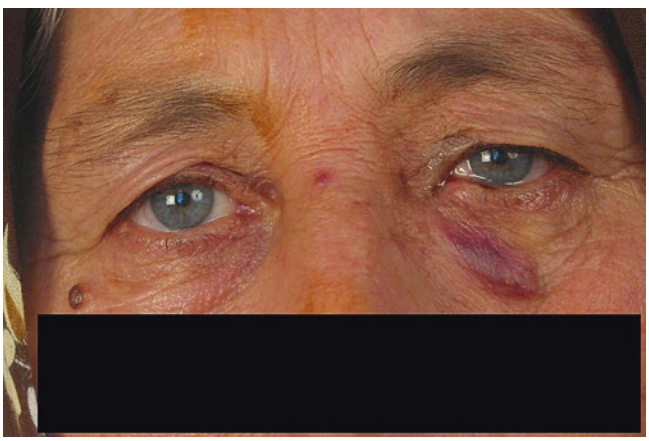


Fig. 20.6 Postoperative view—first day

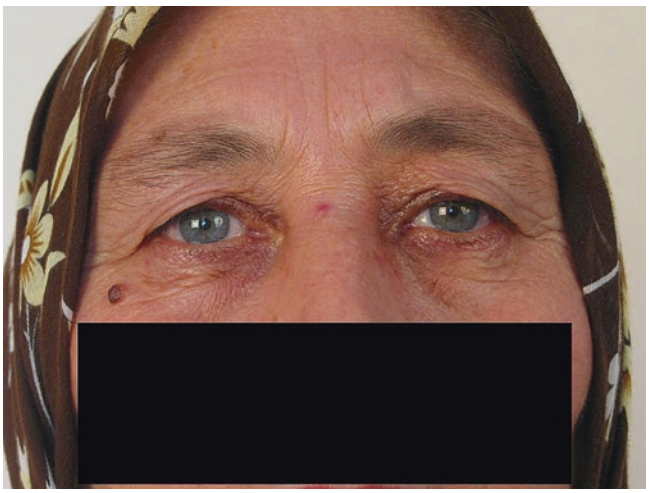


Fig. 20.7 Postoperative view—second week

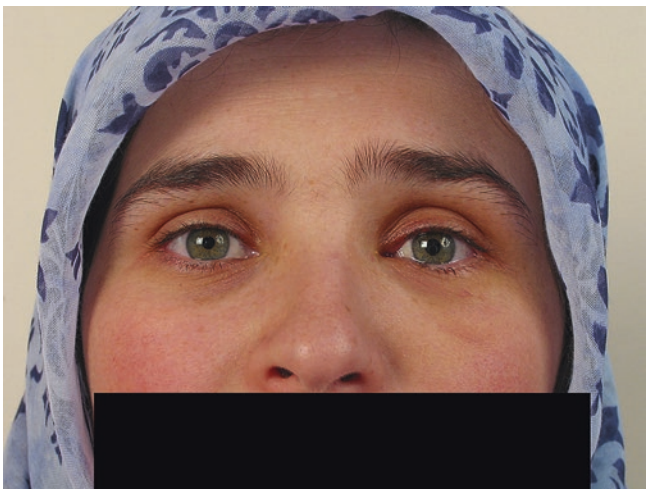


Fig. 20.10 Same patient as Fig. 20.9 at 2 weeks postoperative period

Fig. 20.8 Postoperative view of incision site—second week

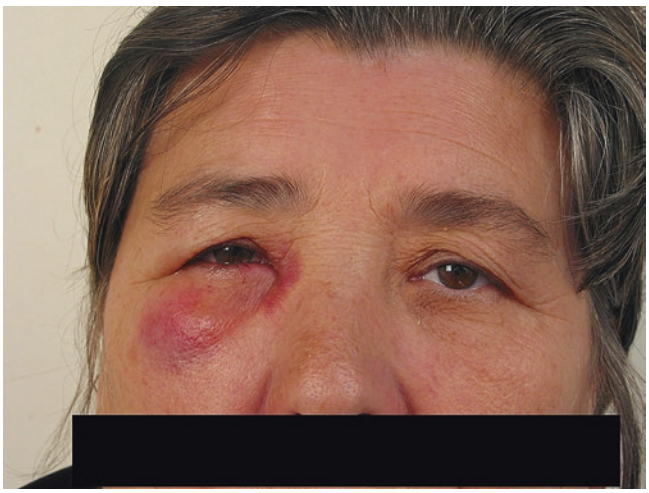


Fig. 20.11 Patient with broad nose with periocular ecchymoses

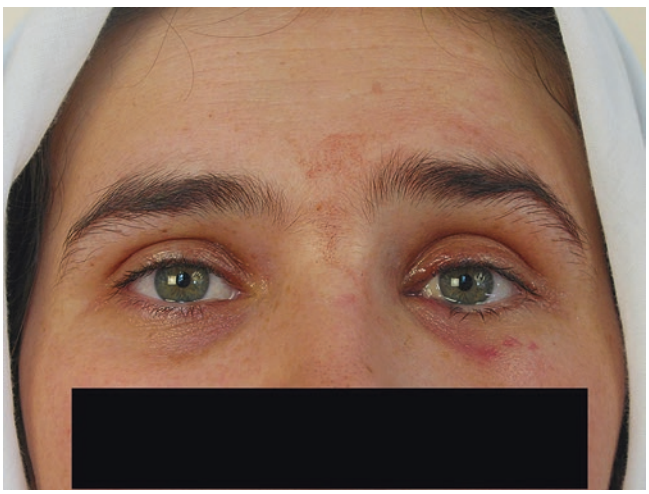


Fig. 20.9 Immediate postoperative photos of a repaired lower eyelid laceration during TC-DCR

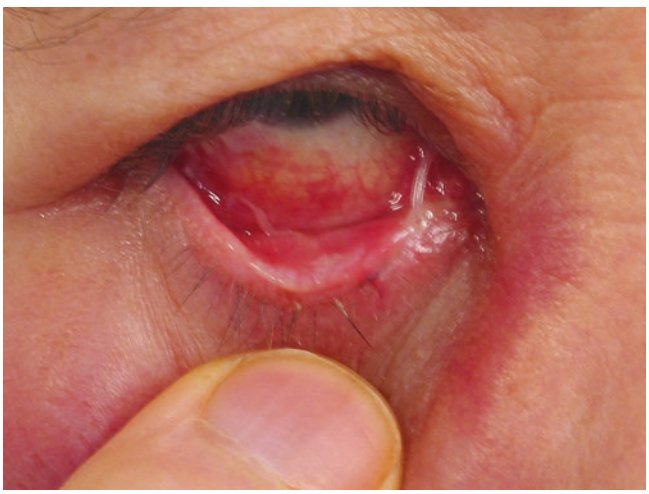


Fig. 20.12 Same patient as in Fig. 20.11 with subconjunctival hemorrhage

Primary Endoscopic Dacryocystorhinostomy

21

Kelvin Kam-Lung Chong and Mohammad Javed Ali

Introduction

Endoscopic endonasal dacryocystorhinostomy (EEDCR), which was first described in the late 1980s [1], has gained considerable popularity in the recent two decades with the advent of the rigid fiber-optic endoscope and its use in paranasal sinus surgery. It avoids a facial incision, disruption of the medial canthal tendon, injury to the terminal branch of facial nerve, or a full-thickness (skin to mucosa) ring contracture over the osteotomy site, all of which may lead to secondary lacrimal pump failure despite anatomical patency. Endoscopic DCR is not contraindicated during active dacryocystitis (minimal risk of fistula formation), presumably allowed faster healing process, and is perceivably less traumatic compared to external DCR. Recent published series of EEDCR reported higher success rates up to 95% as compared to prior studies [2]. This likely reflects an increased experience with endoscopic instrumentation and anatomy among lacrimal surgeons and an improved understanding and control of postoperative mucosal healing [3]. The key to successful EEDCR relies on atraumatic creation of a large osteotomy [3] with adequate superior bony clearance, complete marsupialization of the lacrimal sac [4], maximal preservation of the nasal and lacrimal sac mucosa with close approximation of the mucosal edges [2, 5], as well as regular endoscopic monitoring of ostial healing during the early postoperative period.

There are multiple surgical variations in performing endonasal DCR including use of endoscope (versus direct visualization using headlight and/or endoilluminator), preservation of mucosal flaps (versus excision), powered instruments (versus cold steel), suturing/gluing of the mucosal flaps, use of mitomycin C, intubation, triamcinolone, and absorbable (Gelfoam, MeroGel) or nonabsorbable (Merocel, ribbon gauze) packings. These variations are based on surgeon's preferences rather than strong evidence in favor of one over the other.

Surgical Technique

Preparation and Anesthesia

EEDCR may be performed under either general anesthesia or local anesthesia. Two percent Xylocaine with 1:200,000 adrenaline can be used for regional transcaruncle, infratrochlear, and infraorbital nerve block. The operation is performed with a video camera system attached to a rigid 4-mm endoscope. With the patient in supine position, patients' head should be slightly elevated and neck slightly extended so as to facilitate superior osteotomy using the rongeurs. Nasal packing using ribbon gauze soaked in cocaine or alpha-adrenergic type of vasoconstricting solution is placed along the middle meatal area and lateral nasal wall to decongest the nasal mucosa. Xylometazoline and oxymetazoline are commonly used sympathomimetics for decongestion. 0.05% concentration is used in adults and 0.025% in pediatric patients. Alternatively lidocaine 2% with 1:10,000 adrenaline can be used as a topical nasal decongestant. Using a 0° nasal endoscope for visualization, the mucosa of the lateral nasal wall above and below the level of the axilla of middle turbinate can be further infiltrated with 2% Xylocaine with 1:80,000 adrenaline before incision.

Endoscopic Landmarks

The most useful endonasal landmark to identify the lacrimal sac is the axilla of the middle turbinate (Fig. 21.1). An endoilluminator probe may be used to visualize the lacrimal sac through the canaliculus and advanced into the lacrimal sac but

K.K.-L. Chong, M.D. (✉)
Ophthalmic Plastics Surgery, Chinese University of Hong Kong, Hong Kong, Hong Kong SAR, China
e-mail: chongkamlung@gmail.com

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_21

is usually not needed by most experienced endoscopic surgeons. The fundus of the lacrimal sac usually extends above the level of the axilla of middle turbinate [6]. The maxillary line is an important landmark in endoscopic dacryocystorhinostomy. It is the curvilinear ridge on the lateral nasal wall that runs from the axilla of middle turbinate to the root of the inferior turbinate. It is the suture line formed by the thick maxillary bone anteriorly and the thin lacrimal bones posteriorly. The lacrimal sac often extends posteriorly behind the maxillary line beneath the middle turbinate. Exposure of the posterior half of the lacrimal sac requires removal of the thin lacrimal bone behind the maxillary line and occasionally a part of the uncinate process inferiorly. Exposure of the anterior half of the lacrimal sac requires removal of the thick frontal process of maxilla. The inferior end of the lacrimal sac tapers as the sac-duct junction when it enters the nasolacrimal canal, formed by the maxillary, lacrimal, and inferior turbinate bones.

Fashioning the Nasal Mucosa Flaps

A crescent or sickle knife or a radiofrequency device is used to make the incision over the lateral nasal mucosa down to the periosteum in front of the maxillary line (Fig. 21.2). The first vertical incision is made around 10 mm anterior to the maxillary line with a length of about two-thirds of the vertical height of the middle turbinate starting from the level slightly above the axilla of middle turbinate. A horizontal incision is then made at right angle at the inferior end of the vertical incision until reaching the maxillary line. The upper horizontal incision can be completed with the knife or a pair of Westcott scissors starting from the top of the vertical line over and cut beyond the axilla of the middle turbinate (Fig. 21.3). A freer periosteal elevator is then used to elevate the mucoperiosteal flap and folded around the middle turbinate to keep it out of the operating field. Alternatively, an anteriorly based nasal mucosal flap can be created in a similar fashion but usually required sutures to retract anteriorly during osteotomy. An anteriorly based flap may allow better mucosal coverage of bare bone at the end of the osteotomy procedure.

Osteotomy

A Kerrison Rongeur or forward-biting Hajek-Koeffler punch is used to engage and remove the hard bone of the frontal process of the maxilla, starting from the maxillary line (Fig. 21.4). Removal of the maxillary bone should expose the inferior half of the lacrimal sac (Fig. 21.5). Bone removal is continued anteriorly and as far superiorly as possible (Fig. 21.6). The thin lacrimal bone at the posterior half of the lacrimal sac is elevated with freer elevator and removed using a pair of Takahashi forceps (Figs. 21.7 and 21.8). An osteotomy of at least 15 mm in vertical length is usually required to expose the lacrimal sac from fundus to sac-duct junction. All bones over the lacrimal sac fundus and common canaliculus opening should be removed.

Boundaries of the Ostium

Superoanteriorly, the orbicularis oculi muscle is often exposed (Fig. 21.9). Superoposteriorly, the agger nasi air cells or operculum of the middle turbinate is entered to ensure full fundus exposure (Fig. 21.10). Posteriorly a limited anterior ethmoidectomy may occasionally be required, but care should be taken to avoid undue exposure of the medial periorbita. This allows maximal superior bone removal without using powered instruments and posterior lacrimal sac flap to lie flat. Lacrimal sac fundus is reached when orbicularis muscle is exposed also superiorly. Alternately, one can use special punches like the Malhotra punch, powered drills, or piezoelectric energy to perform a superior osteotomy. Inferior boundary of the osteotomy is the nasolacrimal duct, which is noted after the canal is de-roofed.

Fashioning Lacrimal Sac Flaps

The position of the internal punctum can be verified using a Bowman probe, passing through the lacrimal canaliculus into the lacrimal sac and tenting the medial sac wall. With the Bowman probe passed horizontally tenting the medial wall of the lacrimal sac, at least 2 mm space should be left between the tented lacrimal probe tip and the superior edge of the osteotomy.

Once tenting the medial wall of the lacrimal sac is achieved (Fig. 21.11), a crescent or sickle knife is used to make a vertical incision along the entire length of the lacrimal sac from the fundus down to the nasolacrimal duct (Fig. 21.12). An "I"- or "Y"-shaped incision is then completed with upper and lower horizontal releasing cuts at the top and the bottom using Westcott scissors or crescent knife (Fig. 21.13). The lacrimal sac is then completely marsupialized, and both the anterior and posterior sac flap are laid opened and flat on the lateral nasal wall like an open book (Fig. 21.14). Irrigation using the fluorescein-stained saline confirms the patency of the common internal punctum intraoperatively (Fig. 21.15).

Edge-to-Edge Mucosal Apposition

Once both the nasal mucosal and lacrimal sacs are fashioned, an edge-to-edge approximation is performed so as to achieve healing by primary intention. A maxillary osteal seeker

probe is useful to spread open the lacrimal sac flaps thereby avoiding excessive sharp dissection within the sac, particularly around the internal ostium. The nasal mucosal flap can then be trimmed in the center, and edges are repositioned back and approximate the posterior edge of the marsupialized lacrimal sac flap (Fig. 21.16).

Hemostasis

Hemostasis is achieved intraoperatively with nasal packing (Fig. 21.17), medicated patties, cold saline irrigation, head-up position, or bipolar cautery of the bleeding mucosal edges. Small piece of Surgicel (absorbable hemostat, oxidized cellulose polymer) gauze can be left at the end of the surgery to maintain hemostasis. A point to remember is nasal packing after the surgery should never interfere with the flaps.

Adjunctive Modalities

Bicanalicular silicone intubation is thought to prevent sealing of the edges of the lacrimal sac and impede fibrous closure during healing [7]. It may not be necessary in most primary acquired nasolacrimal duct obstruction (PANDO) cases as our study has shown that bicanalicular intubation did not improve the final outcome at 12-month follow-up [8]. However, silicone tubes may be beneficial in cases of canalicular obstruction and poor flaps or in revision DCR cases particularly in those with a fibrotic and scarred sac. If bicanalicular silicone intubation is used, the stents are passed through both superior and inferior canaliculi, and the silicone tube ends can be tied together on themselves or with suture fixation to the nasal ala or with the use of Ligar clips to prevent tube prolapse. Tension on the stent should be avoided to prevent gradual cheese wiring and slitting of the lacrimal punctae. The silicone tubes are removed at around 4–8 weeks postoperatively based on the surgeon's preference and when mucosal healing is complete. A longer period of intubation may be chosen in cases of canalicular obstruction when scarring around the canalicular opening is more difficult to control, but evidence is lacking.

Mitomycin C is an alkylating agent that inhibits fibroblast proliferation. This pharmacological adjuvant is used by many endoscopic lacrimal surgeons to minimize cicatrix formation and maintain ostial patency. Evidence for or against it is lacking in primary cases but appears to be helpful in revision cases. The author's (KC) unpublished data also have not shown any significant advantage in terms of postoperative granulation tissue formation or the final outcome, as long as a large osteotomy is created with well-marsupialized flaps. When needed, the author (KC) use it as 0.04% solution, soaked in dental roll applied topically over the opened lacrimal sac for 5 min. However, evidence with the help of basic science studies suggests that 0.02% for 3 min may be adequate to prevent cellular proliferation of the fibroblasts [9].

A piece of absorbable packing, e.g., Gelfoam is sometimes used to keep the flaps in place, and triamcinolone solution can be added which may decrease inflammatory response during mucosal healing [2]. Packing with ribbon gauze to tamponade the marsupialized lacrimal sac in the first few days postoperatively is another option favored by the author (KC), but systemic antibiotics should be given to avoid infection. The author noticed slight increase in postoperative granulation tissue when Gelfoam was used.

Postoperative Management

Postoperatively, nasal steroid spray and steroid-antibiotic eye drops are prescribed. Systemic antibiotics can be prescribed based on the surgeon's discretion. Patients are instructed to perform nasal douching to remove crusts and improve mucosal healing. The author (KC) adopted a relatively frequent (every 2 weeks) postoperative follow-up with endoscopic monitoring of ostial healing and removal of "ostial-threatening" granulation tissue and found that most granulation tissue formed at around 6 weeks postoperatively. The follow-up of the patient is based upon the presence of silicone stents and the need for frequent follow-up, if any.

Outcomes

A meta-analysis comparing external and endoscopic DCRs (355 studies included) found that mechanical endoscopic DCR had comparable rates of success with external DCR [10]. The scarring, infection, and bleeding were much less in an endoscopic DCR [10]. With equal success rates and better cosmesis, endoscopic DCR is gaining wide popularity.

Update (2015–2016)

Outcomes

The last 2 years has seen a large quantity of data with regard to powered endoscopic dacryocystorhinostomy and its high success rates which equals and occasionally exceeds that of external DCR [11–15]. The long-term outcomes have also been reported to be excellent [13–15]. These could be attributed to better anatomical understanding, better diagnostic workups, high-quality instruments and imaging systems, and better understanding of postoperative ostium evaluation and management. A massive series [16] of 1083 cases of

endoscopic DCR which were followed up for a minimum of 6 months have shown a high success rate of 92.7%, and most of the failures did well subsequently upon additional procedures. The authors advocated it as a first-line therapy for nasolacrimal duct obstruction. Analysis of anatomical failures in another large series did not show any significant differences in the causative factors between an external and an endoscopic DCR [17]. The overall current literature favors endoscopic DCR on par with external DCR.

Pediatric Endoscopic DCR

Pediatric DCRs have their own set of challenges owing to the narrow anatomical confines, mobility of instruments, proximity of various critical structures, and aggressive postoperative healing. A major systematic review of 14 studies on exclusive pediatric endoscopic DCR with an average follow-up of 15 months has shown the mean (95% CI) rate of success was 0.87 (0.80–0.91) and the mean (95% CI) failure rate was 0.14 (0.09–0.21) [18]. Hence the systematic review showed that the outcomes of endoscopic DCR in pediatrics are comparable to that of an external DCR.

Mucosal Flaps

Mucosal flaps can be fashioned using numerous instruments like blades, electrocautery, and radiofrequency. A comparative study on flap creation in endoscopic DCR has shown that cold instruments like sickle knife have better wound healing as compared to the electrocautery [19]. A systematic review has shown that there is a trend toward reduced granulation and improved outcomes when both the lacrimal sac flaps and the nasal mucosal flaps were preserved [20].

Entire Lacrimal Sac Within Ethmoid Sinuses

The bony lacrimal fossa has an intricate relationship with the ethmoid sinuses, and it is not uncommon to encounter anterior ethmoid air cells during a DCR. However, occasionally, the lacrimal sac may be malpositioned entirely within the boundaries of ethmoid sinuses (Figs. 21.18, 21.19, 21.20) and can pose a surgical challenge [21]. The bony ethmoid lateral to the sac in such cases should be carefully preserved to avoid orbital injury. The lateral ethmoidal wall mucosa should be utilized for a mucosa to mucosa approximation. The anatomical variations of ethmoidal vessels must be kept in mind to avoid injury. Good sinus surgery training, through endoscopic anatomy, careful maneuvering, and occasional use of image-guidance techniques are helpful in achieving good outcomes [21].

Endoscopic DCR in Acute Dacryocystitis

Endonasal approach dacryocystorhinostomy is fast evolving as a first-line primary modality of management of acute dacryocystitis [22–25]. Unlike an external DCR, it can be performed safely in an acute infective scenario. The other advantages include reducing the incidence of fistula formation and complications, hastening of recovery, and decreased morbidity because the root cause, nasolacrimal obstruction, is effectively bypassed. The success rates of both endoscopic and non-endoscopic endonasal approaches in acute dacryocystitis and lacrimal abscess are beyond 90%, and these results have been seen to be maintained on long-term follow-ups [22–25]. The current practice of the authors is to administer antibiotics immediate preoperatively, perform the surgery, and continue postoperative antibiotics for 5 days.

Postoperative Ostia

Evaluation of postoperative ostia is important from the outcome perspective, and numerous parameters to detect aberrant healing have been described earlier [26, 27]. Ali et al. [28] reviewed their ostia following powered endoscopic dacryocystorhinostomy for up to 2 years following the surgery. They showed that most healing happens by 4 weeks, and beyond that there is little change, if any, in the behaviors of the ostia. This study along with certain electron microscopic studies of biofilms on stents provides reasonable evidence for not using stents (if at all used) beyond 4 weeks in routine cases.

Learning Curve of Endoscopic DCR and Trainee Outcomes

Endoscopic DCR is often associated with a steep learning curve. However, good surgical outcomes in the hands of trainees (rhinology and oculoplasty fellows) are possible [29–31]. The factors that affect outcomes include endoscopic anatomical knowledge, adequate planning of operating times, instrument handling, supervision, and structured skill transfers [29–31]. Mucosal trauma is high in the early stage, and intubation during training period is preferred in cases where mucosal adhesions are anticipated.

Endoscopic DCR and Sleep Apnea

The prevalence of obstructive sleep apnea (OSA) is on a rise owing to better diagnostic facilities and awareness. Continuous positive airway pressure (CPAP) is a common modality of management in these patients. The prevalence of OSA in a cohort of DCR patients was reported to be 8.1%

[32]. However, the use of CPAP in a post-DCR setup can lead to numerous ocular surface complications. Compliance to CPAP therapy reduces with the onset of ocular surface symptoms. Numerous modifications to CPAP may be required following a DCR including using of full face masks, reducing the pressures, and adding humidifier heating tubes and ocular lubrication [32]. It is therefore very important to counsel the patients of known OSA or at risk of OSA undergoing DCR, with regard to the complications and possible managements.

References

1. McDonogh M, Meiring J. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–7.
2. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
3. Goldberg RA. Endonasal dacryocystorhinostomy: is it really less successful? Arch Ophthalmol. 2004;122:108–10.
4. Davies MJ, Lee S, Lemke S, et al. Predictors of anatomical patency following primary endonasal dacryocystorhinostomy: a pilot study. Orbit. 2011;30:49–53.
5. Codere F, Denton P, Corona J. Endonasal dacryocystorhinostomy: a modified technique with preservation of the nasal and lacrimal mucosa. Ophthal Plast Reconstr Surg. 2010;26:161–4.
6. Wormald PJ, Kew J, Van Hasselt CA. The intranasal anatomy of the nasolacrimal sac in endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2000;123:307–10.
7. Caversaccio M, Hausler R. Insertion of double bicanalicular silicone tubes after endonasal dacryocystorhinostomy in lacrimal canalicular stenosis: a 10-year experience. ORL J Otorhinolaryngol Relat Spec. 2006;68:266–9.
8. Chong KK, Lai FH, Ho M, Luk A, Wong BW, Young A. Randomized trial on silicone Intubation in endoscopic mechanical dacryocystorhinostomy (SEND) for primary nasolacrimal duct obstruction. Ophthalmology. 2013;120:2139–45.
9. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration—a fundamental study on human nasal mucosal fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
10. Huang J, Malek J, Chin D, et al. Systematic review and meta-analysis on outcomes for endoscopic versus external dacryocystorhinostomy. Orbit. 2014;33:81–90.
11. Ali MJ, Psaltis AJ, Murphy J, et al. Powered endoscopic dacryocystorhinostomy: a decade of experience. Ophthal Plast Reconstr Surg. 2015;31:219–21.
12. Chan W, Fahlbusch D, Dhillon P, et al. Assisted local anesthesia for powered endoscopic dacryocystorhinostomy. Orbit. 2014;33:416–20.
13. Ali MJ, Psaltis AJ, Bassiouni A, et al. Long-term outcomes in primary powered endoscopic dacryocystorhinostomy. Br J Ophthalmol. 2014;98:1678–80.
14. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomy. Int Forum Allergy Rhinol. 2014;4:1016–9.
15. Knisely A, Harvey R, Sacks R. Long-term outcomes in endoscopic dacryocystorhinostomy. Curr Opin Otolaryngol Head Neck Surg. 2015;23:53–8.
16. Jung SK, Kim YC, Cho WK, et al. Surgical outcomes of endoscopic dacryocystorhinostomy: analysis of 1083 consecutive cases. Can J Ophthalmol. 2015;50:466–70.
17. Dave TV, Mohammed FA, Ali MJ, et al. Etiological analysis of 100 anatomically failed dacryocystorhinostomies. Clin Ophthalmol. 2016;10:1419–22.
18. Gioacchini FM, Alicandri-Ciufelli M, Kaleci S, et al. The outcomes of endoscopic dacryocystorhinostomy in children: a systematic review. Int J Pediatr Otorhinolaryngol. 2015;79:947–52.
19. Roh HC, Baek S, Lee H, et al. Comparison of impact of four surgical methods on surgical outcome in endoscopic dacryocystorhinostomy. J Craniomaxillofac Surg. 2016;44:749–52.
20. Green R, Gohil R, Ross P. Mucosal and lacrimal flaps for endonasal dacryocystorhinostomy: a systematic review. Clin Otolaryngol. 2017;42(3):514–20.
21. Ali MJ, Singh S, Naik MN. Entire lacrimal sac within the ethmoid sinus: outcomes of powered endoscopic dacryocystorhinostomy. Clin Ophthalmol. 2016;10:1199–203.
22. Lombardi D, Mattavelli D, Accorona R, et al. Acute dacryocystitis with empyema of the lacrimal sac. Is immediate endoscopic dacryocystorhinostomy justified? Otolaryngol Head Neck Surg. 2014;150:1071–7.
23. Kamal S, Ali MJ, Pujari A, et al. Primary powered endoscopic dacryocystorhinostomy in the setting of acute dacryocystitis and lacrimal abscess. Ophthal Plast Reconstr Surg. 2015;31:293–5.
24. Chisty N, Singh M, Ali MJ, et al. Long-term outcomes of powered endoscopic dacryocystorhinostomy in acute dacryocystitis. Laryngoscope. 2016;126:551–3.
25. Jain S, Ganguly A, Singh S, et al. Primary non-endoscopic endonasal versus delayed external dacryocystorhinostomy in acute dacryocystitis. Ophthal Plast Reconstr Surg. 2017;33(4):285–8.
26. Ali MJ, Psaltis AJ, Wormald PJ. Dacryocystorhinostomy ostium: parameters to evaluate the DCR ostium scoring. Clin Ophthalmol. 2014;8:2491–9.
27. Ali MJ, Psaltis AJ, Wormald PJ. The dacryocystorhinostomy ostium granulomas: classification, indications for treatment, management modalities and outcomes. Orbit. 2015;34:146–51.
28. Ali MJ, Psaltis AJ, Ali MH, et al. Endoscopic assessment of dacryocystorhinostomy ostium after primary powered surgery: behavior beyond 4 weeks. Clin Exp Ophthalmol. 2015;43:152–5.
29. Malhotra R, Norris JH, Sagili S, et al. The learning curve in endoscopic dacryocystorhinostomy: outcomes in surgery performed by trainee oculoplastic surgeons. Orbit. 2015;34:314–9.
30. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes in primary powered endoscopic dacryocystorhinostomy: comparison between experienced versus less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.
31. Kamal S, Ali MJ, Nair AG. Outcomes of endoscopic dacryocystorhinostomy: experience of a fellowship trainee at a tertiary care center. Indian J Ophthalmol. 2016;64:648–53.
32. Ali MJ, Psaltis AJ, Murphy J, et al. Endoscopic dacryocystorhinostomy and obstructive sleep apneoa: the effects and outcomes of continuous positive airway pressure therapy. Clin Exp Ophthalmol. 2015;43:405–8.

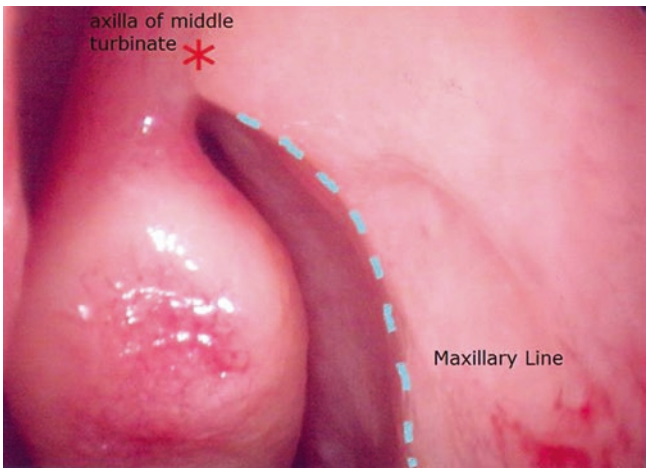


Fig. 21.1 *Asterisk* denotes the axilla of middle turbinate. The important maxillary line is represented by the *blue dashed line*

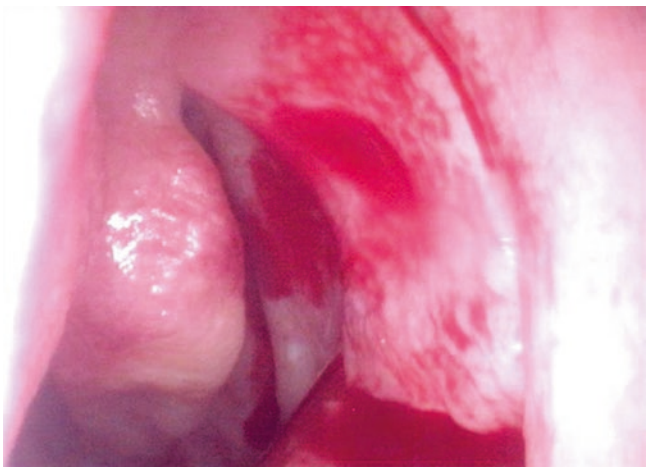


Fig. 21.2 An L-shaped incision is made over the lateral nasal mucosa in front of the maxillary line

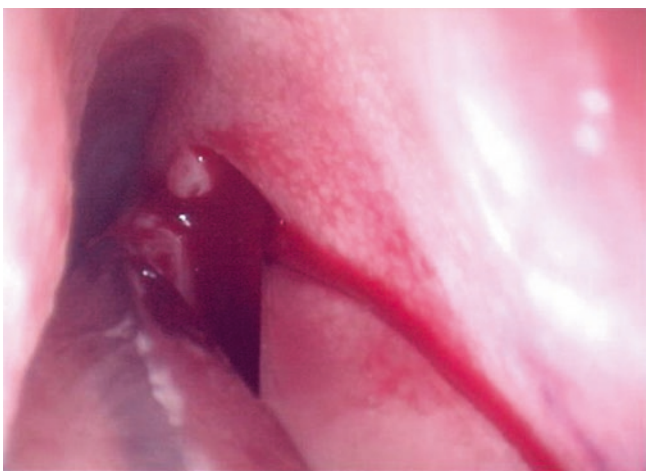


Fig. 21.3 Superior horizontal incision of the nasal mucosal flap using Westcott scissors

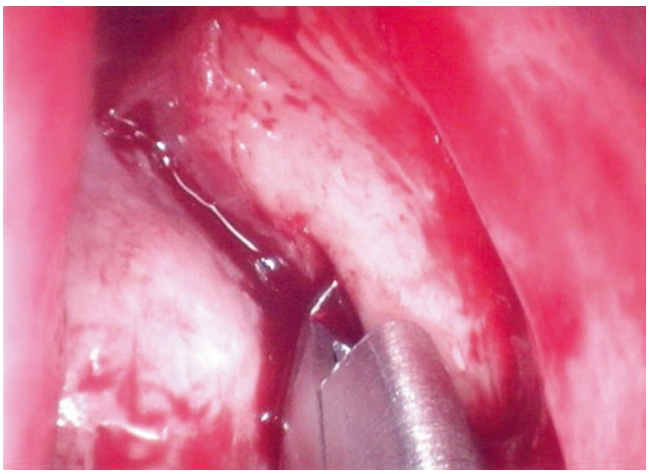


Fig. 21.4 Kerrison Rongeur is used to engage and remove the maxillary bone starting from the maxillary line

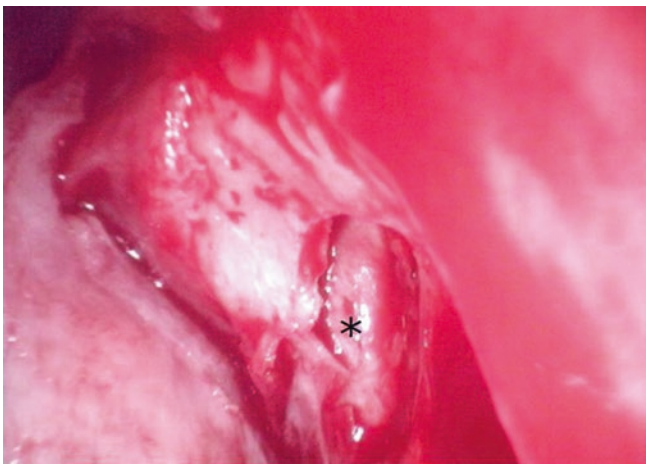


Fig. 21.5 Removal of maxillary bone exposed the inferior half of the lacrimal sac. *Asterisk* denotes the lacrimal sac

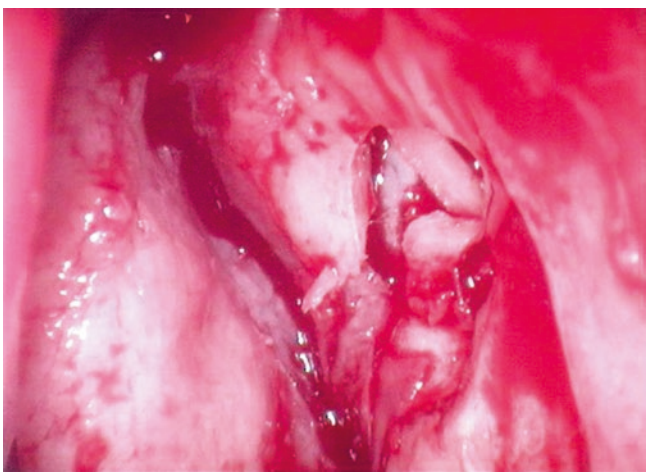


Fig. 21.6 Bone removal is continued anteriorly and superiorly

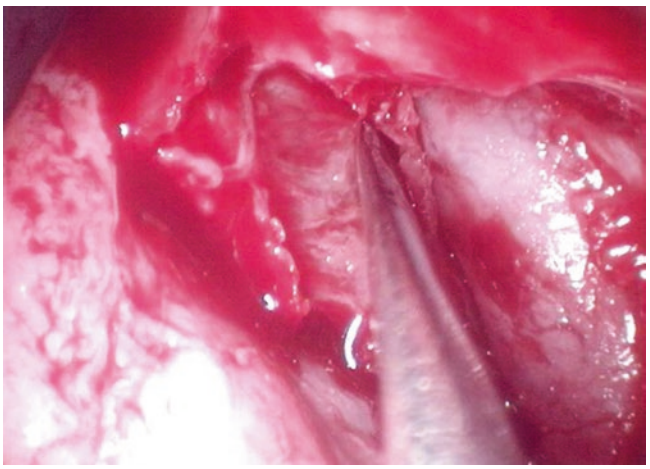


Fig. 21.7 The thin lacrimal bone at the posterior half of the lacrimal sac is elevated with freer elevator

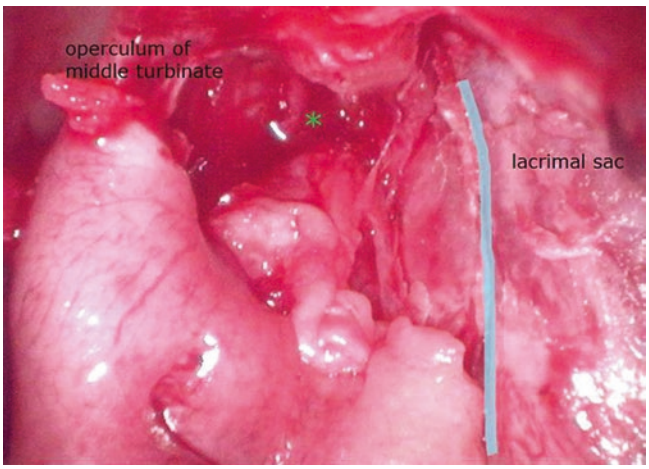


Fig. 21.10 Superoposterior to the unopened lacrimal sac is the operculum of middle turbinate and the opened agger nasi air cell (*asterisk*). *Blue line* represents the lacrimal sac

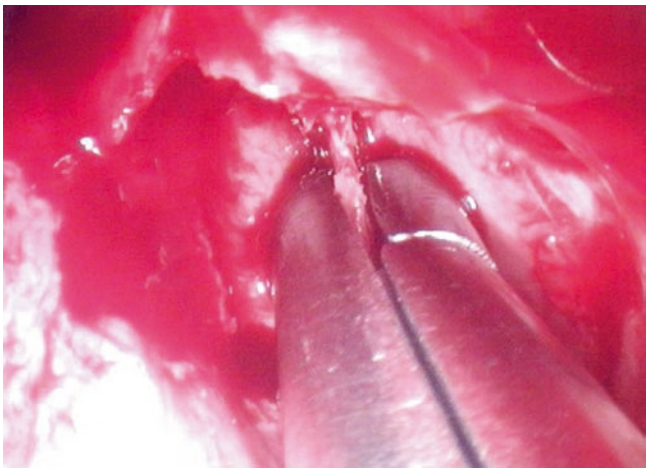


Fig. 21.8 The lacrimal bone being removed using Takahashi forceps

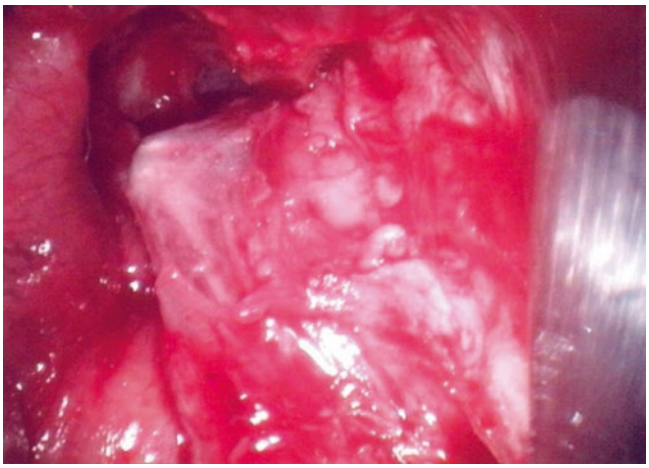


Fig. 21.11 Bowman probes are inserted through the upper and lower canaliculi into the lacrimal sac, tenting the medial wall of the lacrimal sac on the posterior aspect

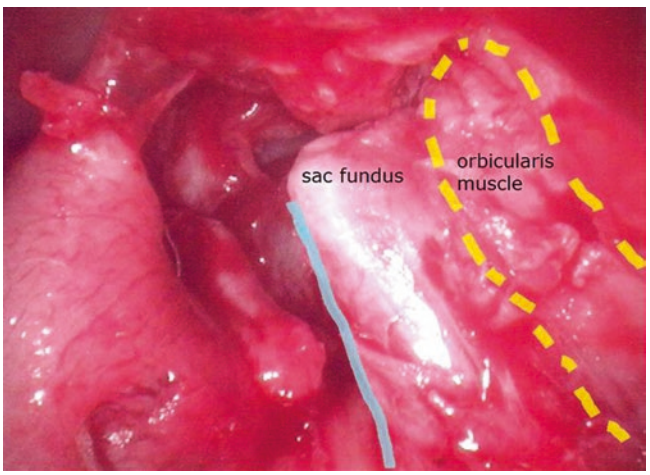


Fig. 21.9 A large osteotomy is required to expose the lacrimal sac fundus. Superoanterior to the unopened lacrimal sac (*blue solid line*), exposed orbicularis muscle is represented by the *yellow dashed line*

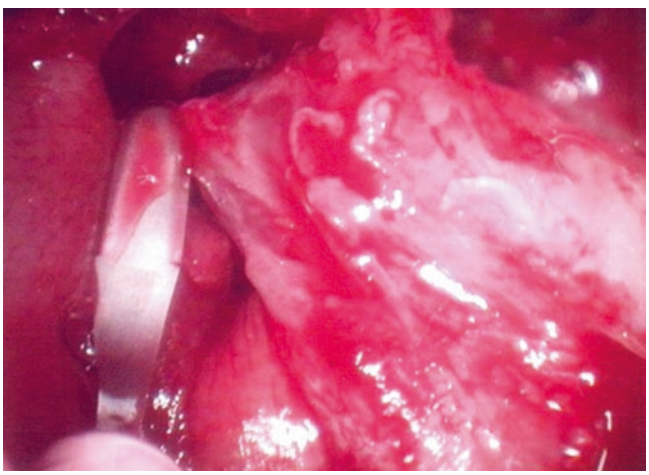


Fig. 21.12 Crescent knife is used to make a vertical incision along the length of the lacrimal sac from the sac fundus down to the sac-duct junction

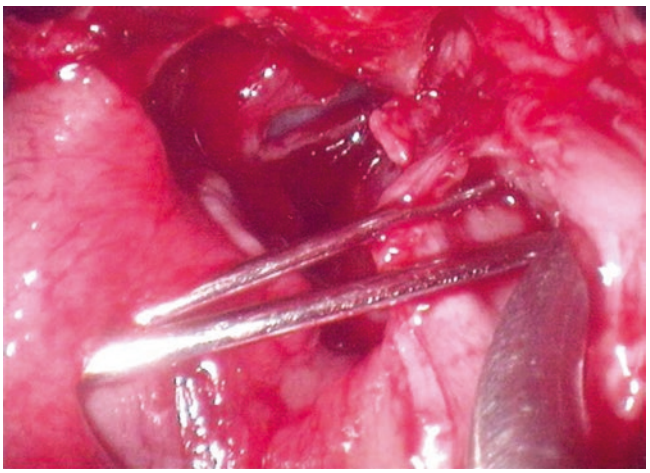


Fig. 21.13 An "I" incision is completed with upper and lower horizontal releasing incision at the top and the bottom of the vertical incision using Westcott scissors or crescent knife

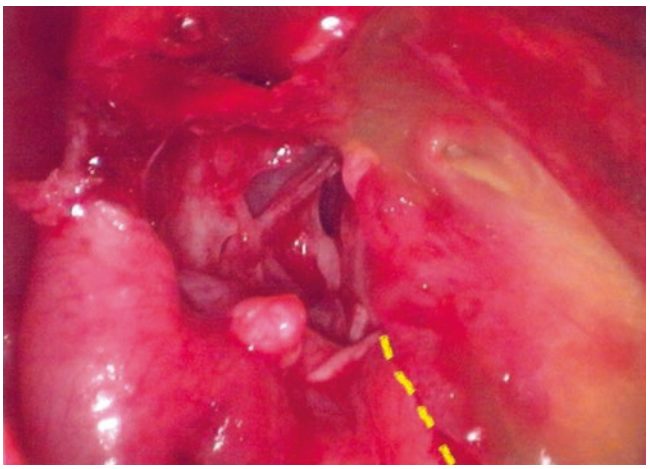


Fig. 21.16 The nasal mucosal flap was repositioned back and approximated the posterior edge of the marsupialized lacrimal sac flap (*yellow line*)

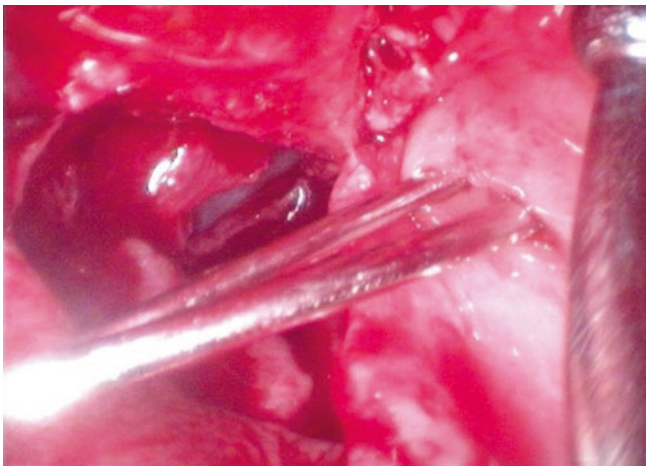


Fig. 21.14 The lacrimal sac was completely marsupialized, and both the anterior and posterior sac flap were laid opened and remained flat on the lateral nasal wall

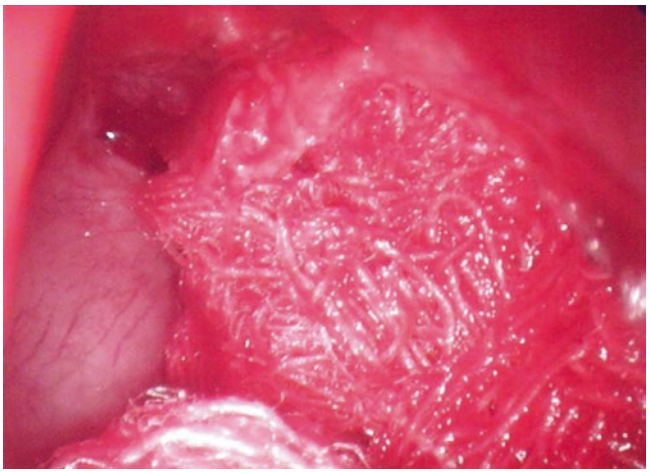


Fig. 21.17 Intraoperative nasal packing with ribbon gauze to achieve hemostasis

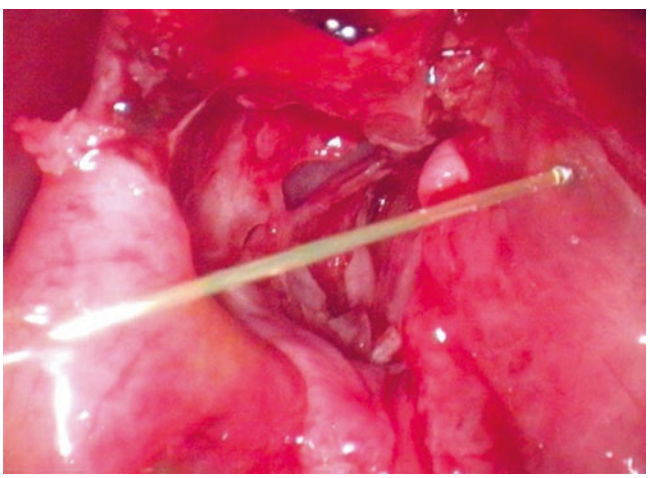


Fig. 21.15 Internal ostium is identified with the fluorescein flushing through

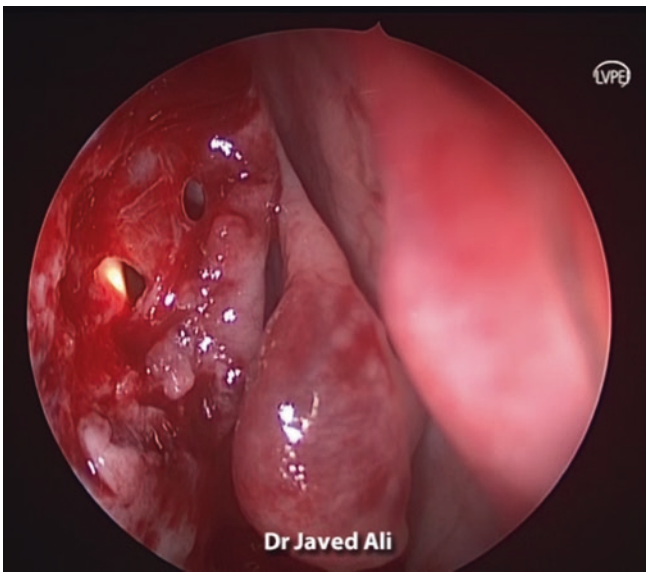


Fig. 21.18 Endoscopic view following partial removal of the bulla ethmoidalis. Note the lacrimal light pipe beyond the mucosa of the bulla

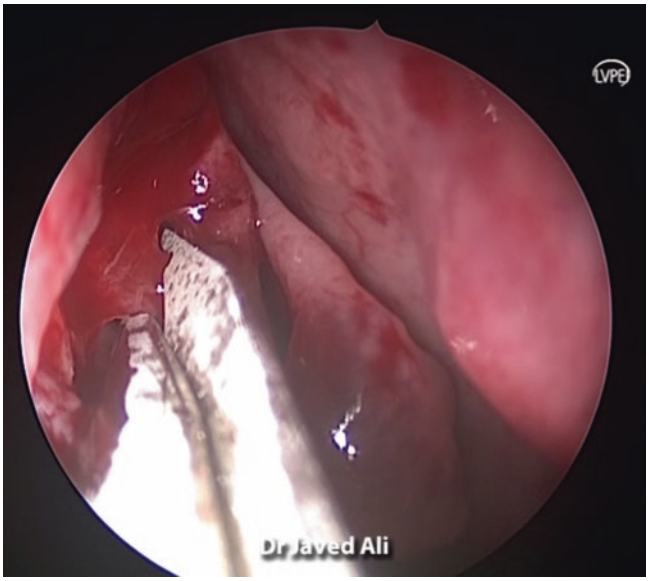


Fig. 21.19 Mucosa of the bulla completely excised to expose the lacrimal sac

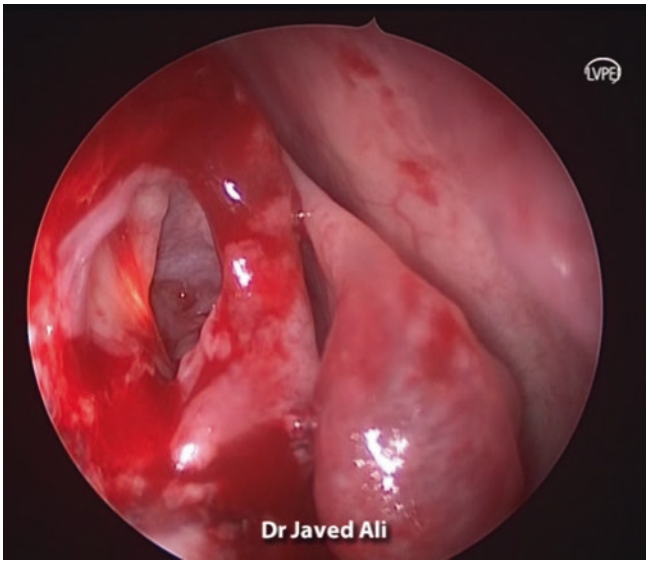


Fig. 21.20 The entire sac is at the level of middle ethmoids

Ultrasonic Endoscopic Dacryocystorhinostomy

22

Mohammad Javed Ali

Introduction

Endoscopic endonasal dacryocystorhinostomy has gained a considerable popularity in the recent two decades with the advent of the rigid fiber-optic endoscope [1, 2]. There are numerous advantages of endoscopic dacryocystorhinostomy (DCR) and include no facial incision, no disruption of the medial canthal tendon, preservation of the lacrimal pump, less traumatic, and feasibility in acute dacryocystitis [1, 2]. Recent published meta-analysis has revealed comparable results with external DCR with lesser risks of infection and bleeding [3]. With increasing understanding, it is clear that among others, two major goals for a successful endoscopic DCR are creating large osteotomy and as minimally traumatic as possible. Both of these can be easily achieved with an ultrasonic osteotomy.

Ultrasonic DCR was first performed by Krasnov in 1971 [4] and reintroduced in 2005 by Sivak-Callcott [5]. This is a technique where piezoelectric or ultrasonic waves in the range of 20–30 KHz are used to cut mineralized tissues only, thus sparing the soft tissues. This technology has been successfully used in neurosurgery, otology, and craniofacial procedures [6–8]. The advantage of safety in crucial areas made its adaptation for orbital and lacrimal surgeries natural. This chapter will elucidate the instrumentation, principles, techniques, and results of ultrasonic DCR.

Instruments and Setup

The author uses Synthes Piezoelectric System (Synthes GmbH, Oberdorf, Germany) that consists of a main device or console, foot pedal, handpiece, and various tips for cutting bone and bone substitutes.

Console

The console is the main control unit, which has two ends like an ear, which are irrigation pumps, one on each side (Fig. 22.1). There are two cable connectors in the front for two handpiece attachments simultaneously (Fig. 22.1). The center of console houses a LCD touch screen with various functions and controls like the irrigation flow, LED light option on handpiece, flush, and operating programs from D1 to D4 (Figs. 22.1 and 22.2).

Each of this can have a range from 1 to 5 (low power to high power). D1 is the most powerful setting used for very dense and thick bones whereas D4 is used for very thin bones and soft tissue detachments (Fig. 22.2).

Pump House

The pump house (one on each side of console) is designed to accommodate peristaltic cassettes and irrigation tubing (Fig. 22.3). They generate flow from 10 to 120 ml/min with an interval of 10 ml/min and a flush rate of 120 ml/min. The other end of tubing is attached to the handpiece.

Handpiece

The handpiece houses an opening at its front for accommodating various tips for different functions (Fig. 22.4). Once the tips are placed, they are secured in a clock wise turning manner using the flat or the torque wrenches (Fig. 22.5). The circumference of this opening has six LED lights for providing visualization in deep cavities (Fig. 22.6). At the rear end is a cable that is attached to the front panel of console. There is also a small metal pipe to which the irrigation tube is attached.

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_22

Cutting Tips

There are numerous cutting tips but can be grouped into four as saw tips, diamond tips, scalpel tips, and decorticating tips (Fig. 22.7). The diamond and saw tips are mostly used in endoscopic DCR.

Foot Pedal

The foot pedal has all the controls as that of the console and helps the surgeon to work in a sterile environment, without much dependency on the assistants (Fig. 22.8).

Principle

The machine uses an alternate current to cause vibrations, contractions, and expansion of the piezoelectric element or quartz particle. These cause generation of micro vibrations which in turn cause inserts to vibrate linearly between 60 and 210 μm. The piezo element thus generates ultrasonic vibrations, which are transmitted to the cutting tips, causing fragmentation of the target bone by acoustic and jackhammer effects.

Advantages in Endoscopic DCR

- Easy osteotomy
- Easy superior osteoplasty
- Minimal heat/no necrosis
- Minimizes bleeding
- Safe for sac and soft tissues
- Enhanced visualization (LED)
- Quicker surgery
- Low surgeon fatigue
- Superior histological healing
- Good for beginners

Surgical Technique

Preparation and Anesthesia

Ultrasonic or piezoelectric-assisted DCR may be performed under either general anesthesia or local anesthesia. The author prefers general anesthesia. The middle turbinate, axilla, and adjacent lateral wall are infiltrated with 2% xylocaine with 1:10,000 adrenaline (Fig. 22.9) and followed by nasal packing with ribbon gauze or preferably neurosurgical patties (Fig. 22.10). The patties are medicated with 0.05% (adults) or 0.025% (pediatric) xylometazoline. It is best to leave the patties for at least 8–10 min for good decongestion. With the patient in supine position, the patients' head should be slightly elevated and neck slightly extended so as to facilitate superior osteotomy.

Fashioning the Nasal Mucosa Flaps

A no. 15 blade or sickle knife or a radio-frequency device (Fig. 22.11) is used to make the incision over the lateral nasal mucosa down to the periosteum in front of the maxillary line (Fig. 22.12). The first horizontal incision of 12–15 mm length is made 10 mm above the axilla of the middle turbinate (Fig. 22.13). The vertical incision begins from the anterior end of the horizontal incision and end at of about two-thirds of the vertical height of the middle turbinate (Fig. 22.14). A horizontal incision is then made at right angle at the inferior end of the vertical incision until reaching the maxillary line, short of uncinate process. A Freer Periosteal Elevator is then used to elevate the mucoperiosteal flap, baring the underlying bone (Fig. 22.15) and is then tucked around the axilla of middle turbinate to keep it out of the operating field.

Osteotomy

A diamond cutting tip at a flow rate of 30 ml/min with D2 program with power of 5 is used to begin the osteotomy from the inferior end of the maxillary line. Place the diamond tip perpendicular to the target bone (Fig. 22.16) and start emulsifying the bone in a brush-stroke movement. Only a slight pressure can be used but force is never needed. A trench is initially created (Fig. 22.17) and subsequently deepened by slight back and forth movement in line with the initial cut, till entire bone is emulsified, exposing the underlying nasolacrimal duct (Fig. 22.18). The osteotomy is then created anteriorly and posteriorly. Simultaneous suction would help in clearing the emulsified debris. The extent of osteotomy anteriorly and posteriorly should be 2 mm beyond complete exposure of the lacrimal sac. One would realize that the cutting tip does not work if it touches the lacrimal sac or surrounding soft tissues (Fig. 22.18). Once the superior part of the ostium is reached, a flow rate of 40–50 ml/min with D1 program with power of 5 is used since the bone is very thick here (Fig. 22.19). Occasionally a long right- or left-sided cutting saw tip may be used (Fig. 22.20), but care should be taken while using it since they are sharp. All bones over the lacrimal sac fundus and common canaliculus opening should be removed. Superoanteriorly, the osteotomy should extend till orbicularis oculi muscle is just exposed, and superoposteriorly, the agger nasi air cells or operculum of the middle turbinate is entered to ensure full fundus exposure (Fig. 22.20).

Fashioning Lacrimal Sac Flaps

The author prefers filling the lacrimal sac with fluorescein-stained viscoelastic since this not only dilates the lacrimal canaliculi and sac (Fig. 22.21) but also protects the lateral wall of sac and internal common opening from inadvertent trauma. The Bowman probe is passed through the upper canaliculus and is held horizontally tenting the medial wall of the lacrimal sac (Fig. 22.22).

A crescent or DCR spear knife is used to make a vertical incision along the entire length of the lacrimal sac from the fundus down to the nasolacrimal duct (Fig. 22.23). An "I"- or "Y"-shaped incision is then completed with upper and lower horizontal releasing cuts at the top and the bottom using a sickle or spear knife (Fig. 22.24). The lacrimal sac is then completely marsupialized, and both the anterior and posterior sac flaps are laid open and flat like an open book on the lateral nasal wall (Fig. 22.25).

Edge to Edge Mucosal Apposition

Once both the nasal mucosal and lacrimal sacs are fashioned, an edge to edge approximation is performed so as to achieve healing by primary intention. A ball probe is useful to spread open the lacrimal sac flaps. No bare bone should be left behind since that may incite granulation tissue. The anterior flap should be in contact with the anterior cut end of the nasal mucosa whereas the posterior flap should lie back flat in apposition with the agger nasi mucosa (Fig. 22.26).

Hemostasis

A correctly done endoscopic DCR rarely would have hemostasis issues! When needed it can be achieved with Merocel nasal packing (Fig. 22.27), cold saline irrigation, head-up position, or judicious bipolar cautery of the bleeding mucosal edges. Small piece of Surgicel (absorbable hemostat, oxidized cellulose polymer) gauze can be left at the end of the surgery to maintain hemostasis.

Adjunctive Modalities

The use of silicone intubation and mitomycin C (MMC) is controversial without concrete proof of benefit or harm. For their endoscopic DCR's, the author prefers using intubation for 4 weeks and 0.2 mg/ml for 3 min of MMC as per protocols described in literature (Figs. 22.28 and 22.29) [9, 10].

Postoperative Management

Postoperatively, topical antibiotics, nasal steroid spray, and steroid-antibiotic eyedrops are prescribed. Prophylactic systemic antibiotics can be used at the discretion of the surgeon. Patients are instructed to perform nasal douching to remove crusts and improve mucosal healing. The follow-up of the patient is at 4 weeks for stent removal and further follow-up only if needed.

Outcomes

In view of this being among newer procedures, very few studies have look into the outcomes [5, 11–14]. Studies have found piezoelectric assistance to be quick and respectful to surrounding tissues [12–15]. The largest series by Murchinson et al. [11] which studied 59 DCRs of 49 patients found it to be comparable to microdrill endoscopic DCR's success. No complications related to ultrasonic emulsification were noted in their series. Salami et al. [13] in their 20 cases found this technique to be successful in all their patients and noted no granulation or synechiae at the ostium. In another comparative study between burr and piezoelectric osteotomy, the histological bone healing was found to be superior with piezo assistance [15]. The bone healing was more rapid and primarily composed of bone rather than fibrovascular tissues. Clinically, the outcomes of USG were similar to those of powered microdrill DCRs [16]. Ali et al. [17] has found that ultrasonic endoscopic DCR can be used with equal efficacy in both pediatric and adult cases. There were no technical difficulties with additional setup of USG along with endoscopic system. One patient in their series has an accidental epithelial nasal burn during the surgery because of temporary disruption of irrigation. Chappel et al. [18] showed significant learning curve with USG endoscopic DCRs; however, the time taken for unilateral and bilateral surgeries reduced significantly by 36.4% and 33.9%, respectively. Another report showed that the time taken for superior osteotomy is not significantly different between the USG and powered burrs [19]. Because of the safety profile with the surrounding soft tissues, it could well be the technique of choice with the beginners in endoscopic surgery!

References

1. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
2. Goldberg RA. Endonasal dacryocystorhinostomy: is it really less successful? Arch Ophthalmol. 2004;122:108–10.
3. Huang J, Malek J, Chin D, et al. Systematic review and meta-analysis on outcomes for endoscopic versus external dacryocystorhinostomy. Orbit. 2014;33:81–90.

4. Krasnov MM. Ultrasonic dacryocystorhinostomy. Am J Ophthalmol. 1971;72:200–1.
5. Sivak-Callcott JA, Linberg JV, Patel S. Ultrasonic bone removal with sonopet omni: a new Instrument for orbital and lacrimal surgery. Arch Ophthalmol. 2005;123:1595–7.
6. Yamasaki T, Moriatke K, Nagai H, et al. A new miniature ultrasonic surgical aspirator with a hand piece designed for transphenoidal surgery. Technical note. J Neurosurg. 2003;99:177–9.
7. Pribitkin EA, Lavasani LS, Shindle C, et al. Sonic rhinoplasty: sculpting the nasal dorsum with the ultrasonic bone aspirator. Laryngoscope. 2010;120:1504–7.
8. Hadeishi H, Suzuki A, Yasui N, et al. Anterior clinoidectomy and opening of the internal auditory canal using an ultrasonic bone curette. Neurosurgery. 2003;53:867–70.
9. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration—a fundamental study on human nasal mucosal fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
10. Kamal S, Ali MJ, Naik MN. Circumostial injection of mitomycin C (COS MMC) in external and endoscopic dacryocystorhinostomy: efficacy, safety profiles and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
11. Murchinson AP, Pribitkin EA, Rosen MR, et al. The ultrasonic bone aspirator in transnasal endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:25–9.
12. De Castro DK, Fay A, Wladis EJ, et al. Self-irrigating piezoelectric device in orbital surgery. Ophthal Plast Reconstr Surg. 2013;29:118–22.
13. Salami A, Dellepiane M, Salzano FA, et al. Piezosurgery in endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2009;140:264–6.
14. Antisdel JL, Kadze MS, Sindwani R. Application of ultrasonic aspirators to endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2008;139:586–8.
15. Salami A, Verecellotti T, Mora R, et al. Piezoelectric bone surgery in otologic surgery. Otolaryngol Head Neck Surg. 2007;136:484–5.
16. Steele TO, Wilson M, Strong EB. Ultrasonic bone assisted endoscopic dacryocystorhinostomy. Am J Otolaryngol Head Neck Surg. 2016;37:202–6.
17. Ali MJ, Singh M, Chisty N, et al. Endoscopic ultrasonic dacryocystorhinostomy: clinical profile and outcomes. Eur Arch Otorhinolaryngol. 2016;273:1789–93.
18. Chappel MC, Moe KS, Chang SH. Learning curve for use of the sonopet ultrasonic aspirator in endoscopic dacryocystorhinostomy. Orbit. 2014;33:270–5.
19. Ali MJ, Ganguly A, Ali MH, et al. Time taken for superior osteotomy in primary powered endoscopic dacryocystorhinostomy: is there a difference between an ultrasonic aspirator and mechanical drill? Int Forum Allergy Rhinol. 2015;5:764–7.

Fig. 22.1 The piezoelectric console

Fig. 22.4 The piezo handpiece

Fig. 22.2 Control panel on the console

Fig. 22.5 Wrench used to secure the tip

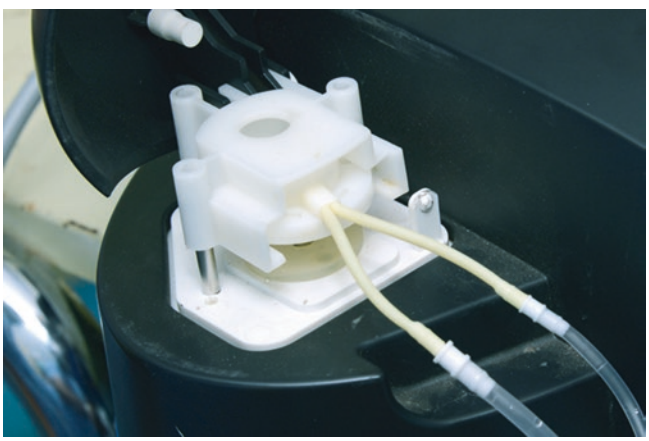


Fig. 22.3 The pump housing

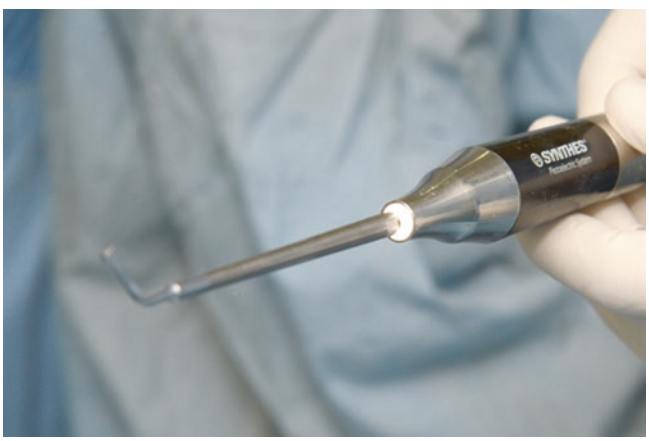


Fig. 22.6 Handpiece with LED light

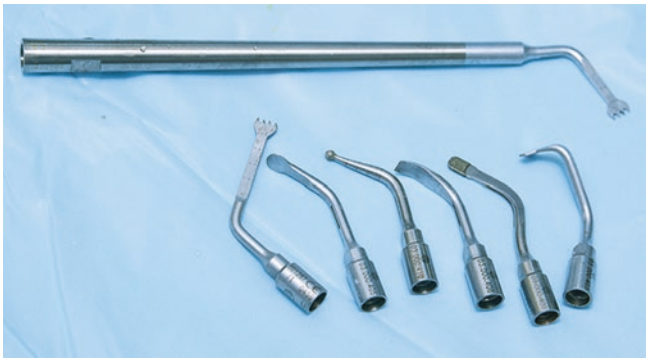


Fig. 22.7 Various cutting tips

Fig. 22.8 The control panel on foot pedal

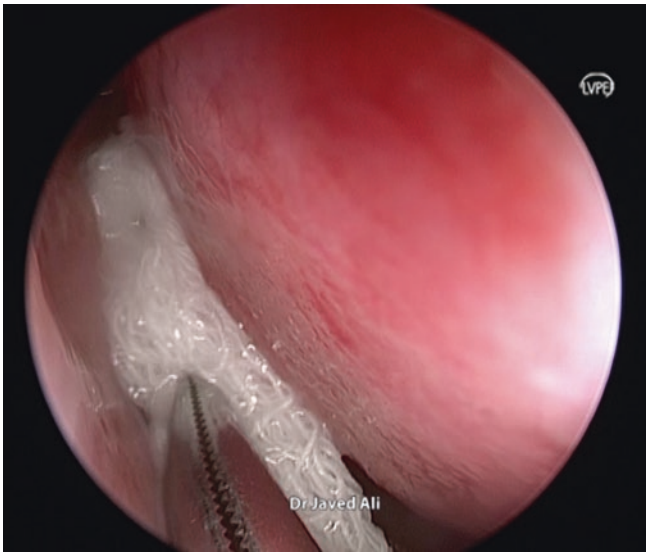


Fig. 22.10 Nasal decongestive packing

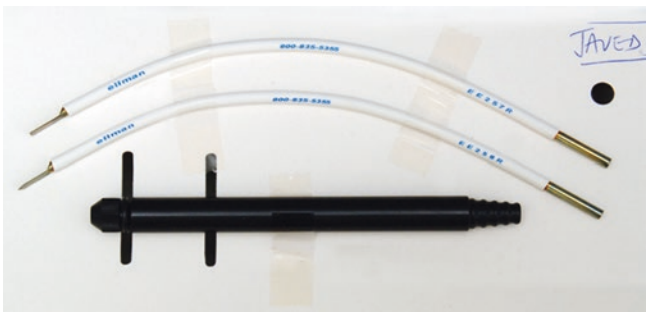


Fig. 22.11 Endoscopic malleable radio-frequency probes

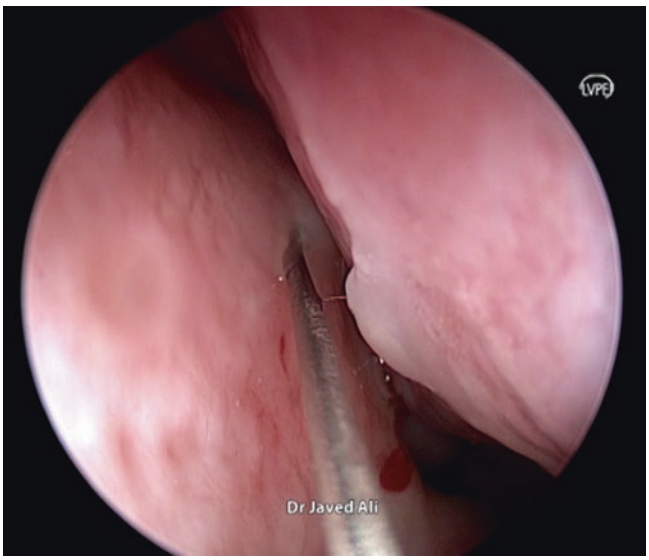


Fig. 22.9 Infiltration anesthesia

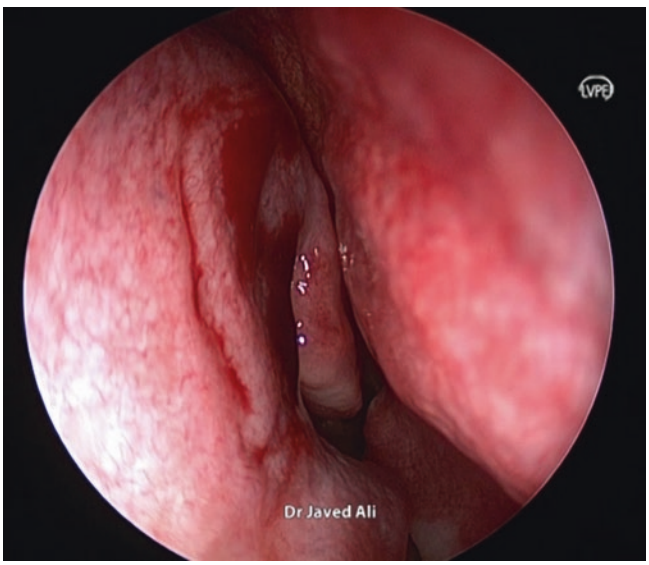


Fig. 22.12 Outline of the nasal mucosal incision

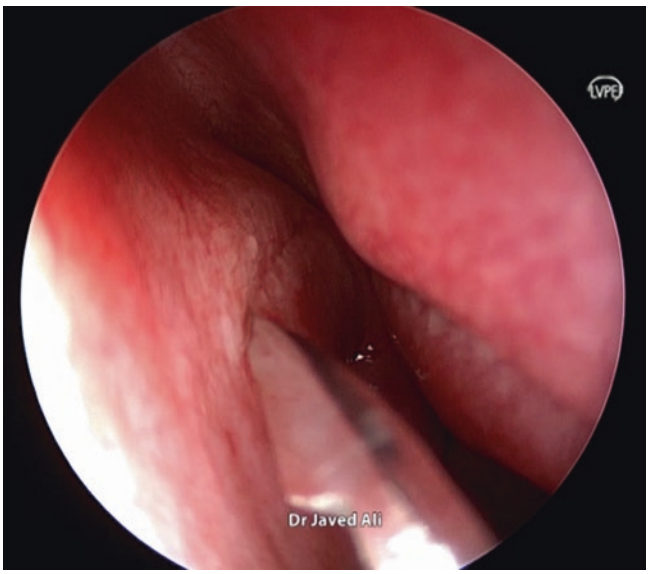


Fig. 22.13 Horizontal incision

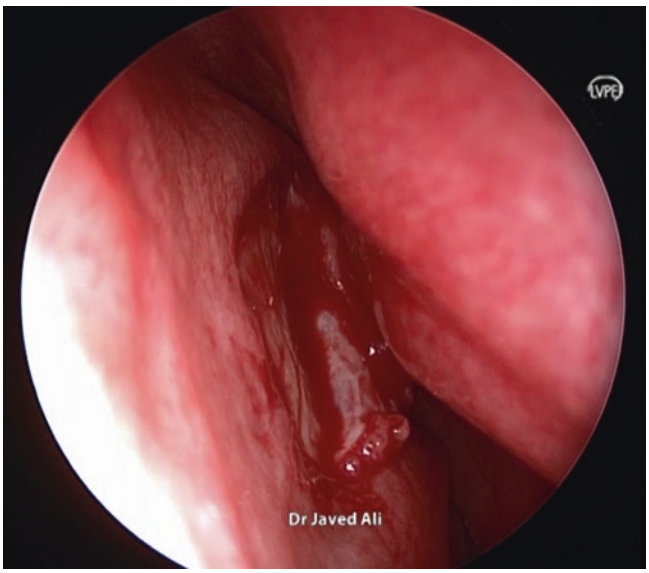


Fig. 22.15 Mucoperiosteal flap elevation

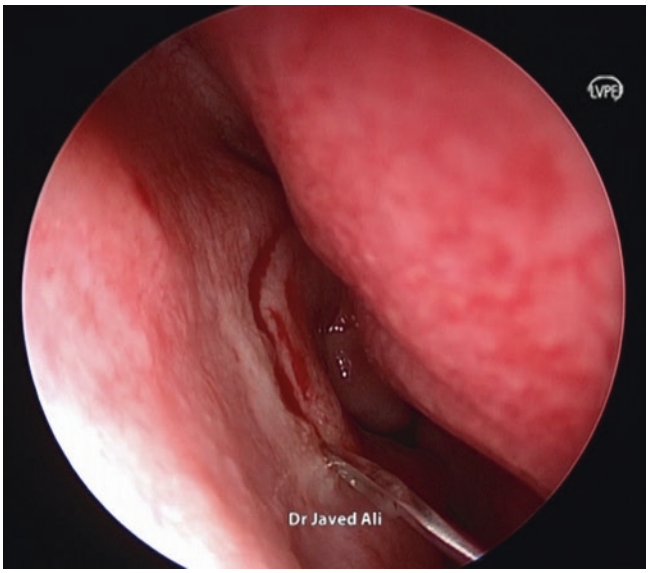


Fig. 22.14 Vertical incision

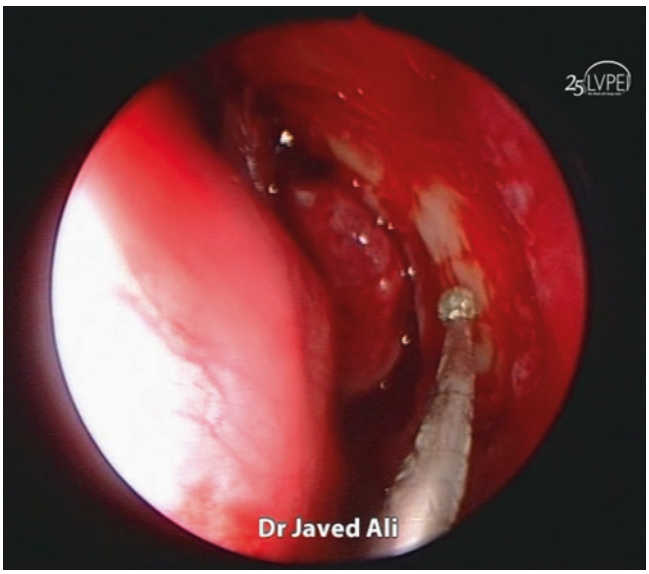


Fig. 22.16 Ultrasonic probe position

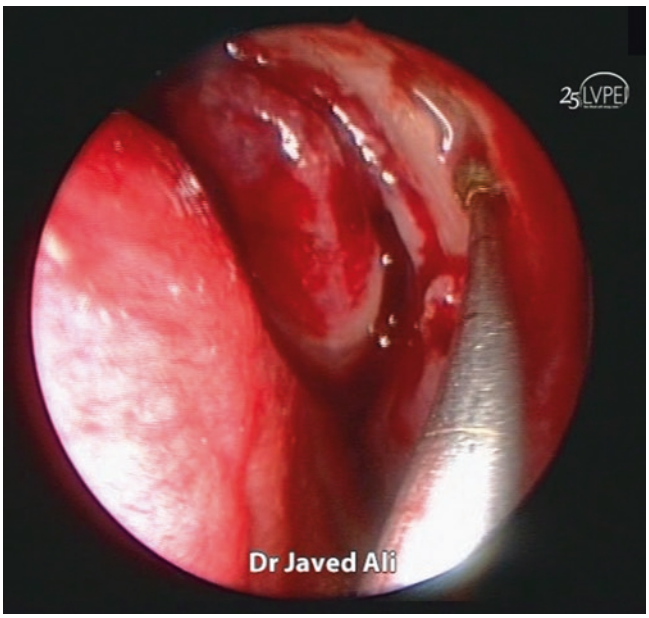


Fig. 22.17 Trench creation

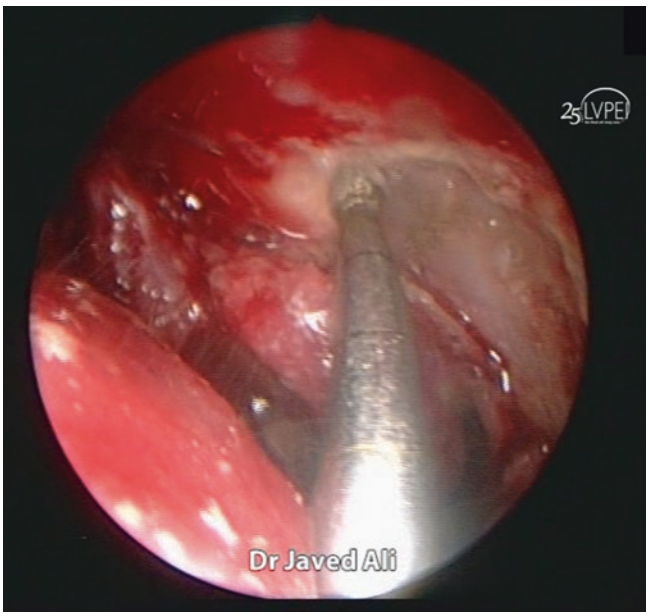


Fig. 22.19 Superior osteotomy with diamond tip

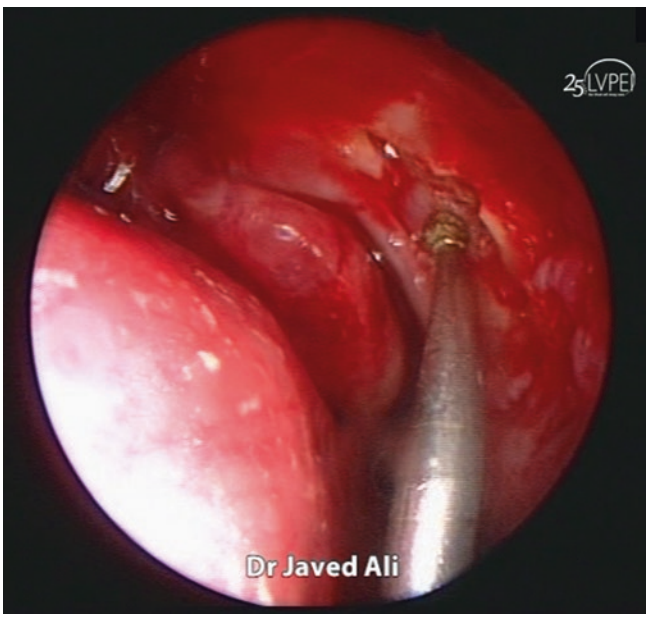


Fig. 22.18 Osteotomy completed in one area. Note the lacrimal sac underneath

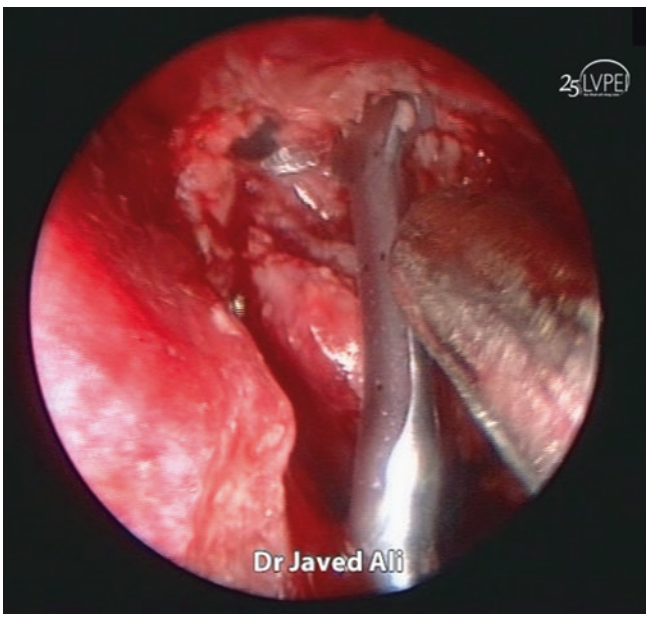


Fig. 22.20 Superior osteotomy with saw tip. Note the opened agger nasi

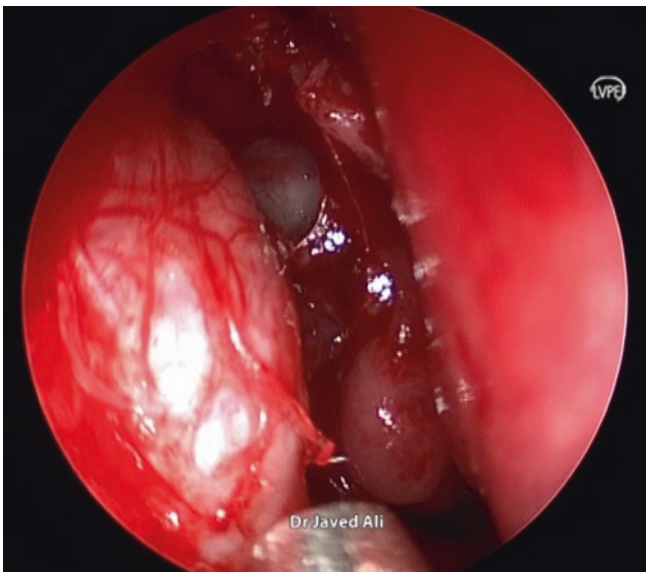


Fig. 22.21 Lacrimal sac filled with fluorescein viscoelastic

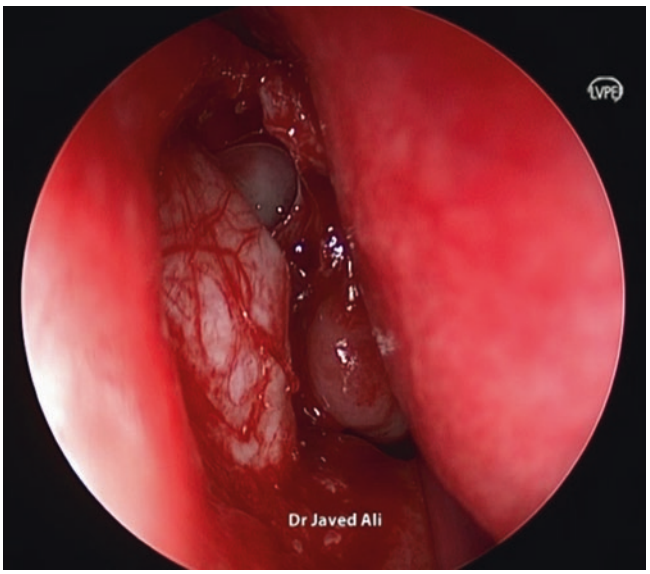


Fig. 22.22 Tenting of medial wall of lacrimal sac by a probe

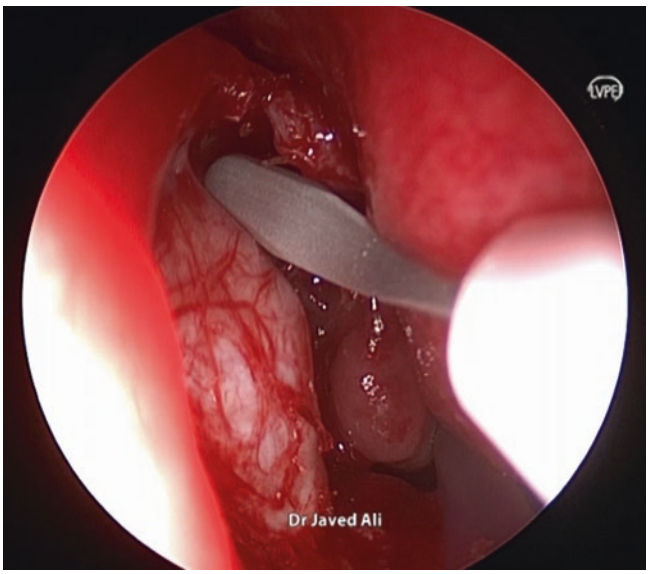


Fig. 22.23 Vertical lacrimal sac incision

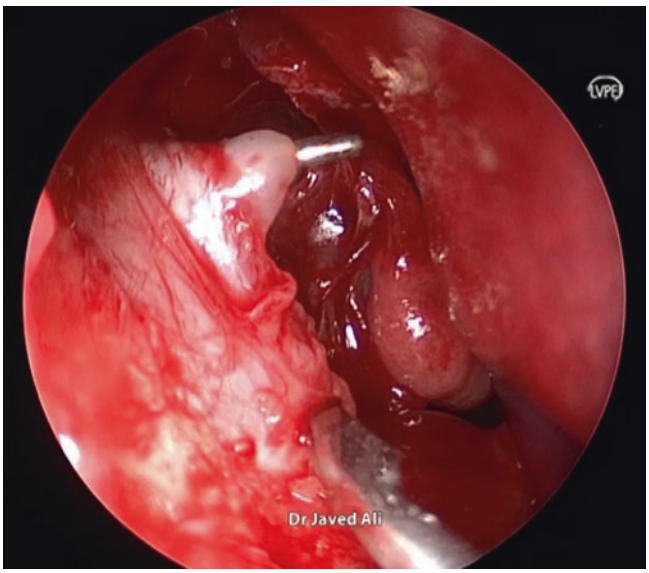


Fig. 22.24 Horizontal lacrimal sac incision

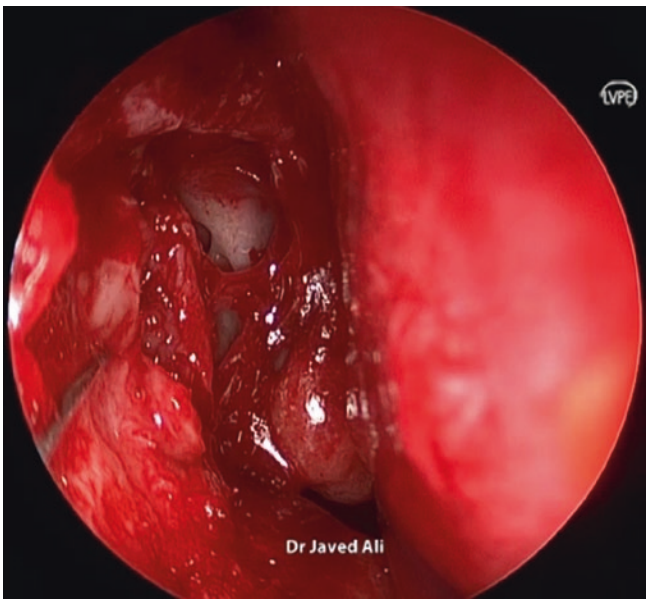


Fig. 22.25 Complete sac marsupialization

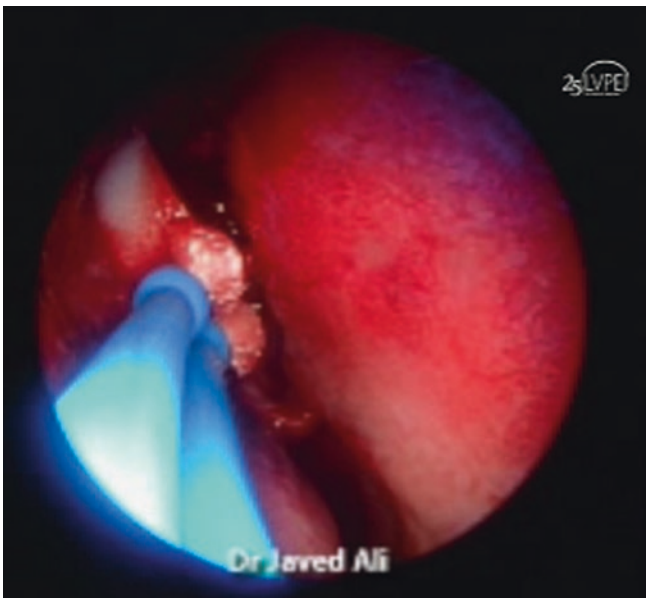


Fig. 22.28 Mitomycin application on Merocel sponges

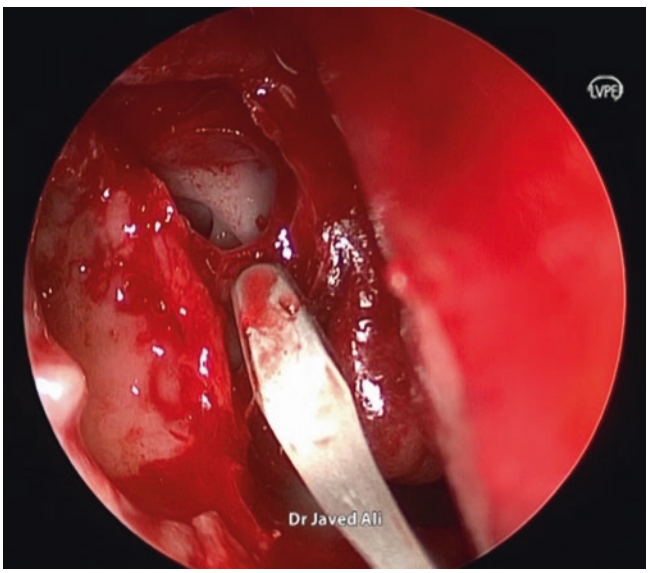


Fig. 22.26 Edge to edge mucosal approximation. Crescent points toward posterior lacrimal flap and agger nasi mucosa approximation

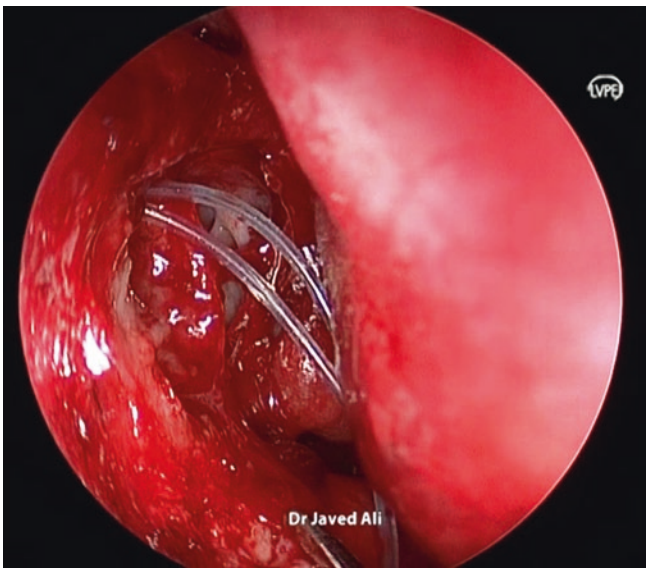


Fig. 22.29 Bicanalicular intubation

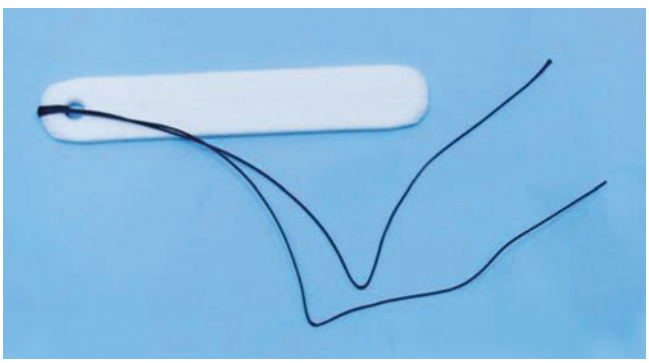


Fig. 22.27 Merocel pack

Non-endoscopic Endonasal Dacryocystorhinostomy

23

Suryasnata Rath, Samir Mahapatra, and Peter J. Dolman

Introduction

Caldwell (1893) and Toti (1904), respectively, described the endonasal and external approaches to dacryocystorhinostomy (DCR) [1, 2]. Because of difficulty in visualizing the nasal cavity, the endonasal approach fell out of favour, and for the next 100 years, a slightly modified external approach remained the treatment of choice for primary acquired nasolacrimal duct obstructions (PANDO). Interest in endonasal DCR saw resurgence around 1990 with availability of rigid and fibre-optic imaging systems. Despite these advancements, identification of the precise site for DCR remained a concern, because of the possibility of injury to adjacent orbital and intracranial tissues. In 1990 Bruce Massaro introduced the concept of transilluminating the lacrimal sac with a vitrectomy light pipe [3]. Over the last two decades, the technique and technology in endonasal DCR had evolved to make this an effective, scarless option in the treatment of NLDO with several authors reporting success rates (≥90%) equivalent to that of external DCR [4–6].

The main advantages of endonasal DCR include the absence of a visible scar, minimal postoperative morbidity, faster recovery and comparable success rates to that of external DCR [4, 6, 7]. Also, there are certain advantages of non-endoscopic endonasal approach in comparison to endoscopic approaches (Table 23.1). We describe in this chapter the technique of non-LASER, non-endoscopic endonasal DCR (NEN-DCR) which retains the benefits of an endonasal approach while alleviating the need for expensive video endoscope or laser systems.

Indications

1. Primary acquired NLDO (PANDO)
2. Acute dacryocystitis with lacrimal abscess
3. Revision in failed external or endonasal DCR
4. NLDO with associated nasal pathology
5. Post-traumatic secondary acquired nasolacrimal duct obstruction (SANDO)
6. Persistent congenital NLDO (CNLDO)

NEN-DCR is usually not preferred in certain complex conditions which are as follows:

1. Suspected lacrimal sac neoplasm
2. Severe midfacial trauma with hyperostosis around the lacrimal sac and nasolacrimal duct
3. Lacrimal sac diverticulum/fistulae extending to eyelid skin
4. Thick bones causing difficulty in initiating osteotomy
5. Down's syndrome

Surgical Technique

A. Instruments used for the technique include (Fig. 23.1):
   1. Endoilluminator and 23G vitrectomy retinal light pipe
   2. Long (5 cm) bladed nasal speculum with self-lock
   3. Myringotomy sickle knife
   4. Freer's or Cottle's periosteal elevator
   5. Straight Weil-Blakesley ethmoid forceps
   6. 2 and 3 mm right-angled Kerrison-Ruggles rongeur
   7. Suction apparatus with cannula

B. Technique:
   Endonasal dacryocystorhinostomy can be performed under general or local anaesthesia. An area of 10 mm^2

S. Rath, M.S., F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Bhubaneswar, India
e-mail: drsuryasnata@gmail.com

S. Mahapatra, M.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Vishakapatnam, India

P.J. Dolman, M.D., F.R.C.S.C.
Ophthalmic Plastics Surgery, University of British Columbia, Vancouver, Canada

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_23

Table 23.1 Comparison of endoscopic endolaser DCR and non-laser non-endoscopic DCR

	Endonasal DCR assisted by endoscope/LASER	Non-LASER non-endoscopic DCR
Equipment	Complex instruments like endoscope and LASER units a prerequisite; LASER protective shields for safety required	Simple instruments—Halogen/LED light source and endoilluminator 23G/20G required
Technique	Steeper learning curve: familiarity with the nasal anatomy [10]	Easier to learn [9]; lacrimal sac transillumination makes procedure easier for a novice surgeon
Frequent follow-ups	Required for nasal lavage in endolaser DCR especially after LASER	Not required as less damage to nasal mucosa
Portability of instruments	Difficult to transport bulky equipment; often done at large multi-speciality hospitals	Simpler equipment can be easily transported; suited for remote clinics and in developing regions
Operation cost	High maintenance of LASER, endoscope sterile sleeves for instruments, antifog solution, increased OR time for setup of equipment	Affordable

anterior to the attachment of the middle turbinate on the lateral nasal wall is infiltrated with 2% lidocaine with epinephrine (1 in 200,000) till mucosal blanching is evident. The nasal cavity is decongested for 5 min with a nasal pack soaked in 0.05% oxymetazoline nasal drops. The surgeon positions himself on the contralateral side, i.e., on the right side of the patient to do a left endonasal dacryocystorhinostomy. After punctal dilatation with a Nettleship dilator, a 23-gauge vitrectomy light pipe is gently introduced (Fig. 23.2a, b) through the upper canaliculus until a hard stop is felt. A self-locking nasal speculum with 5-cm-long blades is then introduced into the nasal cavity with the blades of the retractor placed vertically in the nostril and locked in a dilated position with the length of the speculum draped across the face, allowing self-retraction. The transillumination effect of the sac can be easily seen in the lateral nasal wall. A myringotomy sickle knife is used to incise the lateral nasal mucosa (Fig. 23.2c, d) showing maximal transillumination effect. The incision for the mucosal flap begun 8 mm above the insertion of the middle turbinate and is then carried out vertically or in a curvilinear fashion down to the bone. A Freer's or Cottle's periosteal elevator is used to elevate the incised nasal mucosa and expose the frontal process of the maxilla and its articulation with the lacrimal bone. The posteriorly hinged nasal mucosal flap is excised (Fig. 23.2e, f) with Weil-Blakesley forceps. Once the lacrimal fossa is exposed, the thin lacrimal bone is elevated off the posterior half of the lower lacrimal sac up to the insertion of the uncinate process. With the use of a 3 mm forward-biting straight Kerrison rongeurs (Fig. 23.2g, h), the thick bone of the frontal process of the maxilla is sequentially removed. The osteotomy is gradually enlarged superiorly so that the light pipe held horizontally can easily be seen tenting the lacrimal sac from within the nasal cavity, confirming that the bone has been removed to the level of the common internal punctum. Any residual bone that appears dark against the bright red transillumination of the lacrimal sac needs to be meticulously removed. Finally the medial wall of the lacrimal sac is incised (Fig. 23.2I) with a myringotomy sickle knife, while the lacrimal sac is tented by a light pipe, and a large posteriorly hinged lacrimal mucosal flap is created. The overhanging edge of the lacrimal mucosal flap is trimmed with Weil-Blakesley forceps to create a marsupialized sac. Irrigation (Fig. 23.2j) is done to check for the patency of the drainage system. Bicanalicular silicone tubes are introduced through the canaliculi, retrieved and secured by two square knots in the nasal cavity.

The patients are followed at 3 months after surgery and are asked to return subsequently if their symptoms return. At each visit the patient is specifically asked about epiphora and syringing of the lacrimal passage is done. Tubes are usually removed after 6–8 weeks of surgery and/or earlier if there is spontaneous extrusion.

Outcomes

In a large comparative series of 354 patients reported by Dolman in 2003, complete success was achieved in 89.1% (179/201) of NEN-DCRs compared to 90.2% (138/153) of traditional external DCRs [1]. Amongst patients who underwent further revision NEN-DCR, 90% achieved success and complete relief from symptoms in the above series of patients [1]. In 2009 Razavi et al. [8] reported combined symptomatic and anatomic patency in 96% patients in a series of 99 NEN-DCRs performed in 95 patients. They achieved favourable outcome in 51/53 (96%) patients with chronic NLDO, 31/32 (96%) patients with acute/subacute dacryocystitis and 13/14 (93%) revision surgeries [8]. The above studies clearly show that NEN-DCR has outcomes comparable to external DCR [1, 8].

Ophthalmologists often prefer external over endonasal DCR owing to non-familiarity with the nasal anatomy and longer learning curve in the endonasal approach. Preechawai et al. [9] studied the learning curve of NEN-DCR in 75 DCRs

which were performed by the author who had no prior training in nasal endoscopy and by residents under his supervision. The functional success rate in their study was 74.7%, and anatomical patency was 92% [9]. Onerci et al. [10] observed that success of endoscopic DCR could range from 94% in the hands of experienced surgeons to 58% in inexperienced hands. The above studies go to show that endoscopic DCR has a longer learning curve than NEN-DCR [9, 10]. The simpler instrumentation and lacrimal sac transillumination acting as a guide in NEN-DCR may be responsible for easier learning of the technique.

Complications

NEN-DCR is a relatively safe procedure with few serious complications reported [4, 8, 9]. Unlike external DCR, the average intraoperative bleeding is minimal (≤12 ml) in NEN-DCR [8]. More serious complications include orbital fat prolapse and medial rectus incarceration [4]. In an endonasal approach, most sharp instruments point towards the orbit [9]. It is important to remember that the posterior landmark to the lacrimal sac is the uncinate process of the ethmoid bone, and therefore surgical manipulations must be restricted to the area anterior to this landmark [5].

Mild postoperative epistaxis is common [9].The most common complication of NEN-DCR is failure in 5–10% [8]. The varied patterns of failure described are cicatrization at the ostium, synechiae between ostium and middle turbinate and/or nasal septum and granuloma formation within the ostium [4, 8]. Canalicular obstruction, orbital and subcutaneous emphysema, conjunctival fistula formation and retrobulbar haemorrhage as well as transient medial rectus paresis are other rare postoperative complications reported after endonasal DCR [10]. Tube-related complications include punctal erosion, granuloma formation and spontaneous extrusion [8].

Updates (2015–2016)

Non-endoscopic endonasal dacryocystorhinostomy (NEN-DCR), first described in 2003, relies on direct visualization rather than video endoscope to perform endonasal dacryocystorhinostomy [4]. The surgical technique obviates the need for expensive lasers, ultrasound or mechanical drills. Good surgical outcomes of NEN-DCR (~90%) have been reported by several authors [4, 8, 9].

A search on PUBMED with the keywords “endoscopic” and “dacryocystorhinostomy” published between January 1, 2015 and December 31, 2016 showed 62 publications. A large majority of these dealt with endoscopic endonasal DCR and were thus excluded. Four publications pertaining to NEN-DCR were included in this update.

Outcomes in PANDO

A recent publication by Ganguly et al. [11] reported the outcome of NEN-DCR in 122 Asian Indian patients (134 eyes). Of these 81 were female, and the mean age of the group was 37 ± 18 years. Indications for NEN-DCR included primary acquired NLDO (68%), NLDO in children (16%), acute dacryocystitis ($n = 13$), failed prior DCR in six eyes and secondary acquired NLDO in one patient. The mean duration of surgery was 36 min (range, 16–92). At a median follow-up of 6 months (range, 3–15), 86% eyes had functional success, and 85% had anatomical success [11].

Revision NEN-DCR was done in 16 eyes who failed primary surgery. In all, after revision surgery, 13/16 (81%) eyes were relieved of epiphora [4]. Overall, functional success was achieved in 129/134 (96.2%) eyes and anatomical success in 106/109 (97.2%) eyes at a median follow-up of 7 months (range, 3–15 months) [11].

Bicanalicular Stents in Endonasal Dacryocystorhinostomy

Bicanalicular intubation is believed to enhance success in endonasal dacryocystorhinostomy [3, 8, 9]. However, there was little evidence to support this belief. Definitive evidence favouring the use of bicanalicular intubation in endonasal DCR was lacking either due to poor study design or inadequate sample size in previously published reports.

A recent randomized controlled trial by Fayers and Dolman [12] evaluated the role of bicanalicular intubation in endonasal DCR. This was a large prospective clinical trial in which 300 patients completed 12 months of follow-up. Of these 152 patients received tubes, and 148 patients did not. Overall success both subjectively and objectively was 94.7% in the stented group and 87.8% in the nonstented group (P ¼ 0.034, Pearson chi-square 1-tailed test) [12]. The most common complications of stents included canalicular cheesewiring and tube prolapse in approximately 4% each. The results of the randomized controlled trial provide level I evidence favouring the use of bicanalicular stents in endonasal DCR. A similar ongoing randomized controlled trial on the role of mitomycin C (MMC) in NEN-DCR is likely to prove or disprove the role of MMC as an adjuvant.

Acute Dacryocystitis

Acute dacryocystitis is an ophthalmic emergency characterized by acute pain, swelling and redness in lacrimal sac region. Conventional treatment of acute dacryocystitis has been warm compresses and a short course of antibiotics and non-steroidal anti-inflammatory drugs (NSAIDs) followed by EXT-DCR. Most ophthalmologists prefer to perform

EXT-DCR 3–4 weeks after quiescence of periocular inflammation. Primary endonasal DCR achieves earlier resolution of symptoms (Fig. 23.3a–d) with comparable functional and anatomical outcome in acute dacryocystitis compared to conventional treatment [13].

Jain et al. [13] compared the outcome and time to complete resolution in a group of 46 patients presenting with acute dacryocystitis. Patients were divided into two groups of 23 patients each. Group A included those who received conventional treatment (systemic broad-spectrum antibiotics followed by EXT-DCR), and group B underwent early primary NEN-DCR. Mean age and gender distribution were comparable in both groups. The mean duration from presentation to surgery was shorter for NEN-DCR (7.82 ± 4.65 vs. 27.3 ± 12 days; $P = 0.00001$, independent T test). Patients who underwent NEN-DCR had an earlier complete resolution of symptoms (21.4 ± 6 vs. 38.69 ± 15.8 days; $P = 0.000014$, independent T test) than those who received conventional treatment [13]. Functional and anatomical success were similar in both groups. Complications included disfiguring scar in four,, recurrent acute dacryocystitis in three and punctal ectropion in one patient in the EXT-DCR group [13]. This study showed that primary NEN-DCR achieved faster complete resolution of symptoms with comparable outcomes in acute dacryocystitis and thus may help in earlier rehabilitation of patients.

Ostium Size

Despite the lack of credible evidence, ostium size in EXT-DCR was believed to be larger than that in endonasal DCR. A recent cross-sectional study compared the ostia in EXT-DCR versus NEN-DCR [14]. All patients had a minimum of one month follow-up. Pictures of the ostium were captured with a nasal endoscope (4 mm, 30°) after inserting a lacrimal probe pre-marked at 2 mm, and image analyses were performed using Image J and Contour softwares (Fig. 23.4). A total of 113 patients were included of which the EXT-DCR group had 53 patients and NEN-DCR group had 60 patients. As would be expected, the mean age of patients in the NEN-DCR group (38 years) was significantly ($p < 0.05$) lower than the external dacryocystorhinostomy group (50 years) [14]. There was no statistically significant difference (2 sample t test, $p > 0.05$) in mean follow-up (6 vs. 4 months), maximum diameter of ostium (8 vs. 7 mm), perpendicular drawn to it (4 vs. 4 mm), the area of ostium (43 vs. 36 mm^2) and the minimum distance between common internal punctum and edge of the ostium (1 vs. 1 mm) between the external and NEN-DCR groups [14]. Interestingly the relative position of the ostia differed with the ostia in EXT-DCR more posteriorly placed compared to the inferior in NEN-DCR.

Conclusion

NEN-DCR is a safe and effective procedure in the treatment of PANDO. Transillumination of the lacrimal sac makes learning easier for even a novice surgeon. It can be performed without expensive instrumentation and therefore may be particularly suited for the developing regions of the world. NEN-DCR is relatively simple to master and has excellent outcome based on several large independent international series. It offers rapid resolution of symptoms in patients with acute dacryocystitis. Bicanalicular stents in NEN-DCR are here to stay with proven benefit in enhancing success. The final size of the ostium in NEN-DCR is comparable to EXT-DCR.

References

1. Caldwell GW. Two new operations for obstruction of the nasal duct with preservation of the canaliculi and an incidental description of a new lacrymal probe. NY Med J. 1893;57:581–2.
2. Toti A. Nuovometo do conservatore di curare di caledelle suppurazioni croniche del sacco lacrimale (dacriocistorinostomia). Clin Mod Firenze. 1904;10:385–7.
3. Massaro BM, Gonnering RS, Harris GJ. Endonasal laser dacryocystorhinostomy. A new approach to nasolacrimal duct obstruction. Arch Ophthalmol. 1990;108:1172–6.
4. Dolman PJ. Comparison of external dacryocystorhinostomy with non-laser endonasal dacryocystorhinostomy. Ophthalmology. 2003;110:78–84.
5. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
6. Hartikainen J, Grenman R, Puukka P, et al. Prospective randomized comparison of external dacyrocystorhinostomy and endonasal laser dacryocystorhinostomy. Ophthalmology. 1998;105:1106–13.
7. Tarbet KJ, Custer PL. External dacryocystorhinostomy. Surgical success, patient satisfaction and economic costs. Ophthalmology. 1995;102:1065–70.
8. Razavi ME, Eslampoor A, Noorollahian M, et al. Non-endoscopic endonasal dacryocystorhinostomy—technique, indications, and results. Orbit. 2009;28:1–6.
9. Preechawai P. Results of non-endoscopic endonasal dacryocystorhinostomy. Clin Ophthalmol. 2012;6:1297–301.
10. Onerci M, Orhan M, Ogretmenoglu O, et al. Long-term results and reasons for failure of intranasal endoscopic dacryocystorhinostomy. Acta Otolaryngol. 2000;120:319–22.
11. Ganguly A, Videkar C, Goyal R, Rath S. Nonendoscopic endonasal dacryocystorhinostomy: outcome in 134 eyes. Indian J Ophthalmol. 2016;64:211–5.
12. Fayers T, Dolman PJ. Bicanalicular silicone stents in endonasal dacryocystorhinostomy: results of a randomized clinical trial. Ophthalmology. 2016;123:2255–9.
13. Jain S, Ganguly A, Singh S, et al. Primary nonendoscopic endonasal versus delayed external dacryocystorhinostomy in acute dacryocystitis. Ophthal Plast Reconstr Surg. 2017;33(4):285–8.
14. Ganguly A, Kaza H, Kapoor A, et al. Comparative evaluation of the ostium after external and non-endoscopic endonasal dacryocystorhinostomy using Image processing (Matlabs and Image J) softwares. Ophthal Plast Reconstr Surg. 2016. https://doi.org/10.1097/IOP.0000000000000786.

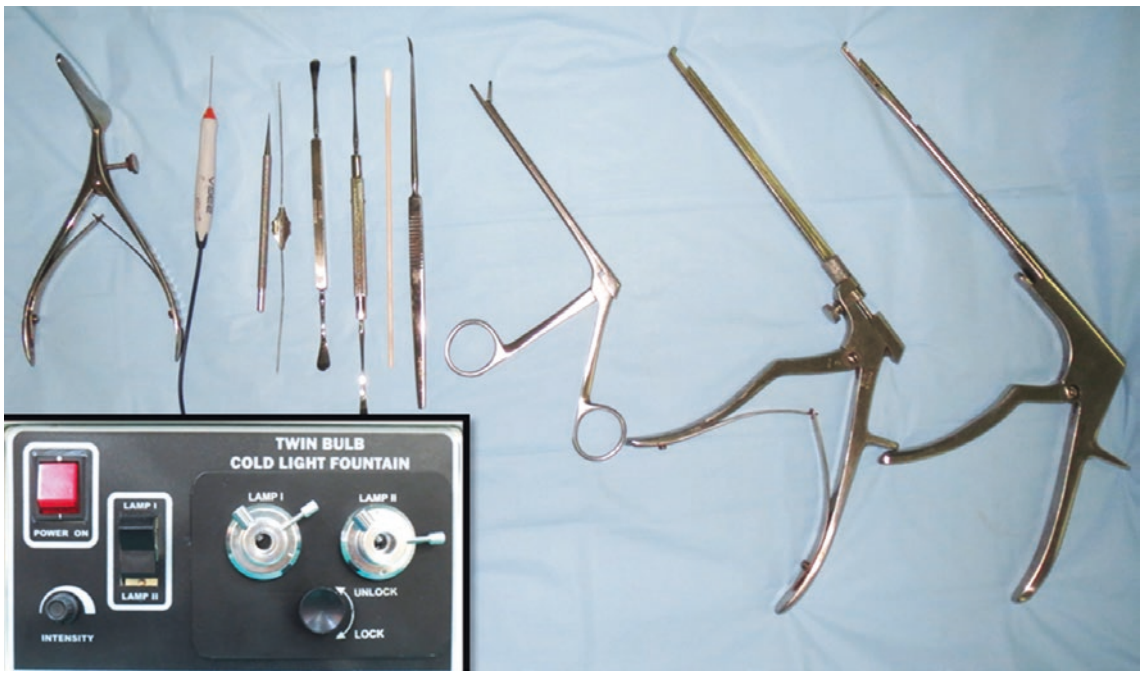


Fig. 23.1 Instrumentation for NEN-DCR

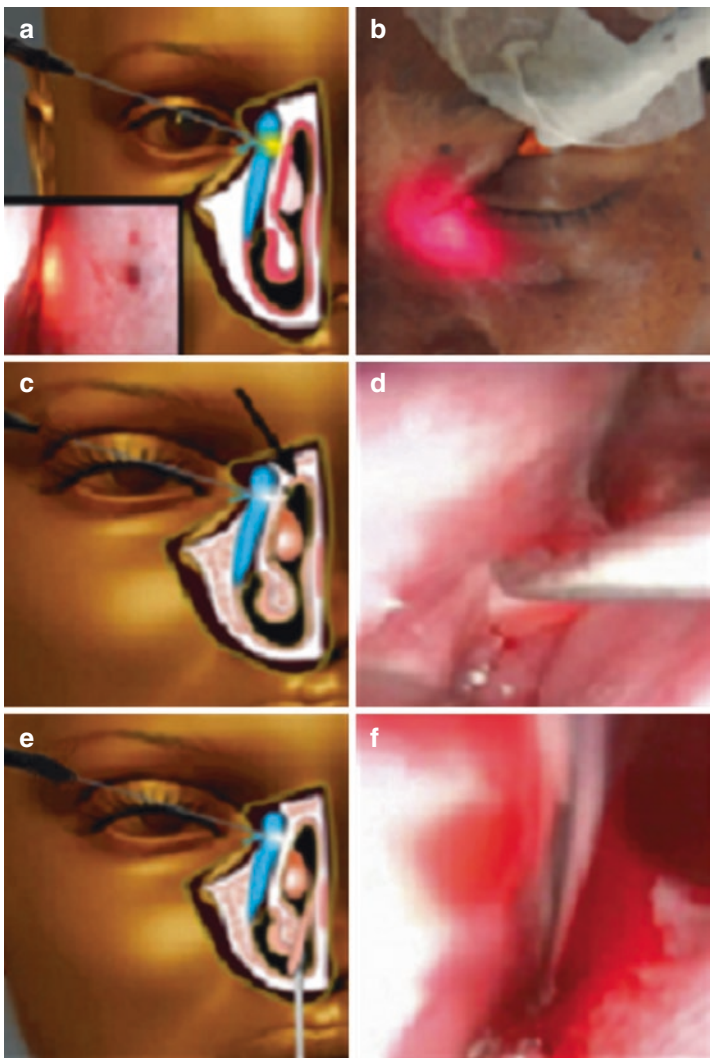
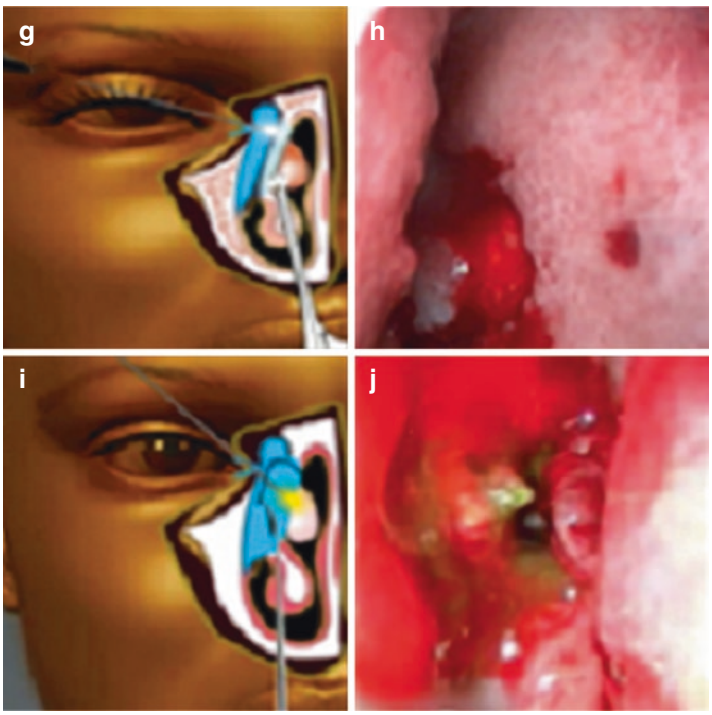


Fig. 23.2 (**a**) Transillumination of the lacrimal sac with the vitrectomy light pipe touching the medial wall of the lacrimal sac. *Inset* shows the glow in the medial wall of the nasal cavity. (**b**) Oblique positioning of the light pipe through the upper canaliculus with the lacrimal sac transillumination as seen externally. (**c**, **d**) Incision on the lateral nasal wall with a myringotomy sickle knife. (**e**, **f**) The nasal mucosal flap is removed with Weil-Blakesley forceps. (**g**) Kerrison rongeur is used for enlarging the bony ostium. (**h**) The lateral nasal wall shows a bony ostium with the pale lacrimal sac mucosa showing through the ostium. (**i**) The lacrimal sac is tented with the light pipe, and a myringotomy sickle knife is used to incise the lacrimal sac. (**j**) The marsupialized lacrimal sac shows a free flow of fluorescein-stained saline into the nasal cavity

Fig. 23.2 (continued)



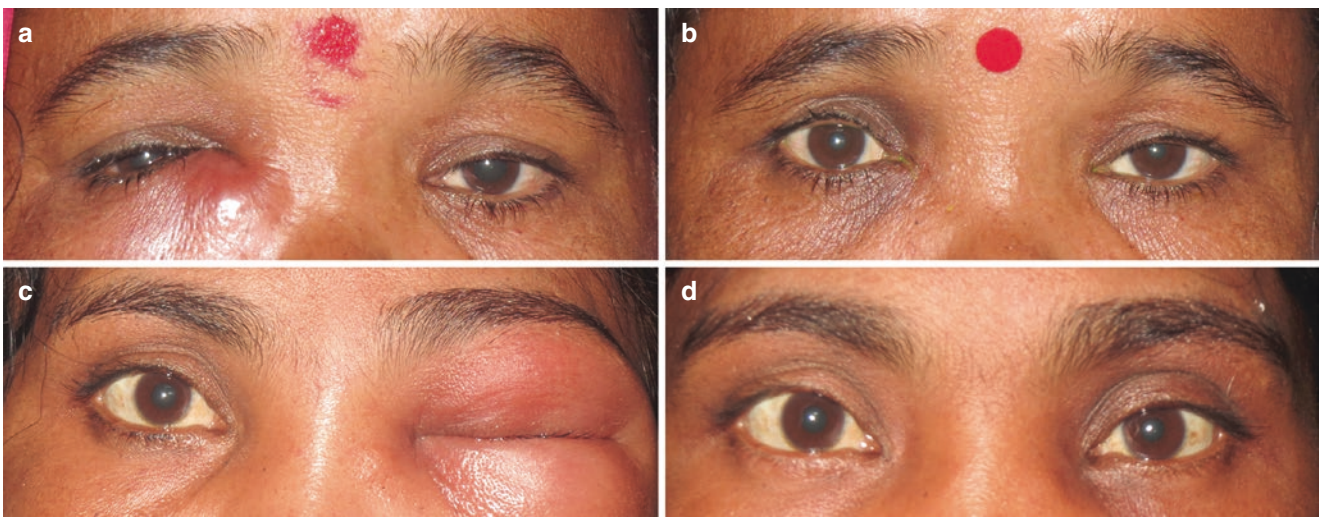


Fig. 23.3 Primary non-endoscopic endonasal DCR in acute dacryocystitis: a right acute dacryocystitis with evolving lacrimal abscess (**a**) and its resolution following a primary NEN-DCR (**b**). A left acute dacryocystitis with severe preseptal cellulitis (**c**) showing a dramatic response following a primary NEN-DCR (**d**). These results are comparable to that of conventional management followed by surgery

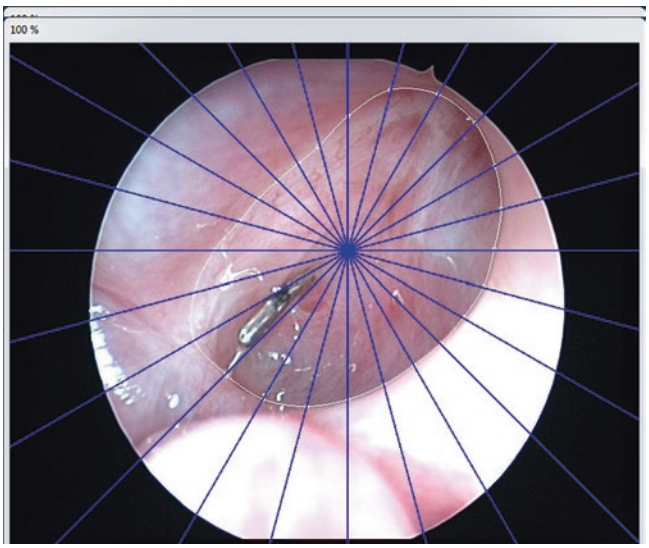


Fig. 23.4 Endoscopic picture of an ostium and its analysis using the Image J[R] and Contour[R] softwares

Primary Endocanalicular Laser Dacryocystorhinostomy

24

Raoul Paolo D. Henson

Introduction

External dacryocystorhinostomy (EX-DCR) is believed to be the current gold standard in the treatment of primary acquired nasolacrimal duct obstruction (PANDO). Description of a transcanalicular DCR was first published in 1963 by Jack [1]. In recent years, endoscopes have been modified and are now able to visualize the canaliculus, sac, and duct. Similarly, lasers have evolved and are smaller, portable with thinner-diameter fiber optics and can be inserted through small orifices like the canaliculus. All these advances in endoscopy and laser technology led to the discovery of endocanalicular laser dacryocystorhinostomy (ECLDCR). Levin and Silkiss were the first ones to describe this laser technique using cadavers in 1992 [2, 3]. Micahalos et al. also followed suit with cadaveric studies using ECLDCR in 1995 [4]. Christenbury was the first to perform ECLDCR in patients using an argon laser [5, 6]. Since then, numerous papers have been published using ECLDCR with varying success rates of 47–97% [5–30].

The principle of ECLDCR remains the same as that of any DCR. In ECLDCR, a laser fiber optic is inserted in the punctum and passed through the canaliculus and finally into the lacrimal sac. A standard-diameter nasal endoscope is used to visualize the laser glow from the nasal side (Fig. 24.1). Then the laser fiber optic is utilized to puncture into the nasal cavity thereby creating an osteotomy. Since there is no marsupialization of the lacrimal sac with the nasal mucosa, the patency of the ostium is of utmost importance in ECLDCR. The surgical success of a primary ECLDCR will depend on proper patient selection, thorough preoperative nasal endoscopy, appropriate laser machine, good technique, and appropriate timing of adjuvant therapy (mitomycin C) [19, 20, 24, 28].

R.P.D. Henson, M.D.
Ophthalmic Plastics Surgery, St Luke Medical Center, Manilla, Philippines
e-mail: Henson_raoul@yahoo.com.ph

Patient Selection

Proper screening tests should confirm the diagnosis of primary acquired NLDO. Patients with chronic epiphora without infection and discharge (dacryostenosis) can undergo ECLDCR. Patients with a history of acute dacryocystitis and mucocoele formation are not very good candidates [31]. These conditions should preferably be treated with the external or endonasal approach. This procedure is also contraindicated in patients with suspected dacryolithiasis, neoplasm, and NLDO secondary to sarcoidosis or Wegener's granulomatosis [7, 13, 16]. Table 24.1 summarizes the oculo-lacrimal contraindications for ECLDCR.

Proper antibiotic treatment and thorough lacrimal irrigation should be initially performed to remove the purulent material before ECLDCR. Nasal endoscopy should be a routine practice for preoperative evaluation before ECLDCR. This will give the surgeon an overview of what to expect before the surgery. The two most important nasal structures to look out for are the septum and the middle turbinate. Severe septal deviation is a relative contraindication; therefore, a septoplasty if one is competent or a referral to an ENT surgeon is warranted before proceeding to ECLDCR. An enlarged middle turbinate can be partially resected to expose the surgical area [24, 32]. Patients who have undergone previous nasal surgery (functional endoscopic sinus surgery (FESS), polypectomy, etc.) are not good candidates for ECLDCR [20, 25]. Patients who also had naso-orbital trauma involving the lacrimal system are

Table 24.1 Oculo-lacrimal contraindications of primary ECLDCR

1. Acute dacryocystitis
2. Chronic dacryocystitis with mucopurulent discharge
3. Mucocoele
4. Lacrimal fistula
5. Suspected dacryolithiasis
6. NLDO secondary to sarcoidosis or Wegener's granulomatosis
7. Previous lacrimal surgery
8. Lacrimal tumors

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_24

undesirable for this type of surgery [20, 25]. Table 24.2 summarizes the nasal contraindications for ECLDCR.

Diode Laser and Set Up

The ideal laser in ECLDCR must produce enough power to allow the surgeon to create an adequate osteotomy without inducing damage to surrounding tissues [17, 30]. Different types of lasers have been applied in ECLDCR. These are the argon laser, holmium (Ho):yttrium aluminum garnet (YAG) laser, neodymium (Nd):YAG laser, potassium titanyl phosphate (KTP):YAG laser, erbium (Er):YAG laser, and diode laser [6–30] (Table 24.3). In recent years, the diode laser (Fig. 24.2) has been gaining popularity due to a number of advantages.

Diode lasers are designed for multispecialty application in minimally invasive surgery (ophthalmology, otorhinolaryngology, and urology), open surgery (obstetrics and gynecology), interstitial laser therapy, and vascular applications (dermatology and vascular surgery) [5]. Therefore, from a financial perspective, a single diode laser in a hospital setting can be shared by multiple surgical specialties. Operating at a wavelength of 810–980 nm in the near-infrared portion of the spectrum, this laser induces excellent hemostasis due to its high absorption in melanin and hemoglobin. It is compact, is portable, and can fit neatly into any doctor's clinic or operating suite. Due to its portability, it can be easily transported from one clinic to another or between hospitals. Setting up this laser is also simple and easy. All diode lasers run from a standard electrical wall socket and are ready for use within seconds. The menu-driven user interface is simple, and it gives immediate access to treatment options with continuous, pulsed, or repeat pulse mode. There is also minimal maintenance and service requirements needed because this surgical laser has a solid-state system and has no moving parts. The laser energy delivery system uses a flexible fiber whose diameters range from 400 to 1000 μm [20, 33] and gives easy access to confined areas and is also compatible with endoscopic instrumentation for surgical applications (Fig. 24.3).

Table 24.2 Nasal contraindications of primary ECLDCR

1. Previous nasal surgery (e.g., functional endoscopic sinus surgery)
2. Extensive nasal polyposis
3. Severe allergic rhinitis
4. Atrophic rhinitis
5. Naso-orbito-ethmoid facial fractures involving the nasolacrimal canal
6. Nasal malignancy

Surgical Procedure

General or local anesthesia can be used for ECLDCR. Any laser with a rigid laser fiber optic can be utilized, but in the past decade, the diode laser has been the preferred laser of choice due to the advantages reported above. The diode laser setting used is at an average of 10 W with continuous laser delivery using the contact mode. A 600 μm semirigid laser fiber optic is used. Nasal packing is done with a ¼ in. gauze soaked with 0.5% oxymetazoline hydrochloride. This will be left in place for 10 min and removed just before the laser treatment. The punctum is dilated using a punctum dilator and a Bowman 0 probe slid through the canaliculus to also dilate it before the insertion of the fiber optic. Once a hard stop is felt, the Bowman probe is removed. The 600 μm laser fiber optic is inserted in the lower punctum into the canaliculus up to the level of the lacrimal sac in a 45° fashion (Figs. 24.4 and 24.5). The nasal pack is removed, and a 0° nasal video endoscope, attached to a TV monitor (Fig. 24.6), is inserted through the nostril to visualize the transilluminated laser light from the lacrimal sac. We call this the "laser glow." If the laser glow cannot be visualized, an assistant can minimize the light source from the nasal endoscope. This will

Table 24.3 Different types of lasers in ECLDCR

Laser	Wavelength (nm)	Power (W)	Fiber size (μm)	Comments
Diode	810–980	0.5–60	400–1000	Good cutting effect
				Good hemostasis
				Good coagulation
				Less collateral damage
Nd:YAG	1064	3–10	600	Good cutting ability
				More collateral damage
KTP	532	10	300	Good cutting effect
				Good coagulation
				Need protective wear
Er:YAG	2940	0.1–0.4	350–425	Good bone ablation
				Poor coagulation
				OK for canaliculoplasty
Ho:YAG	2140	2.5–20	300–1000	Adequate coagulation
				Soft tissue ablation
				Easily penetrates the bone

reveal the location of the laser glow corresponding to the thinnest portion of the lacrimal bone. This area is anterior and inferior to the insertion of the middle turbinate [16] (Fig. 24.7). A periosteal elevator can be used to medialize the middle turbinate for good exposure during the laser procedure while protecting it from the heat of the laser probe (Fig. 24.8). Laser osteotomy is done by first puncturing the laser fiber optic through the lacrimal bone and nasal mucosa via contact energy mode with continuous setting. This is called "laser puncture" (Fig. 24.9). Once the laser penetration is done, an area of coagulation and necrosis will be seen on the nasal mucosa surrounding the laser fiber optic. From this position, the fiber optic can be moved sideways, upward, and downward in a circular fashion thereby enlarging the osteotomy (Fig. 24.10). The direction of the laser fiber optic is emphasized mostly on the inferior area. Enlarging this area using a downward direction of the laser fiber optic may prevent the lacrimal sump syndrome. A 10 mm cotton ball is soaked with 0.1 ml of a 0.2 mg/ml of mitomycin C (MMC). This is placed on the osteotomy site for 5 min with no irrigation after the application (Fig. 24.11). Nonirrigation of MMC will increase its maximum pharmacologic effect on the osteotomy site [20]. The silicone stents are guided through the inferior and superior canaliculi and retrieved with hooks or mosquito forceps under endoscopic visualization (Fig. 24.12). They are tied in a square knot and encircled using 6-0 silk sutures.

Postoperative Care and Mitomycin C Application

Postoperative medications for ECLDCR including tobramycin-dexamethasone eye drops used four times a day in the ipsilateral conjunctival sac and mometasone furoate steroid nasal spray one dose to the operated nostril three times per day are prescribed. The medications are tapered gradually over a 12-week period. Postoperative examinations are done at 1 week, 2 weeks, 3 weeks, 1 month (Fig. 24.13), 3 months, 6 months (Fig. 24.14), and 12 months (Fig. 24.15).

In each postoperative visit, nasal endoscopic-guided cleaning of the ostium from blood clots, dried mucus, and debris is done using a suction machine. This is of paramount importance in ECLDCR because it can reduce the inflammatory stimuli that these may create after the surgery [19, 24, 33]. Lacrimal irrigation is also done to further clear the debris inside the lacrimal passageway. Postoperative nasal endoscopy may also be needed to assess problematic cases [33].

The use and advantages of MMC in lacrimal surgeries are well known [31, 32, 34–44]. MMC, the preferred adjuvant during ECLDCR, can be applied not only during surgery but also in the postoperative phase of osteotomy healing [25]. After cleaning the osteotomy during each postoperative visit, a 10 mm cotton ball soaked with 0.1 ml of MMC (0.2 mg/ml) is applied at the ostium site for 3 min without irrigation. This will inhibit fibroblast formation around the edges of the ostium thereby reducing the chance of phimosis or closure. Topical MMC application to the ostium can be performed on a weekly basis for a maximum of 3 weeks after the surgical procedure. Residual fibroblasts, which remained on each follow-up visit, can be further inhibited until the ostium edges are healed, resulting in its continued patency [25].

Once the edges of the ostium are fully healed, the silicone tubes are removed approximately 6–8 weeks after the surgery. The combination of naso-endoscopic cleaning, nasal steroid application, and adjuvant application can increase the chance of non-closure of the ostium during the postoperative period.

Adjuvant Endoscopic Procedures

In recent years, combined nasal surgery and ECLDR have been done to maximize the exposure of the surgical area to ensure the patency of the ostium. This is true for patients with enlarged middle turbinates that need to be partially removed [24, 30, 32]. The laterally retracted middle turbinates can also be medialized to expose the surgical area [20, 32]. It is important not to attempt rapid movement of the middle turbinate, since that may lead to fracture of the cribriform plate and CSF rhinorrhea. Good exposure will lead to a bigger osteotomy and can prevent turbinostial synechial adhesions. One recent study utilized endonasal mucosal flaps with ECLDCR. Their success rate is 89%, but only seven eyes were studied [30]. This mucosal flap-ECLDCR technique appears to be promising; however, larger sample size with long follow-up is needed to prove its efficacy.

Advantages and Disadvantages of ECLDCR

ECLDCR is one of the alternatives to an external or endoscopic DCR for the management of PANDO. There are numerous advantages of ECLDCR [5–30] and are listed in Table 24.4. However, the additional expense of the laser and the endoscope, steep learning curve initially, and poor outcomes if improperly done are the hindrances most doctors face, although its similarity to lacrimal probing makes the procedure much easy to adapt for the ophthalmologist [6, 9, 16, 18, 20].

Table 24.4 Advantages of ECLDCR

1. Absence of a skin incision
2. Preservation of the medical canthal structures
3. Preservation of the lacrimal pump mechanism
4. Less operative time
5. Local anesthesia and outpatient surgery
6. Laser directed away from the orbit
7. Minimal intraoperative and postoperative bleeding
8. Decrease or no periorbital swelling postoperatively
9. Low morbidity
10. Shorter functional recovery

Complications

Despite ECLDCR being a novel alternative to EX-DCR, it has its share of complications [5–30, 45, 46]. Table 24.5 enumerates the possible complications of ECLDCR.

Table 24.5 Complications of ECLDCR

1. Occasional bleeding
2. Eyelid hematoma
3. Preseptal cellulitis
4. False passage
5. Canalicular stenosis and obstructions
6. Lacrimal sump syndrome
7. Tissue necrosis
8. Nasocutaneous fistula
9. Orbital infarction syndrome

Outcomes

Success after lacrimal bypass is defined as patency to irrigation and resolution of epiphora. Through the years, the success rates of ECLDCR surgeons have been varied ranging from 47% to 97% [6–30] (Table 24.6). Reports on short-term success rates of less than a year of follow-up range from 47% to 94% [7, 8, 11, 13, 16, 18, 23, 26, 28]. Medium-term success rates of more than 1 year range from 64% to 97% [9, 10, 12, 14, 19–21, 24, 25, 27, 29]. Long-term success rates of more than 3 years follow-up were reported by Nuhoglu and Maeso at 88% and 95.2%, respectively [22, 27]. These success rates have been widely variable owing to the use of different lasers and technical modifications [21]. However, the use of the diode laser has started a new era in ECLDCR. Most studies using this type of laser have more successful outcomes than their YAG laser counterparts (Table 24.4).

Table 24.6 Published literature on primary ECLDCR

Author	*N* (eyes)	Laser	Adjunct	Success rate, %	Follow-up (months)
Christenbury (1992)	12	Argon	None	50	N/A
Piaton (1994)	41	Nd:YAG	None	75	6
Dalez (1996)	26	Ho:YAG	None	47	7
Pearlman (1997)	49	Nd:YAG	None	85	24
Rosen (1997)	14	Nd:YAG	None	64	20
Eloy (2000)	26	Diode	None	65	N/A
Muellner (2001)	48	KTP	None	83	6
Caversaccio (2001)	12	Er:YAG	None	75	19
Piaton (2001)	317	Nd:YAG/Ho:YAG	MMC/5FU	63.2	6
Hofmann (2003)	78	KTP	None	83	12
Alanon (2004)	34	Diode	None	94.1	11
Hong (2005)	102	Nd:YAG	None	73.6	9.5
Alanon (2006)	150	Diode	Intraop MMC	92	15
	50	Diode	None	78.2	15
Henson (2007)	40	Diode	Intraop MMC	87.5	12
Plaza (2007)	25	Diode	None	88	36
Maesso (2007)	75	Diode	None	92	16
	75	Diode	Intraop MMC	97	16
Cintra (2008)	32	Diode	None	88	6
Basmak (2011)	37	Diode	None	65.7	14
Henson (2012)	125	Diode	Intraop and post-op MMC	92.8	12
Drnovsek-Olup (2012)	126	Diode	None	83.3	6
Nuhoglu (2012)	42	Diode	None	95.2	42
Derya (2013)	25	Diode	None	68	7
Dogan (2013)	30	Diode	Intraop MMC	84.3	24
	27	Diode	None	80	24
Robert (2013)	7	Diode	Mucosal flaps	89	10

Since there is no flap anastomosis in ECLDCR, the patency of the ostium is the most important concern. The ostium can be reduced in size during the postoperative phase; therefore, the bigger the ostium intraoperatively, the better for the patient, although this is not substantiated with strong evidence. The ostium should be endoscopically monitored in the postoperative period just like monitoring a bleb after glaucoma surgery [25]. Intranasal application of MMC intraoperatively has shown to reduce scar formation and prevent closure of the ostium in DCR [13, 19, 20, 22, 25, 29, 31, 32, 34–44]. Hu and Ugurbas have proven that a longer contact time with MMC will lead to apoptosis of nasal mucosal cells with in vitro studies [47, 48]. Ali et al. [49] have shown the ideal in vitro concentrations and durations of MMC using numerous molecular biology techniques on the nasal mucosa fibroblasts; however, these need to be verified with in vivo studies. Kamal et al. [50] have described a new technique of circumostial mitomycin C or COS-MMC where 0.02% of MMC was injected intraoperatively into the circumostial mucosa with good results. All these studies along with variable results of intraoperative MMC with ECLDCR suggest that possibly intraoperative and postoperative application of MMC may be the next logical step for maintaining the patency of the ostium.

Updates (2015–2016)

Since the publication of the first edition of this text in 2014, several articles have been published on endocanalicular laser dacryocystorhinostomy (ECLDCR) concerning the diode laser, refinement of techniques, comparative studies, managing coexistent septal deviation, and complications. In my practice, we have been using an 810 nm diode laser (Diomed, United Kingdom) for the past 14 years. However, Diomed has now discontinued the manufacture of diode lasers for DCR; hence, we cannot anymore purchase laser fiber optics and spare parts for our diode laser. We recently purchased a new 980 nm diode laser (Orbeam, Turkey) for ECLDCR. The major difference with the old laser is the new interface of the Orbeam diode laser with touchscreen capabilities. Just like any diode laser, it can be transported from one hospital to another for maximal usage (Figs. 24.16 and 24.17). We are also using a 400 μm laser fiber optic instead of the 600 μm from the old laser. The advantage of the smaller laser fiber optic is its easy insertion in the punctum and sac and enhanced maneuvering when performing the osteotomy [51].

Diode Laser

The diode laser is a solid-state laser that has a laser fiber optic and is the most widely used laser for ECLDCR. Laser companies have been manufacturing both the 980 nm and the 810 nm, and it seems that there is a debate on which is better in terms of efficiency and degree of collateral burn. Goel et al. [52] described the advantages and disadvantages of each. The 980 nm is more preferable due to its better ablation and narrower tissue area involvement as compared to the 810 nm which creates better coagulation than vaporization. The 810 nm resembles the argon green laser and is better absorbed by hemoglobin, while the 980 nm is closer to the Nd:YAG laser and is better absorbed by water. They also recommend starting the laser power at 3 watts in a graded approach and then increasing the energy as required [52].

Techniques and Outcomes

Kaynak et al. [53] reported a retrospective and interventional study on the 2-year follow-up of patients who underwent ECLDCR for primary acquired nasolacrimal duct obstruction (PANDO). The patients were given mitomycin C (MMC) intraoperatively. At third month follow-up, 85.4% of post-ECLDCR patients had complete resolution of their symptoms. However, at 6 months, the functional success rate decreased to 67.7% and then to 63.3% at first year and finally 60.3% at second year follow-up. However, the anatomical patency was higher at 93.1%, 74.6%, 69.5%, and 68%, respectively. In their hands, ECLDCR seemed to have high success rates in the first 6 months but subsequently deteriorated significantly. According to the authors, this low success rate can be ascribed to the high laser energy used or the trauma to the canalicular system during insertion of the laser fiber optic [53].

Schlachter et al. [54] conducted a prospective interventional study on ECLDCR for PANDO. They had a total of 40 eyes that underwent ECLDCR. At 1-week follow-up, 88% of the eyes had improvement in tearing, and all patents were on lacrimal irrigation. At 1 month, 3 months, and 6 months postoperatively, the improvement in tearing was in 86%, 83%, and 77% of the eyes, respectively. No adjunctive modalities were given during and after ECLDCR. The author's noted the low success rate of their study and concluded that they will reserve this technique for patients who are unable to stop anticoagulant therapy prior to surgery. They are also embarking on a future study on ECLDCR using intraoperative MMC with modification of their surgical technique [54].

Ozsutcu et al. [55] did a retrospective study and compared the success rates of ECLDCR with and without MMC on patients with PANDO. In the MMC group, MMC was applied at a concentration of 0.2 mg/ml intraoperatively for 3 min with irrigation. At 12 months following surgery, the success rate of the non-MMC group was 80% compared with the MMC group at 78.8%. This result was deemed not statistically significant. In conclusion, the authors stated that intraoperative use of MMC may not have additional beneficial effects on the success rates of ECLDCR [55].

Comparative Studies

Comez et al. [56] did a retrospective study and compared the success rates, complications, and patient discomfort rates of ECLDCR and external dacryocystorhinostomy (EX-DCR). The ECLDCR group had a total of 34 eyes, and the EX-DCR group had 46 eyes. The ECLDCR group was given intraoperative MMC except for the first 8 patients, and the EX-DCR group had MMC applied on 29 patients. The success rates were 79.4% for ECLDCR and 89.1% for the EX-DCR group at the final follow-up. There were also no major complications with the ECLDCR procedure. Moreover, patient discomfort was less in the ECLDCR group as compared to the EXDCR group [56]. However, MMC application was not consistent, and it is not clear how patients were chosen for this.

Uldag et al. [57] did a prospective study on 38 eyes of 19 patients comparing the outcomes of EX-DCR and ECLDCR. All 19 patients had bilateral PANDO. ECLDCR was done on the right eye, and EX-DCR was done on the left eye on each patient. The success rate of ECLDCR at 1 year was 73.7% while for the EX-DCR was 89.5%. The subjective outcome was determined by comparing the satisfaction rates and the quality of life scores. They evaluated ocular symptoms (tearing, pain, irritation, and discharge) and visual outcome score (VAS) on different follow-up periods. They noted more tearing in the ECLDCR group on all postoperative visits. There was more pain noted in the EX-DCR group than the ECLDCR group. Both scores were statistically insignificant. Only the discharge scores were statistically significant in the ECLDCR group compared to the EX-DCR group. VAS showed more satisfaction with the EX-DCR group than the ECLDCR group at 8.6 and 6.8, respectively, but this was also not statistically significant. Finally, they inferred that ECLCDR has worse long-term results compared to the EX-DCR [57].

A prospective study was done comparing all three DCR procedures by Balikoglu-Yilmaz et al. [58]. They analyzed the surgical times, success rates, the size of the ostium, and complications in patients undergoing EX-DCR, endonasal dacryocystorhinostomy (EN-DCR), and ECLDCR. Ninety-two patients were divided into each surgical group. EX-DCR had 33 eyes, EN-DCR had 29 eyes, and ECLDCR had 30 eyes. In terms of anatomical and functional success rates, there was no significant difference between the three groups (anatomical—EX-DCR with 81.8%, EN-DCR with 75.9%, and ECLDCR with 76.75%) (functional—81.8% for EX-DCR, 72.4% for EN-DCR, and 73.3% for ECLDCR). Surgical time was longest with EX-DCR (average, 46.6 min) and shortest with ECLDCR (average, 20.3 min). The final size of the ostium was largest with the EX-DCR group with an average size of 33.7 mm^2 and smallest with the EN-DCR at 19.0 mm^2. No major complications were noted during and after the procedures were done. The authors surmised that all three DCR procedures have similar success rates and complication rates. EX-DCR is still the gold standard for DCR, but ECLDCR was also effective and appeared to have the shortest surgical time [58].

Yildrim et al. [59] retrospectively compared the surgical outcome of ECLDCR with and without silicone tubes. Out of 113 eyes, 58 eyes underwent ECLDCR with bicanalicular silicone tubes, while 55 eyes underwent the same procedure without bicanalicular silicone tubes. After 18 months of follow-up, they discovered that patients who had silicone tubes had a success rate of 84.4% compared to 63% success rate for those without tubes. This result was statistically significant compelling the authors to conclude that placing bicanalicular silicone tubes during ECLDCR was more successful than without tubes. They recommend placing bicanalicular silicone tubes in all patients for ECLDCR [59].

Septal Deviation

Septal deviation in EN-DCR and ECLDCR has been a hindrance when doing these procedures due to visualization problems [60]. However, two articles revealed that a surgeon can still do ECLDCR with significant septal deviation. Goel et al. [61] published a prospective interventional study regarding the success rate of ECLDCR with deviated nasal septum (DNS). The level of deviated septum was divided into high, mid, and basal on the basis of involvement of the upper, middle, or lower one-third of the septum. Severity was defined as mild, moderate, and severe: mild for deviation less than half the total distance to the lateral nasal wall, moderate for a deviation more than half the distance, and severe for deviations touching the lateral nasal wall [60]. Patients with severe DNS were excluded from the study. The main difficulty experienced intraoperatively in all patients was the visualization of the laser aiming beam in the nose. This was more evident in patients with a high DNS. Bleeding was also a problem due to increase manipulation of the endoscope. Despite the mild to moderate DNS, difficulty in visualization, and occasional bleeding during ECLDCR, the authors still had an 88.9% success rate with an average ostium size of 21.94 mm^2 at 12 months postoperatively. They also postulated there was no difference in complication rate between mild and moderate DNS [61].

Raposo et al. [62] reported a prospective study to determine the influence of septal deviation (SD) on the success rate of ECLDCR. Patients were divided into two groups. The first group had 102 eyes without SD, and the second group had 39 eyes with SD. Their classification was based on Hong-Ryul's classification of SD of mild, moderate, and severe [60]. They also included the assessment of 18 eyes which had other naso-anatomical variations like concha bullosa and hypertrophic turbinates. The group without SD had

a success rate of 67.6% at 6 months postoperatively. The success rates of ECLDCR were not statistically significant in mild SD (66.67%), moderate SD (66.60%), and severe SD (66.66%). However, the success rate for the patients with naso-anatomical variants was statistically significant at 44.1%. With these results, they postulated that surgeons can avoid previous or concomitant septoplasty in cases of mild and moderate SD [62].

Complications

Complications are part and parcel of any surgical procedure. We have enumerated these in our chapter. Three reports have been published on complications of ECLDCR [63–65]. Goel et al. [63] reported a case of nasocutaneous fistula following ECLDCR. Immediately after the laser treatment, they noticed a burn with soft tissue erythema and edema in the area of the lower canaliculus. Four days after the surgery, they noticed redness, tenderness, and discharge which developed into a nasocutaneous fistula. Culture revealed staphylococcus. Intravenous antibiotics and wound hygiene led to granulation tissue formation and spontaneous closure of the fistula [63]. The author of this chapter advocates care when performing the laser inside the lacrimal sac. It is important that only a small portion of the laser tip is exposed from the silicone sleeve. A longer exposed laser tip will result in burns all the way to the border of the silicone sleeve and can damage the common canaliculus up to the punctum. The 2-min rule is useful here. After 2 min of performance with the laser, remove the laser fiber optic and check for severe charring of the tip. This charred end needs to be cut to expose a new tip. A newly cut laser fiber-optic tip is better than a charred tip which may go all the way to the sleeve, and further damage is prevented. Moreover, if erythema or burns are noted after the surgery, it would be prudent to give oral and topical antibiotics to prevent any unwanted infection after surgery.

McClintic [65] described three cases of tissue necrosis on the medial canthal area following ECLDCR. Their first case was a straightforward fistula formation and tissue necrosis of the right medial canthal area 10 days after ECLDCR. Tissue specimens revealed necrotic tissue and inflammation. The patient underwent surgical debridement with closure of the fistula, and the wound healed uneventfully but with persistence of the epiphora. The second case was the discovery of basal cell carcinoma after repairing a necrotic left medial canthal area following ECLDCR. A glabellar flap was performed to cover the defect; however, the flap broke down after the repair and was allowed to granulate with complete excision of the basal cell carcinoma. The last case was a failed case of ECLDCR. After having difficulty creating an ostium using the laser fiber optic, the surgeon abandoned the procedure and did a non-laser endonasal DCR. A first-degree burn at the medial canthal area was noted on the first operative day. Tissue necrosis was evident on day 7, and debridement was carried out along with a glabellar flap at tenth week post-op. Multiple bony erosions were seen in the frontal process of the maxilla during the debridement which appeared to be consistent with the laser damage [65].

Yildirim et al. [66] opined two major findings in their study. First is the decrease in olfactory function after ECLDCR, and the second is the return of the olfactory abilities after 3 months. They suggested that a temporary decrease of olfactory function after ECLDCR should be taken into account when obtaining informed patient consent.

Conclusion

The beauty of ECLDCR lies in its minimally invasive nature [30]. It is a simple procedure that is more familiar to an ophthalmologist and oculoplastic surgeon. It is also an effective procedure that can be performed faster than other methods of DCR [31]. Improvements in laser technology, surgical technique, use of adjuvants, proper training, appropriate instrumentation, and good patient selection have improved the success of ECLDCR and can be a good alternative to an external or endoscopic DCR.

References

1. Jack MK. Dacryocystorhinostomy: description of a transcanalicular method. Am J Ophthalmol. 1963;56:974–7.
2. Levin PS, Stormogipson DJ. Endocanalicular laser-assisted dacryocystorhinostomy. An anatomic study. Arch Ophthalmol. 1992;110:1488–90.
3. Silkiss RZ, Axelrod RN, Iwach AG, et al. Transcanalicular THC:YAG dacryocystorhinostomy. Ophthalmic Surg. 1992;23:351–3.
4. Michalos P, Pearlman SJ, Avila EN, et al. Hemispheric tip contact Nd:YAG translacrimal-nasal dacryocystorhinostomy. Ocular Surg News. 1995;13:40.
5. Mchugh JDA, Rose GE, Marshall J. The application of high-power diode lasers in ophthalmology. Laser Light Ophthalmol. 1994;6:229–38.
6. Christenbury JD. Translacrimal laser dacryocystorhinostomy [letter]. Arch Opthalmol. 1992;110:170–1.
7. Piaton JM, Limon S, Ounnas N, et al. Transcanalicular endodacryocystorhinostomy using Neodymium:YAG laser. J Fr Ophthalmol. 1994;17:555–67.
8. Dalez D, Lemagne JM. Transcanalicular dacryocystorhinostomy by pulse Holmium-YAG laser. Bull Soc Belg Ophthalmol. 1996;263:139–40.
9. Pearlman SJ, Michalos P, Leib ML, et al. Translacrimal transnasal laser-assisted D\dacryocystorhinostomy. Laryngoscope. 1997;107:1362–5.
10. Rosen N, Barak A, Rosner M. Transcanalicular laser-assisted dacryocystorhinostomy. Ophthalmic Surg Lasers. 1997;28:723–36.
11. Muellner K, Wolf G, Luxenberger W, et al. Laser-assisted transcanalicular dacryocystorhinostomy. Initial results. Ophthalmologe. 2001;98:174–7.
12. Caversaccio M, Frenz M, Schar P, et al. Endonasal and transcanalicular Er:YAG laser dacryocystorhinostomy. Rhinology. 2001;39:28–32.

13. Piaton JM, Keller P, Limon S, et al. Holmium: YAG and neodymium: YAG laser assisted trans-canalicular dacryocystorhinostomy. Results of 317 first procedures. J Fr Ophthalmol. 2001;24:253–64.
14. Hofmann T, Lackner A, Muellner K, et al. Endolacrimal KTP laser-assisted dacryocystorhinostomy. Arch Otolaryngol Head Neck Surg. 2003;129:329–32.
15. Fay AM, Michalos P, Rubin PA. Endocanalicular Nd: YAG laser dacryocystorhinostomy [review]. Int Ophthalmol Clin. 1999;39:177–84.
16. Hong JE, Hatton MP, Leib ML, et al. Endocanalicular laser dacryocystorhinostomy: an analysis of 118 consecutive surgeries. Ophthalmology. 2005;112:1629–33.
17. Eloy P, Trussart C, Jouzdani E, et al. Transcanalicular didoe laser assisted dacryocystorhinostomy. Acta Otohinolaryngol Belg. 2000;54:157–63.
18. Alanon FFJ, Alanon FMA, Martinez FA, et al. Transcanalicular dacryocystorhinostomy technique using diode laser. Arch Soc Esp Oftalmol. 2004;79:325–30.
19. Alanon FMA, Alanon FFJ, Martinez FA, et al. Results of the application of mitomycin-c during endonasal and endocanalicular dacryocystorhinostomy by diode laser. Acta Otorhinolaryngol Esp. 2006;10(57):355–8.
20. Henson RD, Henson RG Jr, Cruz HL Jr, et al. Use of the diode laser with intraoperative mitomycin C in endocanalicular laser dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2007;23:134–7.
21. Plaza G, Betere F, Noquiera A. Transcanalicular dacryocystorhinostomy with diode laser: long-term results. Ophthal Plast Reconstr Surg. 2007;23:179–82.
22. Maeso RJ, Sellarès FMT. Trans-canalicular diode laser dacryocystorhinostomy: technical variations and results. Acta Otorrinolaringol Esp. 2007;58:10–5.
23. Cintra PPVC, Anselmo-Lima WT. Endocanalicular diode laser-assisted dacryocystorhinostomy. Otolaryngol Head and Neck Surg. 2008;139:159–61.
24. Basmak H, CAkli H, Sahin A, et al. Comparison of endocanalicular laser dacryocystorhinostomy with and without endonasal procedures. Am J Rhinol Allergy. 2011a;249:737–43.
25. Henson RD, Cruz HL Jr, Henson RG Jr, et al. Postoperative application of mitomycin-C in endocanalicular laser dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2012;28:192–5.
26. Drnovsek-Olup B, Beltram M. Transcanalicular diode laser-assisted dacryocystorhinostomy. Indian J Ophthalmol. 2010;58:213–7.
27. Nuhoglu F, Gurbuz B, Eltutar K. Long-term outcomes after transcanalicular dacryocystorhinostomy. Acta Otorhinolaryngol Ital. 2012;32:258–62.
28. Derya K, Demirel S, Doganay S, et al. Endoscopic transcanalicular dacryocystorhinostomy: Is it an alternative method to conventional external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:15–7.
29. Dogan R, Meric A, Ozsutcu M, Yenigun A. Diode laser-assisted endoscopic dacryocystorhinostomy: a comparison of three different combinations of adjunctive procedures. Eur Arch Otorhinolaryngol. 2013;270:2255–61.
30. Robert MC, Maleki B, Boulos P. Endocanalicular laser dacryocystorhinostomy with mucosal flaps. Ophthal Plast Reconstr Surg. 2013;29:294–7.
31. Athanasiov PA, Prabhakaran VC, Mannor G, et al. Transcanalicular approach to adult lacrimal duct obstruction: a review of instruments and methods. Ophthalmic Surg Lasers Imaging. 2009;40:149–59.
32. Basmak H, Cakli H, Sahin A, et al. What is the role of partial middle turbinectomy in endocanalicular laser-assisted endonasal dacryocystorhinostomy? Am J Rhinol Allergy. 2011b;25:160–5.
33. Minasian M, Olver JM. The value of nasal endoscopy after dacryocystorhinostomy. Orbit. 1999;18:167–76.
34. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report of the American Academy of Ophthalmology. Ophthalmology. 2001;108:2369–77.
35. Liao SL, Kao SC, Tseng JH, et al. Results of intraoperative mitomycin C application in dacryocystorhinostomy. Br J Ophthalmol. 2000;84:903–6.
36. Camara JG, Bengzon AU, Henson RD. The safety and efficacy of mitomycin C in endonasal endoscopic laser-assisted dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2000;16:114–8.
37. Selig YK, Biesman BS, Rebeiz EE. Topical application of mitomycin C in endoscopic dacryocystorhinostomy. Am J Rhinol. 2000;14:205–7.
38. You YA, Fang CT. Intraoperative mitomycin C in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2001;17:115–9.
39. Deka A, Bhattacharjee K, Bhuyan SK, et al. Effect of mitomycin C on ostium in dacryocystorhinostomy. Clin Experiment Ophthalmol. 2006;34:557–61.
40. Rathore PK, Kumari SP, Pandey RM. Topical mitomycin C as a postoperative adjunct to endonasal dacryocystorhinostomy in patients with anatomical endonasal variants. Orbit. 2009;28:297–302.
41. Cheng SM, Feng YF, Xu L, et al. Efficacy of mitomycin C in endoscopic dacryocystorhinostomy: a systematic review and meta-analysis. PLoS One. 2013;8:e62737.
42. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
43. Yildirim C, Yaylali V, Esme A, et al. Long-term results of adjunctive use of mitomycin C in external dacryocystorhinostomy. Int Ophthalmol. 2007;27:31–5.
44. Tirakunwichcha S, Aeumjaturapat S, Sinprajakphon S. Efficacy of mitomycin C in endonasal endoscopic dacryocystorhinostomy. Laryngoscope. 2011;121:433–6.
45. Yeniad B, Tuncer S, Kir N, et al. Orbital infarction syndrome after transcanalicular dacryocystorhinostomy with diode laser. Ophthalmic Surg Lasers Imaging. 2012;43:e107–9.
46. Yeniad B, Bilgin LK, Cagatay A, et al. A rare complication after transcanalicular dacryocystorhinostomy: tissue necrosis and nasal-cutaneous fistula. Ophthal Plast Reconstr Surg. 2011a;27:112–3.
47. Hu D, Sires BS, Tong DC, et al. Effect of brief exposure to mitomycin C on cultured human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2000;16:119–25.
48. Ugurbas SH, Zilelioglu G, Sargon MF, et al. Histopathologic effects of mitomycin-C on endoscopic transnasal dacryocystorhinostomy. Ophthalmic Surg Lasers. 1997;28:300–4.
49. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration – a fundamental study on human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
50. Kamal S, Ali MJ, Naik MN. Circumostial injection of mitomycin C (COS-MMC) in external and endoscopic dacryocystorhinostomy: efficacy, safety profile and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
51. Ovet G, Sakarya Y, Senturk M. A comparative study of transcanalicular diode laser supported endoscopic dacryocystorhinostomy and non-laser endoscopic dacryocystorhinostomy. Am J Otolaryngol. 2016;37:497–501.
52. Goel R, Nagpal S, Garg S, et al. Is transcanalicular laser dacryocystorhinostomy using low energy 810 nm diode laser better than 980 nm diode laser? Oman J Ophthalmol. 2015;8:134.
53. Kaynak P, Ozturker C, Yazgan S, et al. Transcanalicular diode laser assisted dacryocystorhinostomy in primary acquired nasolacrimal duct obstruction: 2-year follow up. Ophthal Plast Reconstr Surg. 2014;30:28–33.
54. Schlachter DM, Richani K, Black EH. Diode laser-assisted endocanalicular dacryocystorhinostomy: a prospective study. Ophthal Plast Reconstr Surg. 2016;32:183–6.
55. Ozsutcu M, Balci O, Tanriverdi C, et al. Efficacy of adjunctive mitomycin C in transcanalicular diode laser dacryocystorhinostomy. Eur Arch Otorhinolaryngol. 2017;274:873–7.

56. Comez AT, Karadag O, Arikan S, et al. Comparison of transcanalicular diode laser dacryocystorhinostomy and external dacryocystorhinostomy in patients with primary acquired nasolacrimal duct obstruction. Lasers Surg Med. 2014;47:275–80.
57. Uludag G, Yeniad B, Ceylan E, et al. Outcome comparison between transcanalicular and external dacryocystorhinostomy. Int J Ophthalmol. 2015;8:353–7.
58. Balikoglu-Yilmaz M, Yilmaz T, et al. Prospective comparison of 3 dacryocystorhinostomy surgeries: external versus endoscopic versus transcanalicular multidiode laser. Ophthal Plast Reconstr Surg. 2015;31:13–8.
59. Yildirim Y, Kar T, Topal T, et al. Comparison of transcanalicular multidiode laser dacryocystorhinostomy with and without Silicon Tube Intubation. J Ophthalmol. 2016;2016:6719529.
60. Jin HR, Lee JY, Jung WJ. New description method and classification system for septal deviation. J Rhinol. 2007;14:27–31.
61. Goel R, Nagpal S, Kumar S, et al. Our experience with transcanalicular laser-assisted endoscopic dacryocystorhinostomy (TCLADCR) in patients of chronic dacryocystitis with deviated nasal septum. Int Ophthalmol. 2015b;35:811–7.
62. Raposo A, Piqueras F, Garcia-Purinos F, et al. Influence of septal deviation on the prognosis of transcanalicular diode laser-assisted dacryocystorhinostomy. J Ophthalmol. 2016;2016:9573760.
63. Goel R, Gar S, Nagpal S, et al. Naso-cutaneous fistula following transcanalicular laser dacryocystorhinostomy. Saudi J Ophthalmol. 2014;28:69–71.
64. Yeniad B, Bilgin LK, Cagatay A. A rare complication after transcanalicular dacryocystorhinostomy: tissue necrosis and nasal-cutaneous fistula. Ophthal Plast Reconstr Surg. 2011;27:e112–5.
65. McClintic SM, Yoon MK, Bidar M, et al. Tissue necrosis following diode laser-assisted transcanalicular dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:18–22.
66. Yildirim Y, Salihoglu M, Kar T, et al. Postoperative changes in olfactory function after transcanalicular diode laser dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:94–7.

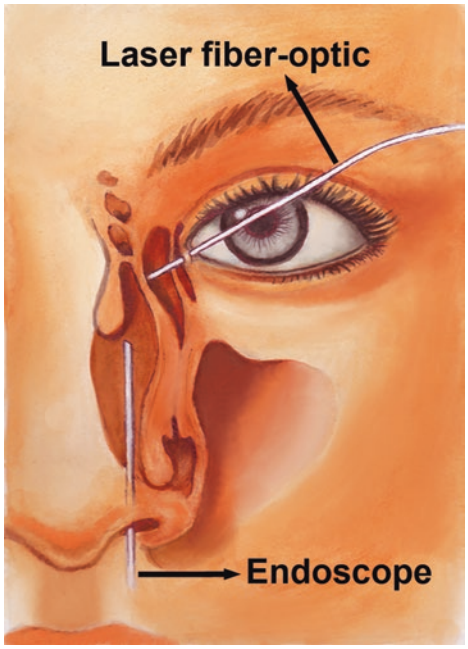


Fig. 24.1 Schematic overview of ECLDCR (Photo courtesy: Josie Henson, Philippines)

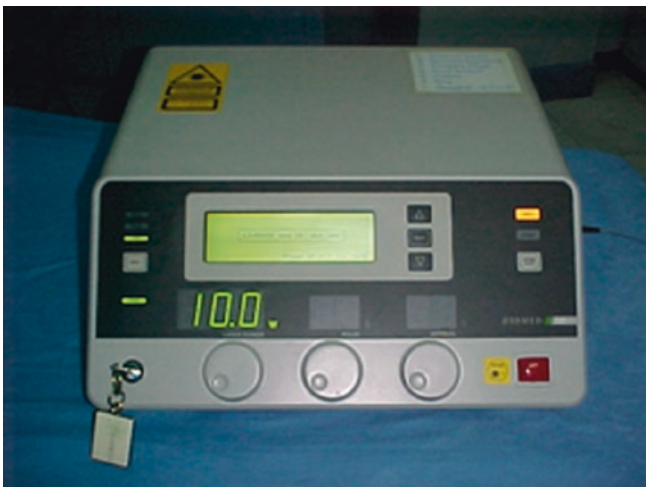


Fig. 24.2 Diode laser (Diomed, Cambridge, United Kingdom)

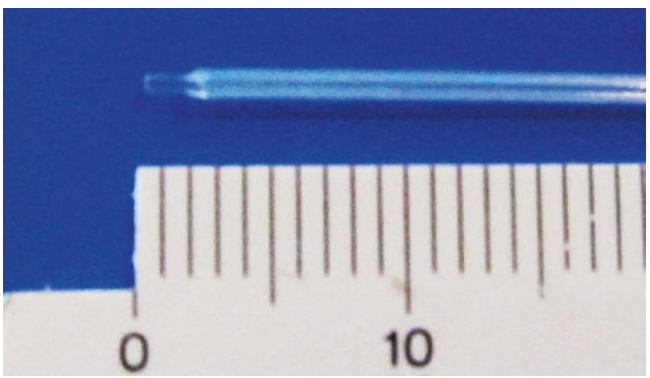


Fig. 24.3 Laser fiber optic (600 μm)

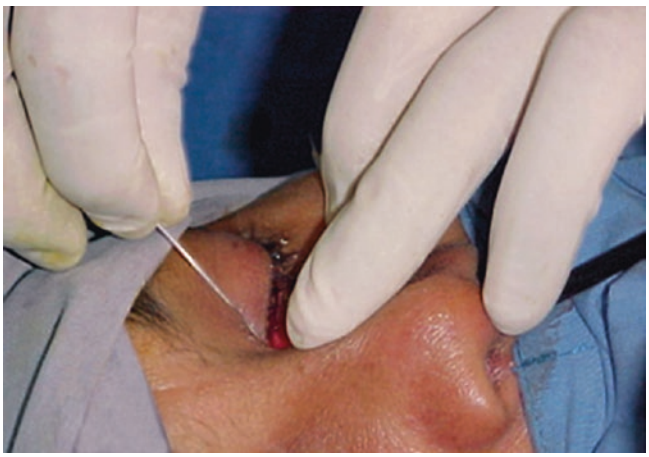


Fig. 24.4 Insertion of laser fiber optic at 45°. Note the glow of the laser from the medial canthal area

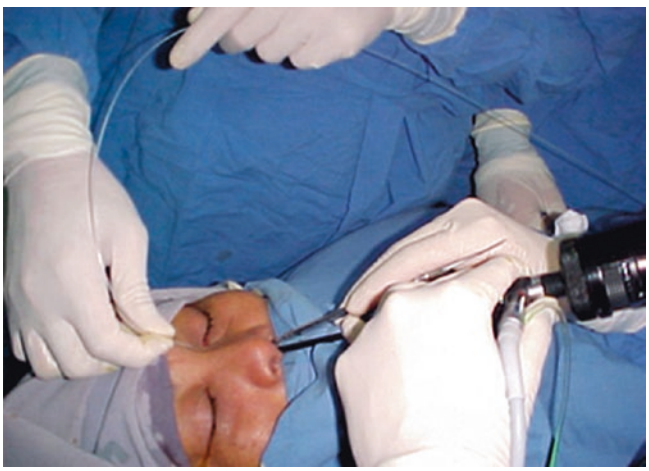


Fig. 24.5 Overview of laser fiber-optic insertion toward the lacrimal bone

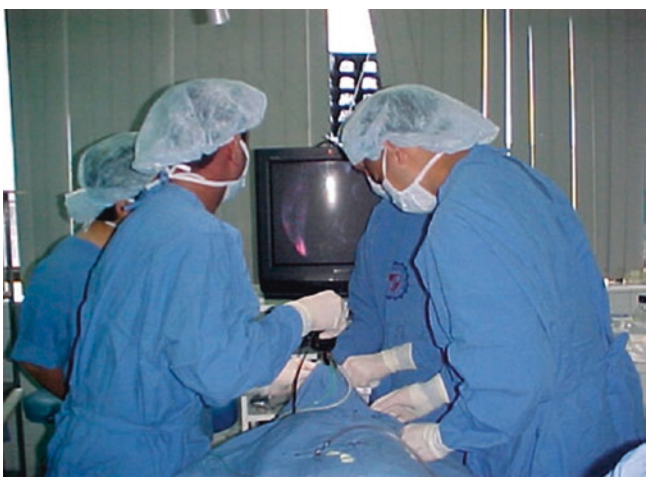


Fig. 24.6 Visualization of the surgery using an endoscopic viewing system

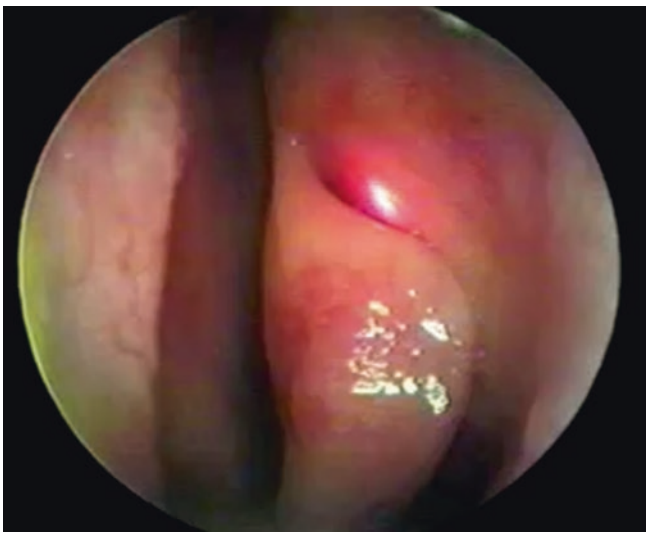


Fig. 24.7 Nasal endoscopic view of the "laser glow." This corresponds to the thinnest portion of the lacrimal bone

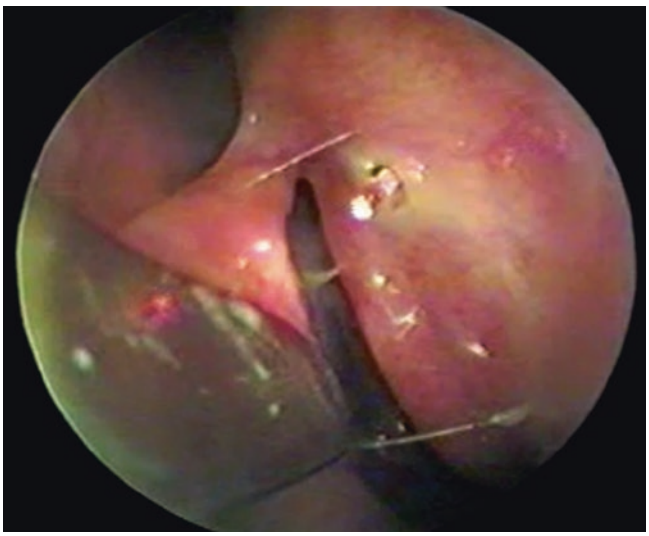


Fig. 24.9 Creating the first osteotomy using the laser fiber optic. This is also called "laser puncture." Note no bleeding during the puncture with whitening and coagulation of the mucosa around the tip

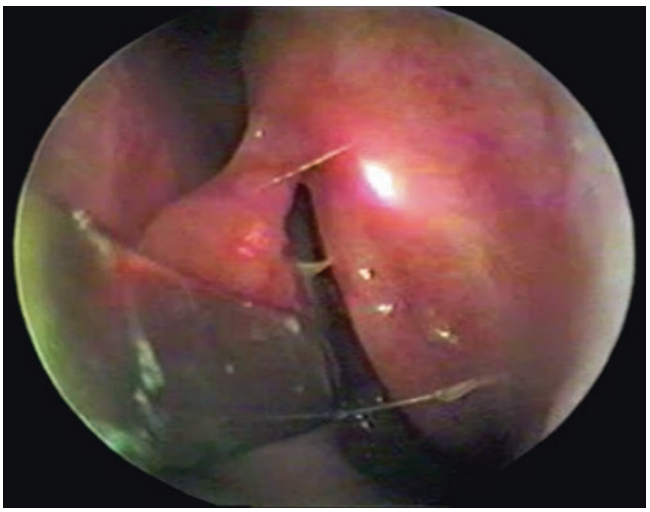


Fig. 24.8 Periosteal elevator medializing and protecting the middle turbinate before the laser application

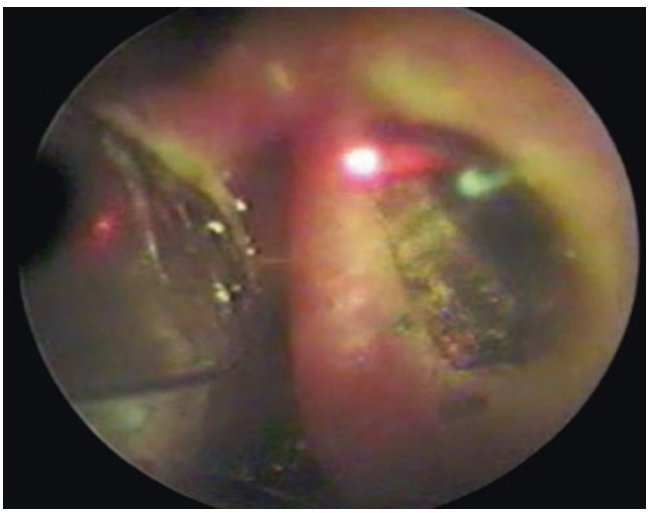


Fig. 24.10 Enlarging the osteotomy. Note the periosteal elevator protecting the middle turbinate and absence of bleeding during the laser process

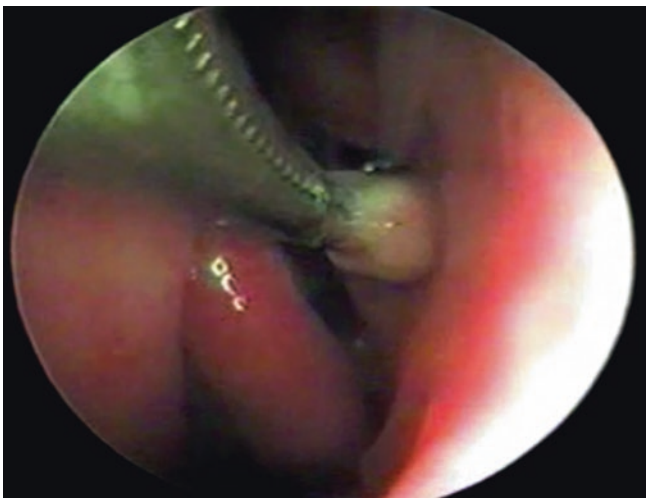


Fig. 24.11 Intraoperative mitomycin C application

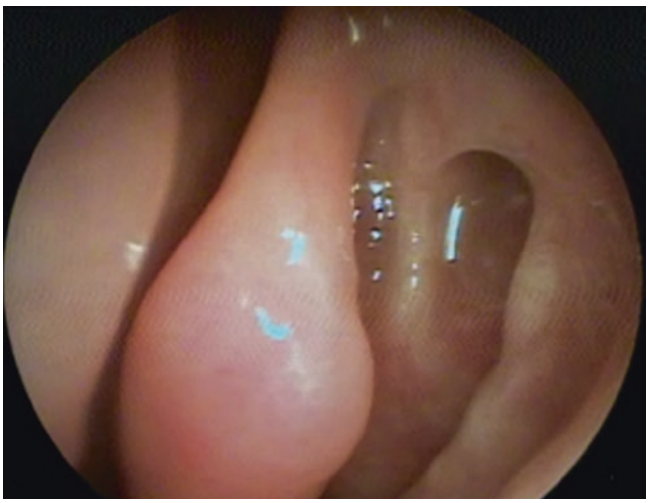


Fig. 24.14 Postoperative image of osteotomy at 6 months

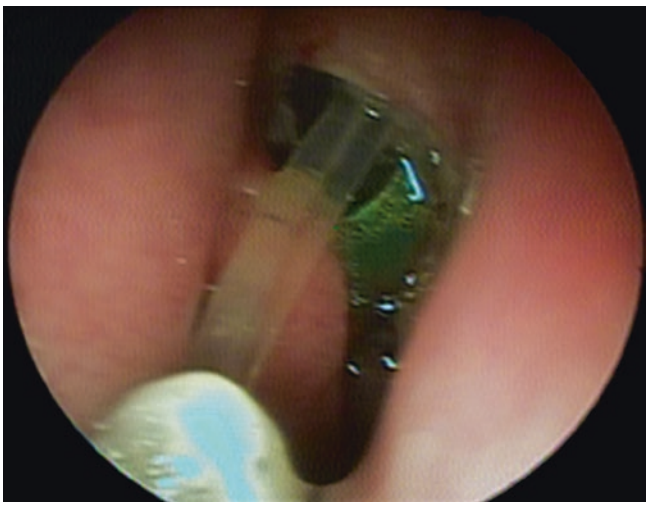


Fig. 24.12 Postoperative osteotomy with silicone tubes

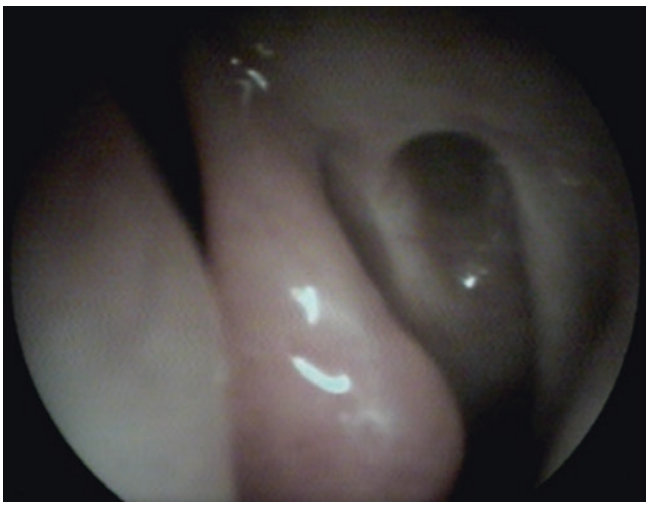


Fig. 24.15 Postoperative image of osteotomy at 1 year

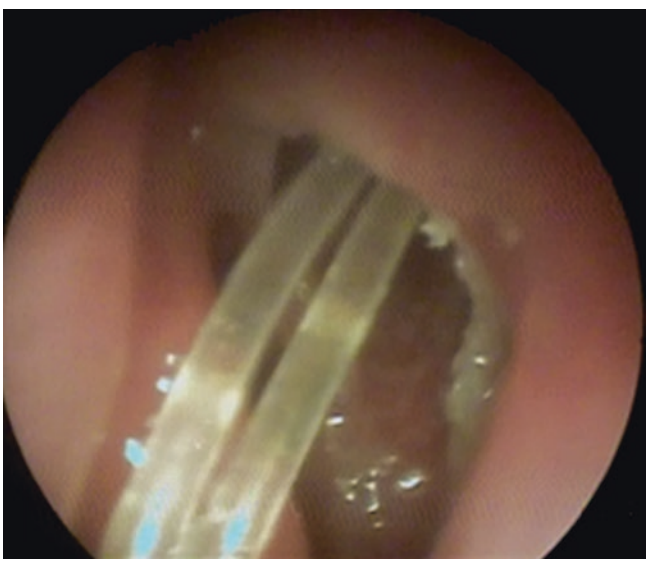


Fig. 24.13 Postoperative image of the osteotomy with the tubes intact at 1 month

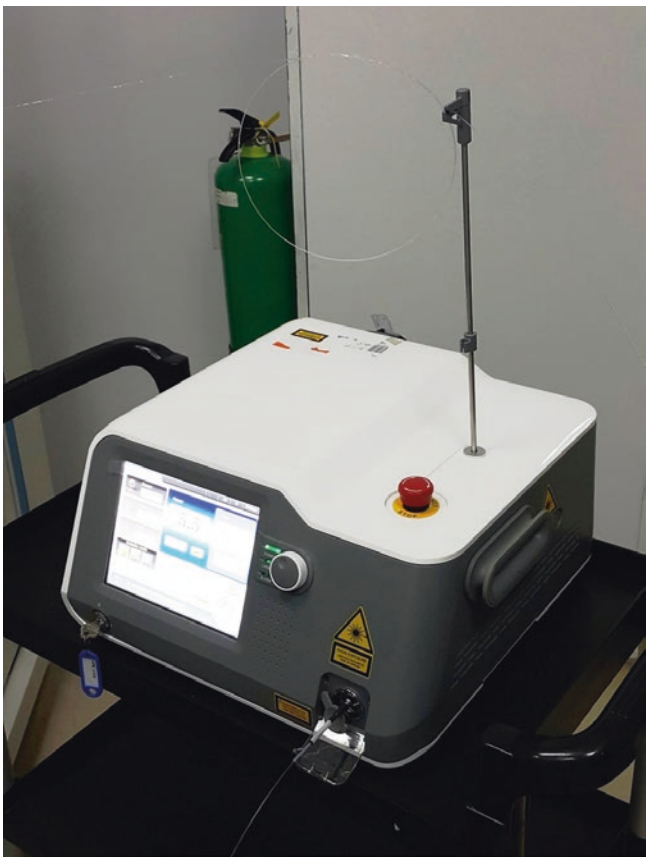


Fig. 24.16 The new 980 nm diode laser (Orbeam^{R})

Fig. 24.17 The new interactive interface of the control panel (Orbeam^{R})

5 mm and 9 mm Balloon-Assisted Dacryocystorhinostomy

25

David I. Silbert and Noelle S. Matta

Introduction

Incisional dacryocystorhinostomy (DCR) was first introduced by Toti in Italy in 1904 [1]. Modifications were introduced over the years resulting in successful procedures by the 1920s. Advances over the past few decades have included the introduction of silicone tubes, antibiotics, and steroids both oral and topical to minimize scarring and infection. Various modifications have been introduced to decrease the size of the external incision or to relocate the incision into the eyelid to decrease the risk of scarring and webbing [2]. Despite this, external DCR remains an invasive procedure with significant morbidity.

In 1988 Becker showed a success rate in external DCR of 92% without creating flaps [3]. Becker later developed balloon catheters to perform both dacryoplasty and DCR procedures endoscopically.

Advantages of external DCR include reported high success rates of 90–95% [4]. It is also widely stated that external DCR is more effective in identifying tumors than endoscopic procedures. Disadvantages of incisional DCR include prolonged recovery, significant risk of blood loss, and risk of hypertrophic scarring [4].

Bleeding can result from injury to the angular vessels, as well as bleeding from the nasal mucosa, which is entered in a relatively blind fashion, and cannot be visualized well from the external incision. Postoperative nasal packing is typically needed in external DCR, which is uncomfortable for patients and increases risk of infection. Finally hypertrophic scarring can lead to difficulty wearing glasses with the nose pad pressing on the incision site.

Endoscopic balloon-assisted DCR offers the experienced lacrimal surgeon a simpler, shorter, and less invasive procedure. Although there is a steep learning curve, once mastered, the procedure has a very low complication rate. The procedure can be performed under monitored anesthesia care, though laryngeal mask anesthesia is often preferred as it provides greater comfort for the surgeon and the patient while minimizing the depth of the anesthesia and the risk of valsalva associated with an endotracheal tube, which can lead to postoperative bleeding. Other advantages of the balloon-assisted endoscopic approach include the absence of a skin incision, minimal bleeding, absence of edema, less discomfort, shorter recovery, and a high success rate.

Endoscopic balloon-assisted DCR is indicated for most cases of nasolacrimal duct obstruction. Since the procedure is less invasive, even cases of relative nasolacrimal obstruction which are non-responsive to other treatments can be considered. Although it is often stated that endoscopic DCR is contraindicated in cases of dacryocystitis or cellulitis, this is not accurate [5]. In fact the endoscopic approach, which drains the infected sac directly to the nose, minimizes the risk of infecting skin structures and the development of cellulitis [5]. Nasal septal deviation is a relative contraindication, though with experience, this becomes less of an issue.

Preoperative Workup

Preoperative workup should include history of tearing, discharge, and infection. It should include dye disappearance test, irrigation of the nasolacrimal system, and probing of the upper and lower canaliculi to verify patency. Endoscopic nasal examination can be performed preoperatively in the office and is useful to assess location of the turbinates and the space in the nose. In cases where patients have significant inflammation in the nose, preoperative inhaled steroids or a visit to ENT to decrease the inflammation can improve outcomes of the endoscopic procedure.

The preoperative regimen for endoscopic balloon-assisted DCR should serve to suppress infection and treat inflammation in the nose. If the patient has significant dacryocystitis or cellulitis, this should be suppressed preoperatively with oral antibiotics, prior to surgery. Amoxicillin with clavulanic

D.I. Silbert, M.D., F.A.A.P. (✉) • N.S. Matta, C.O., C.R.C., C.O.T.
Family Eye Group, Lancaster, PA, USA
e-mail: DSilbert@familyeyegroup.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_25

acid or clindamycin in penicillin-allergic patients is typically a good choice. If there is no response or if *methicillin-resistant Staphylococcus aureus (MRSA)* is suspected, cultures of purulent discharge should be performed which can help in choosing antibiotics. Antiplatelet medications such as Coumadin, aspirin, and clopidogrel bisulfate as well as the newer anticoagulants should be discontinued prior to surgery. They should not be restarted until 48 h following surgery or until any postoperative bleeding has ceased, and this time frame should be decided in consultation with their treating physicians.

Immediately preoperatively, all patients should be treated with intravenous antibiotics. Generally cefazolin 1–2 g IV is given in adults and 25 mg/kg in children. Clindamycin may be used in penicillin-allergic individuals. Intraoperatively, dexamethasone 8 mg is given, though in diabetics and children the dose is often reduced.

Anesthesia

Anesthesia for endoscopic balloon-assisted DCR typically includes a local block, packing of the nose, and general anesthesia with laryngeal mask anesthesia (LMA) or endotracheal tube, though monitored anesthesia care (MAC) or strict local anesthesia is possible. Typically lidocaine 2% with epinephrine mixed 10:1 with bicarbonate is injected intranasally using a 25 G spinal needle to the nasal mucosa beneath and anterior to the middle turbinate (Fig. 25.1). The middle turbinate can also be injected especially if the procedure is being done strictly under local anesthesia (Fig. 25.2). The nose is then packed with cottonoids soaked in 4% cocaine mixed 1:1 with oxymetazoline beneath and around the middle turbinate (Figs. 25.3 and 25.4). Infiltration anesthesia is injected transcutaneously. Infratrochlear and medial canthal blocks are recommended if the procedure is being performed under strict local or MAC anesthesia.

Balloon DCP Equipment

Equipment for balloon-assisted endoscopic DCR includes the following:

- 25 G spinal needle
- Punctal dilators
- Reinforced stainless steel 3–4 Bowman probe (Quest Medical)
- Dandy nerve hook
- Blakesley/trucut forceps
- Backbiting forceps
- Freer elevator
- Turbinate scissors
- Nasal speculum
- Headlight
- Sinuscope, 4.0/2.7 mm, 0°, occasionally 30°
- 5 or 9 mm LacriCATH balloon (Quest Medical)
- Inflation device
- Frazier suction
- Neurosurgical cottonoids
- 4% cocaine/Afrin
- Lidocaine
- Irrigating cannula

9 mm Endoscopic Balloon DCR: Surgical Technique

The packing is first removed from the nose to visualize the decongested nose (Fig. 25.5). The punctum is dilated well to allow passage of a reinforced stainless steel #3–4 Bowman probe. This can be viewed endoscopically if an assistant is available who can hold the endoscope in place but most often is done by feel. After the probe is passed, the endoscope is then introduced into the nares. Optionally, a retinal light pipe can be passed via canaliculus while viewing the nose with the endoscope (Figs. 25.6 and 25.7). This nicely demonstrates the location of the nasolacrimal sac in relation to the middle turbinate and can help the beginning surgeon to appreciate the appropriate orientation for the passage of the probe (Figs. 25.8 and 25.9). After the surgeon is familiar with the procedure, this step can often be omitted.

The reinforced Bowman probe is passed into the nose (Fig. 25.10). The probe should be oriented somewhat inferiorly and posteriorly and is then passed through the soft posterior portion of the lacrimal fossa. The probe should be viewed with the sinuscope. It should be found just inferior and beneath the attachment of the middle turbinate or just slightly inferior and anterior to the middle turbinate. If the probe is inadvertently passed through the turbinate, it should be pulled back slightly. If the probe is in the wrong location or can't be located, it should be removed and repassed. If the turbinate interferes, it can be gently pushed nasally with a freer elevator (Figs. 25.11 and 25.12). Resection of the turbinate can be performed in cases where it is severely encroaching on the area of the osteotomy (Fig. 25.13). Turbinate resection, however, is rarely necessary and can lead to additional scarring.

The nasal mucosa and thin posterior lacrimal fossa bone are filleted open with the stainless steel reinforced Bowman probe, by directing the probe posteriorly and superiorly around its pivot point (Figs. 25.14 and 25.15). In cases where this is difficult, a freer elevator can be used to guide the probe in the nose to perform this filleting process. A medium upbiting Blakesley forceps is then inserted closed into the osteotomy and spread, gently enlarging the osteotomy (Figs. 25.16, 25.17, and 25.18).

At this point, the osteotomy is ready for insertion of the deflated 9 mm endonasal balloon (Fig. 25.19). The placement is viewed endoscopically. The balloon is placed approximately 60% into the osteotomy (Figs. 25.20 and 25.21). It is held in place as viewed with the endoscope as the assistant inflates the balloon to 8 atmospheres of pressure. The balloon gradually enlarges the osteotomy further fracturing the thin bone of the lacrimal fossa (Fig. 25.22). At this point, the balloon is pulled in a nasal direction into the nose while fully inflated (Figs. 25.23 and 25.24). This serves to pull the fractured lacrimal fossa bone and nasal mucosa toward the surgeon where they can be removed with endonasal instrumentation. This can be performed with a medium up-biting Blakesley forceps or an up-biting cutter such as a Greenawalt forceps (Figs. 25.25 and Fig. 25.26). The osteotomy can be enlarged anteriorly with the use of up-biting or backbiting cutters (Fig. 25.27). A motorized suction cutter can also be used but is rarely necessary. We reported a success rate of 92% utilizing this procedure in a series of 97 cases [6].

Fayet et al. [7] have suggested that anterior resection of the uncinate process is important in better exposing the medial aspect of the lacrimal fossa during endonasal DCR to improve outcomes. Rather than enlarging the osteotomy anteriorly, we have begun enlarging the osteotomy posteriorly by performing an unciformectomy (Fig. 25.28). The procedure is performed similarly to its description previously, but following the removal of the balloon rather than removing the mucosal tissue and bone anterior to the osteotomy, attention is focused toward the posterior lip of the osteotomy. The posterior lip is grasped firmly with a straight or up-biting medium Blakesley, not a cutter, and the tissue is pulled firmly toward the surgeon removing the uncinate process, markedly enlarging the osteotomy posteriorly. When done correctly, this is much less likely to induce bleeding than anterior removal of the tissue. With unciformectomy creating such a large ostium (Fig. 25.29), we have found that it is unnecessary in most cases to remove the bone in the area of the anterior lacrimal crest. In 83 eyes of 59 patients, our success rate utilizing the endoscopic balloon technique combined with unciformectomy was 94% with one procedure and 96% following two procedures [8].

At this point, the soft sheath of an Angiocath is used to irrigate an antibiotic/steroid solution through the nasolacrimal system (Fig. 25.30). This serves to present redundant soft tissue and bone fragments into the operative area where they can be removed with Blakesley forceps under endoscopic control. At this point, the stent tubes are placed (Fig. 25.31). The stent tubes are preferable to typical Crawford tubes as they enlarge in diameter as they pass from the canaliculi to the osteotomy [9]. It is important to make sure that the smaller caliber endocanalicular portion of the tube is located properly in the canaliculi. This is done by gently pulling the tube from the canaliculi with a Crawford hook to verify that the superior and inferior portion of small caliber tube is equal in size. Once the tube is placed properly, it is secured to itself with a single 4-0 silk tie. Alternatively the tube may be left in place without securing the tube. Due to the increase in caliber as the tube passes through the osteotomy, it tends to be self-retaining [8, 9]. The author typically leaves the tube untied in children as it allows for removal of the tube from the punctum since endonasal removal without anesthesia is difficult in children. In adults, however, the tube is typically secured with a silk tied to itself. Although it is often stated that endoscopic DCR or placement of tubes is contraindicated in cases of dacryocystitis or cellulitis, this is not accurate [5]. In fact the endoscopic approach, which drains the infected sac directly to the nose, minimizes the risk of infecting skin structures and the development of cellulitis [5] (Figs. 25.32 and 25.33).

Postoperative Care

For the experienced surgeon, there is rarely significant blood loss with the procedure. It is preferable to perform the procedure with laryngeal mask anesthesia as there is less risk of bucking and increased valsalva coming out of anesthesia. This significantly decreases risk of postoperative bleeding. It is rarely necessary to pack the nose postoperatively; however, if there is significant bleeding during the procedure, the nose can be packed with Vaseline gauze and left it in place for up to 3 days. It is important to discontinue anticoagulants prior to surgery.

Postoperatively, patients are treated with a quick steroid taper (methylprednisolone pack) over 6 days, as well as oral antibiotics, topical antibiotic, and steroid drops for 10 days as well as intranasal steroids and saline spray irrigation of the nares for 1 month. Patients are generally seen 2–4 weeks postoperatively for endoscopy and saline irrigation of the nasolacrimal system. Any crusting or scar tissue can be removed from the ostium at the first postoperative visit. Often patients will continue to have tearing due to the presence of the stent tube, which due to its large caliber can impede fluid passage in the short term. The stent tubes are removed endoscopically at 3 months by cutting the tubes at the punctum and then grasping them in the nose and removing under endoscopic control with pediatric up-biting Blakesley forceps. At this visit, additional scar tissue and crusting are removed. Typically the patient is restarted on a topical antibiotic/steroid drop for 1–2 weeks then reexamined and re-irrigated in 1 month.

9 mm Revision DCR

The 9 mm endonasal approach can be utilized in some but not all reoperations following external DCR (Fig. 25.34). Frequently endonasal inspection with an endoscope follow-

ing a failed external DCR can reveal a bony osteotomy that is too small, located too anteriorly or superiorly (Fig. 25.35). In these cases, an endonasal DCR utilizing the 9 mm endonasal balloon can be appropriate. The procedure is completed as previously described, placing the new osteotomy site lower and more posteriorly (Figs. 25.36, 25.37 and 25.38).

5 mm Endoscopic Balloon-Assisted DCR

Some surgeons prefer utilizing a 5 mm endocanalicular balloon rather than the 9 mm balloon [10]. The 5 mm balloon is useful in situations where the nose is quite tight, such as in children. Since the 5 mm balloon is passed via the canaliculus, it requires less space in the nose. The 5 mm balloon is also quite useful in endoscopic reoperations following failed external or endoscopic DCR especially when the failure is primarily due to soft tissue scarring and obstruction.

The procedure is similar to the 9 mm balloon procedure previously described but differs in a few important ways. The punctum is dilated. Optionally, a light pipe is passed into the nose to delineate the area where the probe will pass through. Nasal packing is removed, and the turbinate is typically gently medialized. The probe is then passed into the nose similarly to what is described in the 9 mm procedure (Fig. 25.39). The probe is repositioned, and four to five punctures are created through the lacrimal fossa (Fig. 25.40). These are then coalesced with a Dandy nerve hook (Fig. 25.41). Mucosa and bone fragments are then removed with a Blakesley forceps (Fig. 25.42). The osteotomy can be expanded anteriorly with up-biting and backbiting cutters, if desired. It is more difficult to perform an unciformectomy however without the use of the 9 mm balloon first.

At this point, the balloon is passed via the canaliculus (Fig. 25.43). The balloon is first coated with ointment as this will ease the passage through the canalicular system. Since the balloon is larger in caliber than the 3 and 2 mm balloon that most surgeons are typically familiar with, it is crucial that the punctum and canaliculi are maximally dilated to prevent punctal or canalicular trauma and tearing. The balloon is then passed into the nose via the canaliculus; it is visualized in the nose, inflated to 8 atmospheres for 60 s (Fig. 25.44), deflated, pulled back and forth toward the canalicular system, and reinflated for an additional 60 s; and then the tube is deflated by pulling back on the inflator and locking it with negative pressure to ensure that the balloon has the smallest profile. It is then removed from the canalicular system with gentle traction to prevent canalicular trauma. The ostium is checked with the endoscope, and any additional redundant tissue is removed with Blakesley forceps or cutters. stent tubes are then placed as previously described (Fig. 25.45) and secured (Fig. 25.46).

Conclusion

The endoscopic balloon DCR procedures described herein have a number of advantages as compared to other endoscopic procedures. The two endoscopic balloon DCR procedures are relatively easy to master, as they require minimal mechanical instrumentation. By eliminating the use of blades, burrs, and drills, bleeding can be minimized. The procedure can be mastered easily as a team approach between an ophthalmologist and an ENT surgeon with gradual transition to the ophthalmologist performing the procedure unaided. The experienced surgeon will find improvement in patient acceptance of this procedure as compared to the external approach. Since there is so little morbidity postoperatively, the procedure can also be utilized for partial obstruction when other interventions have been unsuccessful. The procedure is relatively quick typically requiring 15 min. Blood loss is minimal, and recovery is rapid with little postoperative morbidity or swelling. Results in the hands of an experienced surgeon show success rates in excess of 90%, comparable to success rates reported for external DCR. Initial data shows that the addition of unciformectomy further improves outcomes.

Updates (2015–2016)

We had always wondered whether the 9 mm endoscopic balloon dacryocystorhinostomy procedure described in our chapter could be performed without the use of a 9 mm balloon. Our success rate of 94%, however, dissuaded us from modifying the procedure to eliminate the balloon. The use of the endonasal balloon in the procedure has allowed us to enlarge the osteotomy in a very nontraumatic manner, minimizing the need for the use of motorized burrs and cutters both decreasing procedure time and also minimizing tissue touch and bleeding. We recognize, however, that the cost of the endonasal balloon has prevented this simple technique from being adopted in emerging markets where the cost of the balloon is a limiting factor.

Subsequent to publication of the chapter, Quest Medical discontinued production of the 9 mm endonasal balloon. Although unfortunate, this has spurred us to experiment with other approaches to the procedure eliminating the use of the balloon. Currently, we perform the procedure in the same manner as described in the chapter for the 9 mm balloon procedure up to Fig. 25.15 with the following modifications.

Following Fig. 25.15 where we have filleted open the lacrimal sac (Fig. 25.47), the thin posterior bone of the lacrimal fossa, and the nasal mucosa, with a reinforced Bowman probe, we now insert a larger up-biting Blakesley forceps, opening it fully and rotating it slightly as we pull it back into the nose in order to mimic the effect of the absent 9 mm balloon

(Fig. 25.48). In many cases, we now also insert a caudal elevator into the osteotomy to further elevate and infracture the posterior lip of the osteotomy (Fig. 25.48). These two steps help to reproduce the effect of the balloon. Following this we now grasp the posterior lip of the osteotomy with a Blakesley forceps and then remove the uncinate process in one step, serving to significantly enlarge the osteotomy posteriorly (Fig. 25.49).

In cases where an unciformectomy is not possible, we will utilize the 5 mm balloon placed via a transcanalicular approach as described under the 5 mm procedure in the chapter; however, in most cases, we have found that we do not need to utilize the 5 mm balloon since with the removal of the uncinate process, the osteotomy is amply sized. At this point, we now inject a steroid antibiotic ointment through the canalicular system utilizing the soft portion of a 24 or 22 G Angiocath. The ointment helps to present soft tissue into the nose from the osteotomy, so it can be removed with Blakesley or cutting forceps. It also has an anti-inflammatory effect. At this point, stents are placed.

In the recent past, we have switched over to the Kaneka Lacriflow^{R} Stent. The Lacriflow Stent has several advantages and is composed of a proprietary polymer, which makes them very hydrophilic and slippery. The stents are similar to the stent tubes in that the canalicular portion is of a smaller caliber, while the portion past the common canaliculus is of a larger caliber. It is a self-retaining stent, inserted utilizing an introducer (bougie), and thus does not require securing in the nose (Fig. 25.50). The stent is placed via the upper and lower canaliculi, and then the bougie is removed obviating the need to recover the tubes from the nose. This speeds placement and minimizes intranasal trauma from a metal probe typical to most stents. The self-retaining nature of the Lacriflow stents also allows easy removal in the office by grasping between the upper and lower punctum and removing the stents from the canaliculus with a muscle hook or forceps rather than cutting the tube and extracting from the nose as is typical for most stents. The hydrophilic polymer allows fluid to pass nicely around the stent and aids in movement of the stent with blinks, which serve to continuously re-center the stent and clear debris from the area of the common canaliculus and osteotomy (Fig. 25.51). Overall we have found less induced inflammation with the use of the new stent. We typically leave the stents in for 3 months.

Without the use of the 9 mm balloon, the procedure is technically more complex for the novice surgeon. In light of this, in conjunction with Pedro Muel, we are in the process of designing a reusable device, which would emulate and replace the 9 mm balloon. This device will insert into the osteotomy created by the reinforced Bowman probe. It will have multiple flanges, which then will be opened to gradually and nontraumatically enlarge the osteotomy and deliver the tissue into the nose for removal. We hope to have a device to market within the next year.

Lee et al. [11] have recently reported on the use of 3 mm balloons in conjunction with bicanalicular intubation to treat internal ostium stenosis after endoscopic dacryocystorhinostomy. The study was a retrospective, noncomparative interventional case series of patients who underwent balloon dacryoplasty for post-endoscopic dacryocystorhinostomy internal ostium stenosis. Nineteen lacrimal systems of 18 consecutive patients were included in their study.

The authors defined internal ostium stenosis as:

1. Visualization of a tiny internal ostium on nasal endoscopy
2. Minimal dye passage via the tiny internal ostium on dye-stained irrigation
3. Resistance encountered to flow of fluid on syringing
4. Residual tearing symptoms in the presence of the above three factors but with subjective improvement after endoscopic dacryocystorhinostomy

The authors performed the procedure under local anesthesia, utilizing a transcaruncular lacrimal fossa block. A lacrimal probe was passed. The probe was then removed and replaced by the insertion of 3 × 15 mm LacriCATH (Quest Medical Products, Inc.) balloon catheter lubricated with 2% Xylocaine gel. The proper passage of the catheter through the ostium was confirmed endoscopically. The balloon was inflated to 8 atmospheres of pressure for 90 s. Reinflation for 60 s was performed. This was performed at the 15 mm marking and then repeated at the 10 mm marking. Irrigation with normal saline was performed to confirm the patency of the system in all patients. A bicanalicular silicone tube was inserted in 18 of the 19 lacrimal systems and was left in position for 4–6 weeks. Either Gelfoam soaked with 40 mg triamcinolone was threaded through the silicone tube and passed all the way down to the osteotomy or budesonide nasal spray 50 μg daily for a week was utilized in all cases. Antibiotic and steroid combination drops were used at least four times a day for a minimum of 1 month following the procedure.

The authors found an overall anatomical success rate (functional endoscopic dye test with no resistance on irrigation) in 16 of 19 (84%) lacrimal systems and functional success (subjective decrease in tearing symptoms) in 14 of 19 (74%). The authors noted that four of the failure had subsequent repeat endoscopic dacryocystorhinostomy. They noted that the success rates were comparable to the published data on external and endonasal dacryocystorhinostomy but had the advantage of less surgical trauma, no major complications, and no need for a procedure under general anesthesia. They concluded that endoscopically assisted balloon dacryoplasty with silicon intubation can be a treatment option in internal ostium stenosis after endoscopic dacryocystorhinostomy, with results similar to revision external dacryocystorhinostomy and endoscopic dacryocystorhinostomy. The authors

note that balloon dilatation was added to the management of internal ostium stenosis after simple silicone intubation was found to be ineffective in preventing restenosis [12].

References

1. Toti A. Nuevo Metodo conservatore di cura radicale delle soppurazioni chronichee del sacco lacrimale (Dacriocistorinostomia). Clin Moderna (Firenze). 1904;10:385–7.
2. Dave TV, Javed Ali M, Sravani P, et al. Subciliary incision for external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2012;28:341–5.
3. Becker BB. Dacryocystorhinostomy without flaps. Ophthalmic Surg. 1988;19:419–27.
4. Ali MJ, Naik MN, Honavar SG. External dacryocystorhinostomy: tips and tricks. Oman J Ophthalmol. 2012;5:191–5.
5. Madge SN, Chan W, Malhotra R, et al. Endoscopic dacryocystorhinostomy in acute dacryocystitis: a multicenter case series. Orbit. 2011;30:1–6.
6. Silbert DI, Matta NS. Outcomes of 9 mm balloon-assisted endoscopic dacryocystorhinostomy: retrospective review of 97 cases. Orbit. 2010;29:131–4.
7. Fayet B, Racy E, Assouline M. Systematic unciformectomy for a standardized endonasal dacryocystorhinostomy. Ophthalmology. 2002;109:530–6.
8. Silbert DI, Mattah N, Cohen A. Outcomes of 9mm balloon-assisted endoscopic dacryocystorhinostomy combined with unciformectomy. Unpublished ASOPRS presentation 2011.
9. Shinder R, Wu A, Mehendale RA, et al. Experience with Lacrimal Intubation during Dacryocystorhinostomy utilizing the STENTube. Orbit. 2017;36(1):6–12.
10. Ali MJ, Naik MN, Honavar SG. Balloon dacryoplasty: ushering a new and routine era in minimally invasive lacrimal surgeries. Int Ophthalmol. 2013;33:203–10.
11. Lee A, Ali MJ, Li EY, et al. Balloon dacryoplasty in internal ostium stenosis after endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2014;30:7–10.
12. Ali MJ, Yuen HK, Lee A, et al. Reply re: balloon dacryoplasty in internal ostium stenosis after endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2014;30:352–3.

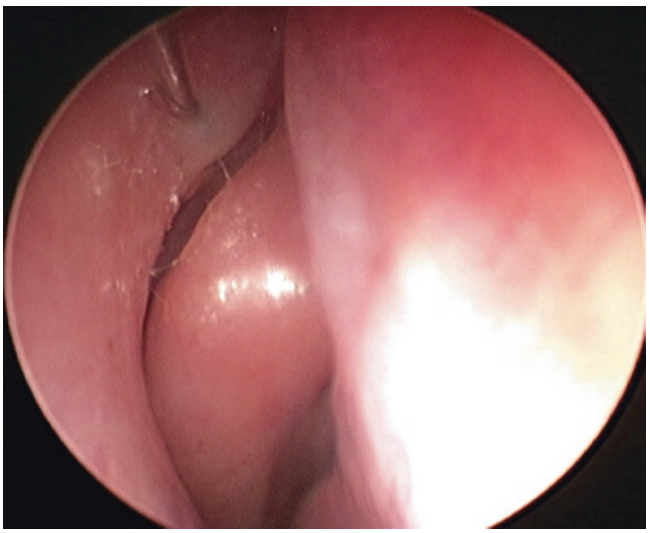


Fig. 25.1 Injection of 2% lidocaine with bicarbonate using 25 G spinal needle into the area of lacrimal fossa and middle turbinate

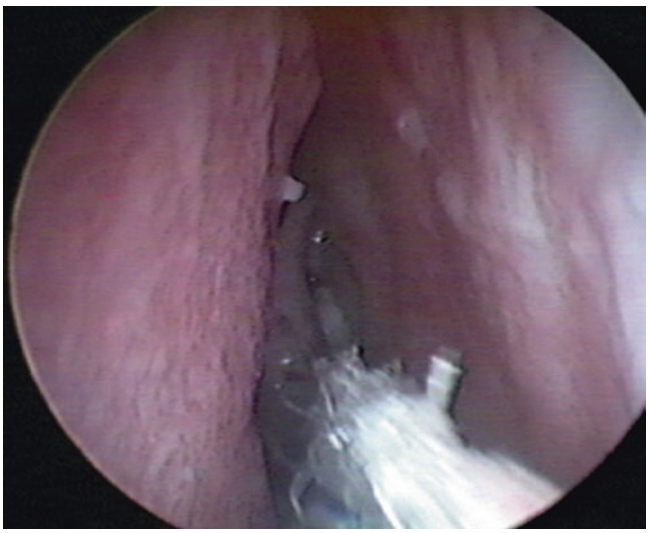


Fig. 25.3 Nose packed with cottonoids soaked in oxymetazoline and cocaine

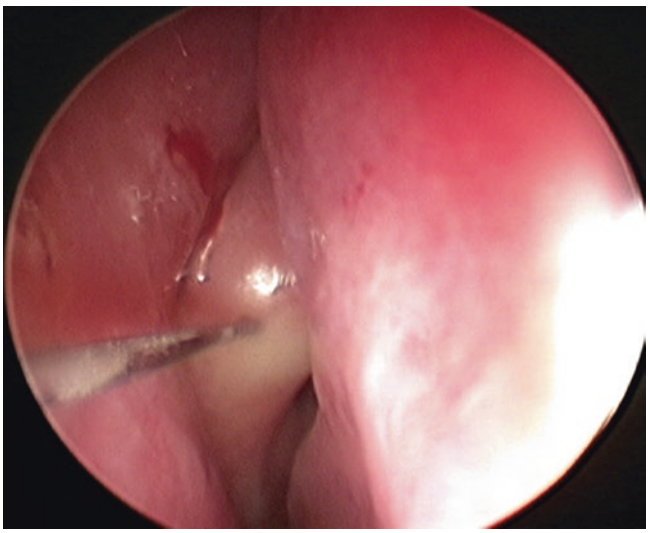


Fig. 25.2 Local anesthetic injection into the middle turbinate

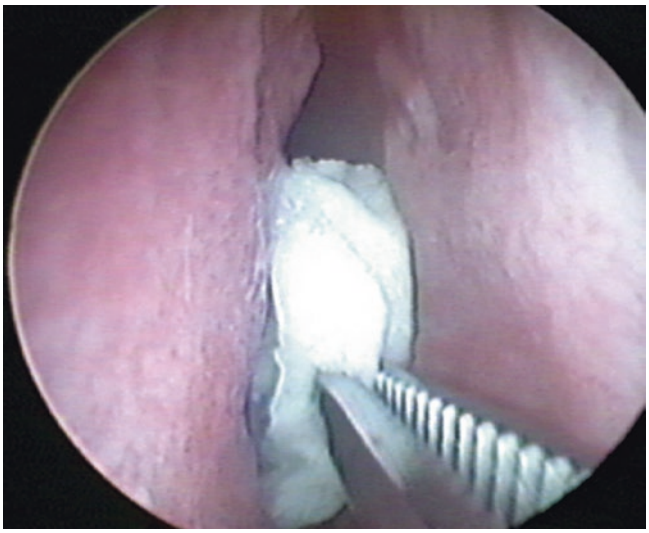


Fig. 25.4 Nose packing completed with cottonoids soaked in oxymetazoline and cocaine

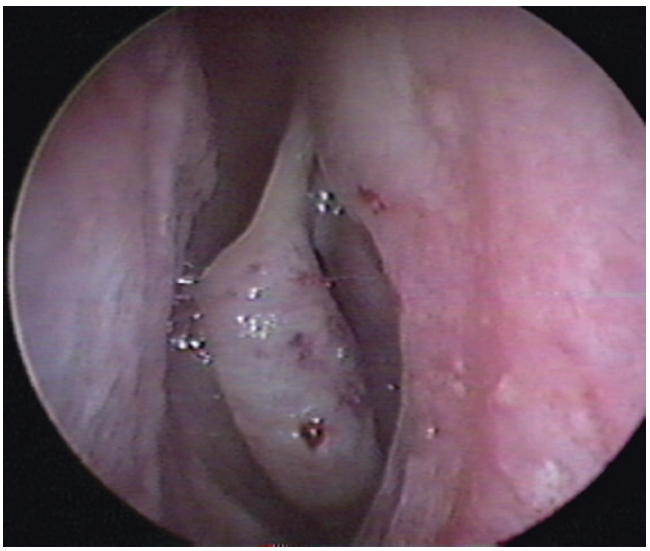


Fig. 25.5 Decongested turbinate after packing removed

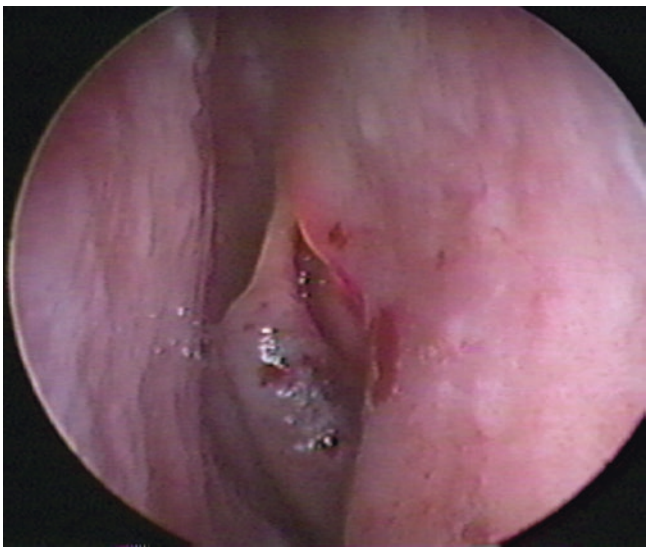


Fig. 25.7 Endo-transillumination of lacrimal sac following passing of transcanalicular light pipe

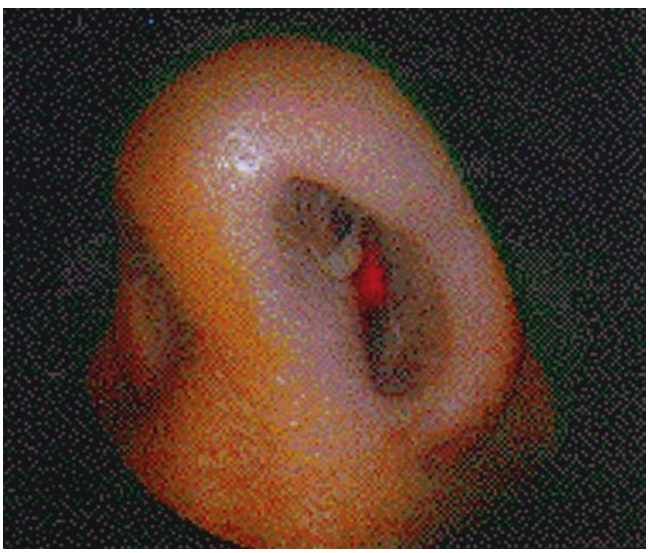


Fig. 25.6 Passing of transcanalicular light pipe. Note the light visualized even externally

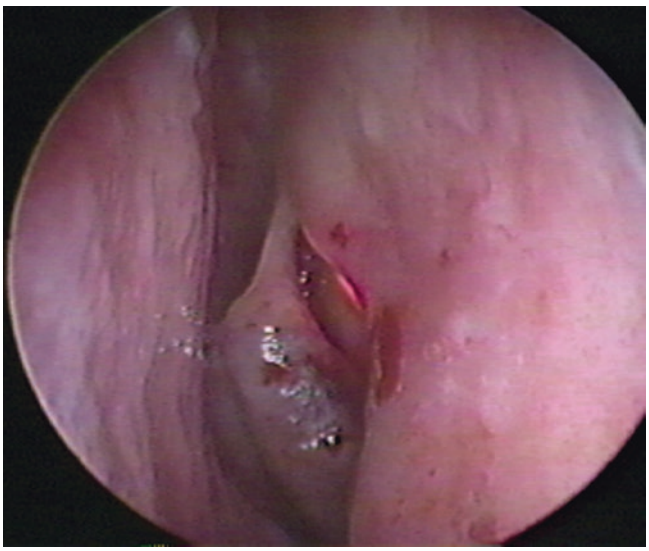


Fig. 25.8 Endo-transillumination of NLD following passing of transcanalicular light pipe

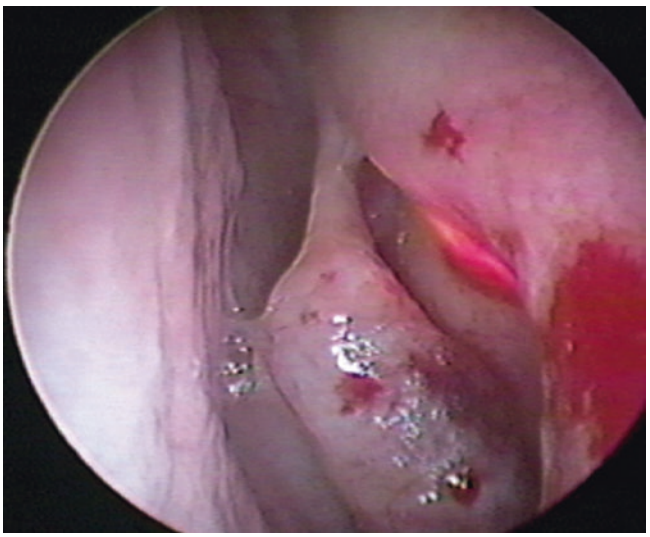


Fig. 25.9 Light pipe demonstrating ideal location for initial entrance into the nose

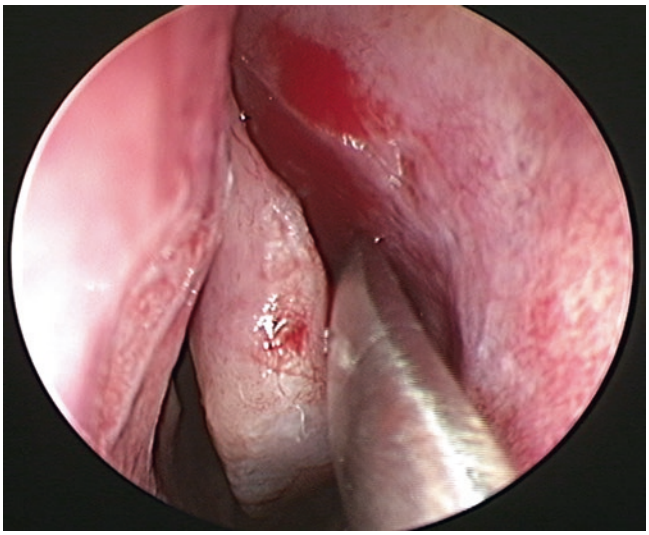


Fig. 25.11 Probe entry assistance to avoid injury to middle turbinate

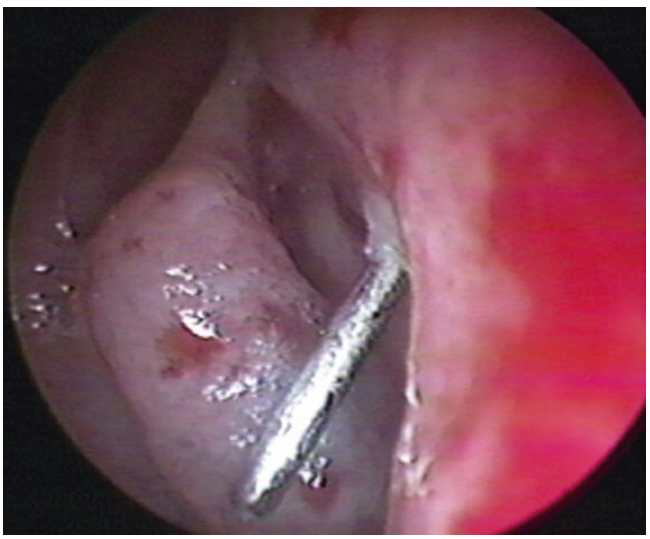


Fig. 25.10 Passage of reinforced probe into the nose

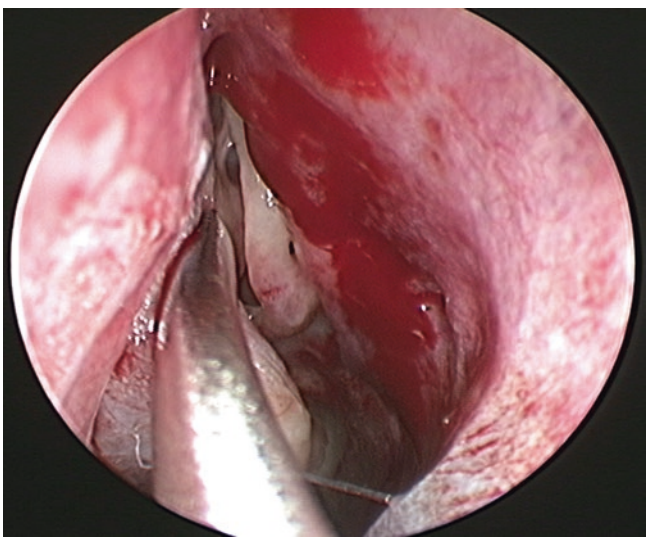


Fig. 25.12 Gentle medialization of middle turbinate

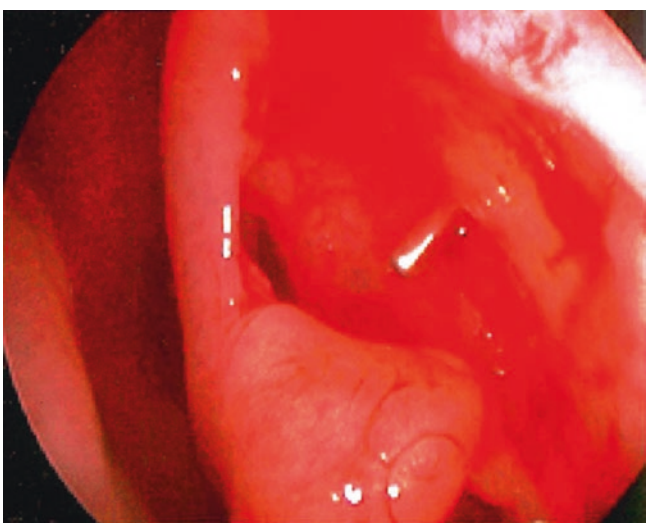


Fig. 25.13 Partial middle turbinectomy where needed

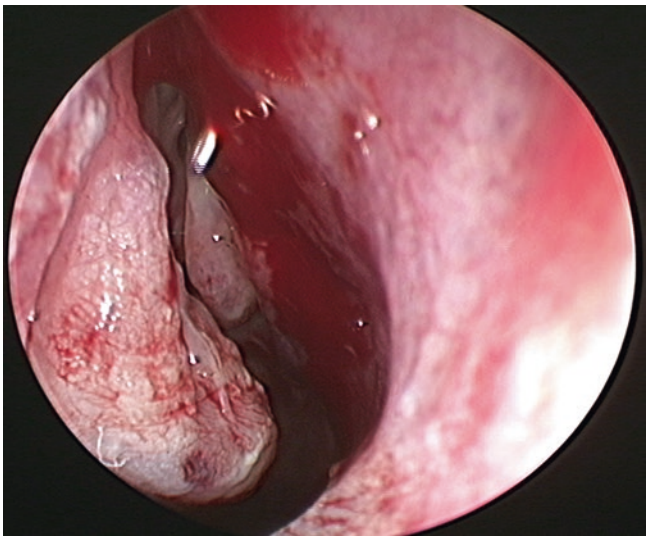


Fig. 25.14 Final probe entry by the reinforced probe

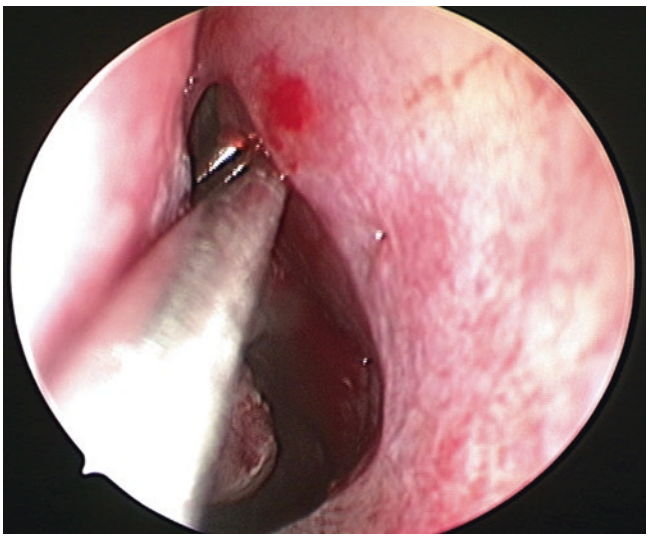


Fig. 25.17 The inserted Blakesley forceps

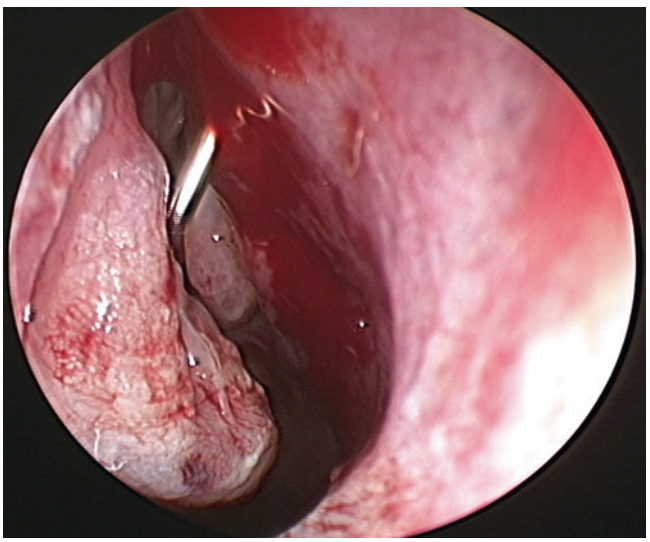


Fig. 25.15 Fillet open mucosa with reinforced probe

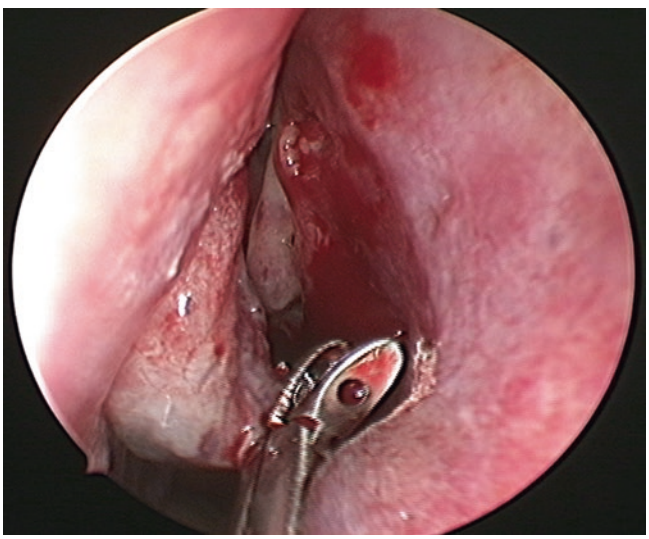


Fig. 25.18 The ostium after the Blakesley spread

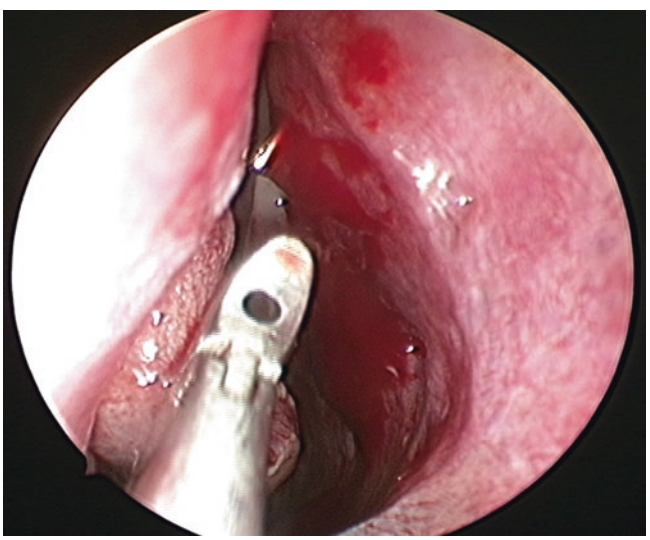


Fig. 25.16 Insert, spread, and remove Blakesley forceps with Bowman probe as guide

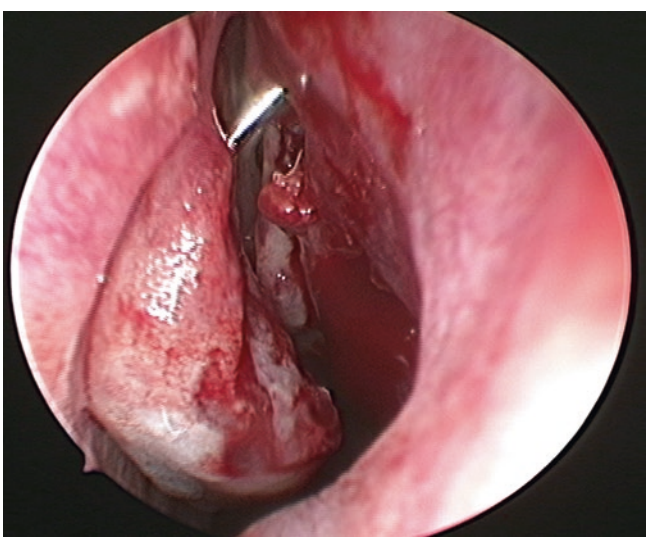


Fig. 25.19 Closer view of the ostium after the Blakesley spread

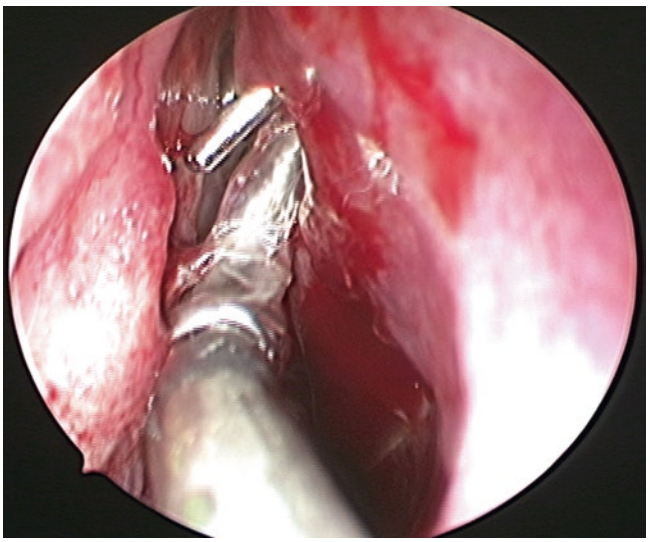


Fig. 25.20 Insertion of the deflated 9 mm balloon into the ostium

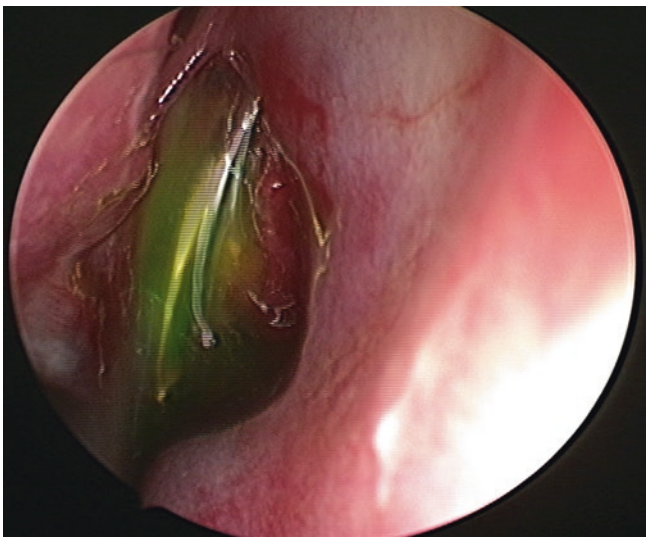


Fig. 25.23 Removal of the balloon in an inflated stage

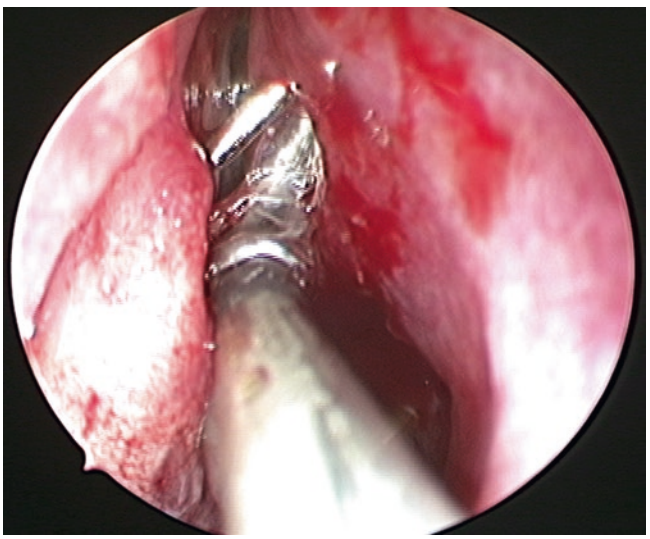


Fig. 25.21 Up-directed balloon to involve the entire ostium

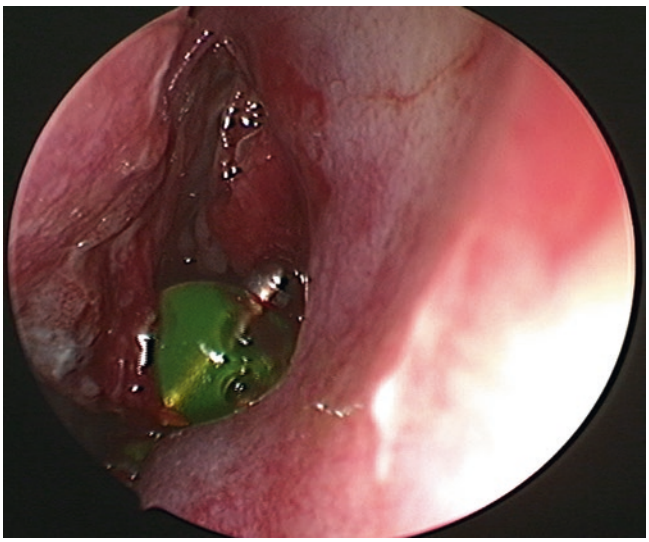


Fig. 25.24 The dilated balloon away from the ostium

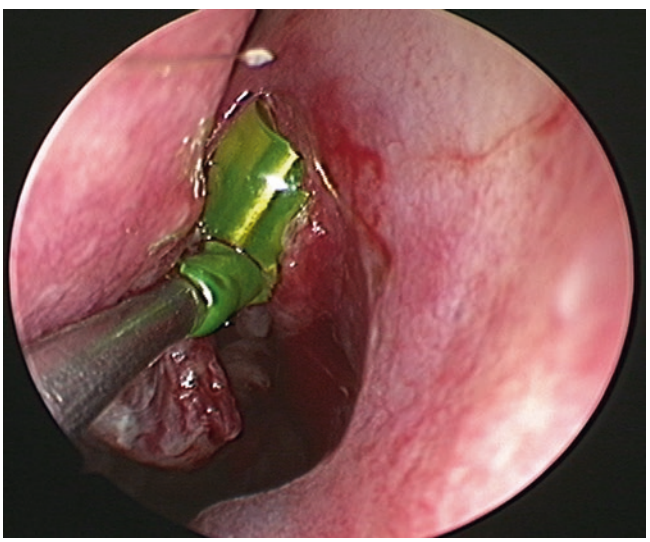


Fig. 25.22 The inflated balloon

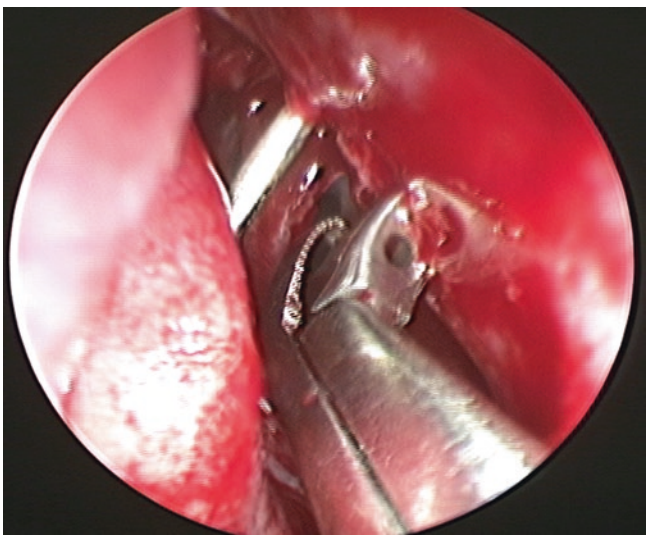


Fig. 25.25 Mucosa removal with Blakesley or trucut forceps

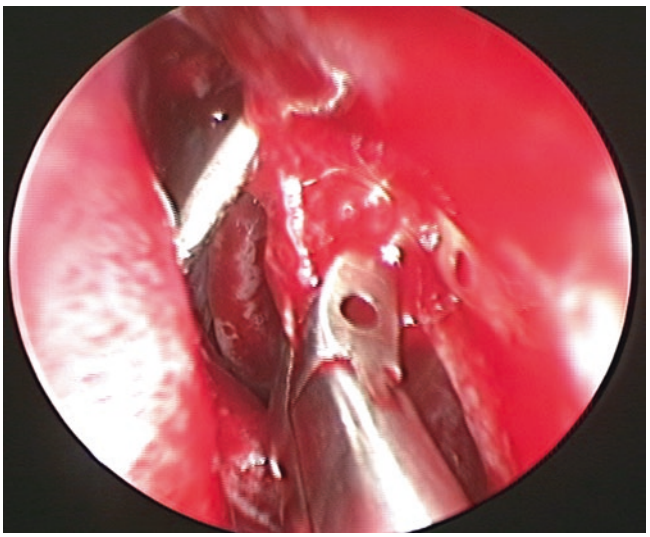


Fig. 25.26 Bone chips removal with Blakesley or trucut forceps

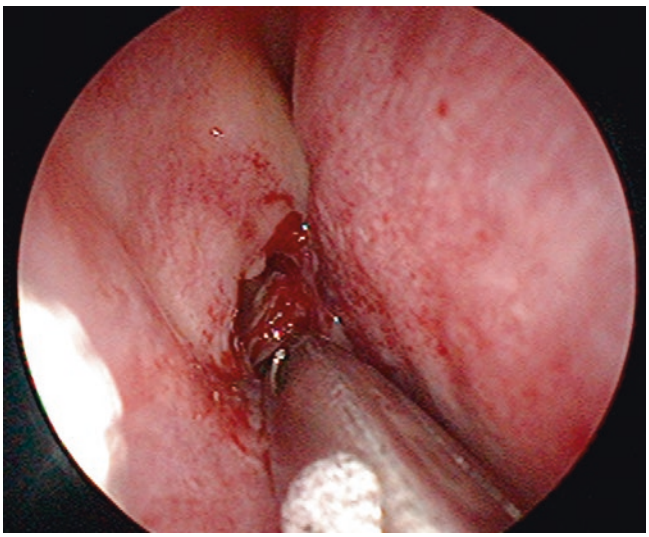


Fig. 25.28 Osteotomy can be enlarged with unciformectomy removing uncinate process with Blakesley forceps creating a large osteotomy

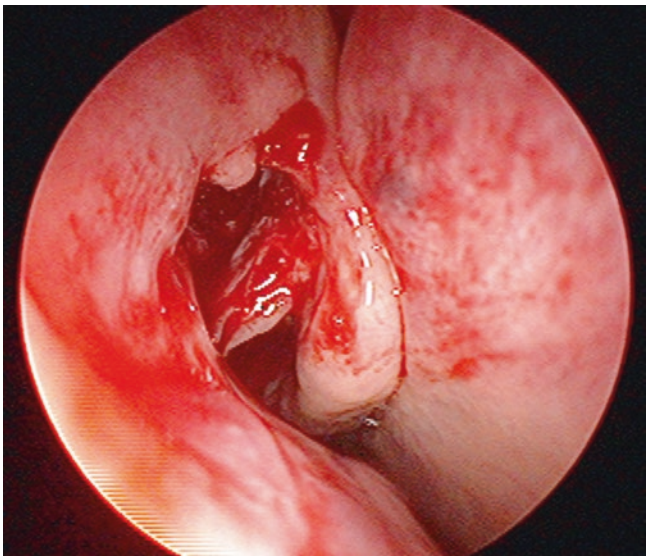


Fig. 25.27 The regular final ostium

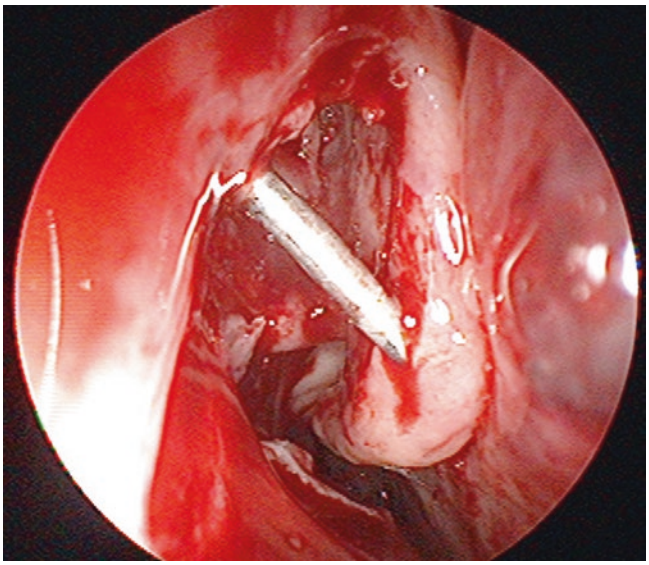


Fig. 25.29 Ostium following unciformectomy

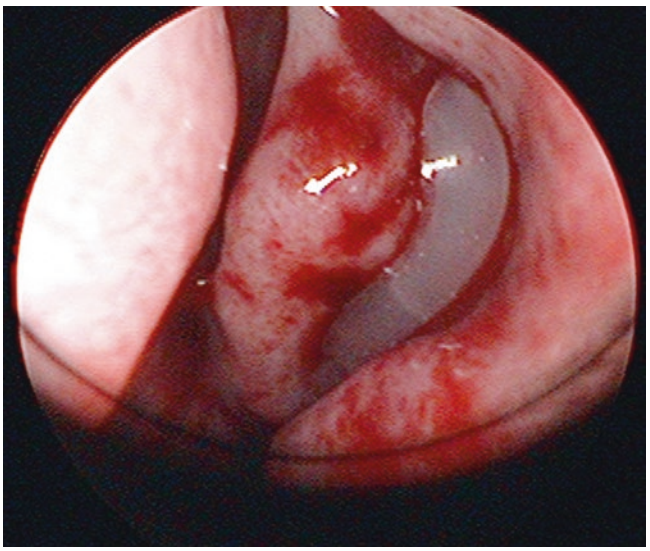


Fig. 25.30 Irrigation of antibiotic and steroid solution

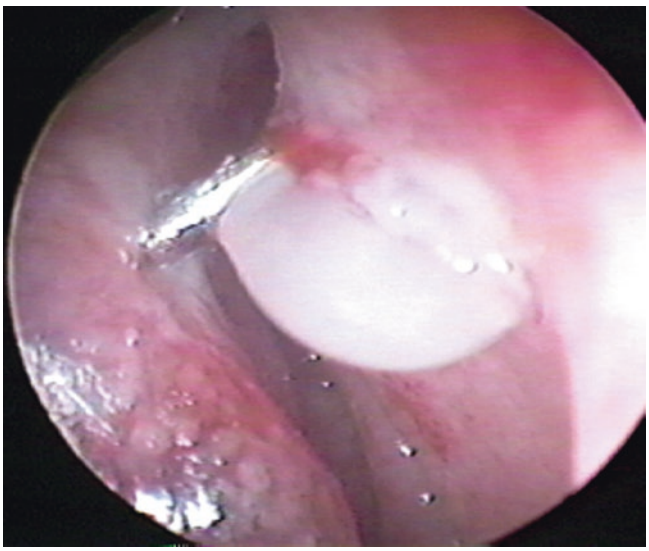


Fig. 25.32 Draining infected sac into the nose

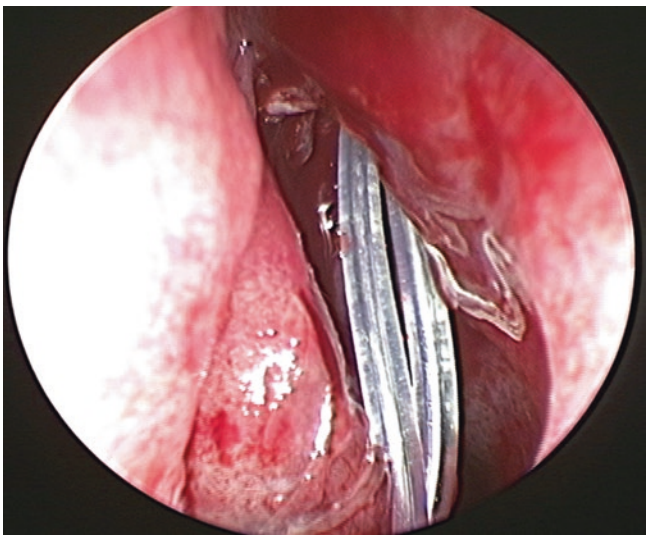


Fig. 25.31 Stent tube insertion

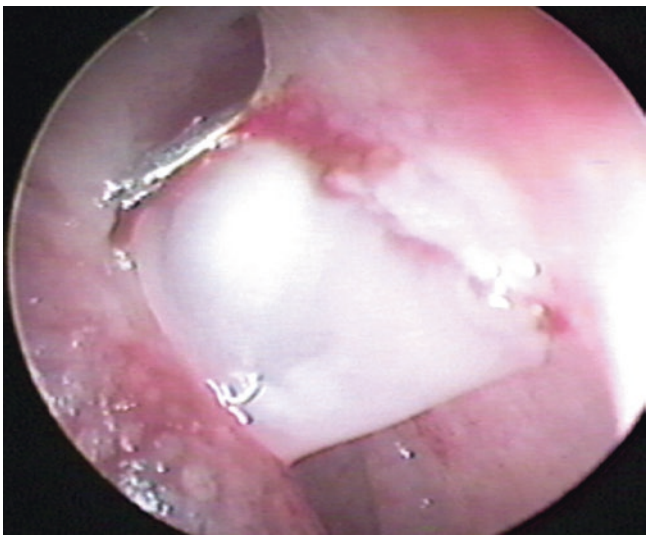


Fig. 25.33 Progressive draining of the infected material into the nose

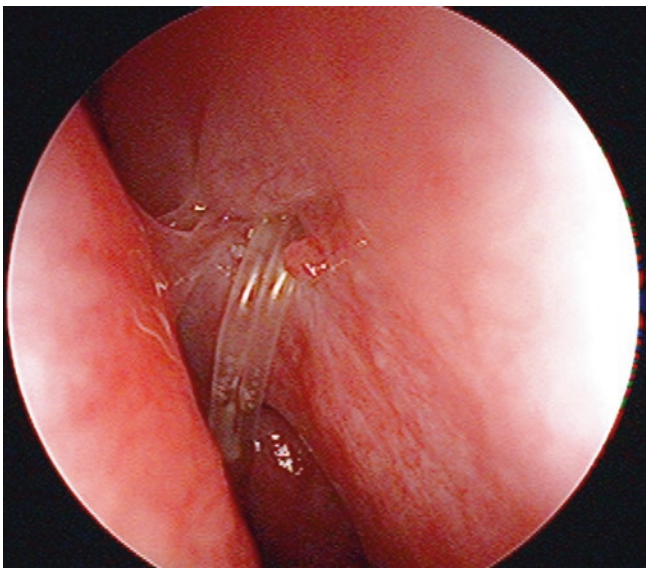


Fig. 25.34 Failed external DCR with osteotomy site anterior and superior to anterior lacrimal crest

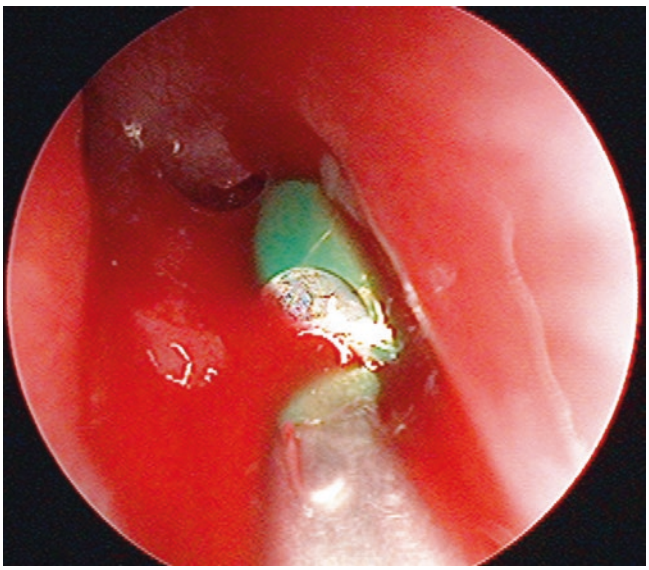


Fig. 25.36 Balloon placement in new osteotomy of the failed DCR case

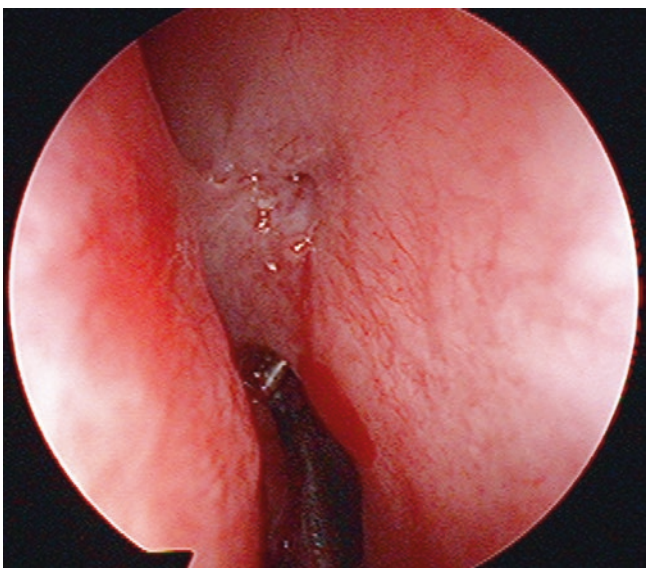


Fig. 25.35 Same patient as in Fig. 25.34. Note probe in new posterior location of osteotomy site posterior to anterior lacrimal crest

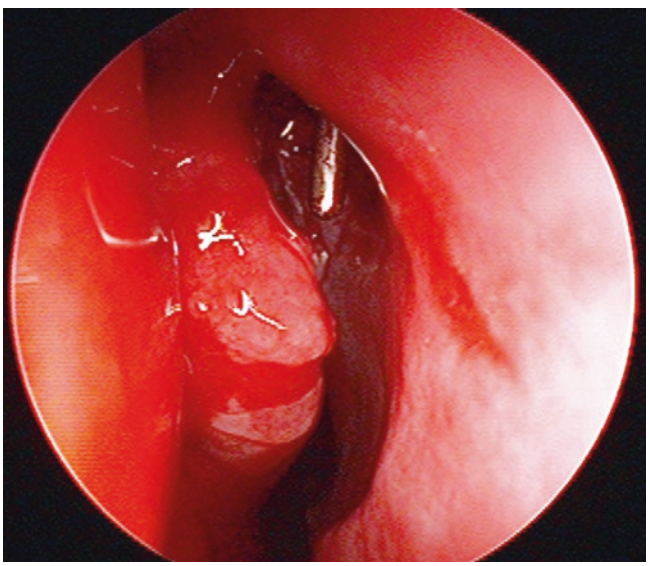


Fig. 25.37 A new large osteotomy following 9 mm balloon-assisted revision DCR

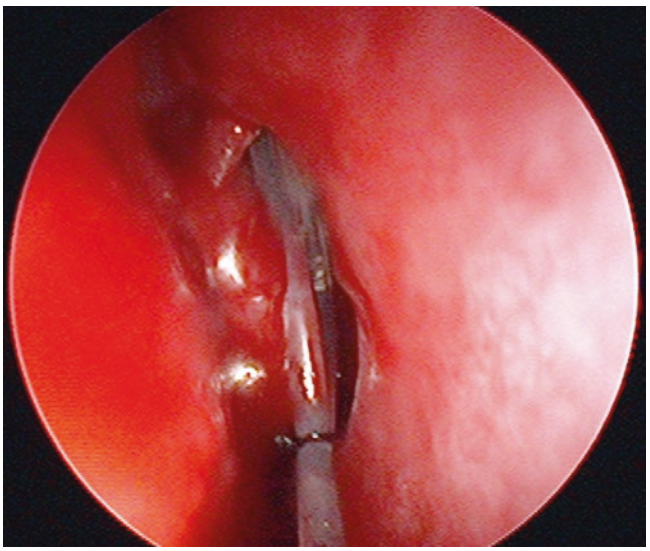


Fig. 25.38 Stent tube secured in the revision case subsequently

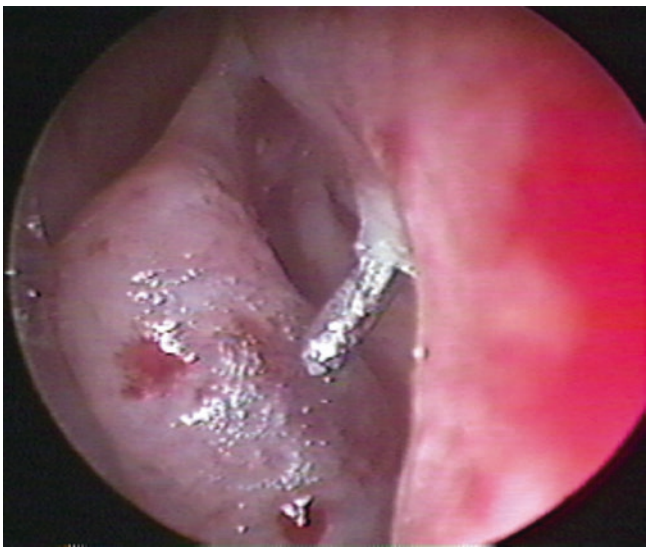


Fig. 25.40 Endoscopic view of the passing of reinforced Bowman probe and creating multiple punctures

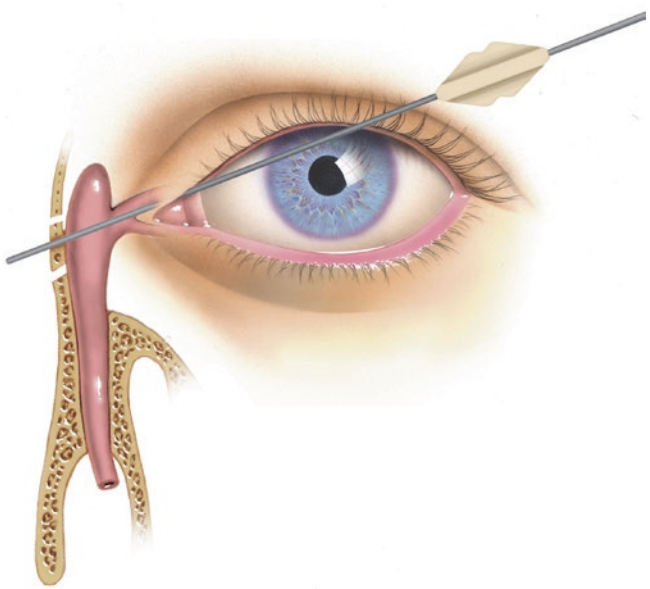


Fig. 25.39 Passing Bowman probe to create multiple punctures

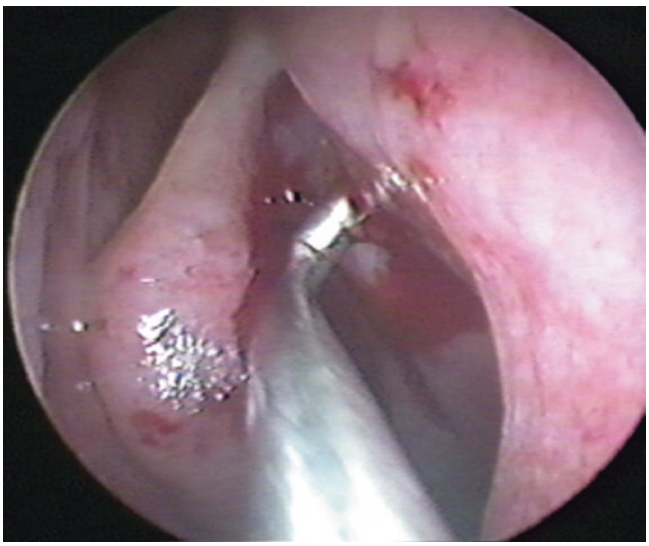


Fig. 25.41 Coalesce of the punctures with Dandy nerve hook

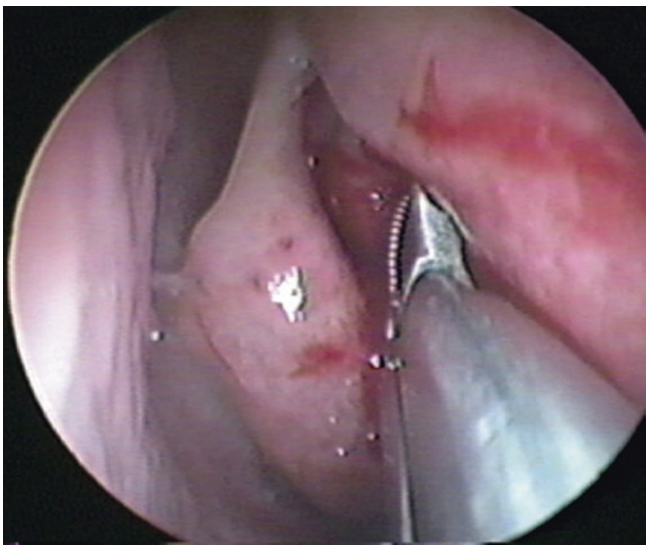


Fig. 25.42 Remove bone chips with Blakesley or cutter

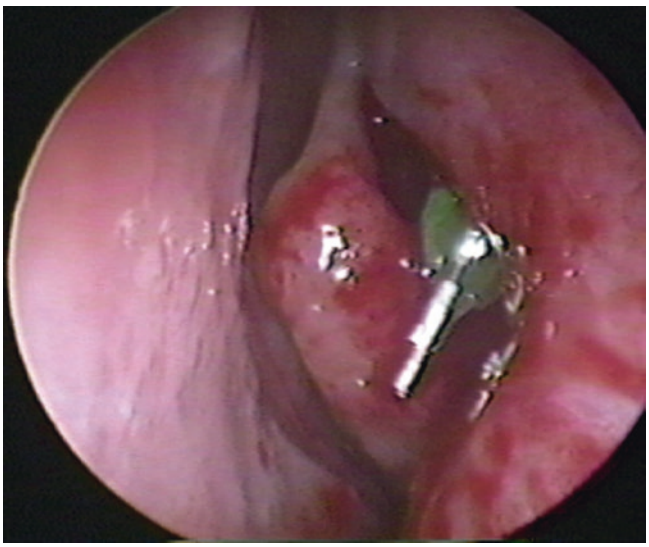


Fig. 25.44 Inflated 5 mm balloon within the ostium

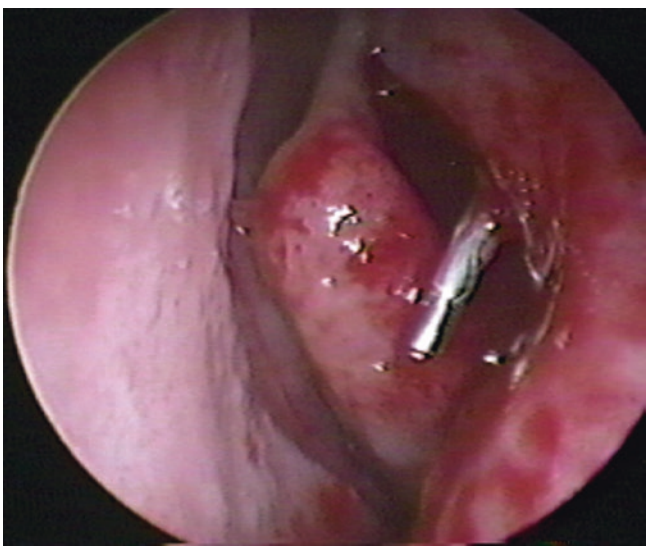


Fig. 25.43 Passing of the 5 mm balloon through transcanalicular route

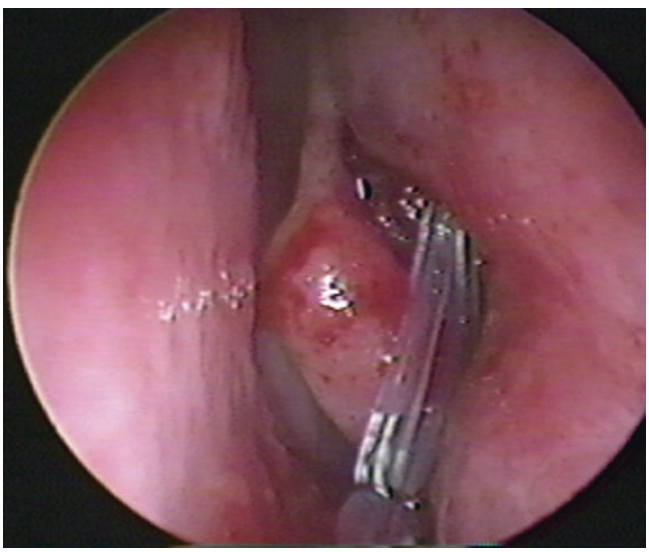


Fig. 25.45 Stent tubes placement following the ostium creation

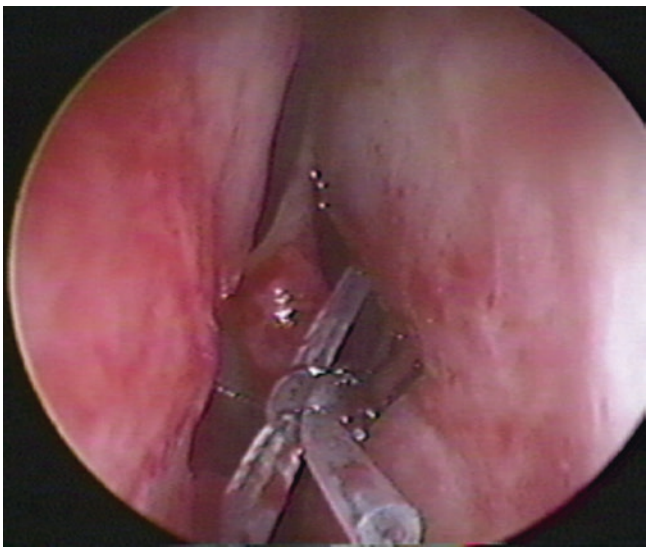


Fig. 25.46 Securing the stents

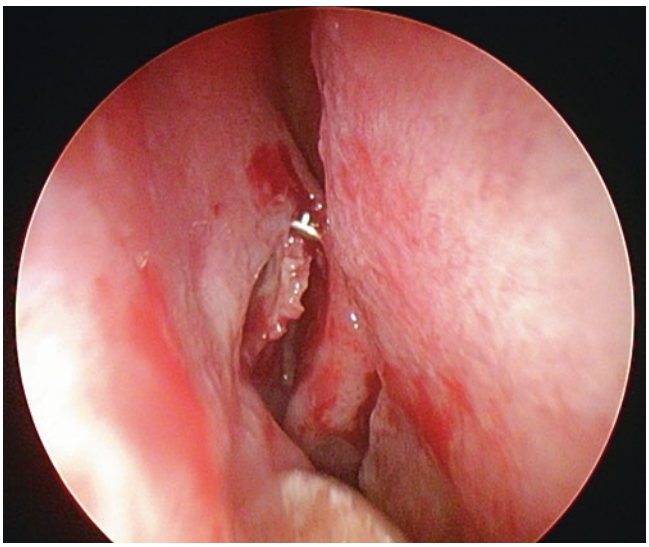


Fig. 25.48 Osteotomy, after enlargement by spreading with large up-biting Blakesley and in-fracturing posterior lip with caudal elevator

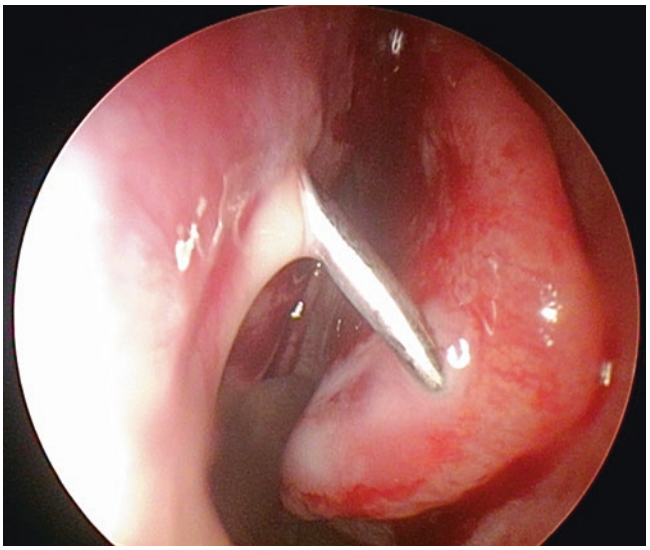


Fig. 25.47 Filleting open: lacrimal sac, lacrimal fossa, and nasal mucosa. Note purulent discharge

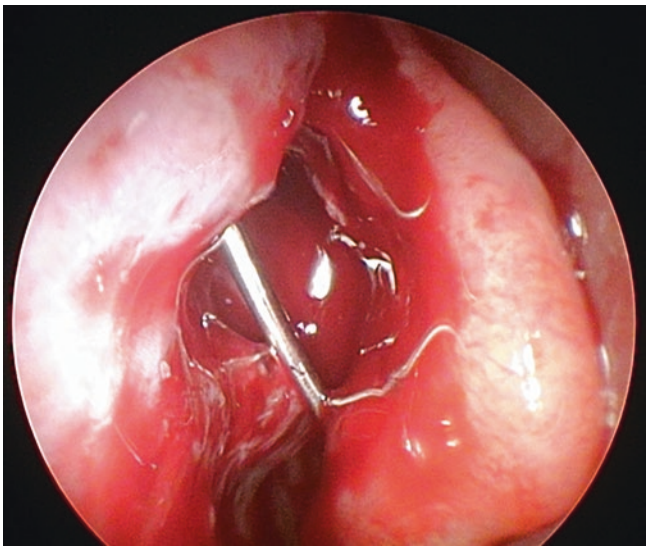


Fig. 25.49 Osteotomy after unciformectomy by removing posterior lip of osteotomy

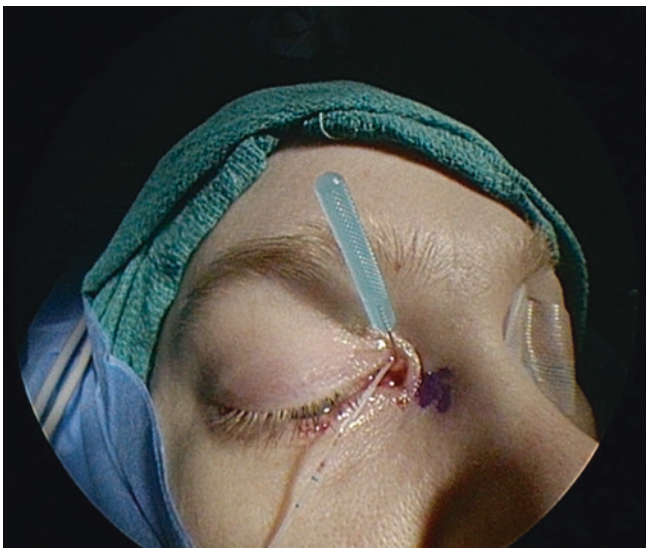


Fig. 25.50 Lacriflow stent placement with bougie in place prior to removal

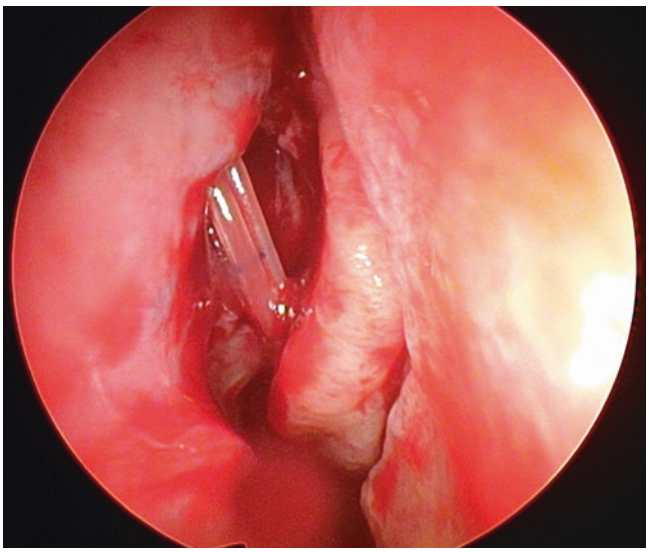


Fig. 25.51 Endoscopic view of the Lacriflow stents in place

Revising a Failed Dacryocystorhinostomy

26

Emmy Li, Hunter Yuen, and Mohammad Javed Ali

Introduction

The aim of dacryocystorhinostomy (DCR) is to establish a patent fistula between the lacrimal sac and the nasal cavity with removal of intervening bone. The main indications for DCR are clinically significant epiphora and/or infection in the presence of nasolacrimal duct obstruction (NLDO). While most NLDOs are primary and acquired, other causes of NLDO include lacrimal sac tumor and nasal and facial fractures involving the nasolacrimal canal. Associated common canalicular obstructions may also be managed along with the DCR be it external or endoscopic, with trephination and intubation.

The success rate of DCR varies with the surgical approach adopted. Although external DCR has been the gold standard with success rates ranging from 85% to 95%, the endonasal endoscopic has gained much popularity in recent years with success rates between 59% and 100% [1]. For endoscopic DCR, the success rates were higher for the mechanical approach when compared to the laser-assisted ones and were similar when ultrasonic bone aspirator was used to create the osteotomy [2]. The experience of the surgeon also counts. Fayers et al. [3] reported an overall lower rate of success for trainees in terms of both functional (64%) and anatomic (68%) improvement as compared to 81% functional and 87% anatomic success rate for the consultant surgeon. However, direct comparison of success rates is difficult given the significant variation in surgical techniques, definition of success, and follow-up duration across studies.

Considering the cause of NLDO, congenital NLDO and traumatic NLDO probably carry a higher risk of failure [4, 5]. Pediatric patients with craniofacial abnormalities are also at greater risk of persistence of symptoms after surgery [6]. Conventionally, it was proposed that endoscopic DCR in the setting of acute dacryocystitis has a higher risk of failure, but recent studies showed that using the mechanical approach, success rates were over 90% and comparable with surgery in the absence of active infection [7, 8].

E. Li, F.R.C.S • H. Yuen, M.R.C.S (✉)
Department of Ophthalmology, Chinese University of Hong Kong, Hong Kong, Hong Kong SAR, China
e-mail: hunterklyuen@gmail.com

M. Javed Ali, F.R.C.S
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

Etiopathogenesis

The best way to prevent a failed DCR is to perform a proper preoperative evaluation and a meticulous primary surgery. Preoperative evaluation should focus on ruling out other causes of epiphora like dry eyes. Careful examination should be done to assess if there are any canalicular or common canalicular obstructions. The common causes of a DCR failure are cicatricial closure of the ostium (Fig. 26.1), inadequately sized osteotomy, inadequate sac opening, common canalicular obstruction, intervening ethmoids, inappropriately placed osteotomy with respect to the lacrimal sac leading to sump syndrome [9], turbinoseptal synechiae in and around the ostium (Fig. 26.2), inappropriate granulation tissue (Fig. 26.3), and internal ostium stenosis (Fig. 26.3) [10]. Not uncommonly, multiple causes for failure may be noted [9, 10]. Other less common causes of failure include a deviated nasal septum (Fig. 26.4) and failure to address concha bullosa where needed. Rare causes may be occult carcinoma, bony obstruction caused by Paget's disease, ethmoidal sinus osteoma, and soft tissue obstruction caused by inflammatory diseases like sarcoidosis and Wegener's granulomatosis (Fig. 26.5) [11–13].

Factors that have been reported to be associated with higher risk of failure include small lacrimal sac opening, prolong surgery, active inflammation, inadequate or inappropriate flaps, and intraoperative prolapse of orbital fat [9–14]. It was also proposed that thermal damage might increase the risk of failure [15].

DCR failures usually occur in early postoperative period. The average time to failure reported is 4.9 months after surgery. Failure can occur as early as 1 week postoperative. Early obstruction was frequently found proximal to the com-

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_26

mon internal punctum [16]. Late failure, defined as recurrence of symptoms at least 12 months after surgery, is uncommon (<1%), and most of the obstruction occurred at the common canaliculus [17].

Clinical Features and Diagnostic Evaluation

The success of DCR can be gauged by functional success and anatomical success. Functional success refers to lack of tearing 3 months after surgery, a good indicator of successful surgery as suggested by the Royal College of Ophthalmologists guidelines. Anatomical success can be confirmed by patency on lacrimal irrigation, visualization of ostium on nasal endoscopy, positive functional endoscopic dye test, and scintillography or contrast dacryocystography.

In most cases, the causes of failed DCR can be determined by lacrimal probing and nasal endoscopy. Irrigation will be non-patent in cases of failed DCR, and probing should be performed to identify the site of obstruction. For a scarred internal ostium, a negative endoscopic dye test will be observed. The use of imaging studies like scintillography or dacryocystography (DCG) with plain films may provide further information in delineation of the lacrimal drainage tract and determination of the exact site and nature of obstruction, helping to formulate a surgical strategy for revision. DCG can also be performed with computed tomography (CT) or magnetic resonance imaging (MRI). However, cost and availability may be an issue. Typically, a patent fistulous tract confirmed by lacrimal probing and irrigation gives a characteristic "Y-on-its-side" configuration of the soft tissue on CT. Occlusion of osteotomy by soft tissue corresponds to a mucocele-like soft tissue density with a central lucency and soft tissue obstruction. Occlusion of osteotomy by inadequately excised bone is evident by bone in the region of osteotomy [11]. Using the spiral technique, CT-dacryocystography (CT-DCG) of high resolution allows measurement of the diameter of the osteotomy window and evaluation of osteotomy position relative to the lacrimal sac and reveals abnormal finding around the osteotomy like extension of ethmoidal air cells medial to the lacrimal sac, concha bullosa, nasal polyp, and any medial canthal mass that might contribute to the failure of DCR (Fig. 26.6) [18]. In the study by Choi et al. [19], preoperative evaluation of obstruction level using DCG was helpful in predicting surgical outcome of endoscopic DCR. Among all, treatment of sac-duct junction obstruction with DCR had the highest success rate, followed by NLDO, common canalicular obstruction. Saccal obstructions carried the worst prognosis [19]. Finally, dacryoendoscopy, if available, may be used to delineate the intraluminal pathology within the lacrimal system.

Differential Diagnosis

Before deciding on revision surgery, patient with a failed primary DCR must be reexamined to determine the etiology of symptoms, especially to rule out other causes of tearing, such as blepharitis; trichiasis; lid malpositions like lower lid laxity, entropion, and ectropion; punctal abnormalities; and canalicular obstructions. Systemic inflammatory diseases like sarcoidosis or Wegener's granulomatosis should also be excluded if there are suspicious endoscopic findings. Standard preoperative evaluation includes dye disappearance testing, lacrimal irrigation, and probing, and endoscopic evaluation of the internal ostium and nasal cavity is essential. If the ostium is found to be patent on irrigation and with a nasal endoscopy, the diagnosis of functional NLDO should be considered. Functional NLDO is defined as delayed tear clearance on scintillography or dacryocystography in the absence of anatomic obstruction. It is thought to be caused by a narrowing of the nasolacrimal duct or failure of the pump mechanism [20, 21]. Functional NLDO has a greater incidence of surgical failure, and patients may experience persistence of symptoms despite adequate surgery. Revision surgery in this subset of patients has been shown to be of little value [22].

Management

In managing a failed DCR, the options are mainly surgical, though some patients may opt for observation. A failed primary external DCR can be revised externally or endoscopically; likewise, a failed primary endoscopic DCR can be amended endoscopically or externally. Various adjunctive measures including intraoperative application of mitomycin C (MMC) and intubation with silicone stents have been proposed to enhance the success rate of revision surgery. Recently, balloon dacryoplasty have been suggested as a less traumatic alternative to salvage a failed primary surgery. In cases of common canalicular obstruction, the revision can be as well performed by external or endoscopic approaches [9].

In the setting of revision DCR, the keys to success include:

1. A thorough understanding of intranasal endoscopic anatomy, especially the location and extent of the lacrimal sac
2. Complete excision of the cicatrix if present
3. An efficient bone removal to achieve complete exposure of the lacrimal sac
4. A complete incision and marsupialization of the lacrimal sac mucosa

Surgical Technique for Revision Endoscopic DCR

The nasal mucosal flap is incised slightly more anteriorly over the frontal process of the maxilla than for primary cases (Fig. 26.7). This allows the mucosal incision to be made onto the bone, and when this flap is elevated off the bone, it allows the correct surgical plane to be established for dissection of the mucosal flap off the underlying scar tissue. The osteotomy is then enlarged with rongeur until the lacrimal sac is completely exposed. If the sac is relatively normal in size, standard mucosal flaps are fashioned. In cases when the sac is scarred and contracted and it is difficult to fashion mucosal flaps, the mucosal apposition between the nasal and lacrimal mucosa can be obtained by trimming correspondingly less of the nasal mucosal flap (Fig. 26.8). One may also consider using the agger nasi mucosa as a free graft to create functional mucosa surrounding the common canaliculus-sac junction [23]. It is very important to clear the area around common canaliculus and expose it well (Fig. 26.9). Correction of nasal pathologies such as deviated nasal septum or turbinoseptal synechiae around the ostium might be required to allow adequate surgical exposure [24].The rest of the procedure is similar to primary cases. Intraoperative MMC (Fig. 26.10) and silicone intubation (Fig. 26.11) should ideally be used. Additional use of Sisler's canalicular trephines for distal canalicular obstructions and balloon dacryoplasty to dilate the ostial stenosis can be combined with revision endoscopic DCR as a multimodal management for selected cases.

Apart from the established advantages for endoscopic primary DCR, namely, the avoidance of cutaneous scar and preservation of pump action of the orbicularis muscle, some authors suggested that the endonasal approach is well catered for revision surgery given its direct access to the residual lacrimal sac through the previously created bony ostium, improved visualization of osteotomy position relative to the lacrimal sac, easier hemostasis, and the ability to address concurrent intranasal pathologies [25]. However, like the primary procedure, the potential drawbacks are steep learning curve and high equipment cost.

Surgical Technique for Revision External DCR

A skin incision is made through the original scar (Fig. 26.12). Orbicularis is separated at the junction of orbital and palpebral portions (Fig. 26.13). Bowman lacrimal probes are used to check the patency of both inferior and superior canaliculi. The anterior limb of medial palpebral tendon, if present, is divided. A combination of sharp and blunt dissection is used to separate the scar above and below the probes. Great care is taken not to enter the lumen of the common canaliculus. The anterior edge of the original rhinostomy is identified, and periosteum is freed from the bone for approximately 4 mm anterior to the bony edge of the original rhinostomy to expose the uncut bone all around (Fig. 26.14). The bony ostium is enlarged (Fig. 26.15) to allow adequate exposure of the sac and to expose the virgin nasal mucosa (Fig. 26.16). A trapdoor incision based on the newly exposed virgin nasal mucosa is cut so that the lateral free edge is close to the previously identified common canaliculus and the upper and lower edges are next to the edges of the newly enlarged rhinostomy. The nasal mucosal flap is reflected anteriorly with or without traction sutures. The interior of the rhinostomy is then examined for any intervening bone, ethmoid air cell, synechiae, dacryoliths, or simple cicatrix and appropriately removed. The virgin lacrimal sac flaps, if any, are fashioned as usual, but in cases of intense fibrosis, careful elevation is mandatory (Fig. 26.17). Anterior alone or both anterior and posterior mucosal flaps are sutured with fine absorbable suture like Dexon or Vicryl (Fig. 26.18). If common canalicular obstruction is present, the area can be trephined to remove the cicatrix. An endocanaliculotomy can be carefully performed where the internal common opening has consolidated membranous obstructions. It is important that the flaps be sutured under slight tension so that they do not adhere internally and predispose to an obstruction. Mitomycin C (Fig. 26.19) and silicone stents (Fig. 26.20) have been found to be beneficial in revision DCRs specially if there is canalicular pathology or if the sac is small, scarred, or inflamed. Lastly, orbicularis and tendon are repositioned with an absorbable suture, and the skin is closed with an interrupted nylon suture [9].

The success rates for revision endoscopic DCR are in the range of 76–100% [23, 26–29], comparable to that reported for external revision DCR, which varied from 80% to 90% [9, 30]. Tsirbas A et al. [23] showed a direct comparison of the endoscopic and external techniques and showed that revision endoscopic DCR surgery was successful in 77% of cases and external revision was successful in 85%, yet this difference was not statistically significant. In another study by Paik et al. [31] which included 82 endoscopic revisions, a success rate of 84% was achieved for those with failed primary external DCR and 81% for those who failed a primary endoscopic DCR. In preoperative nasal endoscopy, more of those who underwent primary external DCR exhibited a hypertrophic middle turbinate or severe septal deviation, whereas more of those who underwent primary endoscopic DCR exhibited a small ostium.

The success rates of revision surgery would be lower if there is scarring and cicatrization of the lacrimal sac. It is

because even with adequate bony ostium and full sac exposure, only a small amount of the lacrimal mucosa can be marsupialized. This leads to a higher risk of repeated scarring and stenosis. This may partly explain why those who failed the first revision surgery are likely to fail additional revision [5]. In the study by Tsirbas et al. [23], all the failed revisions, both external and endoscopic, have undergone more than one previous DCR. In the presence of proximal canalicular obstruction or multiple failed revisions, a conjunctivodacryocystorhinostomy with the insertion of a Lester Jones or Gladstone-Putterman's tube can achieve the target of resolution of epiphora.

Transcanalicular laser-assisted revision DCR has less been proposed as a simple office-based procedure to reestablish a patent drainage tract when soft scar tissue was the cause of failed DCR. In this procedure, the laser probe is carefully inserted through the upper canaliculus into the nasal cavity. The laser energy is applied until the tip of the laser probe was recognized by nasal endoscopy. Both the use of diode laser and continuous wave neodymium-doped yttrium-aluminum-garnet (Nd:YAG) laser demonstrated a success rate of approximately 80% after the first attempt [26, 32, 33]. Theoretically, the targeted application of laser energy allows effective tissue dissection with accurate removal of the cicatrix away from the internal common opening. It is believed to cause minimal collateral damage and retrograde damage of the lacrimal drainage system. Other advantages include short operative time, avoidance of skin incision, good hemostasis, less surgical trauma, and quick postoperative recovery. However, lack of robust studies and doubtful long-term efficacy of this approach were probably responsible for it not finding much favor worldwide for a revision DCR.

Adjunctive Use of Mitomycin C (MMC)

The adjunctive use of intraoperative MMC is a popular choice to enhance the success rate of DCR. Being an antibiotic isolated from *Streptomyces caespitosus*, MMC impedes the synthesis of DNA, cellular RNA, and protein by inhibiting collagen synthesis by fibroblasts. It has been used widely in other ophthalmic procedures like glaucoma filtration surgery and pterygium excision to enhance surgical success. Based on a histological study, Ugurbas et al. [34] proposed that MMC could enhance success rate of DCR by decreasing the density and cellularity of the nasal mucosa. Many studies have attempted to define the role of MMC in DCR. It was in general recognized to be a safe adjunct but might not necessarily increase the success rate in primary DCR [1, 35–40].

The role of MMC seems to be more definite in revision surgery. Success rates ranging from 89% to 93% were noted for revision endoscopic DCR with intraoperative application of MMC, much higher compared to success rates of 56–60% when MMC was not used, and the difference observed was statistically significant [41, 42]. In the meta-analysis performed by Cheng and his group, which evaluated 11 relevant studies including 574 DCRs, success rates were significantly higher in the MMC groups in comparison with the control groups, both in primary and revision endoscopic DCR. The size of osteotomy was also significantly bigger in the MMC group at 3 and 6 months after surgery. Similar beneficial effects were also reported in another meta-analysis by Feng et al., which assessed 9 randomized controlled trials comprising 562 external DCRs [43]. Based on the existing literature, we believe in the use of MMC for all revision DCRs.

Adjunctive Silicone Intubation

The role of lacrimal silicone in enhancing surgical success of primary or revision DCR is still controversial. Theoretically, the intubation prevents obliteration of the fistulous tract during early postoperative period, yet some has reported that it may cause granulation tissue formation, infection, canalicular laceration, or discomfort to the patient [44, 45]. In a randomized controlled trial by Chong et al., the success rate of primary endoscopic DCR was almost the same (96% vs. 95%) with and without intubation. The difference was not statistically significant [46]. There is no study in the existing literature to specifically define the efficacy of silicone intubation in revision DCR. In the subgroup analysis of Smirnov's study, revision surgery was successful in 100% with silicone tubing and 85% without silicone tubing. However, the sample size was small, and the difference was not statistically significant [47]. Silicone tube placement seems to be more important in the setting of common canalicular obstruction. The duration of silicone tube placement is controversial. In general, we prefer to keep the silicone tubes for up to 6 weeks to 3 months postoperatively in revision surgeries.

Probing, Endocanaliculotomy, and Silicone Intubation

Late failure after primary DCR is rare and can be considered as a distinct clinical entity. Studies have shown that in majority of patients, the level of obstruction was at the common canaliculus. McMurray's et al. [17] showed that in all patients with secondary common canalicular obstruction, they performed a probing with either common canalicular membranotomy (Fig. 26.21) or membranectomy followed by silicone intubation for an average of 8 weeks. The outcomes were favorable, and this can yet be considered as a less invasive surgical alternative to a repeated DCR in selected cases [17].

Balloon Dacryoplasty for Internal Ostium Stenosis

Balloon dacryoplasty has been introduced for over two decades. Using specially designed balloon catheters of various diameter and length (LacriCATH, Quest Medical Products, Inc., Allen, TX, USA), targeted dilatation at different sites of the lacrimal outflow tract can be performed. The use of endoscopically assisted balloon dacryoplasty was initially proposed for congenital NLDO in children [48] and incomplete NLDO in adults [49]. In the largest series for adults, Couch et al. [49] reported that 90% of patients who received balloon dacryoplasty reported symptomatic improvement and 56% experienced complete resolution of symptoms. The use of balloon dacryoplasty for failed DCR was first described by Lee et al. [50] in a cohort of sarcoidosis patients and was subsequently advocated in selected cases using the 5 mm balloon [51]. Of the three failures in the study, two early failures were successfully treated by balloons, while the one late failure case (47 months) was not amendable by balloon catheter dilatation. From our experience, this therapy has a role in a highly selected group of patients with internal ostium stenosis. Internal ostium stenosis was defined by our group as minimal dye passage via a tiny internal ostium on irrigation as visualized on nasal endoscopy and resistance on irrigation, together with partially relieved tearing symptoms. In our series, balloon dacryoplasty could achieve an anatomical success of 84% and functional success of 74% [52, 53]. This provides a less traumatic and minimally invasive alternative to a revision DCR with additional advantages of short operative time and quick recovery and can be performed under local anesthesia.

Update (2015–2016)

Over the past 2 years, advances in various aspects of revision DCR have been reported, from etiology to histopathology and from diagnostic evaluation to management options.

Malhotra et al. [54] examined the learning curve of trainee oculoplastic surgeons. Intraoperative analysis suggested that inadequate superior bony rhinostomy, incomplete retroplacement of posterior nasal mucosal flaps, and significant intraoperative bleeding were the main causes of failed DCR among trainees. Postoperative evaluation reported that failure was primarily due to ostium closure, which can be due to inadequate osteotomy, suboptimal sac marsupialization, or postoperative scarring. For those who underwent revision surgery, all required a flap revision to address closure of the internal ostium and lacrimal sac, one-third of them required further osteotomy supero-posterior to the lacrimal sac. There have been other similar reports in rhinology and ophthalmology literatures which also show lesser failure rates with endoscopic DCR among trainees probably owing to better techniques and better instrumentation [55, 56].

Dave et al. [57] evaluated 100 anatomically failed DCRs. They defined inadequate osteotomy as bone removal that failed to completely expose the lacrimal sac including the fundus. Inappropriate ostium location was defined as a limited osteotomy, located inferiorly, anteriorly, or posteriorly in relation to the internal common ostium. Inappropriate sac marsupialization was defined as failure to achieve full thickness sac wall cut along its entire length and failure to reflect the lacrimal sac flaps adequately. They compared the causes of failures between an external DCR and endoscopic DCR and found that the most common cause was inadequate osteotomy (69.8% in external group vs. 85.1% in endoscopic group). This was followed by inappropriate sac marsupialization (60.2% in external vs. 77.7% in endoscopic group) and cicatricial closure of ostium (50.6% in external and 55.5% in endoscopic group). They concluded that the causes did not differ significantly among the groups.

Cicatricial closure of the ostium, being one of the commonest causes of DCR failure, is related to organization of granulomas, extent of surgical insult, and idiosyncratic tissue response. A histopathology and electron microscopy study on scarred nasal mucosal tissues obtained during endoscopic revision surgery by Ali et al. [58] revealed dense connective tissues comprising of irregularly laid collagen with intervening fibroblasts and focal areas of new bone formation. Electron microscopy showed disorganized collagen fibrils with fibroblasts and mononuclear inflammatory infiltrate, together with metabolically active osteoblasts with ongoing rimming. This provides a better understanding of wound healing process in DCR and justifies the use of the MMC, either topical or circumostial injections, and intranasal triamcinolone in preventing further scarring following a revision endoscopic DCR [59].

Apart from describing the histopathological and electron microscopic features of a DCR ostium cicatrix, Ali's group also proposed a scoring system to standardize the assessment of DCR ostium [60]. The DCR ostium scoring (DOS) system was designed based on a retrospective evaluation of a total of 125 ostia. Ten parameters, namely, (1) location of the ostium, (2) shape of the ostium, (3) size of the ostium, (4) ostium cicatrization, (5) synechiae, (6) internal common opening, (7) silicone stent, (8) functional endoscopic dye test, (9) ostium granuloma, and (10) other ostium pathologies, were included, each with a maximum score of 4 and a minimal score of 1, resulting in a final score ranging from 10 to 40. It was recommended that ostia achieving overall DOS scores of 36–40 be graded as excellent, 31–35 as good, 21–30 as fair, and 10–20 as poor. Failed DCR cases were look into specifically. It was noted that anatomical failure was related to a complete cicatrization of the ostium with unrecognizable parameters, while poor internal common opening movements were observed in cases of functional failure.

For revision surgery, apart from the conventional endoscopic endonasal approach, clinical efficacy and safety of some other modalities were reported. First is the use of ultrasonic DCR. Various instruments, including the Sonopet Omni UST-2001 (Synergetic Inc., O'Fallon, MO, USA), Sonopet ultrasonic bone aspirator (Stryker, Kalamazoo, MI, USA), and piezoelectric surgery system (Synthes USA, West Chester, PA), have been used as an alternative to mechanical drills for creation of the osteotomy. These instruments produce low-frequency microvibrations (25–35 kHz), which selectively emulsify mineralized bone while sparing collateral soft tissues. The theoretical advantages include targeted destruction, better visibility as less bleeding from surrounding soft tissues, and less inadvertent damage of the lacrimal sac. Ultrasonic DCR was reported to have a good success rate over 90% with few minor complications, like ostial edge granulomas and focal thermal burns [61, 62]. The application on revision cases awaits further exploration; initial outcomes appear to be promising. Second is the use of diode laser-assisted transcanalicular DCR. As mentioned earlier in this chapter, it can be an office-based procedure, which aims to reestablish a patent drainage tract by targeted tissue dissection and removal of the cicatrix away from the internal common opening using laser energy. Two studies attempted to assess its application in revision surgery for failed DCRs [63, 64]. When compared to non-laser endoscopic endonasal revision surgery, there was no statistically significant difference in success rate, both achieved patency in close to 90%, yet diode laser transcanalicular revision DCR was associated with a significantly shorter operating time and lower pain score [63]. The other study by Lee et al. [64] reported an overall success rate of 83% for diode laser transcanalicular revision DCR, and among them 100% success rate for membranous obstruction or synechial obstruction, 50% success rate for granulomatous obstruction, and 100% failure rate for sump syndrome. This highlights the importance of preoperative assessment of the causes of failed DCR and plan revision surgery accordingly. Ali et al. [65] reported anatomical and functional success rates of 91.3% and 86.9%, respectively, at a mean follow-up of 26.4 months, in their series on powered revision endoscopic DCRs. They reported that over 44% of the patients required additional endoscopic adjunctive procedures for good outcomes. Lastly, an Indian group reported their results for non-endoscopic endonasal DCR (NEN-DCR) [66]. The success rate was 85% when performed as a primary procedure for various indications like primary acquired NLDO, acute dacryocystitis, and NLDO in children. Revision NEN-DCR was successful in 81%. The technique obviates the need for an endoscope, thus particularly useful in developing nations or rural areas when relevant setups are not available or feasible.

Conclusion

Common causes of failed DCR include inadequately sized osteotomy or sac opening, inappropriately placed osteotomy and scarring causing contracture, and granulation tissue or synechiae formation at the ostium. Meticulous primary surgery, intraoperative adjuncts where needed, and good postoperative care can prevent the reoccurrence of some of these factors. Most failed primary procedures can be revised via endoscopic or external approaches with relatively good success rates. MMC is likely to have a role in revision DCRs. Silicone tube placement can be considered in the presence of common canalicular obstruction or scarred lacrimal sac or inadequate fashioning of the lacrimal sac flaps. Balloon dacryoplasty, in carefully selected patients, may achieve comparable results. However, a subset of patients with functional epiphora may not improve with revision surgery. Standard scoring system would help both surgeons and researchers in communicating and reporting when conducting perioperative assessment. Increasing options are available for revision surgery, and the ultimate choice should be based on the causes of failure and availability of instruments, taking into consideration the surgeon's competence in the relevant technique.

References

1. Dolmetsch AM. Non-laser endoscopic endonasal dacryocystorhinostomy with adjunctive mitomycin C in nasolacrimal duct obstruction in adults. Ophthalmology. 2010;117:1037–40.
2. Murchison AP, Pribitkin EA, Rosen MR, et al. The ultrasonic bone aspirator in transnasal endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:25–9.
3. Fayers T, Laverde T, Tay E, et al. Lacrimal surgery success after external dacryocystorhinostomy: functional and anatomical results using strict outcome criteria. Ophthal Plast Reconstr Surg. 2009;25:472–5.
4. Walland MJ, Rose GE. Factors affecting the success rate of open lacrimal surgery. Br J Ophthalmol. 1994;78:888–91.
5. Ben Simon GJ, Joseph J, Lee S, et al. External versus endoscopic dacryocystorhinostomy for acquired nasolacrimal duct obstruction in a tertiary referral center. Ophthalmology. 2005;112:1463–8.
6. Jones DT, Fajardo NF, Petersen RA, et al. Pediatric endoscopic dacryocystorhinostomy failures: who and why? Laryngoscope. 2007;117:323–7.
7. Wu W, Yan W, MacCallum JK, et al. Primary treatment of acute dacryocystitis by endoscopic dacryocystorhinostomy with silicone intubation guided by a soft probe. Ophthalmology. 2009;116:116–22.
8. Madge SN, Chan W, Malhotra R, et al. Endoscopic dacryocystorhinostomy in acute dacryocystitis: a multicenter case series. Orbit. 2011;30:1–6.
9. Welham RA, Wulc AE. Management of unsuccessful lacrimal surgery. Br J Ophthalmol. 1987;71:152–7.
10. Hull S, Lalchan SA, Olver JM. Success rates in powered endonasal revision surgery for failed dacryocystorhinostomy in a tertiary referral center. Ophthal Plast Reconstr Surg. 2013;29:267–71.

11. Mauriello JA Jr, Vahedra V, Fleckner M, et al. Correlation of orbital computed tomographic findings with office probing and irrigation in 17 patients after successful and failed dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 1999;15:116–20.
12. Konuk O, Kurtulmusoglu M, Knatova Z, et al. Unsuccessful lacrimal surgery: causative factors and results of surgical management in a tertiary referral center. Ophthalmologica. 2010;224:361–6.
13. Gupta N. Improving Results in Endoscopic DCR. Indian J Otolaryngol Head Neck Surg. 2011;63:40–4.
14. Hammoudi DS, Tucker NA. Factors associated with outcome of endonasal dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2011;27:266–9.
15. Garcia Vilaro M, Vásquez L, Marin A, et al. Thermal damage influences endonasal dacryocystorhinostomy success. Ophthalmic Res. 2013;49:209–14.
16. McLachlan DL, Shannon GM, Flanagan JC. Results of dacryocystorhinostomy: analysis of the reoperations. Ophthalmic Surg. 1980;11:427–30.
17. McMurray CJ, McNab AA, Selva D. Late failure of dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2011;27:99–101.
18. Gökçek A, Argin MA, Altintas AK. Comparison of failed and successful dacryocystorhinostomy by using computed tomographic dacryocystography findings. Eur J Ophthalmol. 2005;15:523–9.
19. Choi JC, Jin HR, Moon YE, et al. The surgical outcome of endoscopic dacryocystorhinostomy according to the obstruction levels of lacrimal drainage system. Clin Exp Otorhinolaryngol. 2009;2:141–4.
20. Wormald PJ, Tsirbas A. Investigation and endoscopic treatment for functional and anatomical obstruction of the nasolacrimal duct system. Clin Otolaryngol Allied Sci. 2004;29:352–6.
21. Mansour K, Blanksma LJ, Vrakking H, et al. Scintigraphic evaluation for tear drainage, after dacryocystorhinostomy, in relation to patient satisfaction. Eye. 2008;22:414–9.
22. Brewis C, Yung M, Merkonidis C, et al. Endoscopic dacryocystorhinostomy in functional lacrimal obstruction. J Laryngol Otol. 2007;27:1–3.
23. Tsirbas A, Davis G, Wormald PJ. Revision dacryocystorhinostomy: a comparison of endoscopic and external techniques. Am J Rhinol. 2005;19:322–5.
24. Cheng AC, Wong AC, Sze AM, Yuen HK. Limited nasal septoplasty by ophthalmologists during endonasal dacryocystorhinostomy: is it safe? Ophthal Plast Reconstr Surg. 2009;25:293–5.
25. Orcutt JC, Hillel A, Weymuller EA. Endoscopic repair of failed dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 1990;6:197–202.
26. Mickelson SA, Kim DK, Stein IM. Endoscopic laser assisted dacryocystorhinostomy. Am J Otolaryngol. 1997;18:107–11.
27. El-Guindy A, Dorgham A, Ghoraba M. Endoscopic revision surgery for recurrent epiphora occurring after external dacryocystorhinostomy. Ann Otol Rhinol Laryngol. 2000;109:425–30.
28. Demarco R, Strose A, Araújo M, et al. Endoscopic revision of external dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2007;137:497–9.
29. Ramakrishnan VR, Durairaj VD, Kingdom TT. Revision endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2008;19:177–81.
30. Rose GE, Walland MJ. Factors affecting the success rate of open lacrimal surgery. Br J Ophthalmol. 1994;78:888–91.
31. Paik JS, Cho WK, Yang SW. Comparison of endoscopic revision for failed primary external versus endoscopic dacryocystorhinostomy. Clin Experiment Ophthalmol. 2013;41:116–21.
32. Patel BCK, Phillips B, McLeish WM, et al. Transcanalicular neodynium: YAG laser for revision of dacryocystorhinostomy. Ophthalmology. 1997;104:1191–7.
33. Woo KI, Moon SH, Kim YD. Transcanalicular laser assisted revision of failed dacryocystorhinostomy. Ophthal Surg Lasers. 1998;29:451–5.
34. Ugurbas SH, Zilelioglu G, Sargon MF, et al. Histopathologic effects of mitomycin-C on endoscopic transnasal dacryocystorhinostomy. Ophthalmic Surg Lasers. 1997;28:300–4.
35. Zilelioglu G, Ugurbas SH, Anadolu Y, et al. Adjunctive use of mitomycin C on endoscopic lacrimal surgery. Br J Ophthalmol. 1998;82:63–6.
36. Prasannaraj T, Kumar BY, Narasimhan I, Shivaprakash KV. Significance of adjunctive mitomycin C in endoscopic dacryocystorhinostomy. Am J Otolaryngol. 2012;33:47–50.
37. Kao SC, Liao CL, Tseng JH, et al. Dacryocystorhinostomy with intraoperative mitomycin C. Ophthalmology. 1997;104:86–91.
38. Yeatts RP, Neves RB. Use of mitomycin C in repeat dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 1999;15:19–22.
39. Camara JG, Bengzon AU, Henson RD. The safety and efficacy of mitomycin C in endonasal endoscopic laser-assisted dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2000;16:114–8.
40. Dolmetsch AM, Gallon MA, Holds JB. Non-laser endoscopic endonasal dacryocystorhinostomy with adjunctive mitomycin C in children. Ophthal Plast Reconstr Surg. 2008;24:390–3.
41. Ozkiriş M, Ozkiriş A, Göktaş S. Effect of mitomycin C on revision endoscopic dacryocystorhinostomy. J Craniofac Surg. 2012;23:e608–10.
42. Penttilä E, Smirnov G, Seppä J, et al. Mitomycin C in revision endoscopic dacryocystorhinostomy: a prospective randomized study. Am J Rhinol Allergy. 2011;25:425–8.
43. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
44. Unlu HH, Toprak B, Aslan A, et al. Comparison of surgical outcomes in primary endoscopic dacryocystorhinostomy with and without silicone intubation. Ann Otol Rhinol Laryngol. 2002;111:704–9.
45. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report by the American Academy of Ophthalmology. Ophthalmology. 2001;108:2369–77.
46. Chong KK, Lai FH, Ho M, et al. Randomized trial on silicone intubation in endoscopic mechanical dacryocystorhinostomy (SEND) for primary nasolacrimal duct obstruction. Ophthalmology. 2013;120:2139–45.
47. Smirnov G, Tuomilehto H, Teräsvirta M, et al. Silicone tubing after endoscopic dacryocystorhinostomy: is it necessary? Am J Rhinol. 2006;20:600–2.
48. Maheshwari R. Balloon catheter dilation for complex congenital nasolacrimal duct obstruction in older children. J Pediatr Ophthalmol Strabismus. 2009;46:215–7.
49. Couch SM, White WL. Endoscopically assisted balloon dacryoplasty treatment of incomplete nasolacrimal duct obstruction. Ophthalmology. 2004;111:585–9.
50. Lee BJ, Nelson CC, Lewis CD, et al. External dacryocystorhinostomy outcomes in sarcoidosis patients. Ophthal Plast Reconstr Surg. 2012;28:47–9.
51. Ali MJ, Naik MN, Honavar SG. Ushering a new and routine era in minimally invasive lacrimal surgery. Int Ophthalmol. 2013;33:203–10.
52. Lee A, Ali MJ, Wong ACW, et al. Balloon dacryoplasty in internal ostium stenosis after endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2014;30:7–10.
53. Ali MJ, Yuen HK, Lee A, et al. Reply re:"Balloon dacryoplasty in internal ostium stenosis after endoscopic dacryocystorhinostomy". Ophthal Plast Reconstr Surg. 2014;30:352–3.
54. Malhotra R, Norris JH, Sagili S, et al. The learning curve in endoscopic dacryocystorhinostomy: outcomes in surgery performed by trainee oculoplastic surgeons. Orbit. 2015;34:314–9.
55. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes in primary powered endoscopic dacryocystorhinostomy: comparison between experienced and less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.

56. Kamal S, Ali MJ, Nair AG. Outcomes of endoscopic dacryocystorhinostomy: experience of a fellowship trainee at a tertiary care center. Indian J Ophthalmol. 2016;64:648–53.
57. Dave TV, Mohammad FA, Ali MJ, et al. Etiologic analysis of 100 anatomically failed dacryocystorhinostomies. Clin Ophthalmol. 2016;10:1419–22.
58. Ali MJ, Mishra DK, Baig F, Naik MN. Histopathology, immunohistochemistry, and electron microscopic features of a dacryocystorhinostomy ostium cicatrix. Ophthal Plast Reconstr Surg. 2016;32:333–6.
59. Li EY, Cheng AC, Wong AC, et al. Safety and efficacy of adjunctive intranasal mitomycin C and triamcinolone in endonasal endoscopic dacryocystorhinostomy. Int Ophthalmol. 2016;36:105–10.
60. Ali MJ, Psaltis AJ, Wormald PJ. Dacryocystorhinostomy ostium: parameters to evaluate and DCR ostium scoring. Clin Ophthalmol. 2014;8:2491–9.
61. Ali MJ, Singh M, Chisty N, et al. Endoscopic ultrasonic dacryocystorhinostomy: clinical profile and outcomes. Eur Arch Otorhinolaryngol. 2016;273:1789–93.
62. Ali MJ, Ganguly A, Javed Ali M, et al. Time taken for superior osteotomy in primary powered endoscopic dacryocystorhinostomy: is there a difference between an ultrasonic aspirator and mechanical drill? Int Forum Allergy Rhinol. 2015;5:764–7.
63. Go Y, Park J, Kim K, Lee S. Comparison of non-laser endoscopic endonasal revision surgery and diode laser transcanalicular revision surgery for failed dacryocystorhinostomy. J Craniofac Surg. 2015;26:863–6.
64. Lee J, Choi SY, Lee H, et al. The clinical effectiveness of transcanalicular diode laser-assisted revision surgery for failed endoscopic endonasal dacryocystorhinostomy. Br J Ophthalmol. 2015;99:1130–3.
65. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomy. Int Forum Allergy Rhinol. 2014;4:1016–9.
66. Ganguly A, Videkar C, Goyal R, et al. Non-endoscopic endonasal dacryocystorhinostomy: outcome in 134 eyes. Indian J Ophthalmol. 2016;64:211–5.

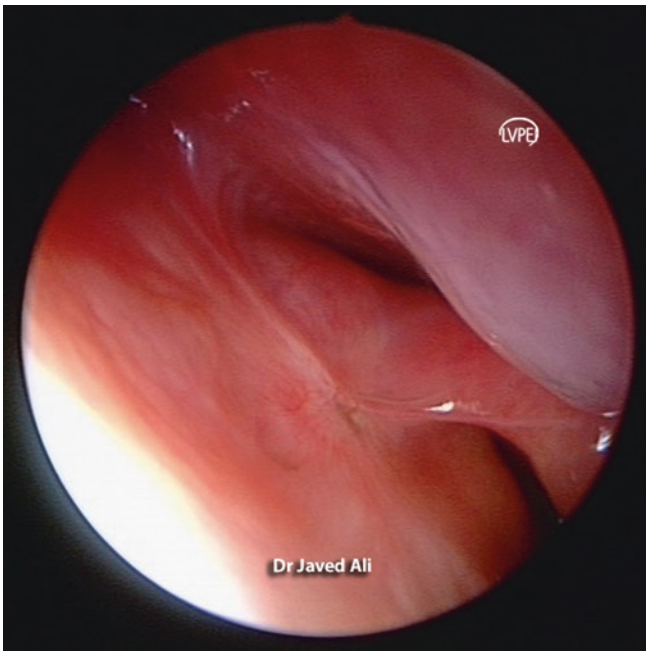


Fig. 26.1 Endoscopic view of a cicatricial closure of the ostium

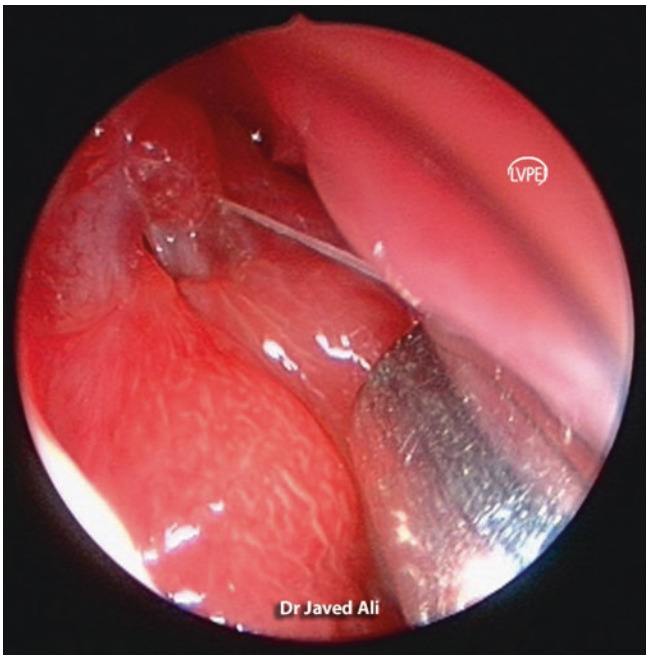


Fig. 26.3 Nasal endoscopic view showing an internal ostium stenosis along with peri-ostial active granuloma

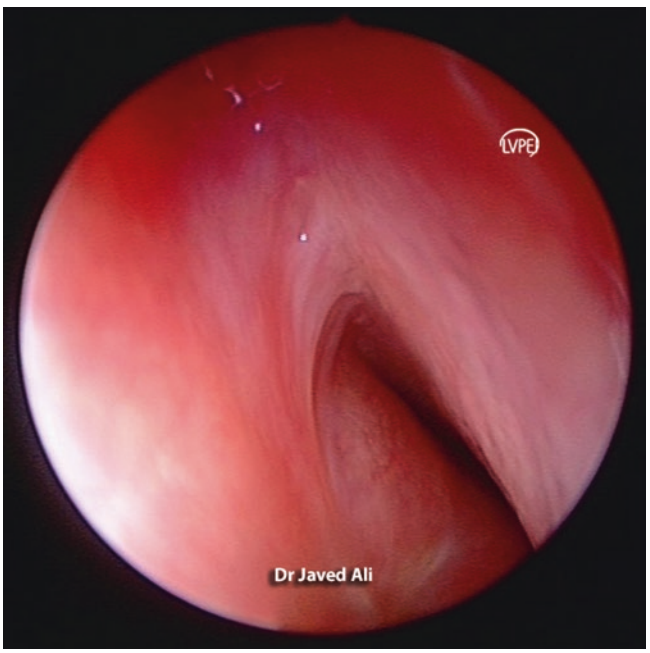


Fig. 26.2 An extensive turbinoseptal synechiae involving the ostium

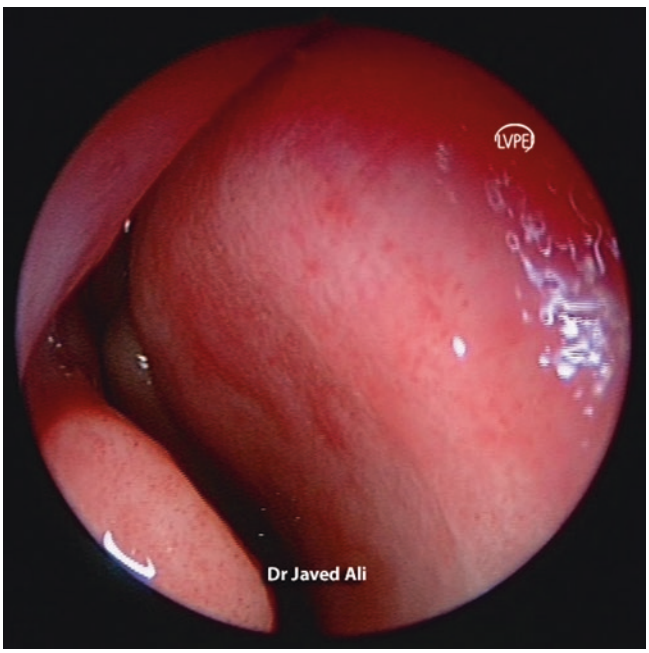


Fig. 26.4 Nasal endoscopic view of a gross deviated nasal septum

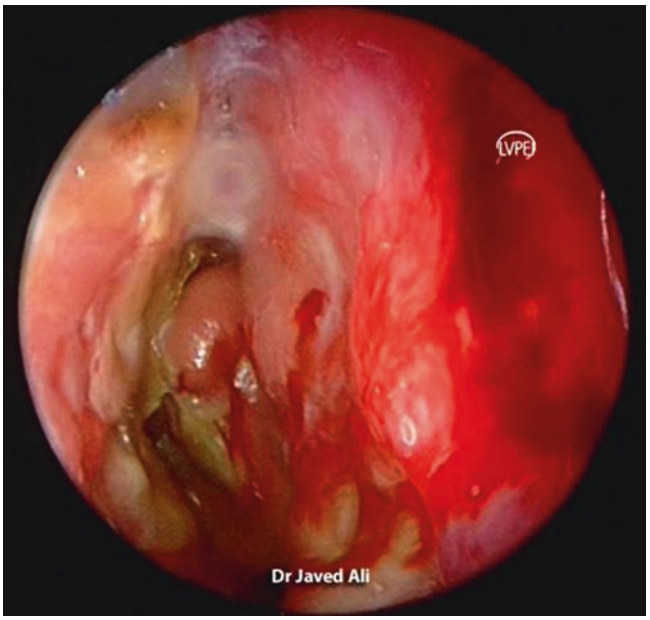


Fig. 26.5 Nasal endoscopic view showing intense inflammation in a case of Wegener's granulomatosis

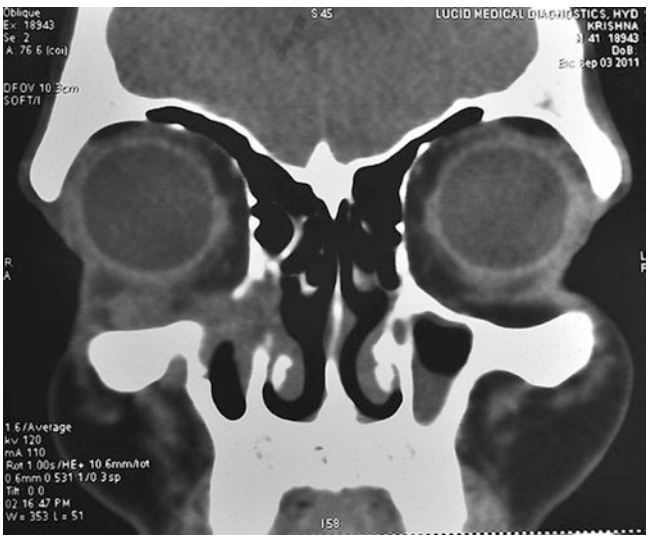


Fig. 26.6 CT scan, coronal view, showing the right DCR ostium with extensive scar tissue in and around the ostium

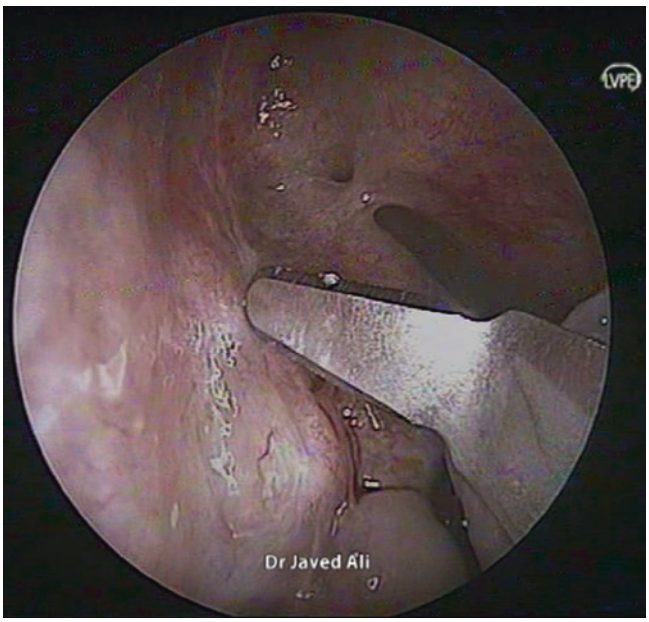


Fig. 26.7 Elevating the nasal mucosal flap at a higher level to expose the underlying bone superiorly

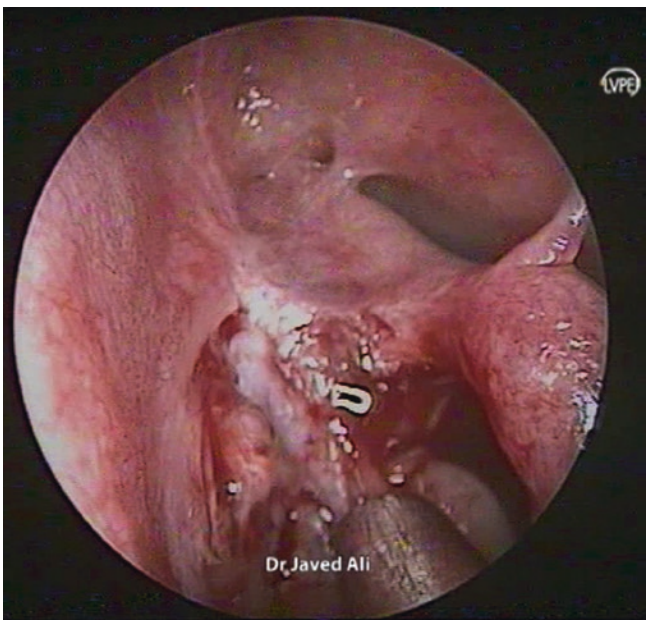


Fig. 26.8 Flaps being raised of the underlying scarred lacrimal sac

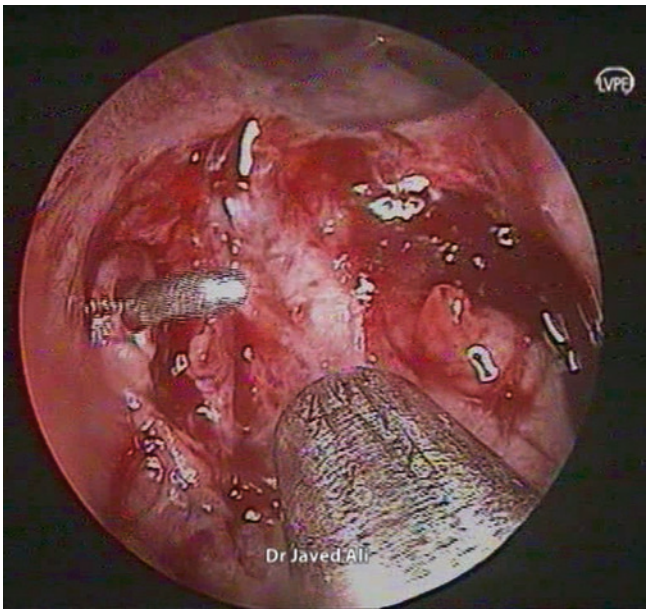


Fig. 26.9 Area of the common canaliculus completely cleared

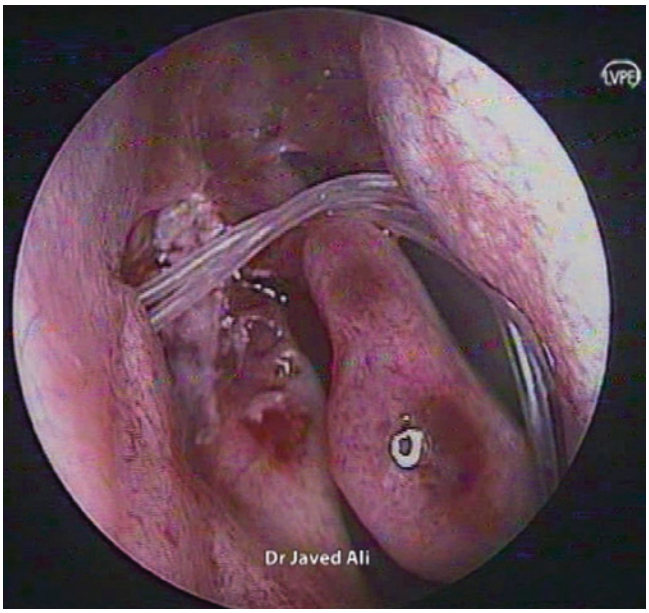


Fig. 26.11 Newly created ostium with intubation

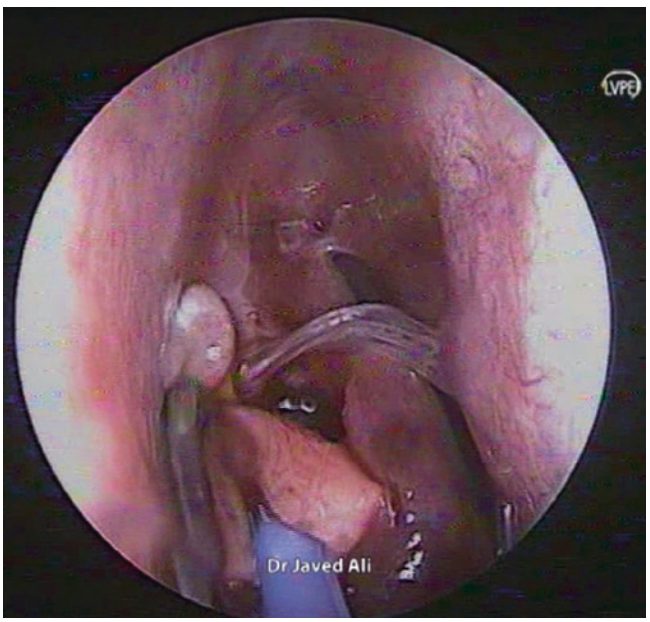


Fig. 26.10 Mitomycin C application to the newly created ostium

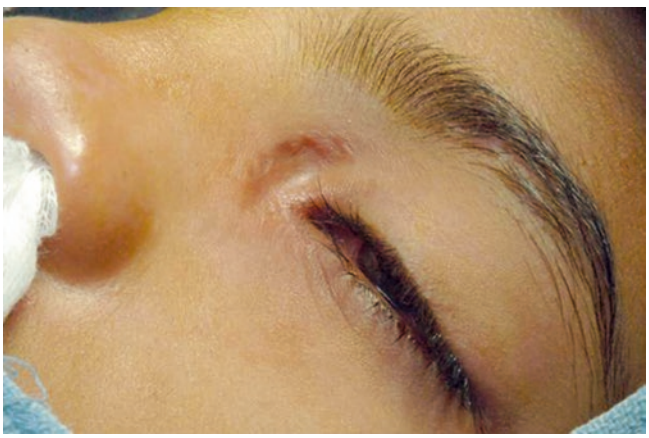


Fig. 26.12 External scar in a failed DCR

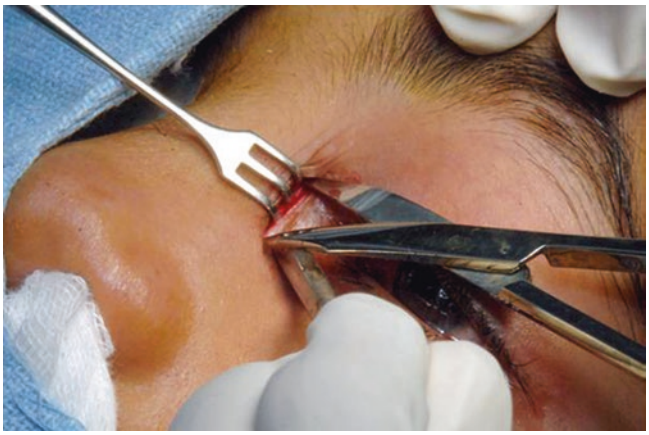


Fig. 26.13 A gentle separation of the orbicularis and underlying scar tissues

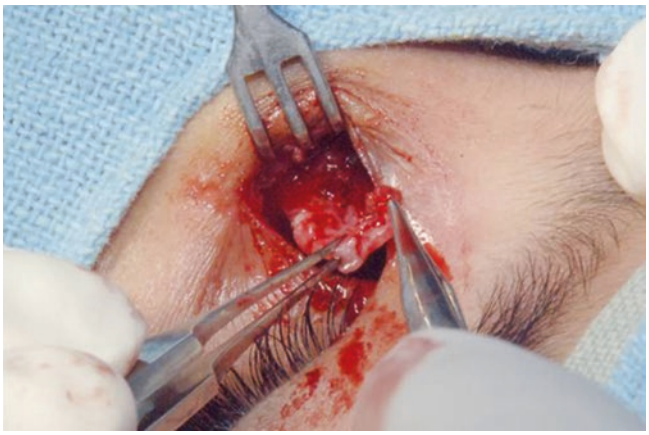


Fig. 26.16 Salvaging the virgin nasal mucosa

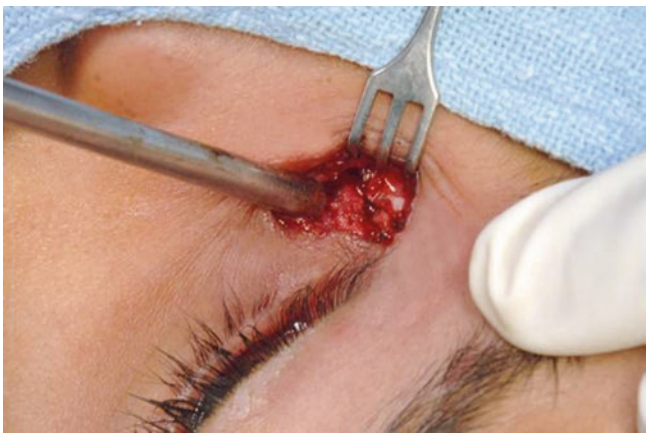


Fig. 26.14 Exposing the virgin bone. Note the ostium with scarring

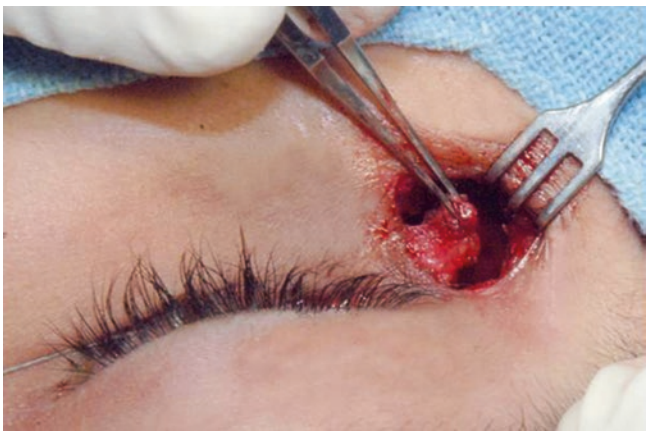


Fig. 26.17 Elevation of anterior sac flap

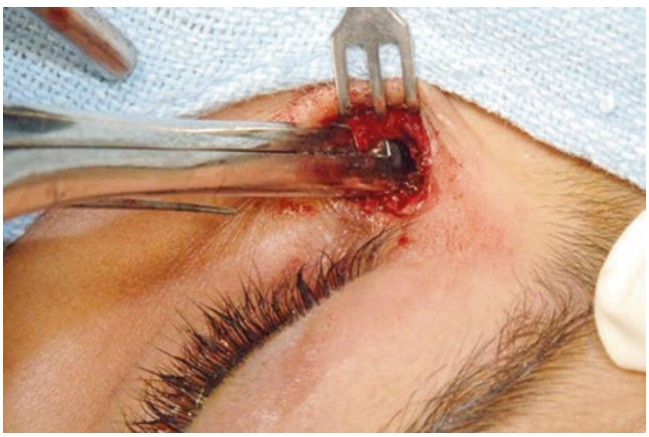


Fig. 26.15 Enlarging the osteotomy with Kerrison bone punch

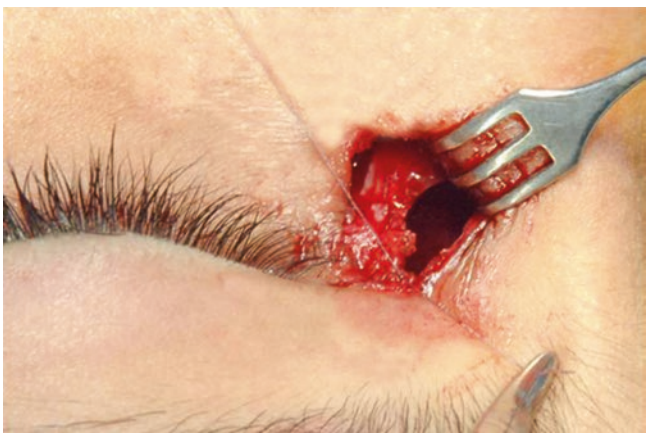


Fig. 26.18 Anastomosis of salvaged anterior nasal and lacrimal sac flaps

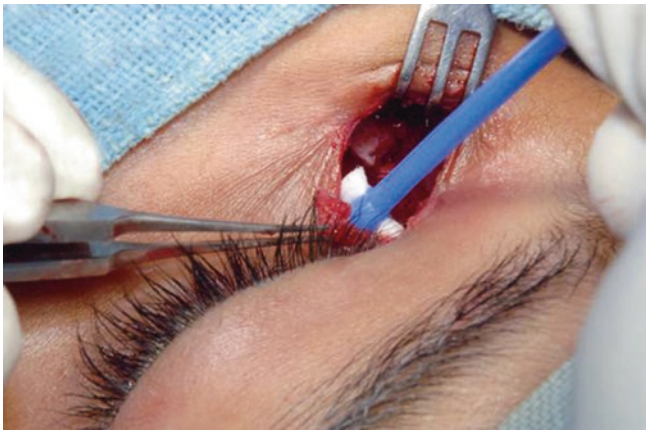


Fig. 26.19 Mitomycin C application

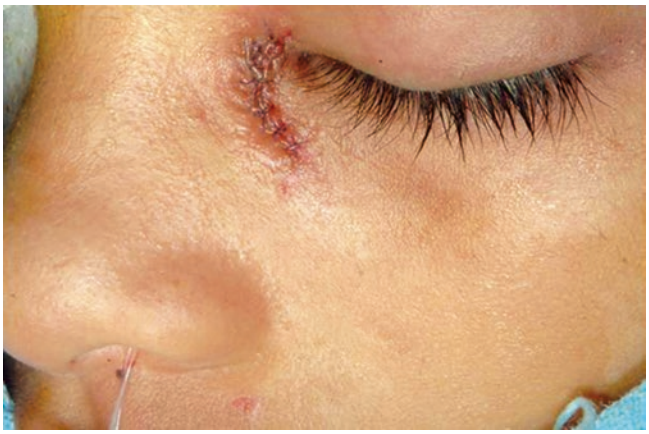


Fig. 26.20 Wound resutured after silicone intubation

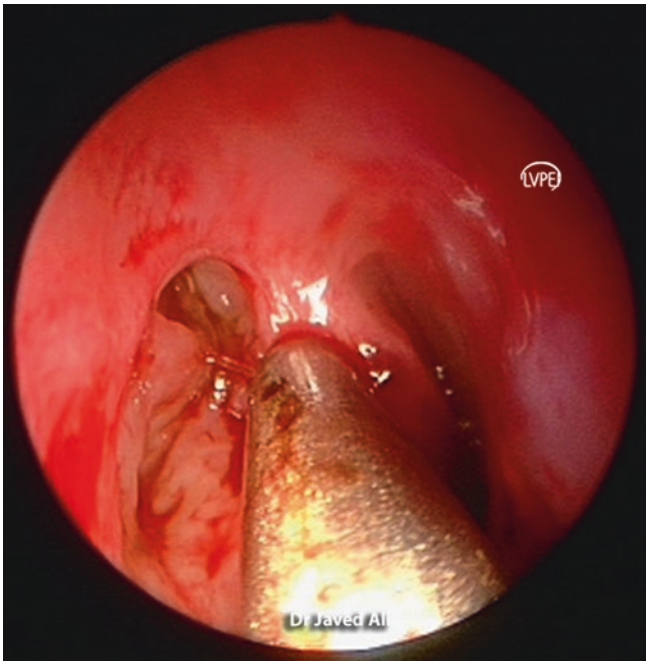


Fig. 26.21 Nasal endoscopic view showing positive FEDT after endocanaliculotomy

Endoscopic-Guided Single Self-Linking of Stents

27

Mohammad Javed Ali

Introduction

External dacryocystorhinostomy (DCR) is a commonly done surgical procedure for treatment of nasolacrimal duct obstructions. Although the success rates are high, the literature reports the failure rates to range from 1 to 10% [1, 2]. Among the causes of failure, the most common ones include occlusion of the rhinostomy by either cicatrix, common canalicular obstruction, ostium granuloma, or synechiae [3–5]. The aim of a DCR surgery is therefore twofold, not only to successfully create an ostium but also to take steps to prevent its reclosure. One such step is the use of bicanalicular stents.

With the widespread use of intubation in routine DCR, many problems have been reported in the literature with stents including granuloma formation, nasal irritation, punctal cheese-wiring, nasal bleeding, chronic infections, and corneal erosions and displacement [6–10]. Stent prolapse is an important complication with the reported incidence of up to 17% [10]. This problem of stent displacement is more likely to be prevalent among the pediatric population due to rubbing of the eyes or pulling it out from the medial canthal end (Figs. 27.1 and 27.2). Such events specifically among pediatric patients may warrant premature tube removal and have the potential to defeat the very purpose of their use. Numerous techniques have been reported in the literature to prevent stent displacements, each with their own sets of advantages and disadvantages [10–14]. The most common modality is to secure the nasal end of the stent to the lateral vestibule with a nonabsorbable suture (Fig. 27.3). Other techniques include the use of Griffith's nasolacrimal catheter, scleral buckling sponges, single-loop stents, silicone sleeves, and aneurysm clips [10–14]. Single self-linking technique was first described by Hui et al. [15] as an effective measure to prevent stent prolapse using both the arms of the Crawford intubation set to cannulate the nasolacrimal duct as well as the internal ostium together. We described our experience with endoscopic-guided self-linking stents in pediatric external DCR [16]. We believe that with the help of self-linking stents not only stent prolapse but also many other complications like nasal irritation, punctal slitting, and corneal erosions can be avoided.

Patient Selection

Careful patient selection is of paramount importance. It is best not to choose patients who underwent a DCR procedure in the past for obvious reason that the nasolacrimal duct in these patients would likely have been violated thereby rendering the nasolacrimal pass unamenable to the self-linking stent. Rarely, those pediatric patients who had persistent complex congenital nasolacrimal duct obstruction with a bony block on probing are not good candidates since this would as well render the nasolacrimal pass unamenable to the self-linking.

Surgical Technique

Self-linked stents are just one simple additional step for all the surgeons who regularly perform an external DCR (Fig. 27.4). Our surgical technique was the same as described before by Hui et al. [11] except that the surgery was partly done under endoscopic guidance. Following flaps creation in DCR, a Crawford silicone stent (FCI Ophthalmics, MA, USA) is passed through the canaliculi, and then each arm is brought out through the nasolacrimal duct (Fig. 27.5) rather than the routine middle meatus. Both the arms of the stent are recovered from the inferior meatus under endoscopic guidance (Figs. 27.6 and 27.7). The bodkins are then passed over the inferior turbinate and redirected toward the middle meatus and the osteotomy under endoscopic guidance (Figs. 27.8 and 27.9) and looped around the proximal portions and tied near the lacrimal sac (Fig. 27.10) thus creating

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_27

a self-linking stent around the inferior turbinate. At the end of surgery, before closing the wound, an attempt to displace the stent superiorly or inferiorly should be met with resistance (Fig. 27.11). At the same time it is also important to make sure that there is no undue tightening of the silicone stent since this may lead to punctal cheese-wiring.

Our Experience

A total of 15 procedures were carried out [12]. Following placement of self-linked stents, the removal was done around 12 weeks. None of the patients had a stent prolapse during this period. All the stents were removed in the outpatient without the use of general anesthesia with minimal endoscopic guidance. One patient has an ostium granuloma around the tube, which was removed, and the patient did well with budesonide nasal spray for a week. The anatomical and functional success rates of DCR were found to be unaffected in our study [12]. We believe from our experience [12] as well as that of Hui et al. [11] that self-linked stents are a very effective measure against stent displacements. In fact at the end of the surgery, any efforts to displace the stent both from the medial canthal end and the nasal end were met with resistance.

Advantages of Endoscopic Guidance

We advocate the use of endoscopy during this procedure since we found certain advantages in its use. The foremost among these is a better control of the stent at the inferior turbinate which plays the most crucial role in self-linking and retaining the stent (Fig. 27.9). We noticed that on few occasions one arm of the stent may only partially link onto the inferior edge of the turbinate and slips down with rubbing of the nose, thereby hanging beneath the turbinate toward the floor and also creating a downward stress on the entire stent. This may at least theoretically lead to punctal or canalicular slitting. In addition it would be helpful in preventing intraoperative trauma in the anterior nose during tube retrieval from inferior meatus and while passing the bodkins up to the internal rhinostomy.

Advantages in Pediatric DCR

Advantages of this procedure in pediatric population include prevention of stent prolapse, prevention of irritation in the nose during sneezing, less amenable to displacement even if pulled, avoiding general anesthesia during removal, reduction in the number of visits in cases of prolapse, better patient cooperation during removal, and of course ease in removal.

Complications

Certain tricky situations include the possibility of negotiating through a blocked nasolacrimal duct, for there is a risk of false passage or tightness around the silicone tubing that could lead to tube impaction. We did not encounter this problem of false passage as it was done under visualization from both the entry and exit points. Second problem could be that of punctal cheese-wiring if the tube is very tight or it slips and hangs beneath the inferior turbinate. Care should be taken to avoid tube being too tight by giving some leverage during the second pass near the sac. The possibility of improper tube pass near inferior turbinate can be taken care by endoscopic monitoring and appropriate corrections performed when needed. Third possible complication could be granuloma formations near the common internal opening. Routine endoscopic monitoring of our cases did not reveal this except in one case which could be easily managed.

References

1. Hartikainen J, Antila J, Varpula M, et al. Prospective randomized comparison of endonasal endoscopic dacryocystorhinostomy and external dacryocystorhinostomy. Laryngoscope. 1998;108:1861–6.
2. Hartikainen J, Grenman R, Puukka P, et al. Prospective randomized comparison of endonasal endoscopic dacryocystorhinostomy and external dacryocystorhinostomy. Ophthalmology. 1998;105:1106–13.
3. Allen K, Berlin AJ, Levine HL. Intranasal endoscopic analysis of dacryocystorhinostomy failure. Ophthal Plast Reconstr Surg. 1988;4:143.
4. Welham RAN, Wulc AE. Management of unsuccessful lacrimal surgery. Br J Ophthalmol. 1987;71:152–7.
5. Linberg JV, Anderson RL, Bumstead RM, et al. Study of intranasal ostium in external dacryocystorhinostomy. Arch Ophthalmol. 1982;100:1758–62.
6. Huggert A. The treatment of stenosis of lacrimal canaliculi. Acta Ophthalmol. 1959;37:355–9.
7. Rosen N, Sharir M, Moverman DC, et al. Dacryocystorhinostomy with silicone tubes: evaluation of 253 cases. Ophthalmic Surg. 1989;20:115–9.
8. Allen K, Berlin AJ. Dacryocystorhinostomy failure: association with nasolacrimal intubation. Ophthalmic Surg. 1989;20:486–9.
9. Walland MJ, Rose GE. The effect of silicone intubation on failure and infection rates after dacryocystorhinostomy. Ophthalmic Surg. 1994;25:597–600.
10. Hopkisson B, Suharwardy J. Sleeves for fixation of nasolacrimal tubes. Br J Ophthalmol. 1995;79:664–6.
11. Jordan DR, Bellan LD. Securing silicone stents in dacryocystorhinostomy. Ophthalmic Surg. 1995;26:164–5.
12. Griffiths JD. Nasal catheter use in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 1991;7:177–86.
13. Hale B, Wilson TW, Reinheimer W. Intubation of the nasolacrimal duct. Tech Ophthalmol. 2009;7:82–7.
14. Merbs SL, Harris LL, Iwamoto MA, et al. Prevention of prolapsed silicone stents in lacrimal intubation using an intrasac fixation suture. Arch Ophthalmol. 1999;117:1092–5.
15. Hui JI, Shriver EM, Tse DT. Intubation of the ostium and the nasolacrimal duct with a single self-linking silicone stent in external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2011;27:87–9.
16. Ali MJ, Gupta H, Naik MN, et al. Endoscopic guided-single self-linked stent in pediatric external dacryocystorhinostomy. Minim Invasive Ther Allied Technol. 2013;22:266–70.

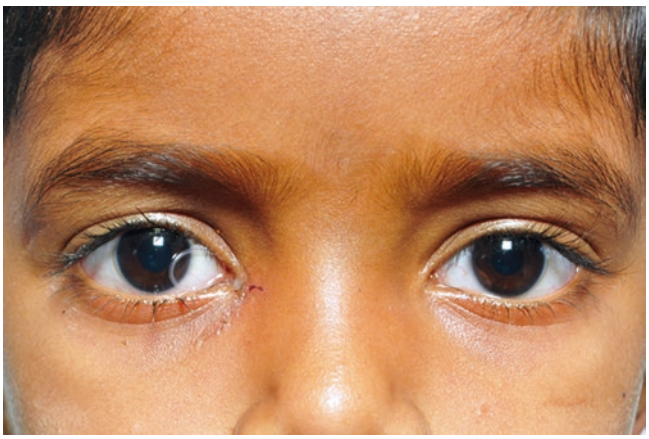


Fig. 27.1 A child with a stent prolapsed

Fig. 27.2 Closer view of a stent prolapse

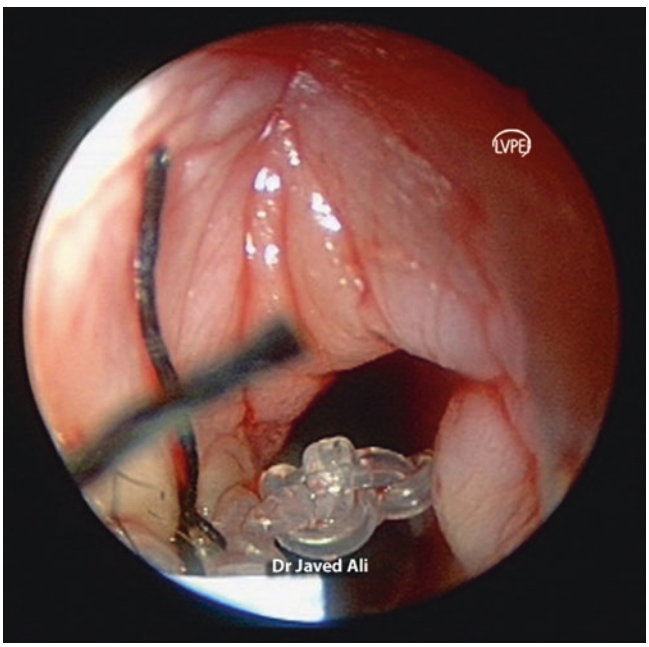


Fig. 27.3 Traditional way of securing the stent at lateral vestibule with a nonabsorbable suture

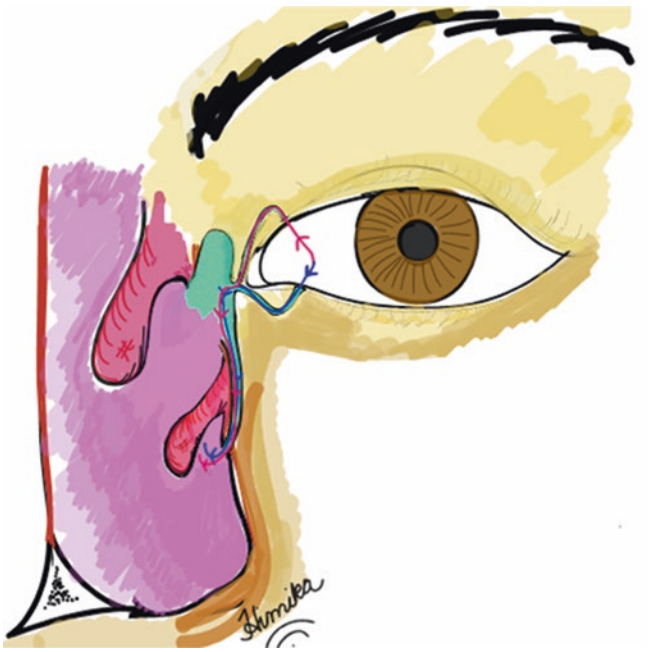


Fig. 27.4 Schematic diagram of the technique showing the nasolacrimal pass of the stent and retrieval at the inferior meatus (Courtesy: Himika Gupta)

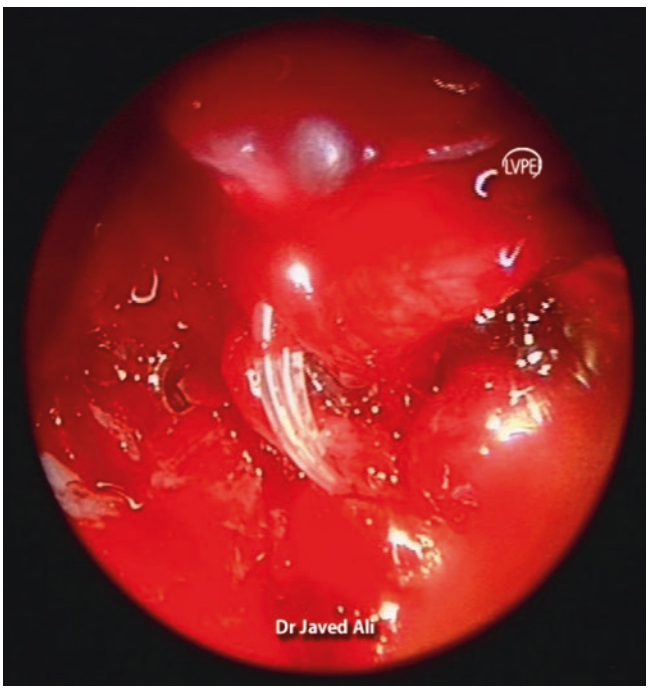


Fig. 27.5 Endoscopic view of the first pass showing the stent coming out of the common canaliculus and entering the nasolacrimal duct

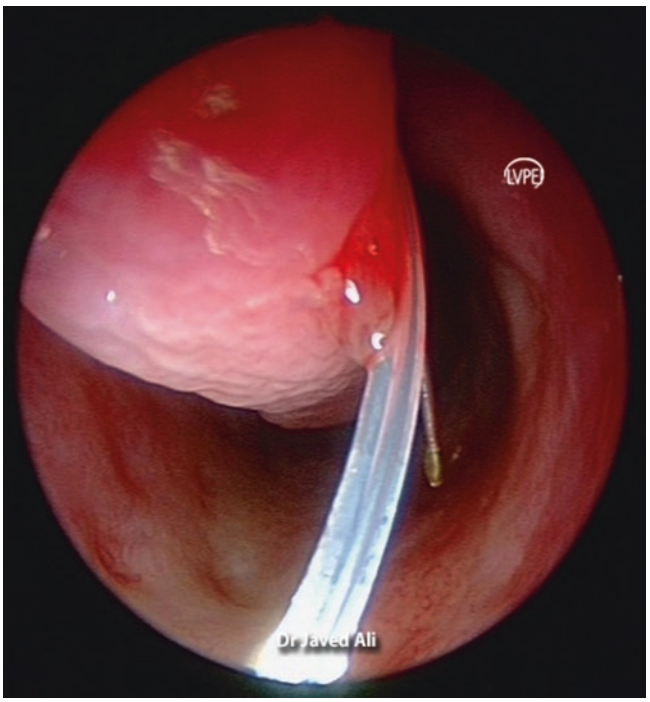


Fig. 27.6 Endoscopic view of one arm of the stent retrieved in the inferior meatus, bodkin of the second arm ready for retrieval

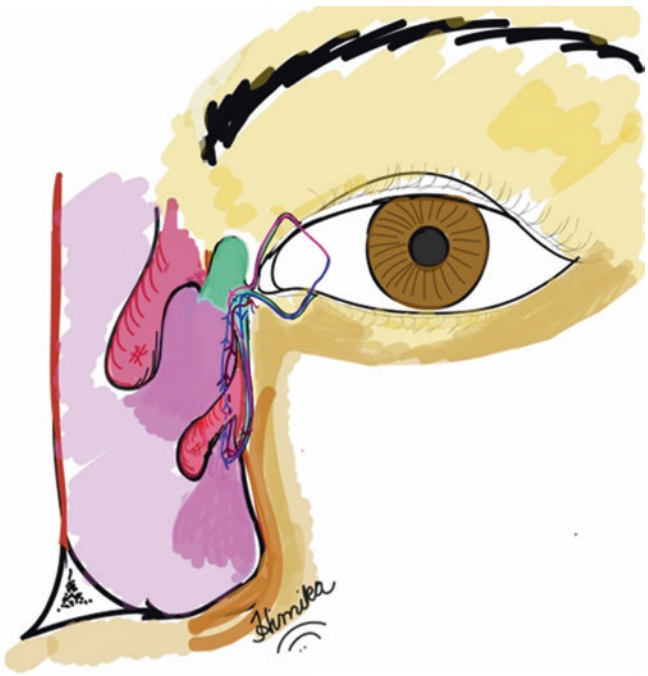


Fig. 27.8 Schematic diagram of the technique depicting redirection of the stent toward the internal nasal ostium and securing around the first pass (Courtesy: Himika Gupta)

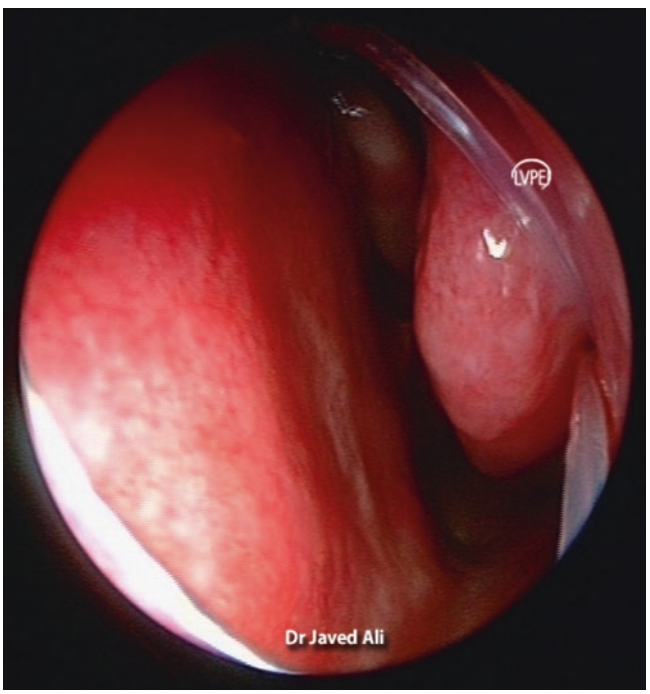


Fig. 27.7 Endoscopic view of the inferior turbinate showing the self-linking of the first arm

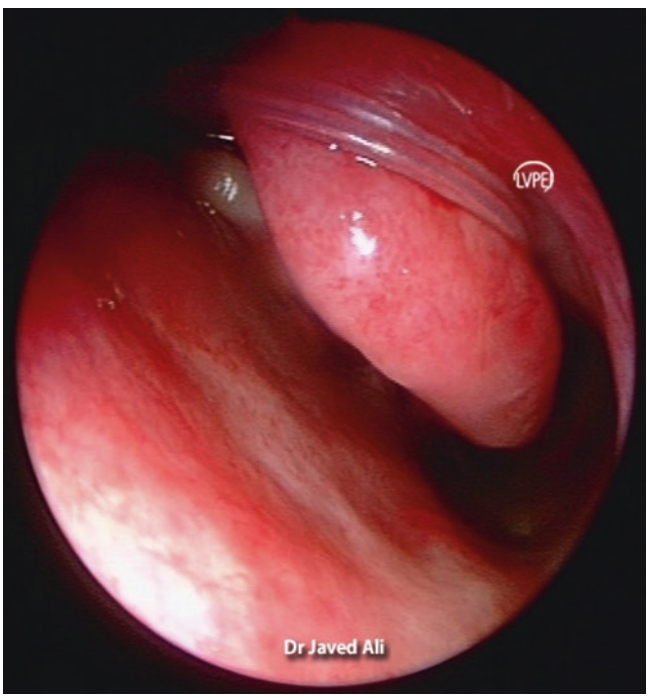


Fig. 27.9 Endoscopic view of the inferior turbinate showing completion of the self-linking

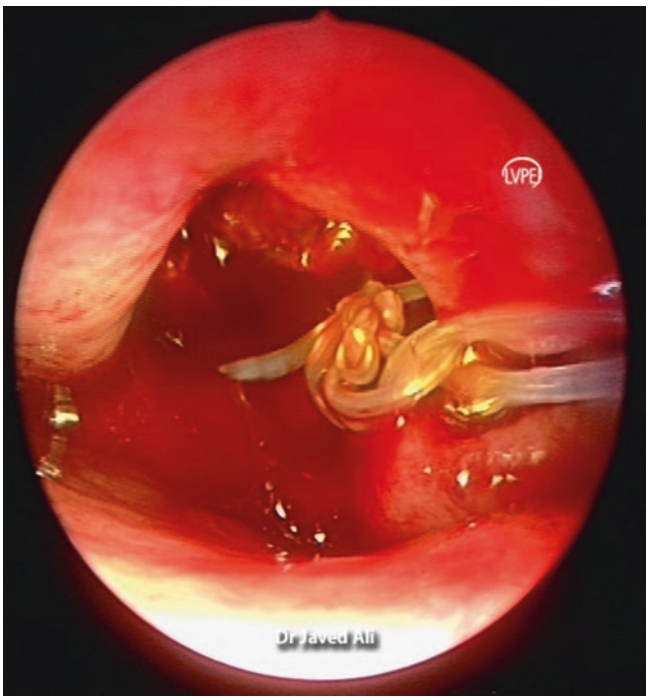


Fig. 27.10 Endoscopic view of the completed loop in front of the lacrimal sac

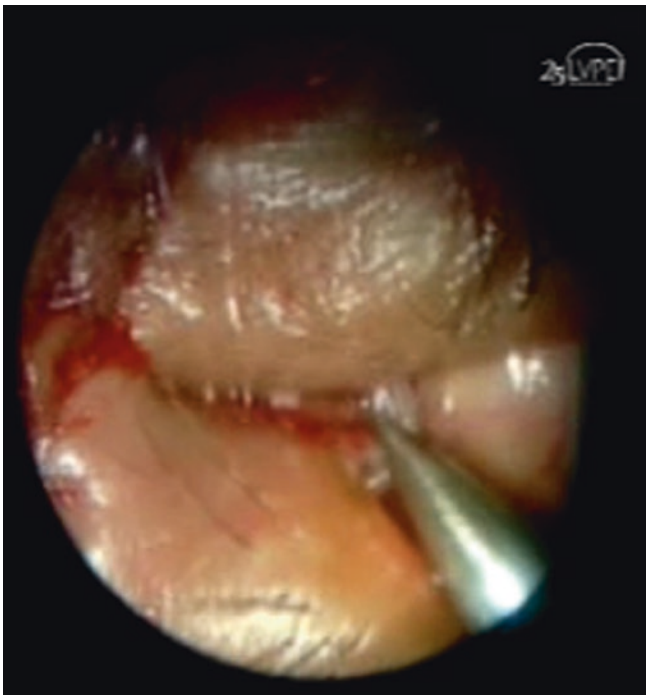


Fig. 27.11 Examination for tube resistance and tension

Conjunctivodacryocystorhinostomy: Indications, Techniques, and Complications

28

Mohammad Javed Ali and Pelin Kaynak

Introduction

Complete proximal bicanalicular obstructions remain one of the most intriguing lacrimal disorders posing dilemma on both diagnostic and management fronts. Conjunctivodacryocystorhinostomy or CDCR was initially described by von Hoffman in 1904 [1] and later with Jones tubes by Lester Jones in 1962 [2, 3]. In this procedure, a new passage is created for drainage of tears from the conjunctival cul-de-sac directly into the nasal cavity. The procedure can be performed via an external approach (external CDCR), an endoscopic approach (endoscopic CDCR), or a minimally invasive approach (MICDCR) or diode laser-assisted (LCDCR) and endoscopic conjunctivorhinostomy (CR) without a DCR. Though the procedure is useful with a success rate hovering around 90%, large series have shown two major complications, namely, extrusion of the tube ranging from 28% to as high as 51% and tube malpositions ranging from 22 to 28% [4–7]. In order to avoid these complications, numerous modifications of the bypass tube have been published including additional flanges, wide medial ends, angulated tubes, and porous polyethylene-coated tubes [8–11]. The complications though reduced still continue to be a matter of concern. Minimally invasive placement of Jones tubes without a DCR with and without the use of endoscopic guidance is gaining popularity in recent times [12–14]. Although most of the contraindications to CDCR are relative, careful patient selection is of utmost importance [12–18]. The chapter will discuss indications, contraindications, techniques, complications, and outcomes of various approaches for CDCR.

M. Javed Ali, F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

P. Kaynak, M.D.
Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey

Indications

1. Punctal agenesis
2. Canalicular agenesis
3. Proximal canalicular obstructions
4. Unsalvageable proximal system post-trauma
5. Post-dacryocystectomy rehabilitation
6. Multiple times failed DCR with canalicular obstructions
7. Lacrimal pump failures
8. Unresolved epiphora following a patent DCR

Contraindications

1. Scarred medial canthus
2. Gross eyelid anomalies
3. Gross nasal deformities
4. Early childhood
5. Mentally unstable patients
6. Unrealistic expectations or patients not keen for tube maintenance
7. Poor systemic health
8. Patient who cannot come for follow-ups (relative)

Instruments and Setup

The standard ophthalmic plastic instrument sets and operating room are adequate to perform a CDCR. To perform the endoscopy-assisted technique of CDCR, a nasal endoscope with viewing system should be available. Laser delivery systems are needed for a laser-assisted CDCR.

The ideal bypass tube is non-hydrophobic, nonreactive to tissues, and rigid enough not to collapse. The original Jones tubes are a set of Pyrex glass tubes of varying sizes; the usual lengths vary from 9 mm to 28 mm (Fig. 28.1). The ocular end has a flange with a diameter of 3, 3.5, or 4 mm. The nasal end has a gentle flange. The outer diameter of the tube is 2.5 mm, and the inner diameter is 1.5–1.7 mm. Straight tubes

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_28

are more commonly used, but curved tubes are also available. Flanges with holes have also been designed to secure the tube by passing suture through the holes. Gold-plated dilators (Fig. 28.2) and tube measuring slabs (Fig. 28.3) are available with the complete set (Fig. 28.4).

Several modifications have been attempted to prevent the migration of the tube. The Gladstone-Putterman modification (Fig. 28.5) of the Jones tube has a flange section in the middle and is believed to have less chance of dislocation [9]. Frosted glass Jones tubes and porous polyethylene-coated tubes have also been used to reduce the incidence of dislocated tubes [10, 11].

Techniques

The nasal cavity of every patient must be inspected in the preoperative evaluation (Fig. 28.6). If a septoplasty for deviated nasal septum or a middle turbinoplasty is required, they can be completed along with the CDCR procedure (Figs. 28.7 and 28.8).

The caruncle and medial canthal soft tissues may be anesthetized by deep infiltration with equal parts of 2% lignocaine and adrenaline 1:200,000, and 0.5% bupivacaine (Fig. 28.9). The nasal cavity is anesthetized by packing with a mixture of 4% lignocaine and adrenaline and submucosal injection of 2% lignocaine with adrenaline (Fig. 28.10). Adrenaline is to be avoided in hypertensive patients.

Once the preparation is complete, the technique may vary. For external or endoscopic CDCR, regular DCR osteotomy is performed respectively followed by creation of the lacrimal sac flaps. A portion of the caruncle is then excised followed by enlargement of the track from the conjunctival cul-de-sac to the middle meatus of the nose with the help of Wheeler of Von-Graefe's knife [4–6]. A Bowman probe is introduced into the track, and it is further enlarged with blunt dissection. The Bowman probe is allowed to just stop short of touching the septum, and this length from the medial canthus to the tip is measured. Subtracting 2 mms from this measurement would give the length of Jones tube to be placed [5]. Other method could be to have a final placement of Jones tube midway between the lateral wall and septum. Jones tubes or bypass tube of the surgeon's preference is then placed in the track under visualization to avoid touching the septum and secured at the medial canthus with 6-0 Prolene. Tubes with a flange hole are preferred for ease of suturing.

For the minimally invasive placement of bypass tubes without a DCR [14], a 4 mm incision is given just below the caruncle and the tissues gently separated with a Westcott scissors (Fig. 28.11). A 14-gauge needle is then used through this track and directed inferomedially through the thin lacrimal bone into the middle meatus under endoscopic guidance (Fig. 28.12). A partial anterior middle turbinoplasty can be performed where needed (Fig. 28.8). The ideal position of the needle in the nasal cavity is midway between the nasal septum and the lateral wall of the nose (Fig. 28.13). Once this position was achieved, the caruncular end of the needle was grasped and the length of the needle measured (Fig. 28.14) which correlated with the length of the Jones or Gladstone-Putterman tube (Gunther Weiss company, Portland, Oregon) to be used. The track was dilated with gold dilators (Gunther Weiss company, Portland, Oregon), and the tube mounted on lacrimal probe steadily placed into the nasal cavity through the newly created track (Fig. 28.15). The nasal end of the ostium is not enlarged, and this leads to a snugly fitted tube (Fig. 28.16). The tube is then secured with a 4-0 Prolene at the caruncular end (Fig. 28.17).

Laser-Assisted CDCR

Lasers have been successfully used as an adjunct to facilitate conjunctivodacryocystorhinostomy (CDCR) [19–24]. Lasers may specifically help in traumatic lacrimal system injuries with unsalvageable proximal system. Hemostatic and less traumatic disruptive properties of LASERs aid the surgeon to perform an easier, fast, and effective procedure. Gonnering et al. [19] first published their CDCR experience with four patients using the potassium titanyl phosphate (KTP) laser and carbon dioxide laser assistance with high success and lesser complications. Kaynak et al. [20] presented the results of Ho:YAG laser-assisted lacrimal bypass surgery with high surgical success and few complications.

Surgical Technique

Laser-assisted CDCR can be performed under general anesthesia or local anesthesia with intravenous sedation. Operation room precautions such as protective goggles with appropriate filters and removal or controlled use of flammable drapes and gases are important for surgical safety.

The patient is premedicated, preferably with 0.05% xylometazoline +1% lidocaine nasal spray, and nasal cavity was packed with absorbent sticks soaked in a mixture of xylometazoline 0.05% with 1:200,000 epinephrine for hemostasis.

Eyelid speculum is helpful and a protective contact lens or a shield is mandatory in laser-assisted procedures. Caruncle size is reduced inferiorly with a partial excision or by shrinking the mucosa by using bipolar cautery (Fig. 28.18). A caruncular incision is performed, and the sac fossa is reached with blunt dissection. As the bone tissue is exposed, a 16-gauge guide needle is placed and directed inferomedially aiming the ostium area facing the middle turbinate and below the axilla. The author (Kaynak P) prefers to apply 2100 nm Ho:YAG laser energy (Versapulse 5000, Coherent Medical Inc., Palo Alto, CA) between 6 and 10 watts which is delivered via a 400 μ fiberoptic probe passed through the 16-gauge

needle guide. In order to ablate the soft tissue, 0.6–0.8 J at 10 Hz (6–8 W) Ho:YAG laser energy and 0.8–1.0 J at 10 Hz (8–10 W) for the bone are usually adequate settings. Single or burst modes are preferred instead of continuous laser modes for meticulous control of ablation and surgical safety. Alternatively, the surgery can also be performed using the 980 nm solid-state diode laser (Multidiode S30 OFT, INTERMEDIC, Spain), equipped with a 600 μm silica-polyamide laser fiber optics. Laser settings are adjusted for each patient between 6 W and 12 W power range, 350–500 ms pulse time, and 350–500 ms pause duration between pulses.

The guide needle holding the laser probe in its lumen is advanced as the laser probe easily ablates and glides through the soft and bony tissues, until a tunnel anastomosis is created between the conjunctival fornix and the middle meatus. Once the aiming beam appears at the targeted place across the middle turbinate (Fig. 28.19), the nasal cavity is entered (Fig. 28.20), and an inferomedially directed Bowman probe is placed into the first narrow tunnel created as a guide to the fiberoptic Ho:YAG laser delivery probe. The tunnel is enlarged with multiple passes around the guide Bowman probe until it is large enough to accommodate the CDCR tube (Fig. 28.21). CDCR tubes wedged onto the laser probe are gently inserted into the tunnel to keep the anastomosis open. The Bowman probe can also be used for the same purpose as described earlier. If polyvinylpyrrolidone (PVP)-coated silicone tube is used, it can be trimmed in the nose to the desired length (Fig. 28.22). An oversized tunnel or a small caliber tube may end up with the migration or loss of the tube. When the tube is in optimal position, it can be anchored to the caruncle with 7-0 nylon or polyglactin sutures (Fig. 28.23). Figure 28.24 shows the tube in its optimal position, inferior to the caruncle at the end of surgery. The mean surgical duration reported with Ho:Yag laser is 22 min (range 12–45 min) [23, 24].

Postoperative Regime

The postoperative regimen includes topical antibiotics and steroids, nasal decongestants, and steroid sprays for a period of 3 weeks. The patients are trained to clean the tubes using negative pressure. Non-viscous lubricating drops or normal saline are placed in operated eye (Fig. 28.25). With the contralateral nostril closed, the patient gently sniffs, which creates a negative pressure in the nasal cavity and drains the cul-de-sac fluid into the nose (Fig. 28.26). The patients are postoperatively followed up on day 1, 1 week, 6 weeks, 3 months, quarterly for 1 year, and 6 monthly thereafter. At every visit, the class of lacrimal drainage is determined, followed by irrigation through the tube to clear the mucus or debris (Fig. 28.27). Suture removal is usually done at 6 weeks follow-up (Fig. 28.28).

Objective Assessment of Tube Functions: Drainage Classes

There are four categories to assess drainage [15]. A few drops of sterile water of non-viscous lubricants are placed in the conjunctival cul-de sac with the head tipped backward and the drainage of the fluid toward the nasal cavity is assessed.

Class I drainage: Spontaneous fluid drainage.
Class II drainage: There is no spontaneous drainage but the fluid disappears on exaggerated nasal respiration.
Class III drainage: Fluid does not drain with respiration but the tube can be irrigated.
Class IV drainage: The tube cannot be irrigated.

Complications

1. Tube extrusion (Fig. 28.29)
2. Tube migration
3. Conjunctival granuloma (Fig. 28.30)
4. Peritubal soft tissue infections (Fig. 28.31)
5. Septum irritation
6. Tube blockage (Fig. 28.32)
7. Tube breakage (trauma)
8. Conjunctival pressure necrosis (Fig. 28.33)

Tube extrusion, malposition, or migration is the most common complication after surgery. These patients often need repositioning of the tube under endoscopic guidance, or even tube replacement, some needing replacement more than once [16]. If a new tube is not inserted within days, the passage created may close. Occasionally in patients, complications, maintenance, and secondary procedures required may cause dissatisfaction even with a successful functioning CDCR [17].

Outcomes

The overall outcomes of a CDCR are good, but subsequent issues related to the tube are one of the main concerns for the surgeon. Steinsapir et al. [4] studied 79 eyes with CDCR and reported a success rate of 96%; however, the extrusion rate was 51%, tube malposition in 22%, and tube obstructions in 23%. Sekhar et al. [5] studied 69 eyes and reported 98.5% of patients to be free of symptomatic epiphora; however, extrusion, malposition, and obstruction rates were 30%, 28%, and 28%, respectively. In the largest study in literature by Rose et al. [6], 326 eyes were studied and an extrusion of 41% was reported and the patient satisfactory outcomes were achieved in 91%. Lee et al. [18] studied 124 eyes and reported a successful out-

come in 97% of patients and also found lower rates of extrusion (10%); however, conjunctival overgrowth was noted in 12% of their patients. The tube fixation techniques also play a crucial role in long-term outcomes of the surgery [25, 26].

Choi and Yang [12] described an endoscopic-guided transcaruncular Jones tube intubation without a DCR with a success rate of 91.4%. They defined success as relief of epiphora along with patency of the tube to irrigation. Idiopathic canalicular obstruction was the commonest indication in their series (77%), and the length of Jones tube varied from 16 to 30 mm. The significant point to note is dramatic reduction in tube extrusions (2.9%). Although 22.9% had inferior migration, majority of them were corrected in the clinic itself with good results. However, neither the time of suture removal was specified nor the lacrimal drainage was assessed objectively. Devoto et al. [13] published a similar technique which they termed "minimally invasive conjunctivodacryocystorhinostomy" (MICDCR) using the Jones tubes with an average length of 16 mm. Notable feature of this series was no case had any extrusion of the tube although inferior migration was seen in 12.7% of the patients which were easily repositioned satisfactorily in all patients. Success in the Devoto series was based on demonstrating the aspiration of 2% topical fluorescein into the nose with endoscopy. Ali et al. [14] studied 15 patients with endoscopically guided minimally invasive bypass tube placement without a DCR and found encouraging results with regard to extrusions. However, they reported other complications like peritubal soft tissue infection and conjunctival pressure necrosis. The success rates reported with laser-assisted CDCR are also good although the rates of migration and extrusions appear to be a little lower than generally reported [19–24].

Patient satisfaction is an important aspect to be studied for CDCR. Rosen et al. [17] in their series of 121 CDCR patients showed a clinical success rate of 92.5%. However, 11.6% of patients with functional success did not feel satisfied, and 32% reported more complications than they had expected. The dissatisfaction was mostly seen in age groups below 19 or above 70 years. Hence, the authors concluded that CDCR in these age groups are best avoided unless they are severely symptomatic.

Conclusion

The choice of approach should be determined by the surgeon's experience and comfort. Endoscopic-guided minimally invasive placement of a bypass tube without DCR is an easy and effective alternative to the traditional conjunctivodacryocystorhinostomy and is likely to help in avoiding major complications of tube extrusion and malpositions seen with the latter procedure. Objective evaluation of lacrimal drainage helps in typifying and uniformly assessing the outcomes in future.

References

1. Athansiov PA, Madge S, Kakizaki H, et al. A review of bypass tubes for proximal lacrimal drainage obstruction. Surv Ophthalmol. 2011;56:252–66.
2. Jones LT. The cure of epiphora due to canalicular disorders, trauma and surgical failures on the lacrimal passages. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:506–24.
3. Jones LT. Conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1965;59:773–83.
4. Steinsapir KD, Glstt HJ, Putterman AM. A 16-year study of Conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1990;109:387–93.
5. Sekhar GC, Dortzbach RK, Gonnering RS, et al. Problems associated with Conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1991;112:502–6.
6. Rose GE, Welham RN. Jones' lacrimal Canalicular bypass tubes: twenty five years' experience. Eye. 1991;5:13–9.
7. Lim C, Martin P, Benger R, et al. Lacrimal canalicular bypass surgery with the Lester Jones tube. Am J Ophthalmol. 2004;137:101–8.
8. Mombaerts I, Colla B. Modified Jones lacrimal bypass surgery with an angled extended Jones tube. Ophthalmology. 2007;114:1403–8.
9. Gladstone GJ, Putterman AM. A modified glass tube for conjunctivodacryocystorhinostomy. Arch Ophthalmol. 1985;103:1229–30.
10. Wojno T. Experience with a Medpor-coated tears drain. Ophthal Plast Reconstr Surg. 2010;26:327–9.
11. Abdulhafez M, Elgazayerli E, Mansour T, et al. A new modification in the porous polyethylene coated Lester-Jones tube. Orbit. 2009;28:25–8.
12. Choi WC, Yang SW. Endoscopy guided transcaruncular Jones tube intubation without dacryocystorhinostomy. Jpn J Ophthalmol. 2006;50:141–6.
13. Devoto MH, Bernardini FP, Conciliis C. Minimally invasive conjunctivodacryocystorhinostomy with Jones tube. Ophthal Plast Reconstr Surg. 2006;22:253–5.
14. Ali MJ, Honavar SG, Naik MN. Endoscopically guided minimally invasive bypass tube intubation without DCR: evaluation of drainage and objective outcomes assessment. Minim Invasive Ther Allied Technol. 2013;22:104–9.
15. Gladstone GJ, Brazzo BG. Endoscopic conjunctivodacryocystorhinostomy. In: Cohen AJ, Mercandetti M, Brazzo BG, editors. The lacrimal system: Springer; 2006. p. 180.
16. Zilelioglu G, Gündüz K. Conjunctivodacryocystorhinostomy with Jones tube. A 10-year study. Doc Ophthalmol. 1996-1997;92:97–105.
17. Rosen N, Ashkenazi I, Rosner M. Patient dissatisfaction after functionally successful conjunctivodacryocystorhinostomy with Jones tube. Am J Ophthalmol. 1994;117:636–42.
18. Lee JS, Jung G, Lee JE, et al. The treatment of lacrimal apparatus obstruction with the use of an inner canthal Jones tube insertion via a transcaruncular route. Ophthalmic Surg Lasers. 2001;32:48–54.
19. Gonnering RS, Lyon DB, Fisher JC. Endoscopic laser-assisted lacrimal surgery. Am J Ophthalmol. 1991;111:152–7.
20. Kaynak-Hekimhan P, Yılmaz ÖF. Holmium:YAG laser assisted lacrimal bypass surgery in management of severe trauma to lacrimal drainage system. 39th Annual Meeting of American Society of Ophthalmic Plastic and Reconsructive Surgery, 2004, New Orleans, LO.
21. Alañón Fernández MA, Alañón Fernández FJ, Martínez Fernández A, et al. Conjunctivodacryocystorhinostomy with the assistance of diode laser. Endoscopic placement of Jones lacrimal tubes. Acta Otorrinolaringol Esp. 2008;59:11–5.
22. Kumar N, Lazar D, Al-Hariri AB. An alternative technique describing laser-assisted conjunctivodacryocystorhinostomy (CDCR) using the 532nm diode laser. ARVO Meetings abstracts. Invest Ophthalmol Vis Sci. 2014;55:2778.

23. Kaynak-Hekimhan P, Yılmaz ÖF. Holmium:YAG LASER lacrimal by-pass surgery. Tech Ophthalmol. 2006;4:39–44.
24. Boboridis KG, Downes RN. Endoscopic placement of Jones lacrimal tubes with the assistance of holmium YAG laser. Orbit. 2005;24:67–71.
25. Putterman AM. Fixation of pyrex tubes in conjunctivodacryocystorhinostomy. Am J Ophthalmol. 1974;78:1026–7.
26. Ma'luf RN, Bashshur ZF, Noureddin BN. Modified technique for tube fixation in conjunctivodacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2004;20:240–1.

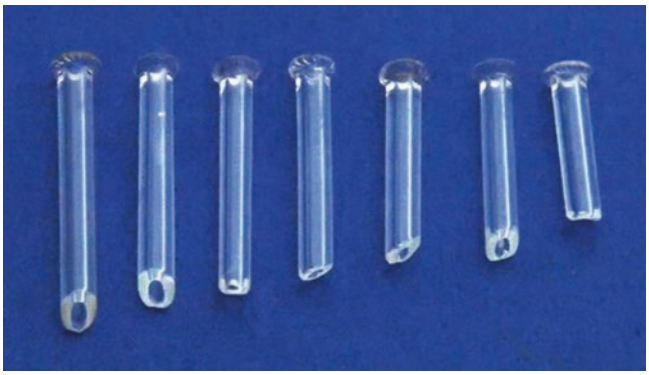


Fig. 28.1 Lester Jones tubes of various sizes

Fig. 28.2 The three gold dilators

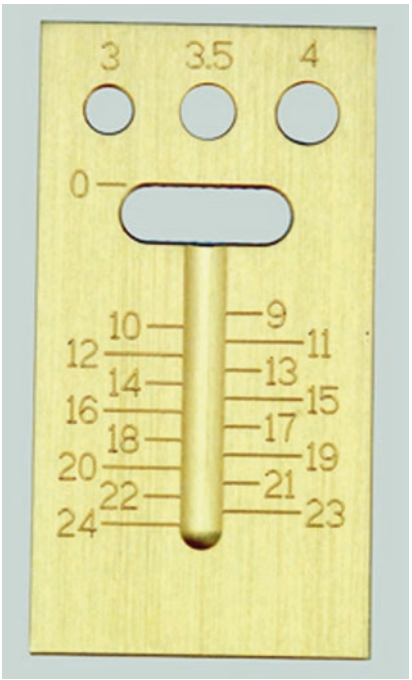


Fig. 28.3 Tube measuring scale

Fig. 28.4 A CDCR set

Fig. 28.5 Gladstone-Putterman tube

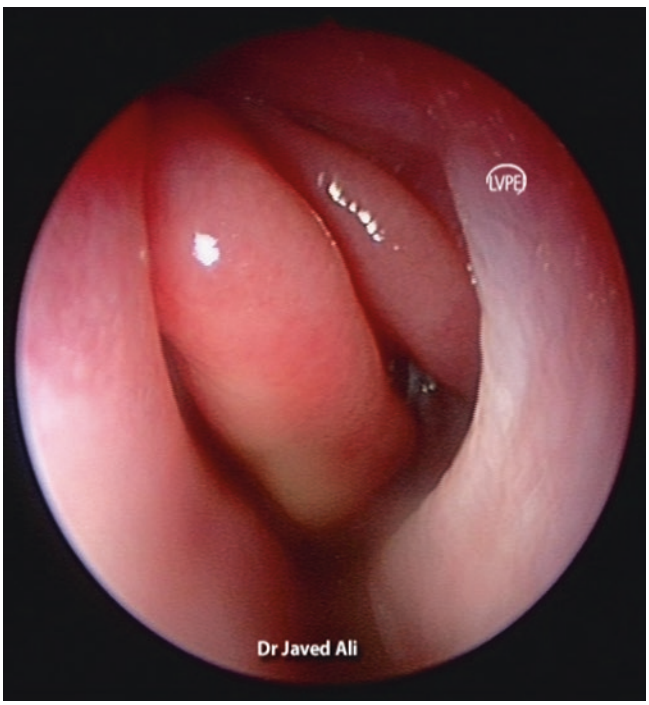


Fig. 28.6 Preoperative endoscopic examination of middle meatus

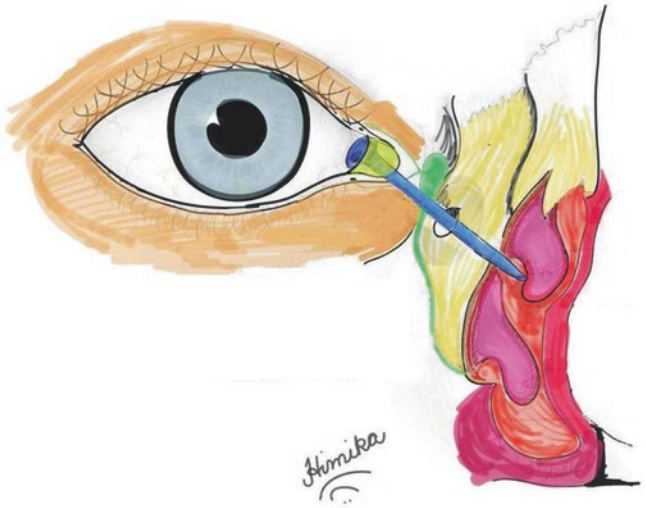


Fig. 28.7 Schematic diagram showing minimally invasive bypass tube placement without DCR. Note the head of middle turbinate obstructing the path of the tube (Photo courtesy: Himika Gupta)

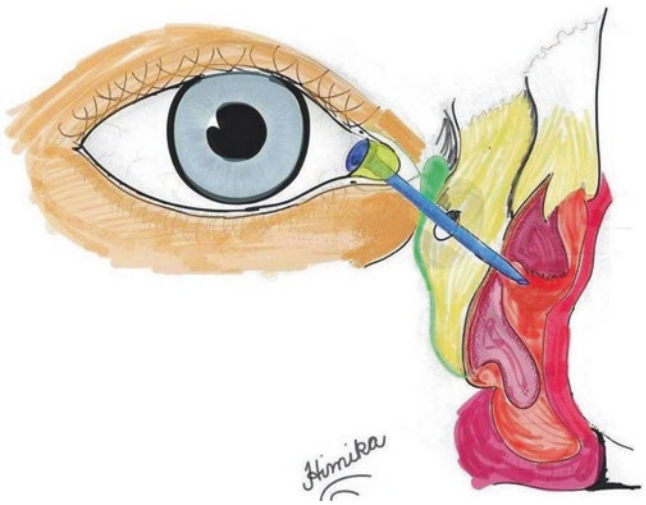


Fig. 28.8 Schematic diagram showing a partial middle turbinectomy (Photo courtesy: Himika Gupta)

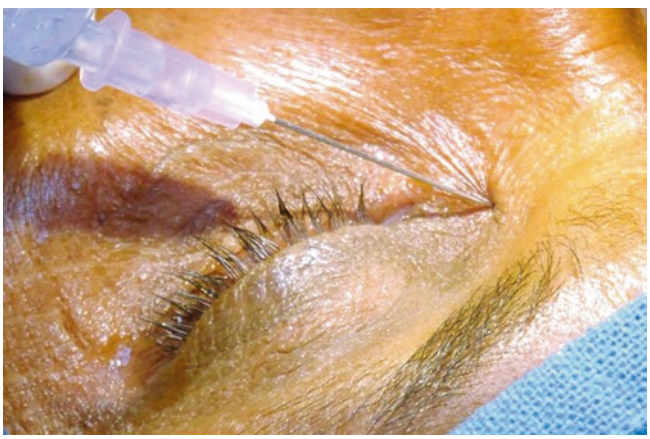


Fig. 28.9 Local anesthetic infiltration

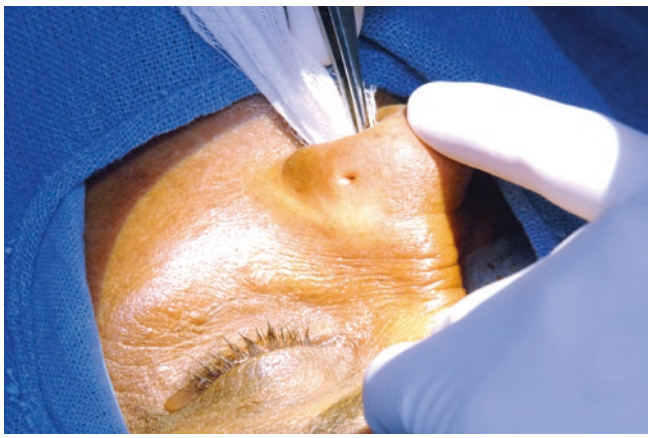


Fig. 28.10 Nasal decongestion with medicated packing

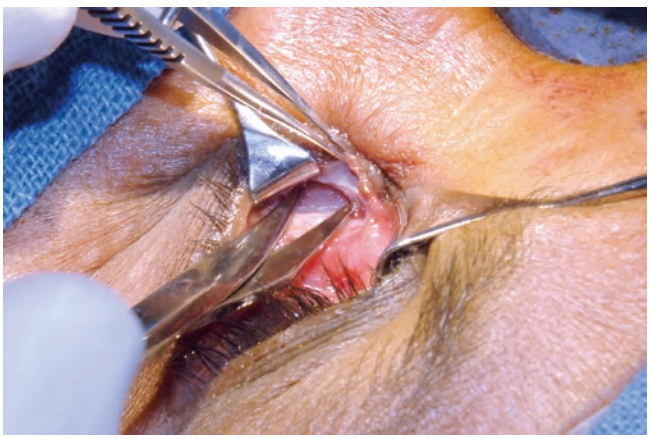


Fig. 28.11 Conjunctival incision and dissection

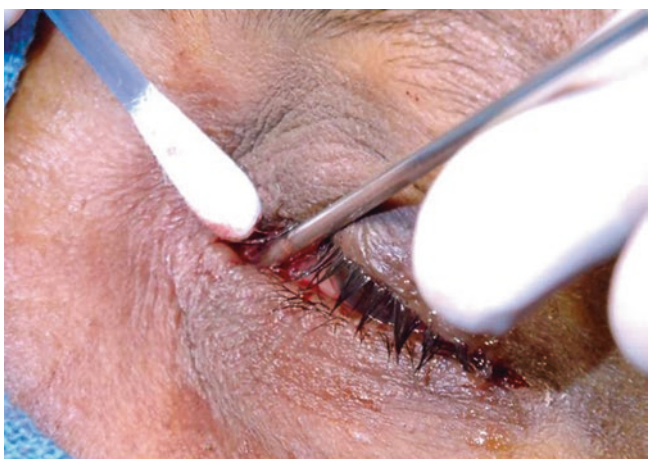


Fig. 28.12 14-gauge needle to create track for bypass tubes

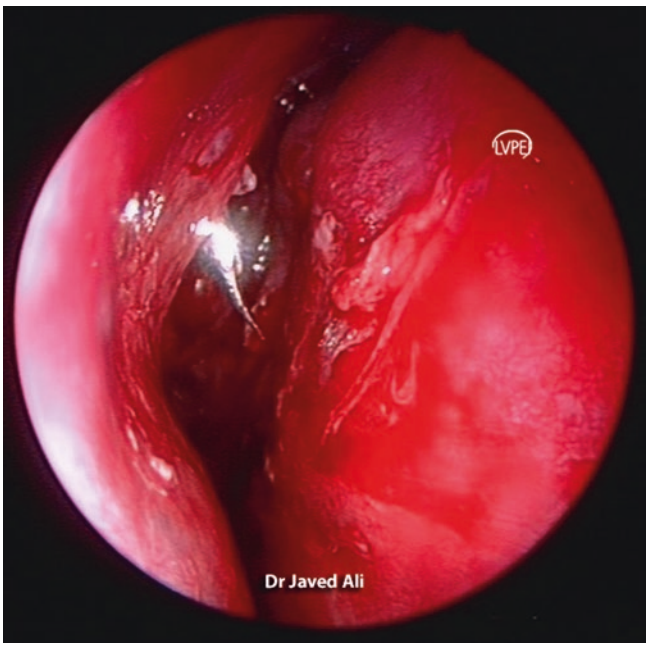


Fig. 28.13 Endoscopic view of the desired tube position being measured with the needle

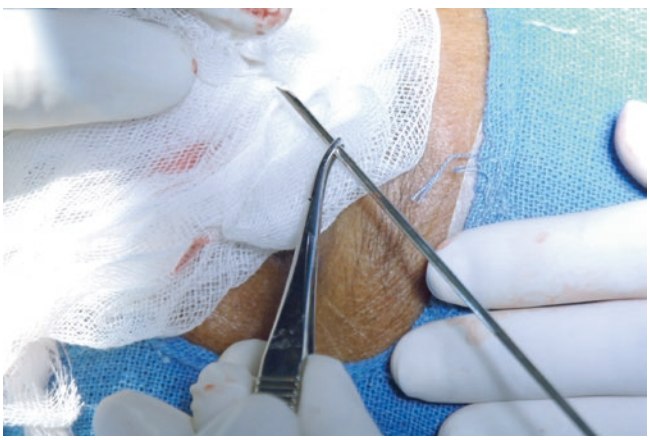


Fig. 28.14 Needle measurement for the Jones tube length

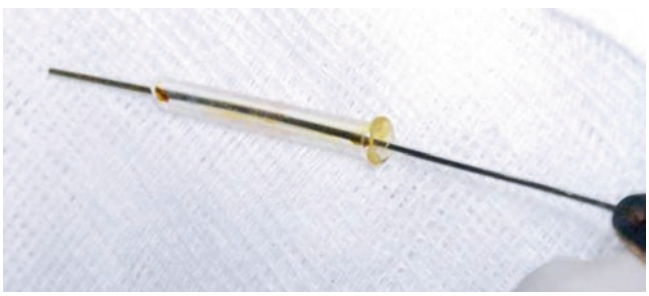


Fig. 28.15 Tube being mounted onto a Bowman probe

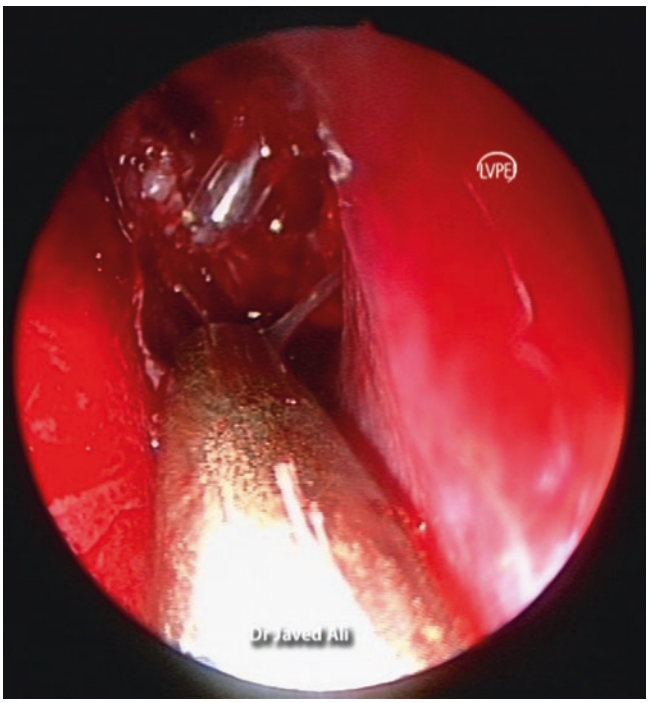


Fig. 28.16 Ideal tube placement. Note middle turbinectomy has already been performed

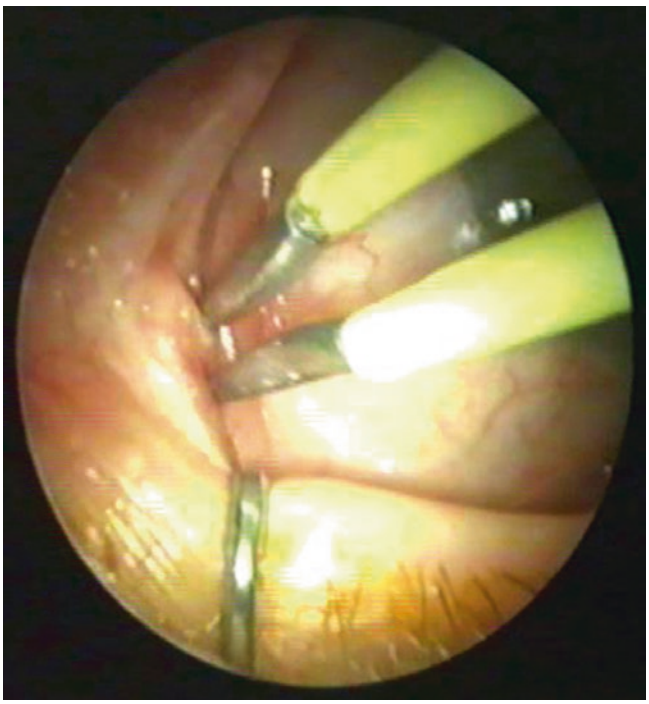


Fig. 28.18 Laser-assisted CDCR (LCDCR). Shrinking of the caruncle

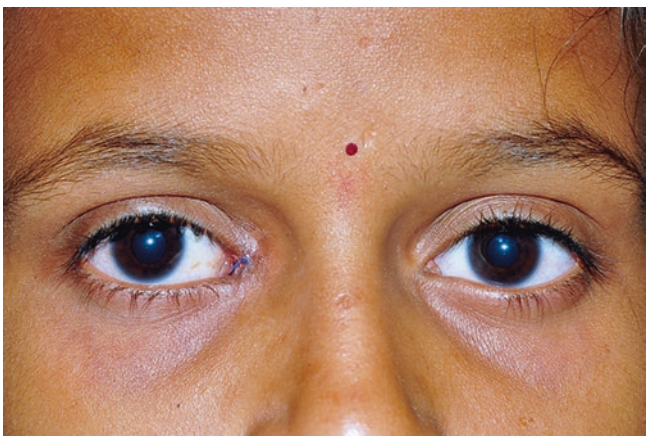


Fig. 28.17 Postoperative view of a patient with right bypass tube placement

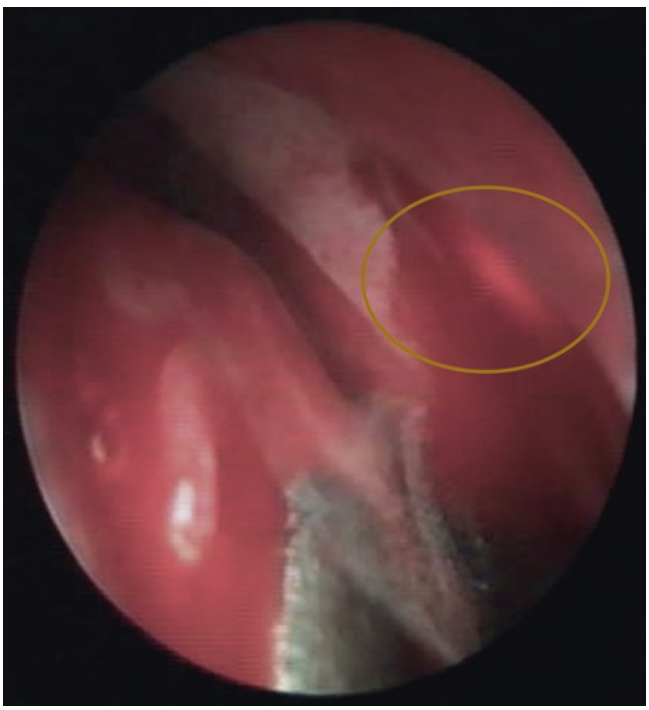


Fig. 28.19 LCDCR: visualization of the light probe endoscopically

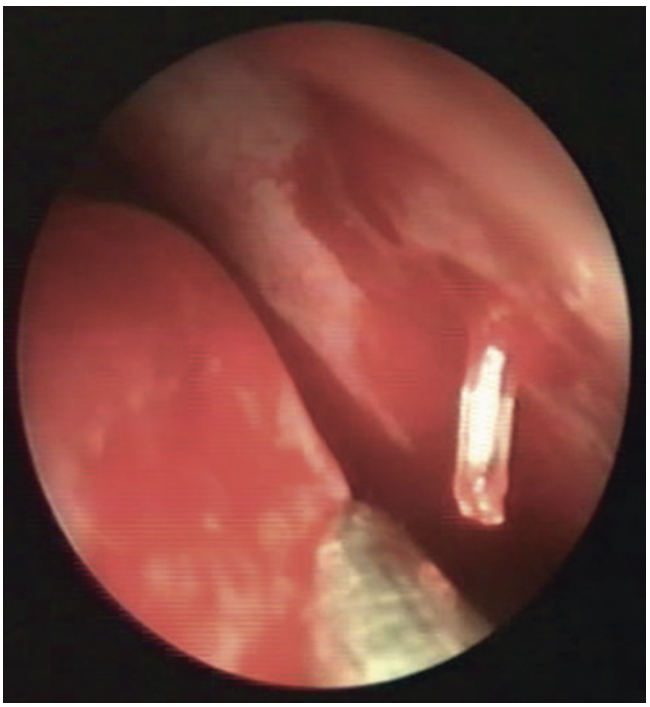


Fig. 28.20 LCDCR: laser osteotomy

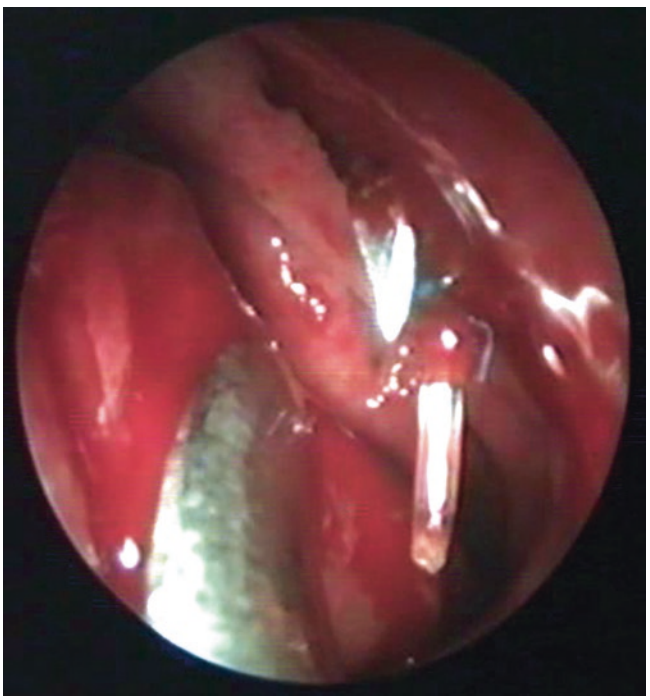


Fig. 28.21 LCDR: enlarging the osteotomy

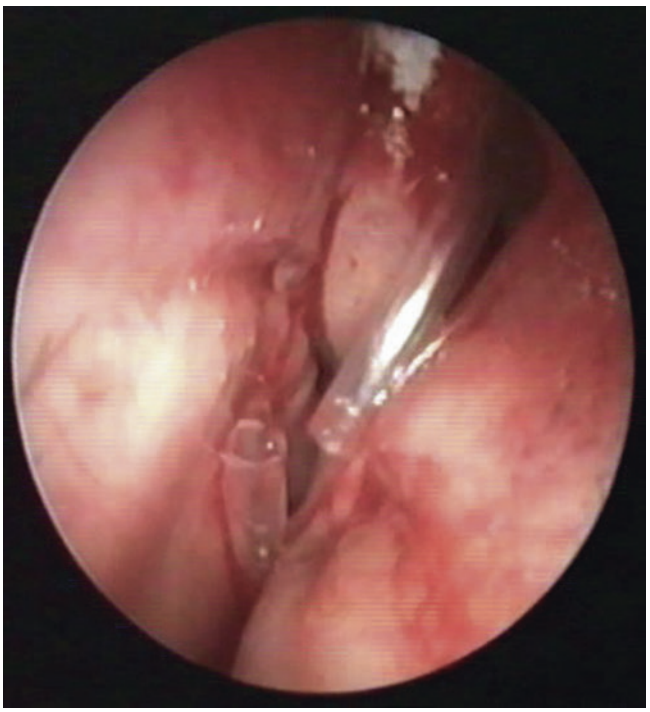


Fig. 28.22 LCDCR: trimming of the PVP tube

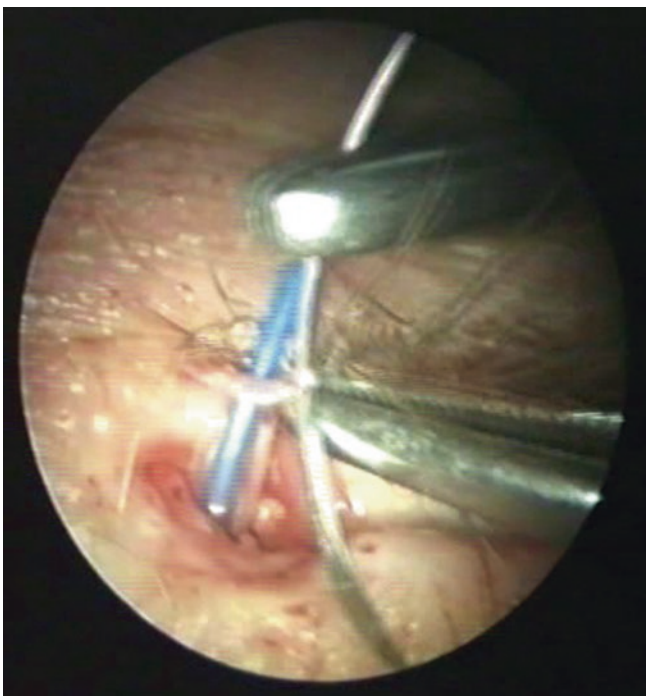


Fig. 28.23 LCDCR: threading the Jones tube over the laser fiber optics

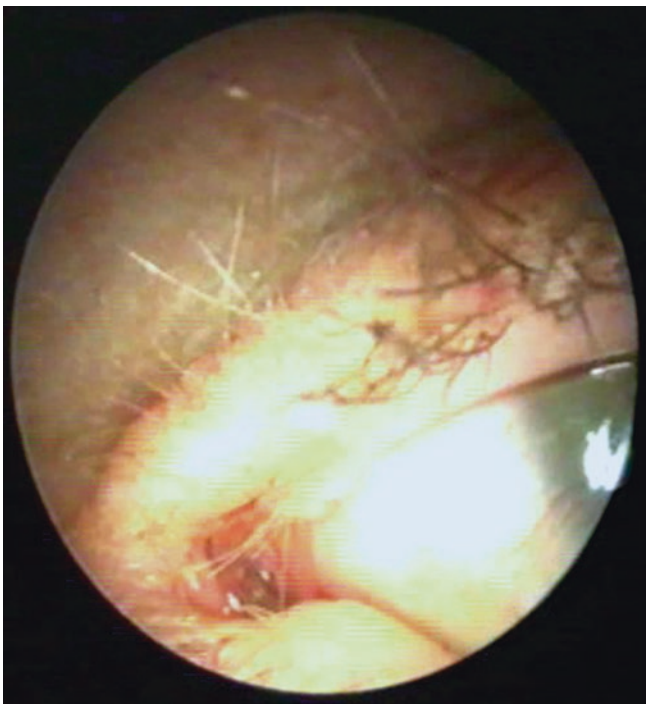


Fig. 28.24 LCDCR: optimal Jones tube positioning

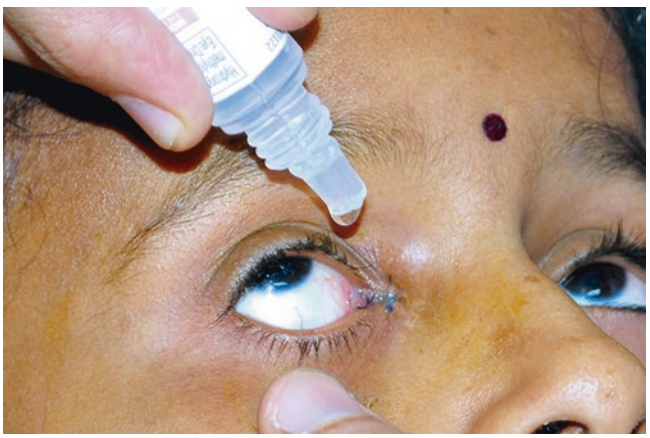


Fig. 28.25 Tube cleaning procedure: introduction of few drops of non-viscous fluid or normal saline

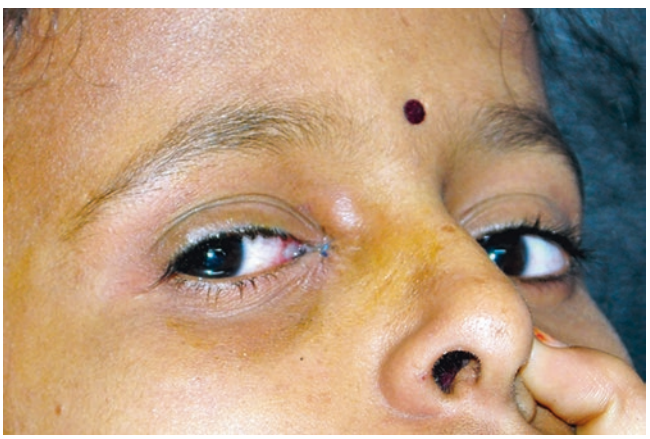


Fig. 28.26 Tube cleaning procedure: drainage into the tube by negative pressure

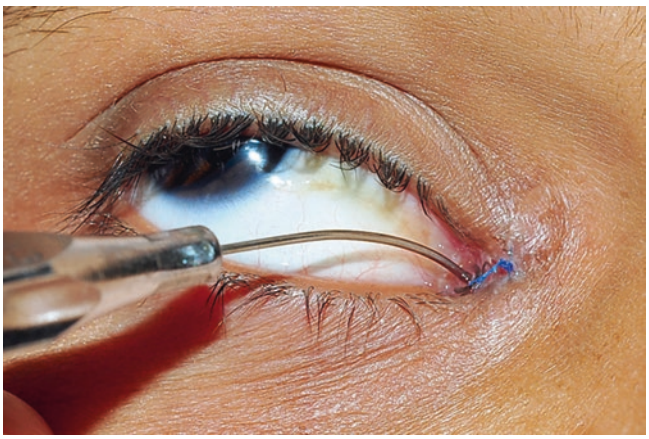


Fig. 28.27 Tube being irrigated to clear off the mucous plugs or debris

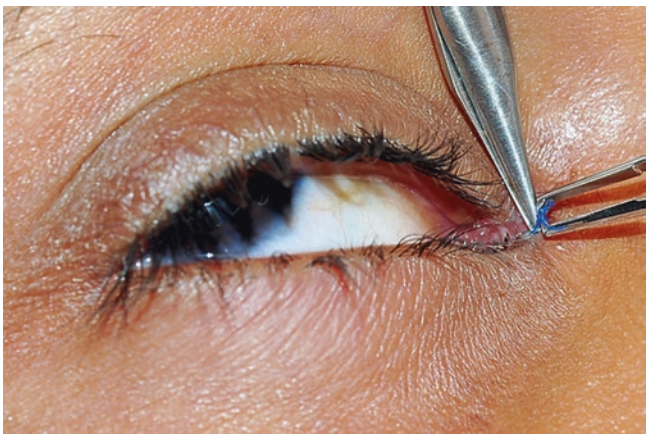


Fig. 28.28 Tube suture removal

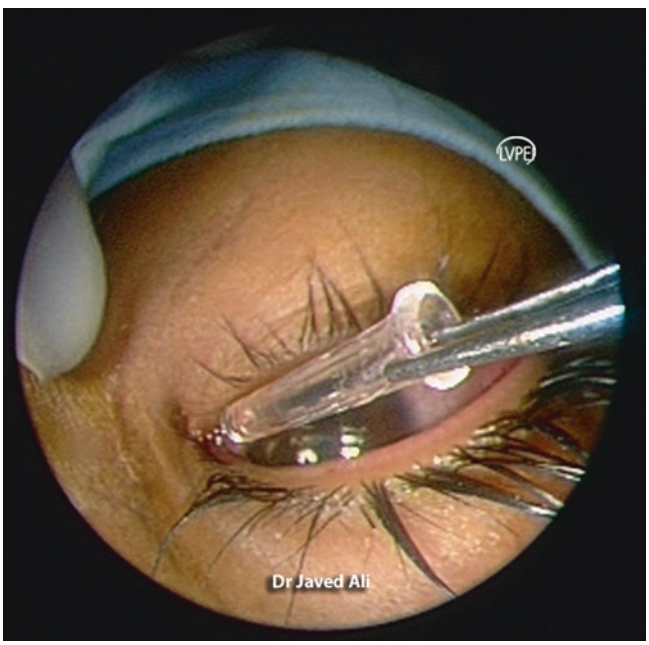


Fig. 28.29 Extrusion of inadequately sized and positioned tube

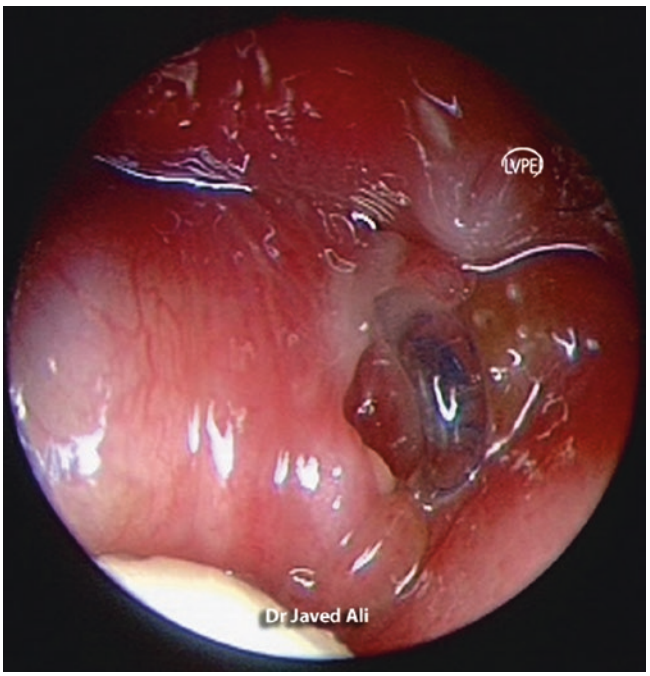


Fig. 28.30 Peritubal conjunctival granuloma

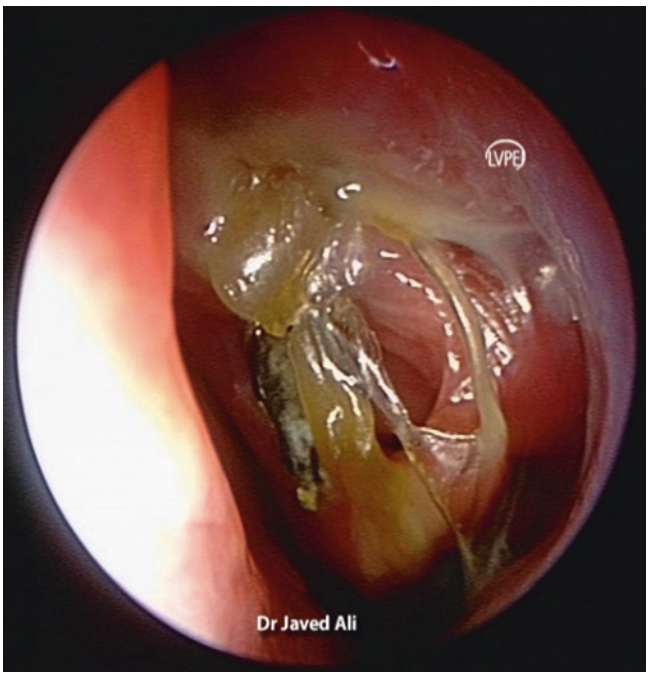


Fig. 28.32 Tube blocked by mucous plugs and discharge

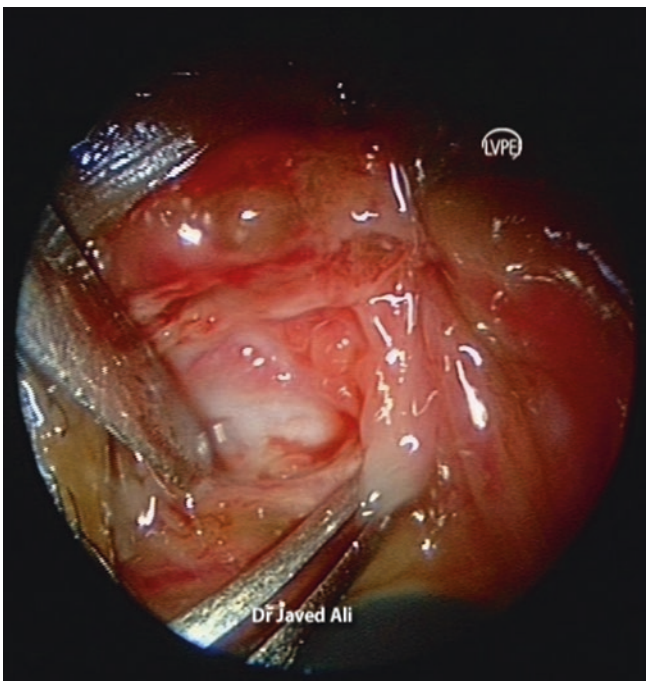


Fig. 28.31 Peritubal soft tissue infection

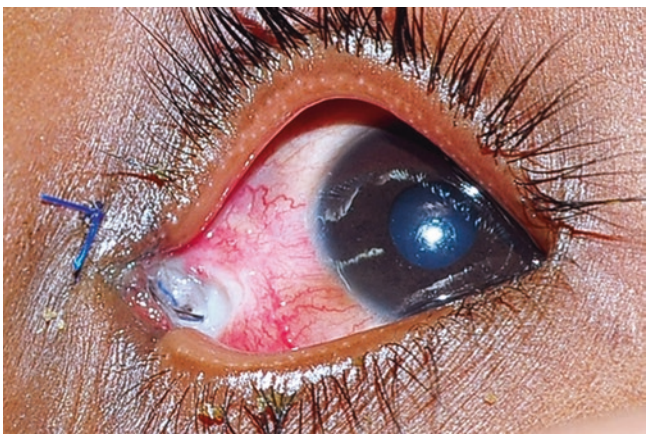


Fig. 28.33 Conjunctival pressure necrosis

Adjunctive Endonasal Procedures During Lacrimal Surgery

29

Alkis James Psaltis and Luis Fernando Macias-Valle

Introduction

Endoscopic dacryocystorhinostomy has become a common procedure for the management of certain lacrimal conditions. Its high success rate and no cosmetic morbidity have made it an attractive alternative to traditional external approaches. To perform this procedure well, the surgeon must have a sound understanding of endoscopic endonasal anatomy and its normal anatomic variants and be well trained in the use of the nasal endoscope. Figure 29.1 highlights important normal endoscopic anatomy that will be referenced in the chapter.

Preoperative Assessment

Prior to endoscopic surgery all patients should undergo a complete endoscopic assessment of their nasal cavity. This examination will allow the preoperative identification of normal anatomical variants such as a deviated nasal septum or pneumatized middle turbinate, which may hinder visualization and access to the lacrimal sac during endoscopic surgery. The decision on whether adjunctive endonasal procedures will be required at the time of lacrimal surgery should therefore occur in the preoperative setting to facilitate the informed consent process and optimize surgical planning. Figures 29.2 and 29.3 represent the basic office setup required to perform the preoperative examination.

A.J. Psaltis, F.R.A.C.S. (✉)
Department of Otolaryngology, Head Neck Surgery, The Queen Elizabeth Hospital, Adelaide, Australia
e-mail: alkispsaltis@gmail.com

L.F. Macias-Valle
The Queen Elizabeth Hospital, Adelaide, Australia

Topical Anesthesia

The preoperative examination occurs in the ambulatory clinic setting under topical anesthesia. Topical agents are most commonly administered in an aerosolized form or on presoaked packing materials and usually contain rapid-onset anesthetic agents such as lidocaine and a vasoconstrictor agent such as phenylephrine or oxymetazoline. Commercially available combination sprays are available and provide an easy and effective way of preparing the nose for the examination. One such example of this is the product Cophenylcaine Forte^{R} (ENT technologies, Melbourne Victoria, Australia) which contains 50 mg/ml of lidocaine hydrochloride and 5 mg/ml of phenylephrine. Figures 29.4 and 29.5 show this product with the patented single-use disposable nozzle that allows delivery deep with the nasal cavity. The use of these agents will not only increase the comfort of the endoscopy but also improve the overall visibility and access by reducing mucosal edema.

Basic Nasal Endoscopy

Patients should be positioned comfortably in an upright position with their head supported by a firm headrest. Ideally, the neck should be in the neutral position with minimal flexion or extension. To perform rigid nasal endoscopy in adults, a 3-mm or 4-mm, 0°or 30°**,** rigid endoscope is typically well tolerated, while in younger children a 2.7-mm scope may be preferred to navigate the smaller nasal cavity. The scope lens is first prepared with a thin layer of antifog solution to prevent the warm expired nasal air clouding the field of vision. Although commercially available preparations are present, cetrimide solution typically works just as well. Endoscopy should then be performed in a structured systematic fashion. The endoscope is introduced into the nasal cavity and anchored at the apex of the nostril superiorly to add stability to the procedure. Contact with the nasal mucosa should be avoided at all times. Employing a three pass technique, the

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_29

first pass is made along the nasal floor to visualize the inferior meatus as well as the post nasal space. The second pass is then made between the inferior and middle turbinates to visualize the middle meatus. Edema, purulence, and polypoid disease should be looked for as possible markers of concomitant sinus disease. If present, then further imaging should be organized typically comprising of a fine-cut computerized tomography of the paranasal sinuses. Close inspection of the shape and size of the middle turbinate will also be performed during this pass to exclude a concha bullosa or paradoxically curved middle turbinate that may need to also be dealt with at the time of DCR surgery to improve access. The third pass should then be performed to visualize the olfactory cleft and swept superiorly to visualize the axilla of the middle turbinate. This will not only allow visualization of any polyps within the sphenoethmoidal recess but will also allow the surgeon to assess whether the patient has a septal deviation that may preclude access to the lateral nasal wall during surgery. If the axilla cannot be visualized completely or the access is deemed too narrow for an obstructed endoscopic DCR, then the patient should be counseled preoperatively of the highly likelihood of also requiring a septoplasty as part of their lacrimal procedure. Having identified all of the anatomical variations on preoperative endoscopy, a clear surgical plan can be conveyed to the patient and informed consent obtained.

Surgery

Patient Positioning

Patient positioning is critical to the safety of the patient, the surgical field attainable, and the ergonomics of the surgery. In our department, the surgery is performed with the surgeon seated on the right of the patient. The operating bed is typically reversed to allow the surgeon to have their legs under the bed while in this sitting position. The surgeon's left elbow is supported on an arm board anchored to the operative bed to increase the stability of the scope held in the nondominant hand. The patient is positioned supine, with their head in a neutral position and the bed placed in a reverse Trendelenburg position. Head elevation has been shown to reduce the mean arterial pressure in the elevated region by 2 mm Hg for every 2.5 mm above cardiac level [1]. Cerebral perfusion studies have also demonstrated that the ideal angle of tilt is between 20 and 30° above the horizontal as this decreases venous congestion without affecting cerebral perfusion [2]. The angle of tilt has also been correlated with improvement of surgical field of view scores and decrease blood loss [3]. The endoscopic tower is positioned in the surgeon's straight line of sight to increase surgeon comfort and avoid rotation of the surgeon's neck. The monitor should be positioned at eye level to minimize extension of the surgeon's neck. Figures 29.6 and 29.7 demonstrate the ideal positioning of the bed and the operating room setup.

Instrumentation

Table 29.1 summarizes a list of the endoscopic surgical instruments required for endoscopic DCR surgery and adjunctive nasal procedures. Items produced only by a single company include the manufacturer's details also. Using a bimanual technique, the surgeon holds the rigid endoscope in his/her left hand, with their elbow firmly positioned on the arm rest. The endoscope is inserted into the nostril retracting the apex of the nasal vestibular skin. Tenting the nostril in this way not only adds further stability to the endoscope but also increases the working space for the second surgical instrument held in the dominant hand. The surgeon should consciously avoid any instrument cross by always maintaining the endoscope in a superior position to the operating instrument. Nasal procedures including septoplasty, middle turbinate surgery, and anterior ethmoid surgery will typically require the use of a 0° endoscope, while the majority of the DCR procedure itself is performed with the 30° endoscope given the lateral location of the lacrimal sac on the nasal wall.

Table 29.1 Endoscopic DCR instrumentation

Basic endoscopic equipment
0° and 30° 4-mm rigid endoscope
Endo-scrub two lens-cleaning sheaths (Medtronic ENT Jacksonville, Fl, USA)
15 scalpel or monopolar needle tip for mucosal incisions (Bovie Medical)
Malleable suction Freer elevator (Medtronic ENT)
Malleable suction curette (Medtronic ENT)
Hajek-Koffler forward-biting punch
Freer's dissector
Tilley-Henkel forceps
Variable sized osteotomes
Endoscopic sinoscopy scissors
DCR instrumentation
Microdebrider instrumentation (Medtronic ENT)
Medtronic integrated power console
M4 or M5 handpiece
25° curved 2.5-mm rough diamond DCR bur
Wormald dacryocystorhinostomy set (Medtronic ENT)
Spear knife
Micro sickle knife
Lusk MicroBite forceps
Lacrimal punctum dilator
Bowman lacrimal probe
O'Donoghue lacrimal intubation tubes (Beaver-Visitec International Waltham, MA, USA)

Surgical Field

Nasal Preparation

Optimizing the surgical field is critical to the performance of safe and efficient endoscopic endonasal surgery. This commences with the preparation of the nasal mucosa. After induction of general anesthetic, the surgeon injects 1–2 ml of 2% lignocaine with 1:80,000 adrenaline into the region of the axilla of the middle turbinate and the adjoining lateral nasal wall. Injection continues until blanching of the mucosa is seen. The use of pre-filled anesthetic cartridges in a dental syringe can eliminate the inadvertent injection of higher concentrations of adrenaline. This injection can be performed with the use of a headlight or under direct endoscopic visualization if access is difficult. If a septoplasty or middle turbinate surgery is to be performed for surgical access, the surgeon should also inject the caudal septal mucosa and head of the middle turbinate, respectively, at the site of the likely incisions. For DCR surgery the lateral nasal wall is injected around the insertion of the middle turbinate. To ensure adequate topicalization of the entire nasal mucosa, the surgeon then places three ½ in. × 1 in. cottonoid pledgets soaked in a mixture of 2 ml 10% cocaine solution, 1 ml 1:1000 adrenaline, and 4 ml normal saline into each nasal cavity. If there is a contraindication to cocaine or difficulty in obtaining cocaine solution, 1:1000–1:10,000 adrenaline can be used alone. For endoscopic lacrimal surgery, we typically recommend placing one pledget along the septal mucosa, one into the middle meatus between the middle turbinate and lateral nasal wall and one along the lateral nasal wall overlying the axilla. Any solution left over from the initial mixture is handed over to the scrub nurse for later use if required.

Anesthetic

The manner in which general anesthesia is induced and maintained is critical for the surgical field. Ideally for nasal surgery, a laryngeal mask (LMA) is preferred over endotracheal intubation. It is associated with less respiratory and cardiovascular reflex responses due to reduced stimulation of the larynx as compared to endotracheal intubation. Moreover, LMA facilitates controlled hypotension, allows for a lighter depth of anesthesia, and is associated with less coughing and strain upon emergence. The use of a small throat pack above the mask can minimize the risk of any contamination of the upper airway by the blood during the case [4]. Total intravenous anesthesia (TIVA) utilizing propofol and an opioid such as remifentanil has been shown to be an effective way of delivering controlled hypotensive general anesthetic. TIVA avoids the use of inhalational agents that typically cause end arteriolar vasodilation and may increase surgical bleeding. Ideally, if not medically contraindicated, pulse rate should be maintained between 60 and 70 beats per minute to increase venous return by increasing end-diastolic filling time, and mean arterial blood pressure should be maintained around 65–70 mmHg to avoid organ and cerebral hypoperfusion [5].

Surgical Technique: Adjunctive Nasal Procedures

A recent review by our department revealed that additional adjunctive procedures are required in approximately half of the patients undergoing endoscopic DCR [6]. These procedures range from those aimed at improving access to the lateral nasal wall such as septoplasty and middle turbinoplasty as well as performing functional endoscopic sinus surgery (FESS) for concomitant sinus disease. The next section describes in detail the surgical steps involved in performing an endoscopic septoplasty and concha bullosa reduction. Oculoplastic surgeons wishing to perform endoscopic lacrimal surgery should be well skilled in these two procedures.

Endoscopic Septoplasty

Exposure and access are the two primary indications for performing a septoplasty during endonasal lacrimal surgery. Deviations precluding complete visualization of the axilla of middle turbinate should be addressed. By performing a septoplasty early, inadvertent trauma to the septal mucosa can be avoided. This further reduces the risk of synechiae formation that may compromise success rates. Before performing this procedure, the operating surgeon should be familiar with the anatomy of the septum and important regions that must be respected to avoid compromising structural support.

The septum is composed of the cartilage anteriorly and bone posteriorly. The cartilaginous component is formed by the quadrilateral cartilage that articulates posteriorly with perpendicular plate of the ethmoid, inferiorly with the maxillary crest, posterosuperiorly with the nasal bones, and postero-inferiorly with the vomer. It is lined by mucosa that firmly attaches to the cartilage by a mucoperichondrial layer and the bone by a mucoperiosteal layer. These layers are not continuous but rather fuse inferiorly to insert into the septum as decussating fibers. When performing a septoplasty, at least 1.5 cm of dorsal and caudal cartilage needs to be preserved to preserve its support and structure. Violation of this can compromise function as well as lead to cosmetic abnormalities such as saddling of the nasal dorsum or ptosis of the nasal tip.

Septoplasty was traditionally performed using a headlight and nasal speculum (Figs. 29.8 and 29.9). The performance of this procedure with an endoscope confers many advantages including improved magnification and illumination.

A recent literature review comparing endoscopic versus open septoplasty concluded that the endoscopic technique had shorter operating times, less mucosal damage, and less residual deformity [7]. Irrespective of the technique employed, the principles of surgery remain the same. A stepwise summary of the procedure is described in Figs. 29.10, 29.11, 29.12, 29.13, 29.14, 29.15, 29.16, 29.17, and 29.18. The procedure commences with the mucosal incision. Broad anterior deviations are best addressed through a hemi-transfixion incision (Fig. 29.9), while more posterior deflections can be addressed through a Killian incision. The advantage of the Killian incision is that it can be performed with the endoscope, while the hemi-transfixion incision still requires the use of a headlight and nasal speculum at the beginning of the procedure. The Killian incision is placed at the mucocutaneous junction and typically performed with a 15″ scalpel blade. It should be broad based extending from the dorsum of the nose, inferiorly onto the maxillary crest. Curving the incision posteriorly at its most inferior extent may prevent the septal mucosal flap from tearing during the procedure. The depth of the incision should traverse all the soft tissue layers of the mucosa down to the cartilage to facilitate early identification of the sub-mucoperichondrial plane. Identification of this plane is critical to the entire procedure as dissecting beneath it yields an avascular surgical plane and maximizes flap vascularity and strength [8]. Given its adherence to the cartilage, this plane can be difficult to identify and raise. The use of a sharp instrument such as the sharp end of a Freer's dissector, a suction curette, the tips sharp tapered iris scissors, or the back of the # blade 15 can help identify the cartilaginous surface. This surface typically is pearly white with a blue tinge when viewed under the endoscope and has a less smooth sensation than the mucoperichondrium. Once identified, the flap is further raised to allow the endoscope to be inserted. The surgeon can then proceed to raise the entire sub-mucoperichondrial plane in a sweeping motion from superior to inferior using Freer's suction instrument. The tip of the freer should always be angled toward the septum and kept in close contact with the septum to avoid causing an inadvertent perforation of the mucosal flap. The flap should be raised beyond the deviation and beyond the osseocartilaginous fusion of the quadrilateral cartilage with the ethmoid plate. Once ipsilateral dissection has been performed, the cartilage is then transected carefully using a freer to allow a contralateral mucosal flap to be elevated. This cartilaginous incision is placed anterior to the deviation and should not extend higher than 1.5 cm beneath the dorsal edge of the septum. In this way the dorsal support of the septum will be maintained and the risk of "saddling" will be minimized. Once the transection incision has been carried through the cartilage, the freer will enter the sub-mucoperichondrial plane on the contralateral side, and the contralateral mucosa can then be elevated off the cartilage and ethmoid bone. This will isolate the cartilage/bone from the mucosa bilaterally and allow it to be resected without injuring the mucosa. Prior to removing the cartilage/bone, a superior cut should be performed parallel but inferior to the dorsum using an endoscopic scissor. This will safeguard against inadvertently fracturing of the skull base at the insertion of the ethmoid plate when the ethmoid bone is removed. The deviated cartilage/bone can then be removed using a grasping instrument such as an Irwin Moore or Tilley-Henkel forceps. Following removal of the deviation, the bilateral mucosal flaps can then be laid back down. If completely intact, a unilateral drainage hole placed as posteriorly as possible in a dependent position should be created to allow drainage of the blood from the surgical site and prevent a septal hematoma. The two flaps can then be approximated using a quilting stitch with a dissolvable suture such as a 4/0 Vicryl Rapide. The anterior incision site can be incorporated into this closure or closed separately. The purpose of the quilting stitch is to remove as much "dead-space" as possible and allow the two mucosal flaps to adhere to each other.

Complications

All patients undergoing septoplasty should be consented of potential complications prior to surgery. Complications include bleeding, infection, septal hematoma or abscess formation, septal perforation, cosmetic complications, loss of structural support, tip ptosis, paresthesia of the upper teeth, and cerebrospinal fluid leak. The rate of perforation varies considerably between studies. Older studies employing more extensive submucosal resection of the septal cartilage quote up to 25%, whereas modern septoplasty techniques aimed at conserving as much cartilage as possible report lower rates, closer to 5%. The risk of perforation can be minimized by meticulous surgical technique, dissecting beneath the sub-mucoperichondrial/sub-mucoperiosteal plane and ensuring that at least one mucosal flap remains completely intact during the procedure. It is important to remember that all surgical procedures have a learning curve to reduce complications and standardize success rates. Champagne et al. [9] recently demonstrated that after 60 endoscopic septoplasties, rates of intra- and postoperative complications decreased satisfactorily.

Concha Bullosa Reduction

Pneumatization of the middle turbinate is not an uncommon occurrence. The reported incidence of concha bullosa ranges anywhere between 14 and 53% with the variation in incidence reflective of differing anatomical definitions [10]. Although most commonly occurring unilaterally, bilateral pneumatization can be present in up to 20% of patients [11].

Although considered a normal anatomical variant, concha bullosa appear significantly associated with a contralateral septal deviation and may require reduction if particularly large or if it interferes with endoscopic access during a DCR (Fig. 29.19). A recent study by Ali et al. [6] reported the necessity for a concurrent middle turbinoplasty in up to 6% of endoscopic DCR cases.

Numerous techniques for reducing a middle turbinate concha bullosa have been described. All share a common principle of resection of the lateral aspect or lamella, with preservation of as much of the medial lamella as possible. Excessive manipulation of this medial portion should be avoided at all times given its insertion into the skull base. Our preferred technique is described as follows. Using a #15 blade, a vertical stab incision is made into the head of the middle turbinate. Using a sawing motion, this incision is extended superiorly and inferiorly. 5-mm endoscopic scissors can then be inserted and rotated 90 degrees to further distract the lateral and medial lamellae. The surgeon can then use the scissors or knife to continue the incision posteriorly along the inferior and superior margins of the middle turbinate to their lateral insertion. Once removed, the straight microdebrider can be used in forward high-speed motion to tidy up the mucosa edges, ensuring preservation of the anteromedial mucosa (Figs. 29.20, 29.21, 29.22, and 29.23).

Often reducing a concha bullosa can destabilize the middle turbinate. If this occurs and there is any risk of lateralization, the remaining middle turbinate should be sutured with a 4/0 Vicryl Rapide to the septum. This will minimize the risk of a postoperative adhesion to the lateral nasal wall that may interfere with the drainage of the ostiomeatal unit.

Inferior Turbinoplasty

Proper patient assessment and a trial of medical therapy should be performed before the decision is made to reduce the turbinates. In those patients that fail medical therapy and in whom other contributing factors have been eliminated (allergies, sinus disease, etc.), turbinate reduction is a valid option with improvement of the patient's nasal airway and frequently in their quality of life. Occasionally the inferior turbinate may be grossly hypertrophied, and one may need a turbinoplasty to gain a comfortable space for other procedures like septoplasty or even balloon lacrimal procedures of the NLD in adults.

Inferior turbinoplasty is the procedure of choice as it maintains the functional medial surface of the turbinate while effectively reducing the size of the turbinate avoiding such complications as atrophic rhinitis and empty nose syndrome. This preservation of the medial wall of the inferior turbinate maintains the airflow receptors in this wall and avoids the "empty nose syndrome" in which the patient cannot perceive airflow despite a widely patent nasal airway. In this technique, local anesthetic agent is infiltrated into the head of the inferior turbinate (IT) (Fig. 29.24), and an incision is taken on the head (Fig. 29.25). The head is trimmed onto the bone allowing space for the endoscope and a powered microdebrider to be placed. The microdebrider is used to remove the soft tissue over the inferior and medial portions of the turbinate. Next a dissector is used to dissect in the subperiosteal plane (Fig. 29.26) the medial mucosa and remaining lateral mucosa from the vertical portion of the inferior turbinate bone, isolating the bone (Fig. 29.27). The bone is removed, and any residual bone fragments are cleared with a ball probe, backbiter, or other endoscopic instruments (Fig. 29.28). Once this bone is removed, the two vessels supplying the inferior turbinate can be visualized in the posterior region of the turbinate. These vessels are cauterized with a bipolar forceps. The residual turbinate is then rolled laterally so that the medial mucosa covers any exposed tissue minimizing postoperative crusting (Fig. 29.29). The rolled turbinate is held in place with a strip of oxidized cellulose or Surgicel. No other packing is used in the nose. The powered inferior turbinoplasty preserves the medial aspect of the mucosal covering of the inferior turbinate and therefore reduces the risk associated with standard turbinectomy procedures while still giving long-lasting results [12] (Fig. 29.30).

Other Adjunctive Procedures

There can be occasions when associated conditions like sinusitis (Fig. 29.31) and polyposis in the middle meatus (Fig. 29.32) may have to be dealt at the same time along with DCR surgery. Literature review has shown that in rhinology practices, up to 6% of patients underwent ancillary endoscopic sinus surgery and concha reduction for ongoing nonresponsive chronic sinusitis or nasal polyposis along with lacrimal surgery [6, 9]. The various nuances of functional endoscopic sinus surgery (FESS) are too numerous to cover in this chapter although certain points are worth mentioning. Due to the small but devastating chances of catastrophic complications such as carotid artery injury, skull base violation, and blindness, sinus surgery is generally performed only by a fully trained otolaryngologist. Regardless of the technique used, the DCR is most often performed prior to the sinus surgery. During the initial steps of the DCR, the axillary flap can be raised and the agger nasi cell opened, thus preparing for further exenteration of the ethmoid and frontal cells during the FESS. Occasionally, severe polyposis requires that the FESS be initiated prior to the DCR as the disease may block the middle meatus and the area of lacrimal dissection.

Conclusion

It is beneficial for both ophthalmologists and otolaryngologists to develop a close liaison with each other when starting an endoscopic DCR practice. Both have expertise in different areas and can improve the overall patient care, the preoperative evaluation, the surgical outcomes, and even the postoperative management. The main advantage of a two-team approach is allowing the ophthalmologist to assess for additional eye disease while the sinus surgeon is able to endoscopically assess the nasal cavity, septum, and perform ancillary endonasal procedures that may be necessary while avoiding multiple trips to the operating room. An oculoplastic surgeon performing endoscopic DCR's should get himself trained in at least septoplasty and concha reduction. Similarly an ENT surgeon should learn all the basics of handling the proximal lacrimal system, probing, and intubation. Hence surgeons should be able to assist each other with ease, when needed, in order to provide optimal patient care.

References

1. Simpson P. Perioperative blood loss and its reduction: the role of the anaesthetist. Br J Anaesth. 1992;69:498–507.
2. Palazon JH, Asensi PD, Lopez SB, et al. Effect of head elevation on intracranial pressure, cerebral perfusion pressure, and regional cerebral oxygen saturation in patients with cerebral hemorrhage. Rev Esp Anestesiol Reanim. 2008;55:289–93.
3. Gan EC, Habib AR, Rajwani A, et al. Five-degree, 10-degree and 20-degree reverse trendelenburg position during functional endoscopic sinus surgery: a double-blind randomized controlled trial. Int Forum Allergy Rhinol. 2014;4:61–8.
4. Atef A, Fawaz A. Comparison of laryngeal mask with endotracheal tube for anesthesia in endoscopic sinus surgery. Am J Rhinol. 2008;22:653–7.
5. Ha TN, van Renen RG, Ludbrook GL, et al. The relationship between hypotension, cerebral flow, and the surgical field during endoscopic sinus surgery. Laryngoscope. 2014;124:2224–30.
6. Ali MJ, Psaltis AJ, Wormald PJ. The frequency of concomitant adjunctive nasal procedures in powered endoscopic dacryocystorhinostomy. Orbit. 2015;34:142–5.
7. Champagne C, Ballivet de Régaloix L, Genestier L, et al. Endoscopic vs conventional septoplasty: a review of the literature. Eur Ann Otorhinolaryngol Head Neck Dis. 2016;133:43–7.
8. Kim DW, Egan KK, O'Grady K, et al. Biomechanical strength of human nasal septal lining: comparison of the constituent layers. Laryngoscope. 2005;115:1451–3.
9. Champagne C, Ballivet de Régloix S, Genestier L, et al. Endoscopic septoplasty: learning curve. Eur Ann Otorhinolaryngol Head Neck Dis. 2016;133:167–70.
10. Stallman JS, Lobo JN, Som PM. The incidence of concha bullosa and its relationship to nasal septal deviation and paranasal sinus disease. AJNR Am J Neuroradiol. 2004;25:1613–8.
11. Lloyd GA. CT of the paranasal sinuses: study of a control series in relation to endoscopic sinus surgery. J Laryngol Otol. 1990;104:477–81.
12. Fradis M, Golz A, Danino J, et al. Inferior turbinectomy versus submucosal diathermy for inferior turbinate hypertrophy. Ann Otol Rhinol Laryngol. 2000;109:1040–5.

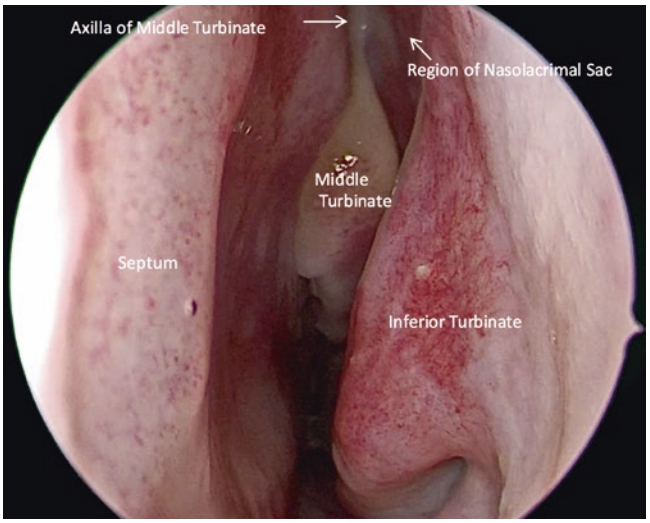


Fig. 29.1 Endoscopic view of the normal nasal anatomy

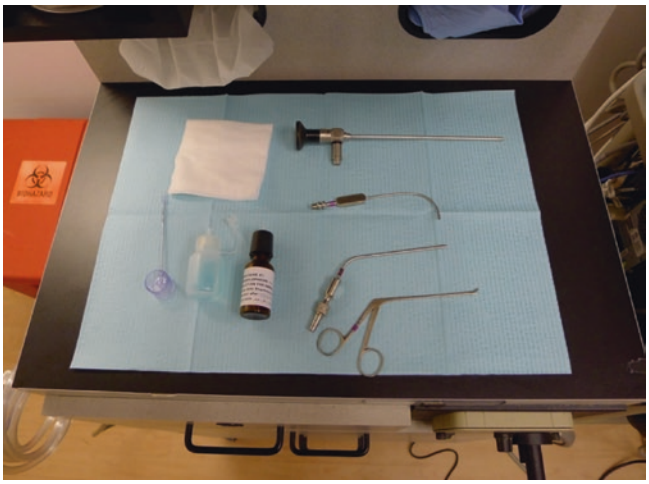


Fig. 29.3 Basic instrumentation includes topical anesthetic, rigid endoscope, angle and straight suctions, and endoscopic forceps

Fig. 29.2 The typical office setup for nasal endoscopy requires an electric adjustable examination chair, instrument trolley, and endoscopic camera stack and screens

Fig. 29.4 Commercially available Cophenylcaine Forte™ (ENT technologies, Melbourne, Australia) is a combination spray containing a vasoconstrictor agent (phenylephrine hydrochloride) and an anesthetic agent (lignocaine hydrochloride)

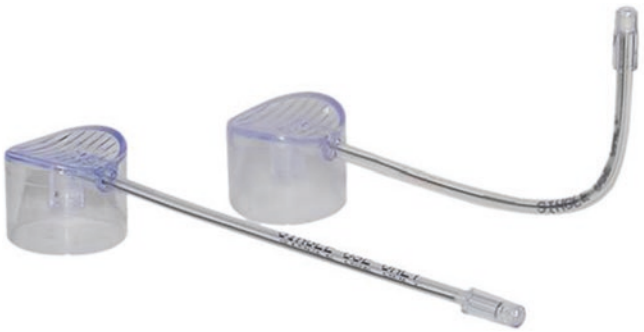


Fig. 29.5 Using a flexible extended nozzle, this agent can adequately decongest and anesthetize the nose

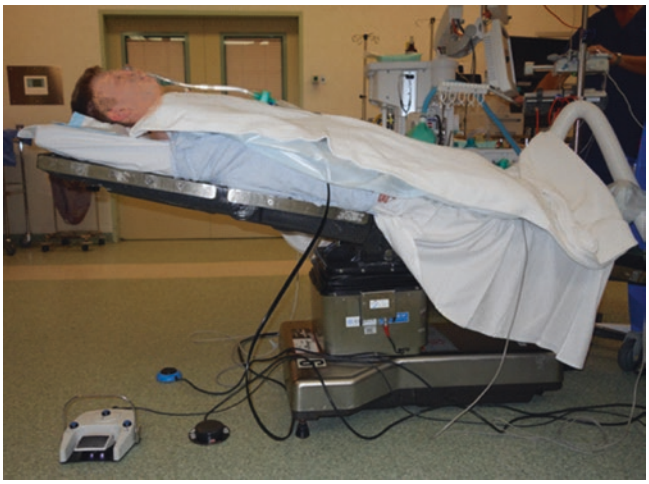


Fig. 29.6 Positioning of the patient. The operating bed is reversed to allow the surgeons to sit and placed in a reverse Trendelenburg position to increase venous drainage away from the surgical field

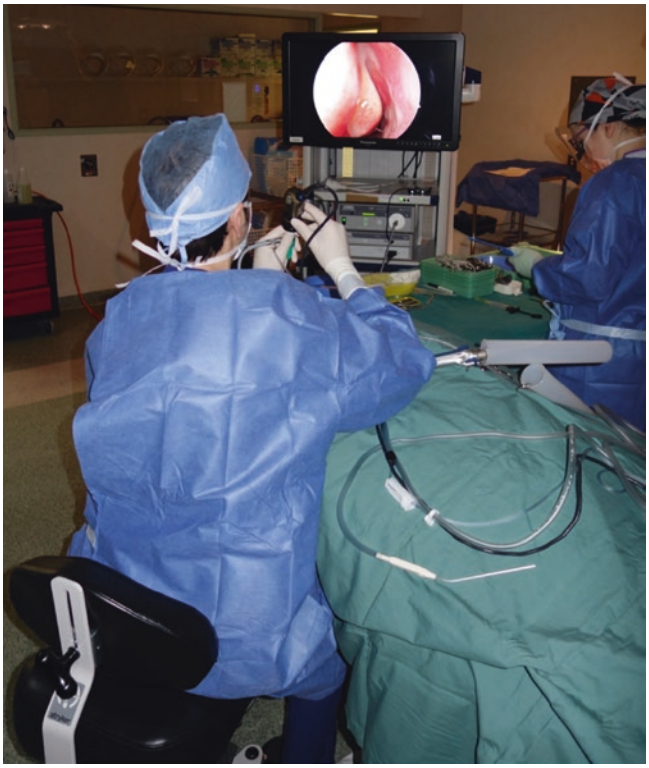


Fig. 29.7 The surgeon is seated with his left elbow supported on an arm board. The monitor is placed directly across at eye level for comfort

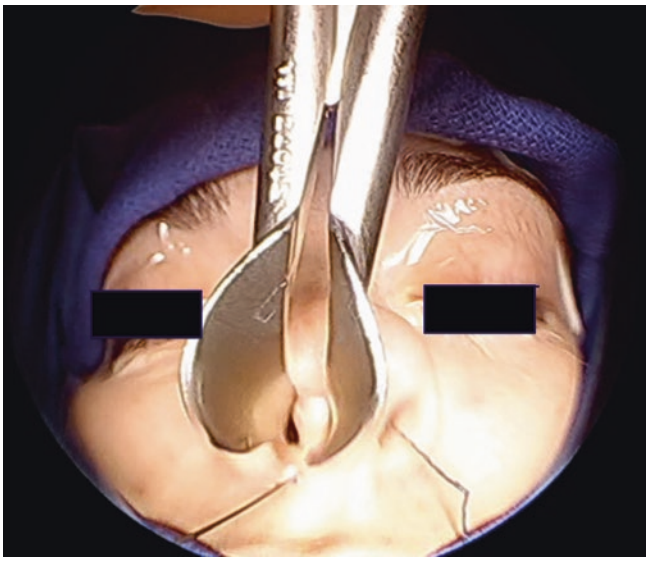


Fig. 29.8 External view of right caudal deviation

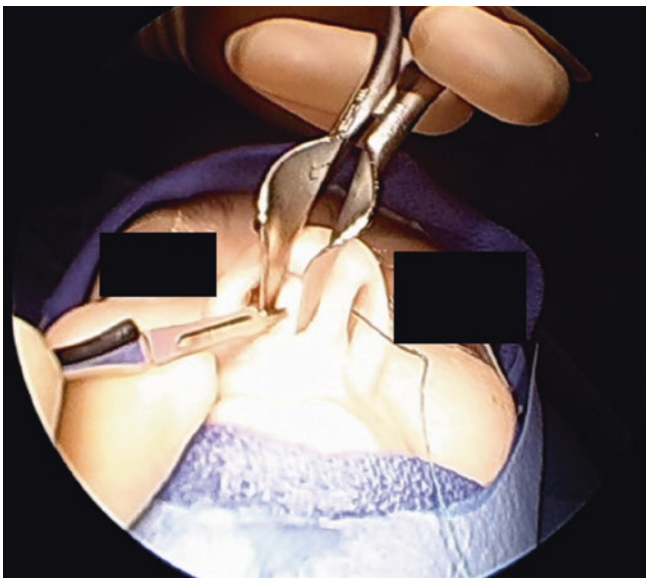


Fig. 29.9 Right hemitransfixation incision

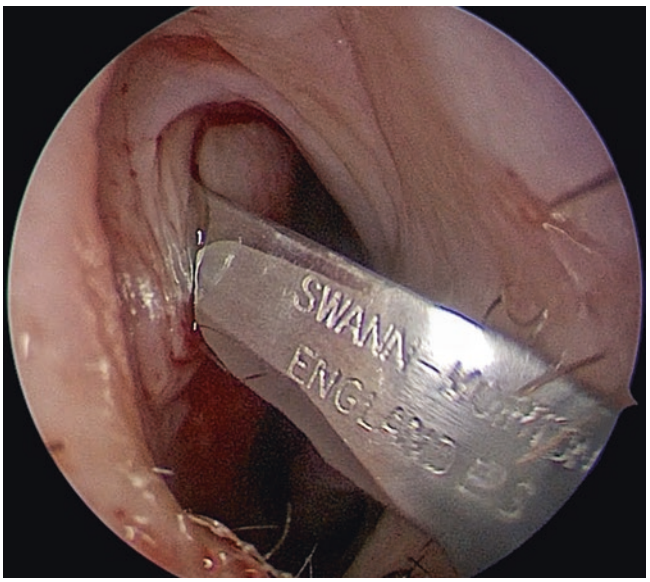


Fig. 29.11 Steps of endoscopic septoplasty. Killian incision with a 15″ blade at the mucocutaneous junction

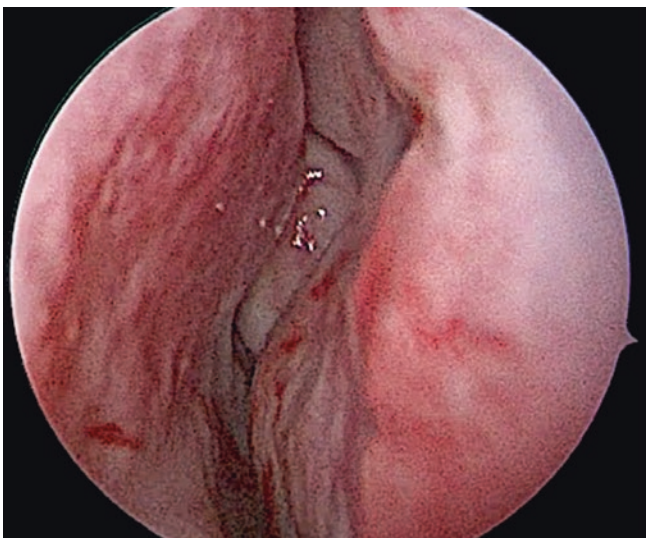


Fig. 29.10 Steps of endoscopic septoplasty. The high deviation of the septum prevents visualization and access to the axilla of the middle turbinate

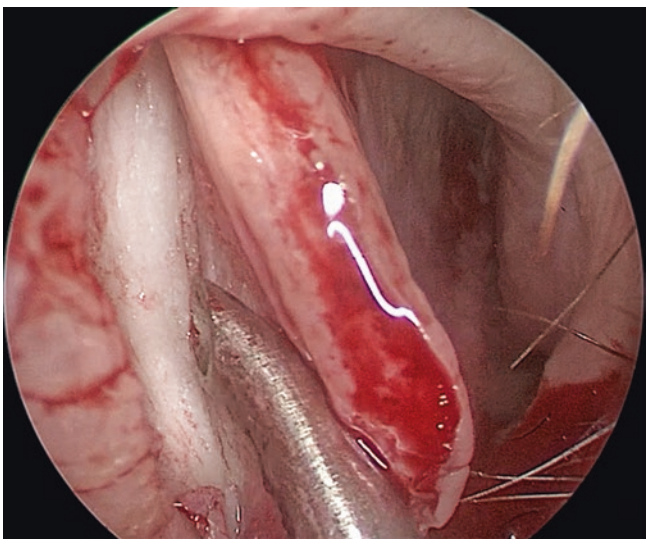


Fig. 29.12 Steps of endoscopic septoplasty. Identification of the submucoperichondrial plane using the sharp end of a malleable suction curette

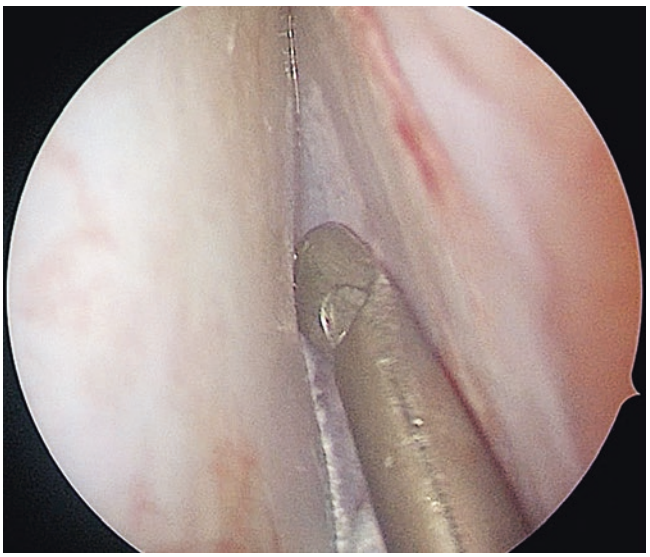


Fig. 29.13 Steps of endoscopic septoplasty. Raising of the sub-mucoperichondrial mucosa flap with the Freer's suction. Note the pearly white appearance of the underlying cartilage

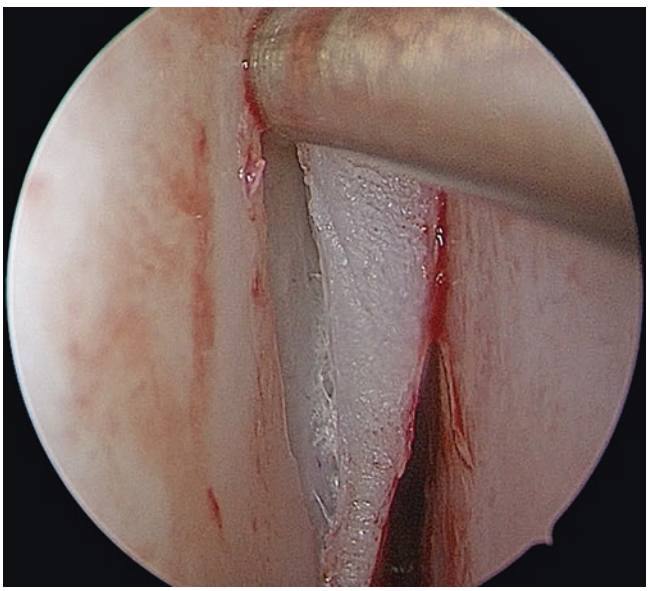


Fig. 29.14 Steps of endoscopic septoplasty. Transection of the cartilage just anterior to the deviation

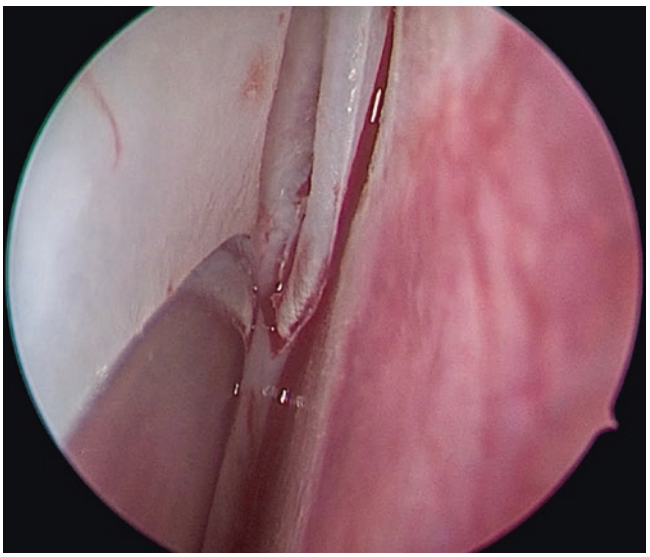


Fig. 29.15 Steps of endoscopic septoplasty. Raising of a contralateral sub-mucoperichondrial mucosal flap with isolation of the cartilage and bone centrally

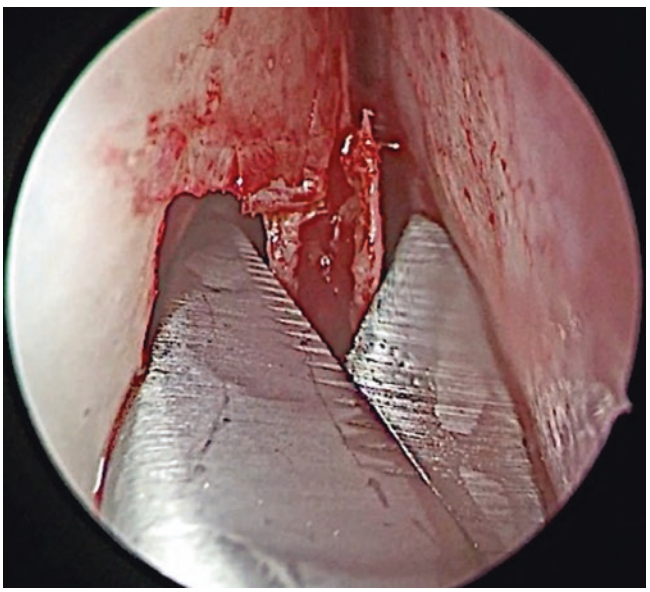


Fig. 29.16 Steps of endoscopic septoplasty. Superior "safety" cut with the turbinectomy scissors to prevent injury of the skull base on removal of the ethmoid bone

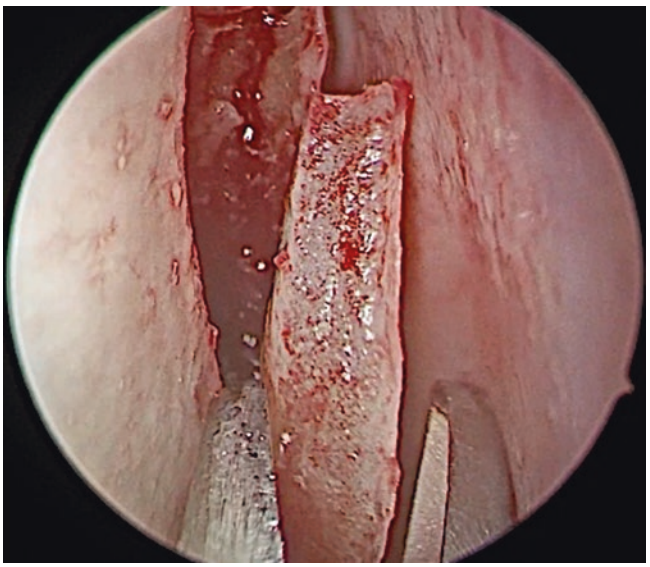


Fig. 29.17 Steps of endoscopic septoplasty. Removal of the cartilage using a grasping instrument

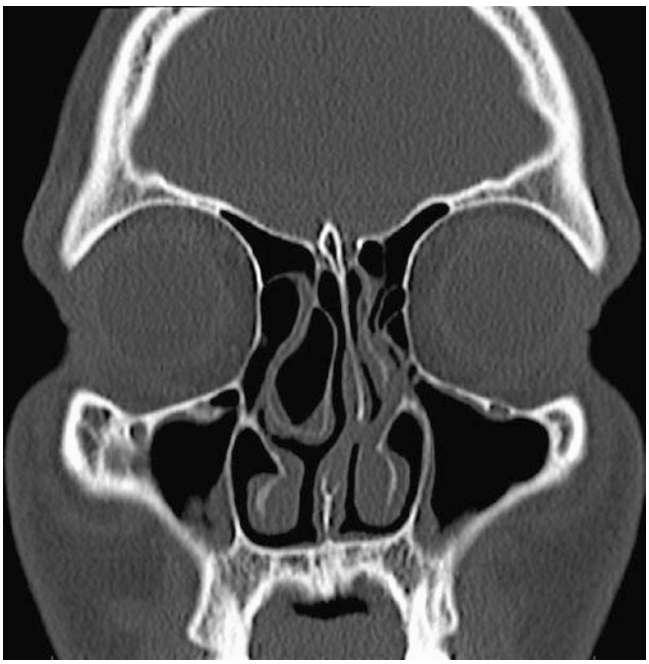


Fig. 29.19 Coronal CT of the sinuses showing a pneumatization of the right middle turbinate (concha bullosa) with a corresponding deviation of the nasal septum to the left

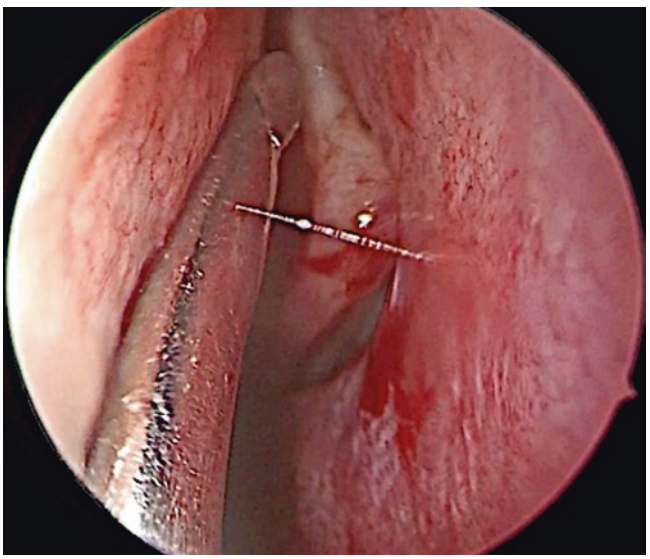


Fig. 29.18 Steps of endoscopic septoplasty. Freer's suction demonstrating the residual soft tissue of the septal mucosa that can now be easily retracted to allow visualization of the axilla of the middle turbinate and direct access to the frontal process of the maxilla for DCR surgery

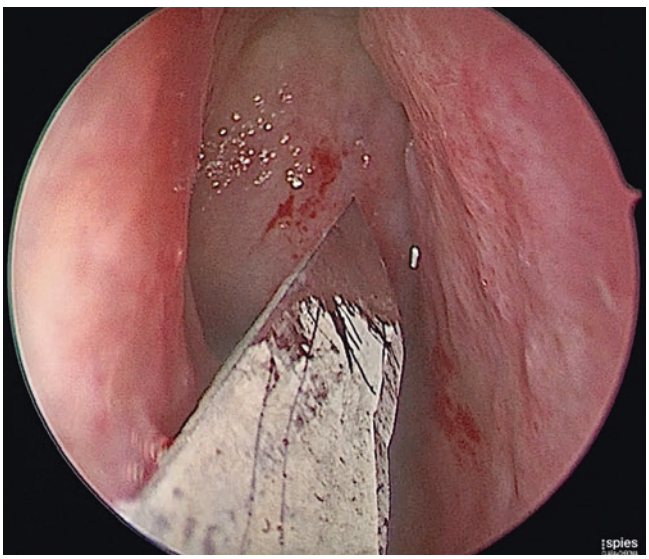


Fig. 29.20 Steps of middle turbinoplasty: stab incision is made in the head of the middle turbinate with a #15 blade

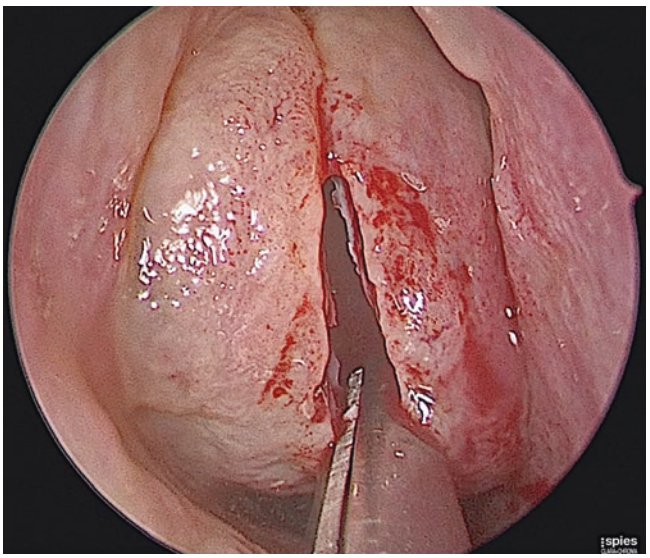


Fig. 29.21 Steps of middle turbinoplasty: incision is extended superior and inferiorly to distract the two leaflets of the middle turbinate

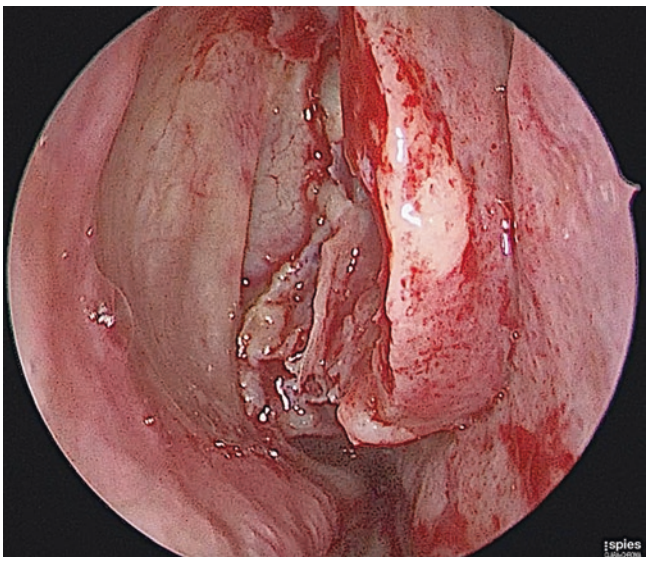


Fig. 29.23 Steps of middle turbinoplasty: completion of the concha bullosa resection. The medial leaflet is preserved and access to the lateral nasal wall increased

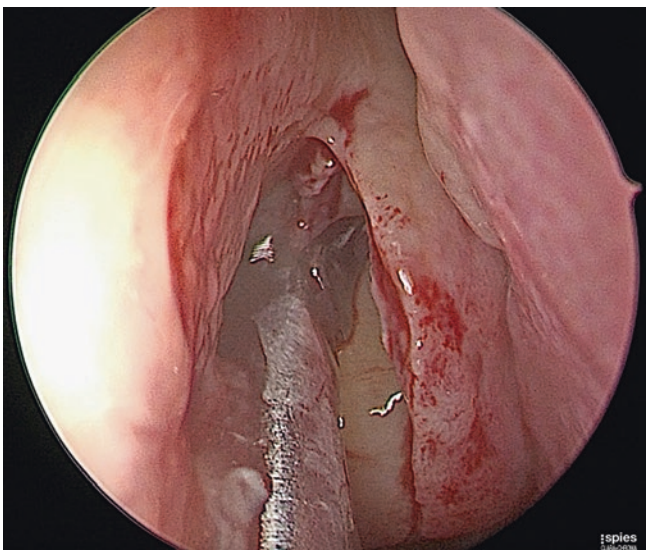


Fig. 29.22 Steps of middle turbinoplasty: cutting Blakesley forceps are used to complete the cut posteriorly

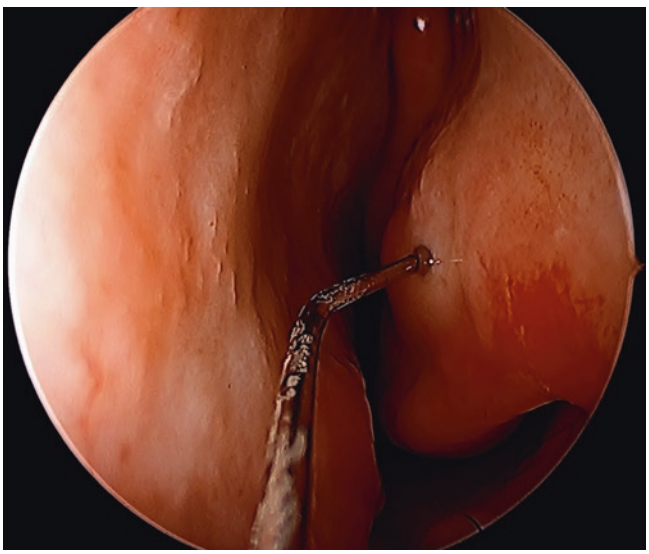


Fig. 29.24 Injecting into the head of inferior turbinate for decongestion

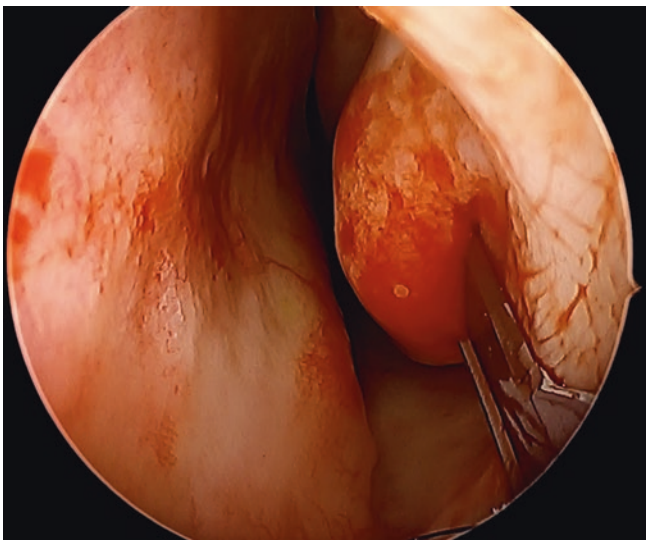


Fig. 29.25 Inferior turbinate incision

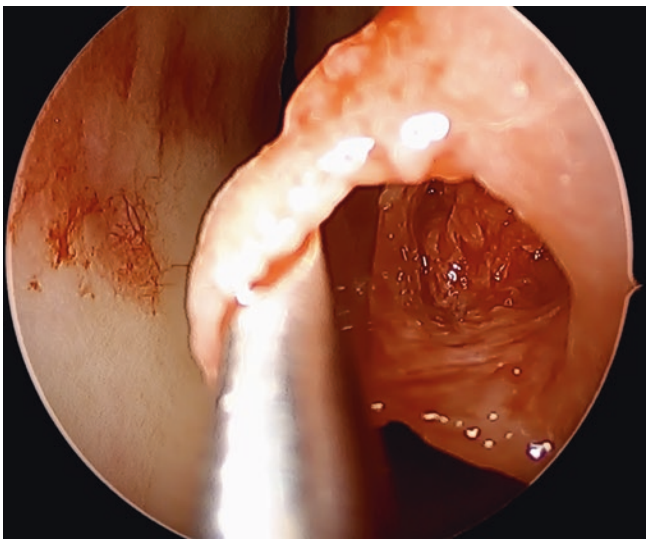


Fig. 29.26 Raising the submucosal plane

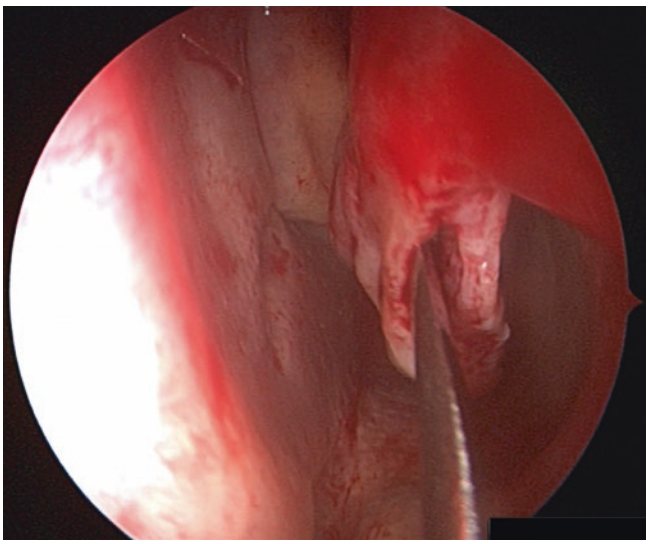


Fig. 29.27 Isolation of the inferior turbinate bone

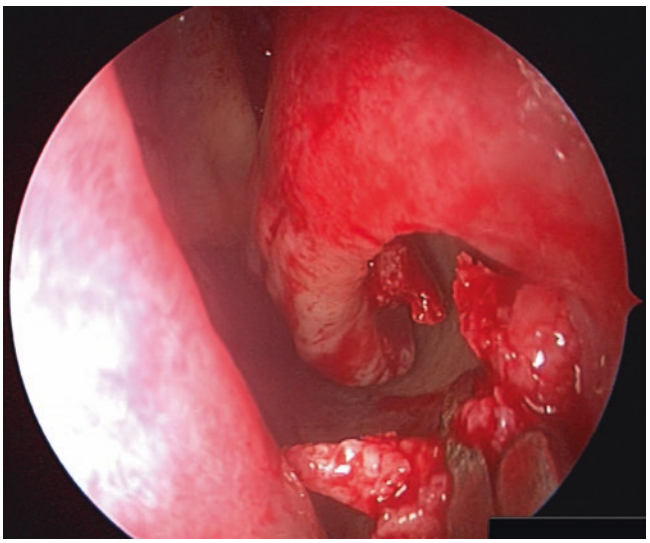


Fig. 29.28 Removal of the inferior turbinate bone

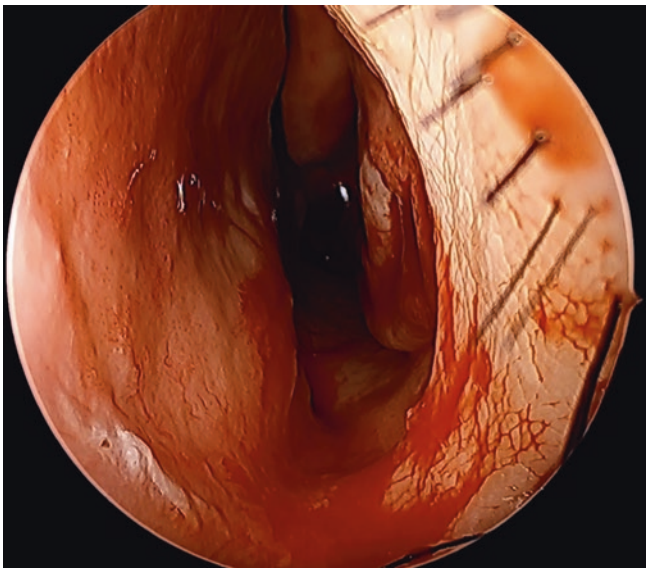


Fig. 29.29 Intraoperative photo following turbinoplasty

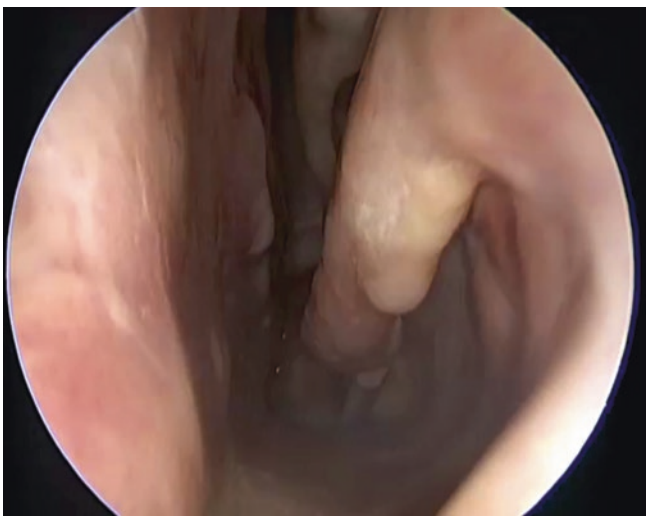


Fig. 29.30 Several months after septoplasty and inferior turbinoplasty, the well-healed mucosa and patent airway

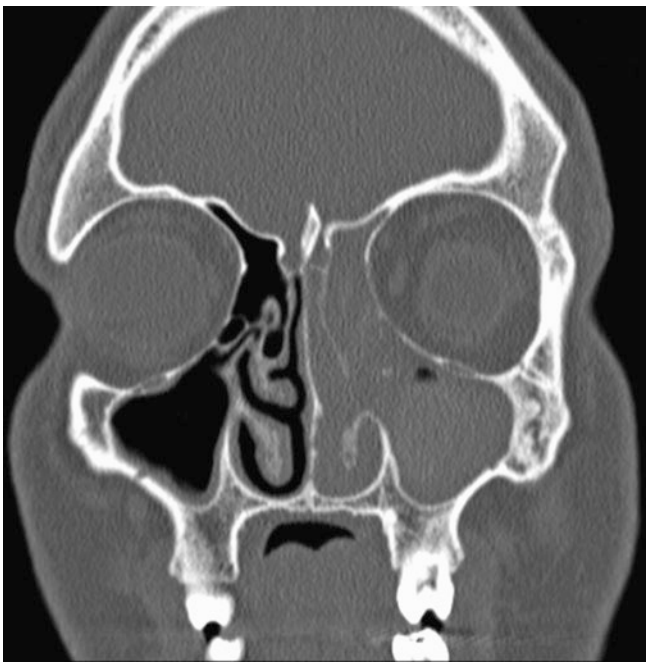


Fig. 29.31 Patient with a one-sided pansinusitis, seen as opacification of the sinuses and involvement of the lacrimal system

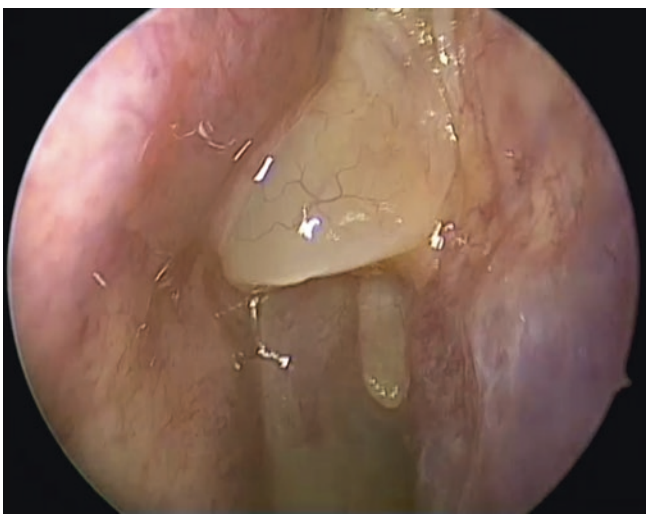


Fig. 29.32 Classic view of severe but benign-appearing nasal polyps

Difficult Scenarios in Endoscopic Dacryocystorhinostomy

30

Mohammad Javed Ali

Introduction

Endoscopic DCR is fast becoming the first choice in the management of nasolacrimal duct obstructions owing to its multiple advantages over other approaches, better instrumentation, better training opportunities, and a newer generation which is far more familiar with it than the previous generations [1–7]. With increasing use, there are numerous circumstances which can be classified under difficult scenarios, and this chapter would elucidate them and provide guidelines in dealing with them.

Thick Frontal Process of Maxilla

Superior osteotomy is a very important step in endoscopic DCR and involves removing the thick frontal process of the maxilla that overlies the fundus of the lacrimal sac. In most instances, this is not difficult unless patients have a very thick frontal process or the lacrimal sac is at a higher position above the axilla of the middle turbinate. Thick processes are commonly noted in Asian ethnicities but may be grossly thick in certain individuals (Fig. 30.1). In these scenarios, powered instruments like regular drills with diamond burr or an ultrasonic bone probe help. There is no significant difference between the two with regard to the time taken for a superior osteotomy [8]. The osteotomy should begin from the medial edge of the frontal process and sequentially proceed laterally (Fig. 30.2) and then posteriorly (Fig. 30.3) in a stepwise manner to avoid injury to the lacrimal sac. Near to the sac, the movements of the burr should be away from the sac. The end point of osteotomy is either 3–4 mm clearance (Fig. 30.4) above the internal common opening or when the superior narrowing of the fundus of lacrimal sac is noted.

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad-34, India
e-mail: drjaved007@gmail.com

Post-trauma Setting

The rise of road traffic accidents globally has contributed to frequent encountering of post-traumatic nasolacrimal duct obstruction. Facial trauma, specifically the naso-orbito-ethmoid (NOE) fractures, involves the lacrimal sac fossa and the bony NLD resulting in symptoms of epiphora, discharge, and dacryocystitis [9]. Endoscopic DCR becomes a challenge in post-trauma setting since endoscopic anatomy may be distorted (Figs. 30.5 and 30.6). Reported distortion includes loss of positional relationship of middle turbinate (MT) with the lacrimal sac, loss of spatial relationship between the MT and bulla ethmoidalis, roof at a lower level, MT fractures, septal perforations, and breach in the periorbita with fat prolapse in the vicinity of lacrimal sac [10]. In cases with additional skull base fractures, there may be associated postoperative encephaloceles or fractured cribriform plates (Fig. 30.6). All these need to be taken into consideration while operating them endoscopically. Image-guided dacryolocalization or IGDL has greatly helped in accurately localizing the lacrimal sac and facilitating the surgery [10, 11]. Meticulous imaging, preoperative endoscopy, and planning are essential for successful outcomes. Details of these have been described in the chapter on image-guided lacrimal surgeries.

Pre- or Post-FESS Surgery

Functional endoscopic sinus surgery is a common rhinology procedure. Surgeries for ethmoidal mucocele can have a potential to damage lacrimal drainage system because of close anatomical proximities (Fig. 30.7) or there could be secondary nasolacrimal duct obstructions due to mechanical compression. When dealing with a SALDO secondary to ethmoidal mucocele, care should be taken to slowly decompress the mucocele and manage it further under complete visualization.

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_30

Nasolacrimal duct injury can also happen during the step of middle meatal antrostomy when a back-biting punch can occasionally damage the bony NLD and subsequently the soft tissue NLD. Hence, it is important for the FESS surgeon to carefully look for preoperative bony NLD dehiscence that has been reported in up to 6.8% of individuals [12]. Similarly lacrimal surgeons should look for post-FESS CT scans to document any postoperative dehiscence (Figs. 30.8 and 30.9) with or without soft tissue NLD prolapsed (reported in up to 3.3% of patients undergoing FESS) [12].

Lacrimal Sac Diverticulae

Lacrimal sac diverticulae are uncommon and are outpouchings from one of the lacrimal sac walls. They can be congenital or acquired. Most common presentation includes epiphora, discharge, and usually a swelling in the lacrimal sac area which may mimic a mucocele [13, 14]. Lacrimal system may not be patent to irrigation either secondary to compression effects of diverticulum or associated NLDO. Most of them are visible following a DCR osteotomy as large sacs, more so in the anteroinferior direction (Fig. 30.10). It is important to recognize this as missing this can lead to a sump syndrome-like situation. The mucosa of the diverticulae can be smooth or inflamed (Fig. 30.11). A good lacrimal sac marsupialization with mucosa to mucosa approximation (Fig. 30.12) is mandatory for successful outcomes. Occasionally one may have to excise the redundant diverticular mucosa to achieve a good lacrimal sac opening on the lateral nasal wall.

Lacrimal Sac in Ethmoid Sinus

The bony lacrimal fossa has an intricate relationship with the ethmoid sinuses, and it is not uncommon to encounter anterior ethmoid air cells during a DCR. However, occasionally, the lacrimal sac may be malpositioned entirely within the boundaries of ethmoid sinuses (Figs. 30.13, 30.14, and 30.15) and can pose a surgical challenge [15]. The bony ethmoid lateral to the sac in such cases should be carefully preserved to avoid orbital injury. The lateral ethmoidal wall mucosa should be utilized for a mucosa to mucosa approximation. The anatomical variations of ethmoidal vessels must be kept in mind to avoid injury. Good sinus surgery training, through endoscopic anatomy, careful maneuvering, and occasional use of image-guided techniques, is helpful in achieving good outcomes [15].

Turbino-Ostial Synechiae

Turbino-ostial synechiae are adhesions between the middle turbinate (MT) and the DCR ostium [16]. These are uncommon and are usually broad-based adhesions (Fig. 30.16). The etiologies can be a lateralized MT or trauma to the MT which facilitates adhesions of two traumatized surfaces. They can cause a gross anatomical failure of a DCR. During the revision surgery, the plane overlying the lacrimal sac should be raised sharply with a No. 15 blade to perform a complete synechiolysis (Fig. 30.17). However, this alone may not help and may require additional focal excision of the MT (Fig. 30.18) or sometimes a full middle turbinoplasty. Care should be taken to preserve as much of the MT mucosa as possible so as to avoid losing flow receptors and air turbulence functions. Details of middle turbinoplasty techniques are discussed in the chapter on adjunctive procedures. Subsequent to turbinoplasty, lacrimal sac flaps are raised (Fig. 30.19), and the remaining surgery is completed as per standard protocols.

Intrasac Granulomas

Intrasaccal granulomas are uncommon and usually result from chronic inflammation [17]. Most of these are accidental detections, and some can be detected on routine dacryoendoscopy. They present as pinkish-red lobular lesion on one of the sac walls (Fig. 30.20). When encountered during an endoscopic DCR, a careful evaluation to assess its location, proximity to the internal common opening, and localization of its base is important (Fig. 30.20). They have been noted to arise from a broad-based intrasac synechiae. Management is based on similar guidelines as those for DCR ostium granulomas [18] and includes very careful excision without traumatizing the underlying lacrimal sac mucosa. Although clinical diagnosis is clear, nonetheless histopathological evaluation is a must to rule out other neoplastic pathologies.

Endoscopic DCR in Autoimmune Disorders

Autoimmune diseases are increasingly being recognized as important causative factors for secondary acquired nasolacrimal duct obstructions. Commonly implicated systemic disorders include lichen planus, sarcoidosis, Wegner's granulomatosis, and polyangiitis. Recently endoscopic findings of lacrimal sac in cases of lichen planus have been described [19]. The sac marsupialization was noted to be diffi-

cult because of its fibrous consistency. Numerous luminal mucosal projections were noted with intervening areas of submucosal fibrosis and intrasac synechiae (Fig. 30.21). Histopathological examination showed the lacrimal sac epithelium to undergo focal squamous metaplasia. There was a dense stromal fibrosis with lymphoplasmacytic infiltrate (Fig. 30.22). The common enemy during a lacrimal surgery is inflammation and its flare-up following an intervention. Hence various authors have advocated steroid protocols preoperatively, and it is best to operate during quiescence. Postoperative steroids are highly recommended. With proper evaluation, teamwork with related disciplines, and management protocol adherence, the outcomes of endoscopic DCR are encouraging.

Intraoperative Instrument Fracture

Intraoperative instrument fracture is a rare occurrence during an endoscopic DCR [20]. This usually happens with powered instruments like drills or burrs (Fig. 30.23). This has been reported once during a superior osteotomy step of endoscopic DCR in a patient with thick frontal process of maxilla [20]. There was a break of the drill and dislocation of the irrigating channel with scattered metal debris (Fig. 30.23). In the event of any instrument fracture, it is important to immediately stop the procedure. Visualize the entire surgical field, and gently retrieve the fractured instrument (Fig. 30.24). It is important to meticulously search for any broken pieces of the instrument that may remain behind, and the metallic debris should be carefully removed. Damage to the tissues should then be ascertained and appropriate measures taken to complete the surgery safely.

References

1. Ali MJ, Psaltis AJ, Murphy J, et al. Powered endoscopic dacryocystorhinostomy: a decade of experience. Ophthal Plast Reconstr Surg. 2015;31:219–21.
2. Chan W, Fahlbusch D, Dhillon P, et al. Assisted local anesthesia for powered endoscopic dacryocystorhinostomy. Orbit. 2014;33:416–20.
3. Ali MJ, Psaltis AJ, Bassiouni A, et al. Long-term outcomes in primary powered endoscopic dacryocystorhinostomy. Br J Ophthalmol. 2014;98:1678–80.
4. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomy. Int Forum Allergy Rhinol. 2014;4:1016–9.
5. Knisely A, Harvey R, Sacks R. Long-term outcomes in endoscopic dacryocystorhinostomy. Curr Opin Otolaryngol Head Neck Surg. 2015;23:53–8.
6. Jung SK, Kim YC, Cho WK, et al. Surgical outcomes of endoscopic dacryocystorhinostomy: analysis of 1083 consecutive cases. Can J Ophthalmol. 2015;50:466–70.
7. Barmettler A, Ehrlich JR, Lelli G Jr. Current preferences and reported success rates in dacryocystorhinostomy among ASOPRS members. Orbit. 2013;32:20–6.
8. Ali MJ, Ganguly A, Ali MH, et al. Time taken for superior osteotomy in primary powered endoscopic dacryocystorhinostomy: is there a difference between an ultrasonic aspirator and mechanical burr? Int Forum Allergy Rhinol. 2015;5:764–7.
9. Ali MJ, Gupta H, Honavar SG. Acquired nasolacrimal duct obstruction secondary to naso-orbito-ethmoid fractures: patterns and outcomes. Ophthal Plast Reconstr Surg. 2012;28:242–5.
10. Ali MJ, Naik MN. Image-guided dacryolocalization in traumatic secondary acquired lacrimal drainage obstructions (SALDO). Ophthal Plast Reconstr Surg. 2015;31:406–9.
11. Ali MJ, Singh S, Naik MN. Interactive navigation-guided ophthalmic plastic surgery: the utility of 3D CT-DCG-guided dacryolocalization in secondary acquired lacrimal duct obstructions. Clin Ophthalmol. 2016;11:127–33.
12. Ali MJ, Psaltis AJ, Wormald PJ, et al. Bony nasolacrimal duct dehiscence in functional endoscopic sinus surgery: radiological study and discussion of surgical implications. J Laryngol Otol. 2015;129:S35–40.
13. Kim JH, Chang HR, Woo KI. Multilobular lacrimal sac diverticulum presenting as a lower eyelid mass. Korean J Ophthalmol. 2012;26:297–300.
14. Ali MJ. Endoscopic approach to management of lacrimal sac diverticula. Ophthal Plast Reconstr Surg. 2016;32:e49.
15. Ali MJ, Singh S, Naik MN. Entire lacrimal sac within the ethmoid sinus: outcomes of powered endoscopic dacryocystorhinostomy. Clin Ophthalmol. 2016;10:1199–203.
16. Ali MJ, Psaltis AJ, Wormald PJ. Dacryocystorhinostomy ostium: parameters to evaluate and the DCR ostium scoring. Clin Ophthalmol. 2014;8:2491–9.
17. Ali MJ, Ezeanosike E. Endoscopic features of intrasaccal lacrimal granuloma. Otolaryngol Head Neck Surg. 2016;155:708–9.
18. Ali MJ, Wormald PJ, Psaltis AJ. The dacryocystorhinostomy ostium granulomas: classification, indication for treatment, management modalities and outcomes. Orbit. 2015;34:146–51.
19. Ali MJ, Naik MN. Endoscopic features of lacrimal sac in a case of lichen planus. Int Ophthalmol. 2017. https://doi.org/10.1007/s10792-017-0476-8.
20. Ali MJ, Naik MN. Intraoperative instrument fracture during endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2017;33:e27.

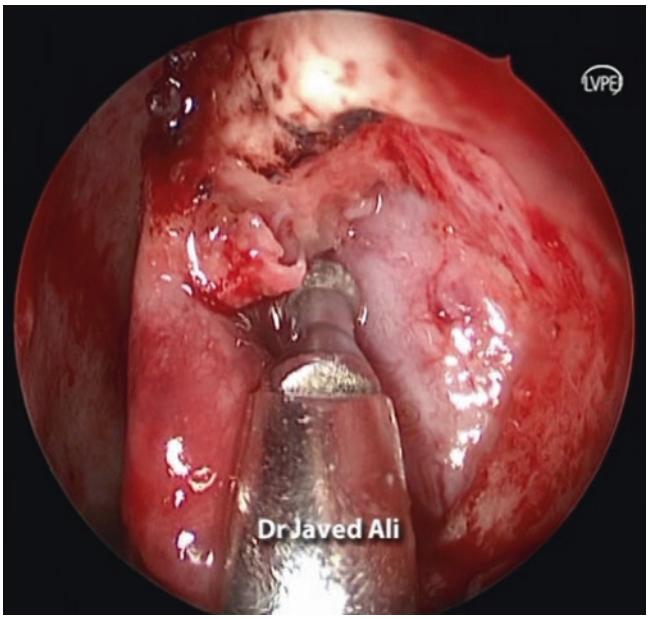


Fig. 30.1 A very thick frontal process of maxilla

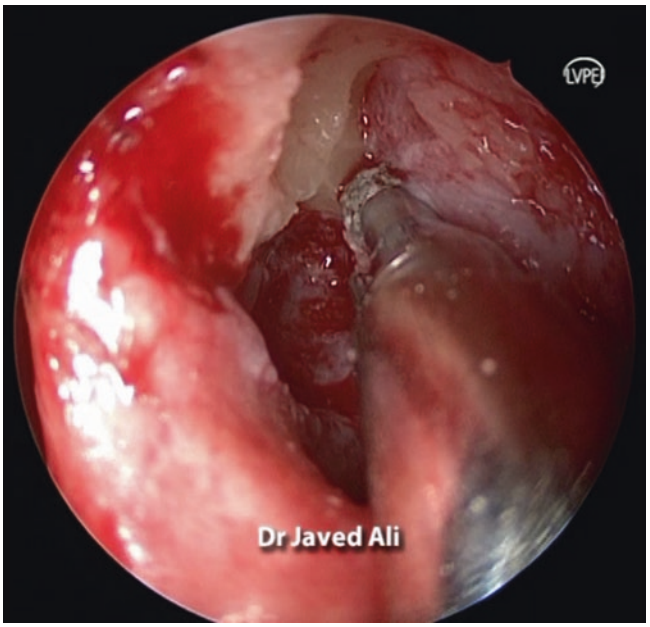


Fig. 30.3 Posterosuperior osteotomy

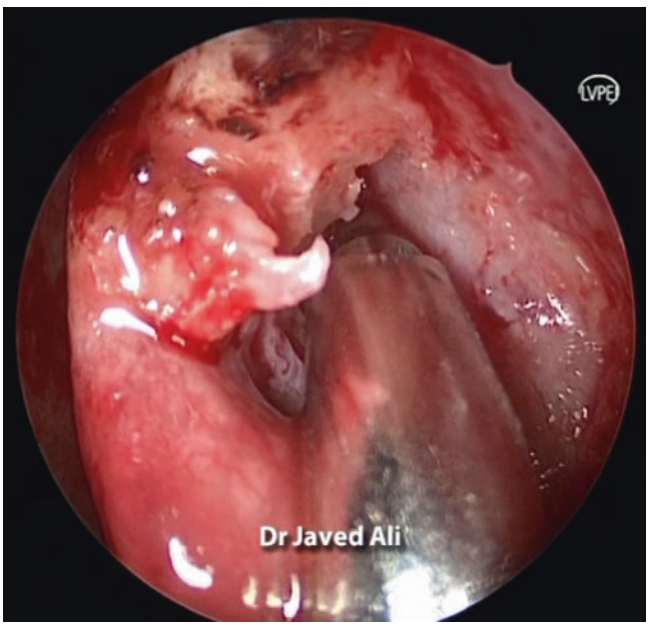


Fig. 30.2 Sequential superior osteotomy

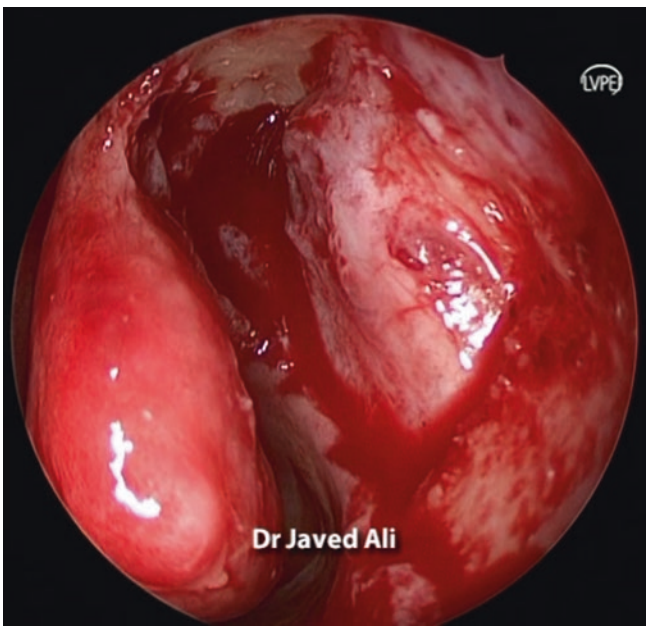


Fig. 30.4 End point of superior osteotomy. Note the clearance of the fundus of lacrimal sac

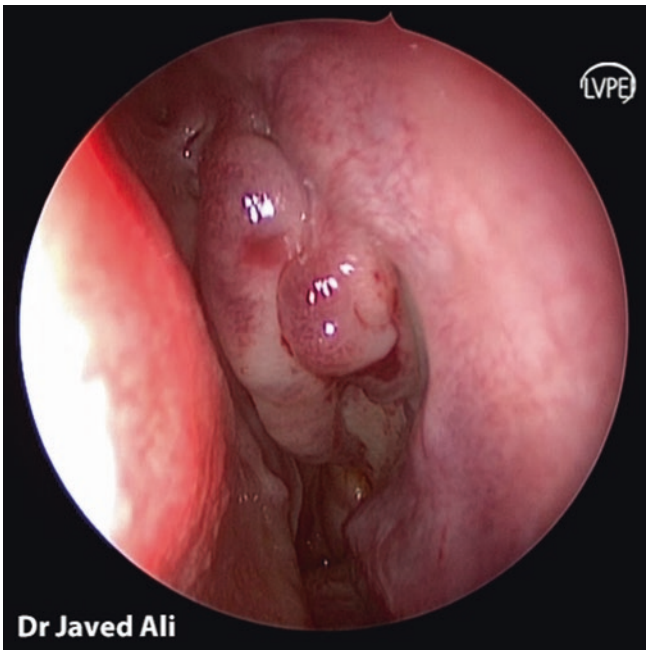


Fig. 30.5 Distorted endoscopic anatomy in a post-trauma setting

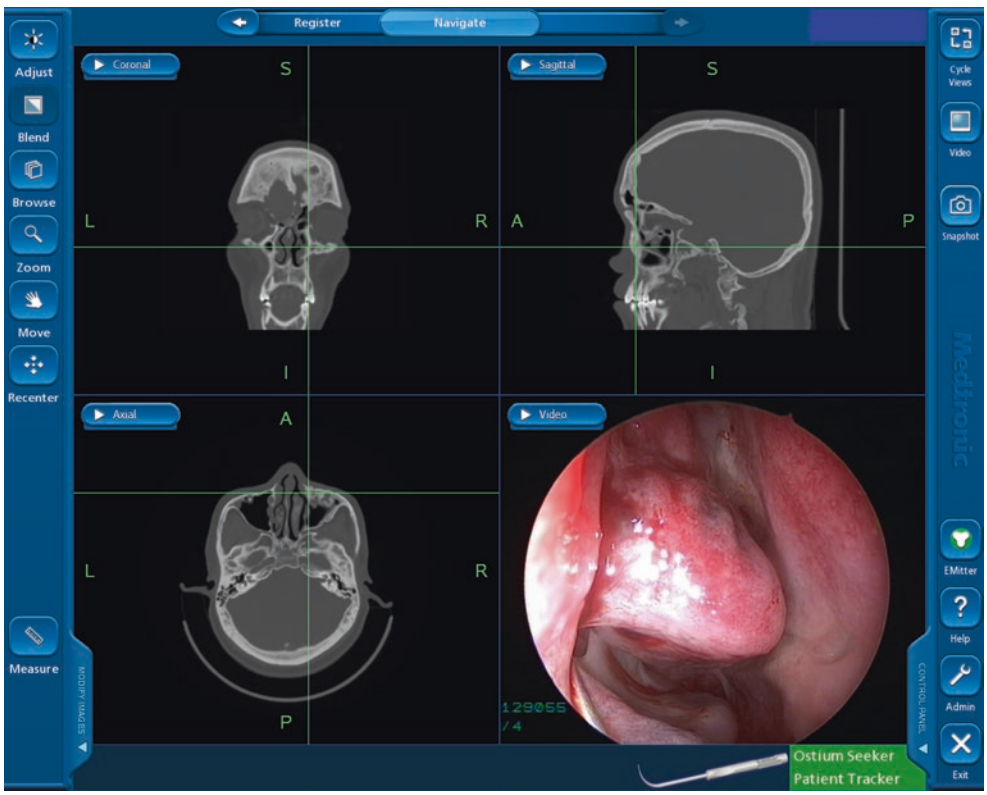


Fig. 30.6 Distorted endoscopic anatomy in a post-trauma setting. Note the fractured middle turbinate, loss of middle meatus, and encephalocele

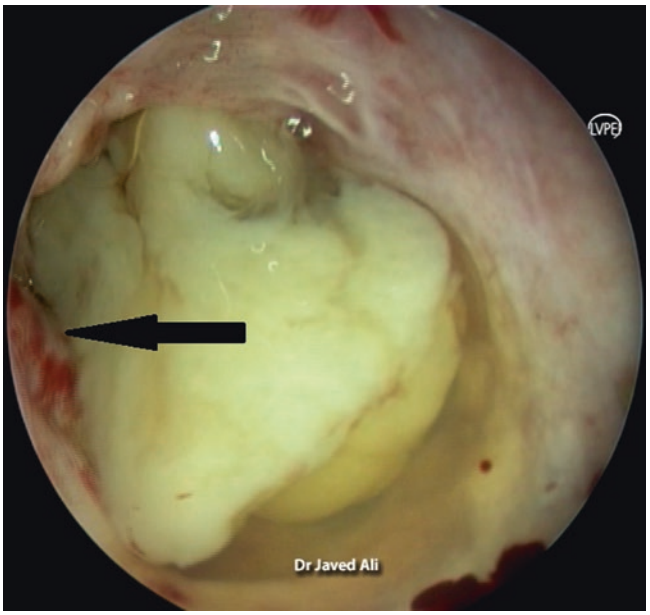


Fig. 30.7 Endoscopic view from within the ethmoid mucocele. Note the close proximity with the lacrimal sac (*black arrow*) in this patient

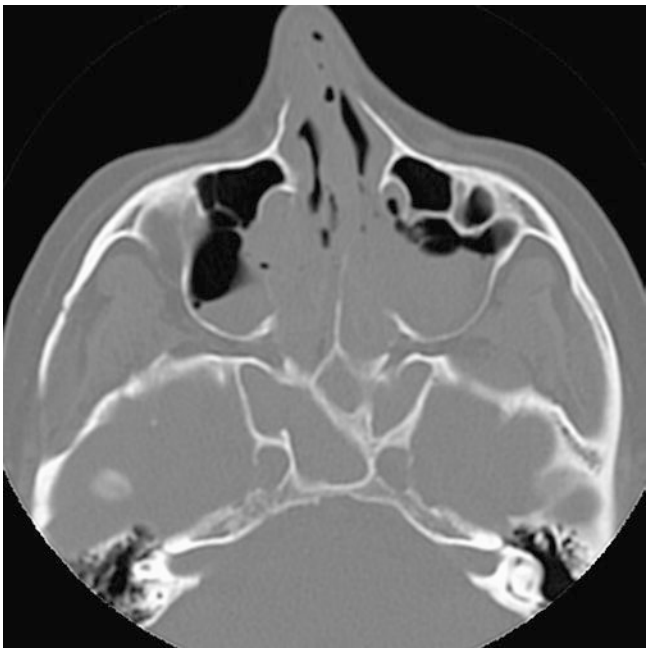


Fig. 30.9 Post-FESS CT scan, axial cut of the same patient as in Fig 30.8 showing gross bilateral bony NLD dehiscence (Courtesy: Ali et al., J Laryngol Otol. 2015;129:35–40)

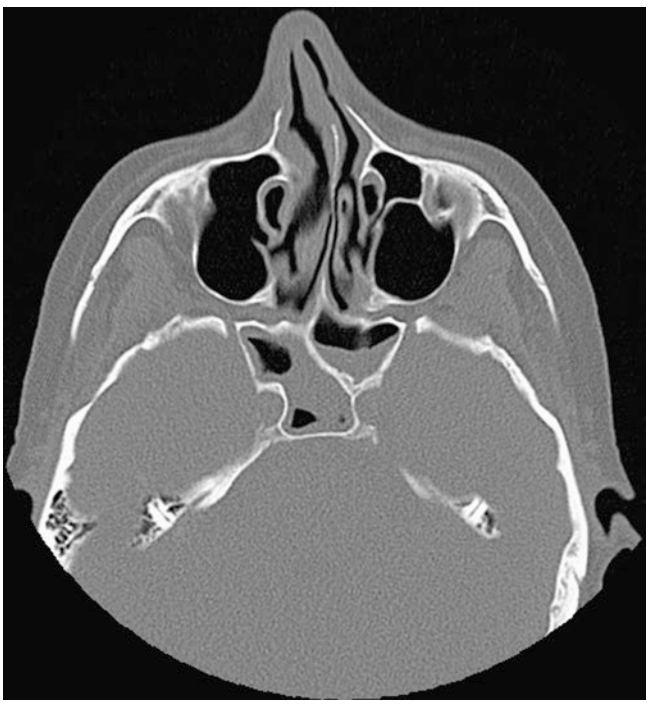


Fig. 30.8 Pre-FESS CT scan, axial cut, showing thinned out but intact bony nasolacrimal ducts. (Courtesy: Ali et al., J Laryngol Otol. 2015;129:35–40)

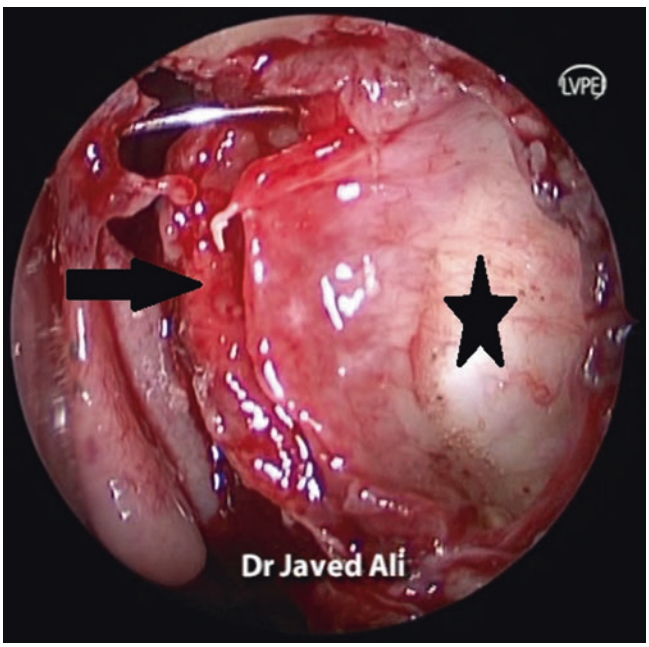


Fig. 30.10 Endoscopic view of a large anteroinferior diverticulum (*black star*) of the lacrimal sac (*black arrow*)

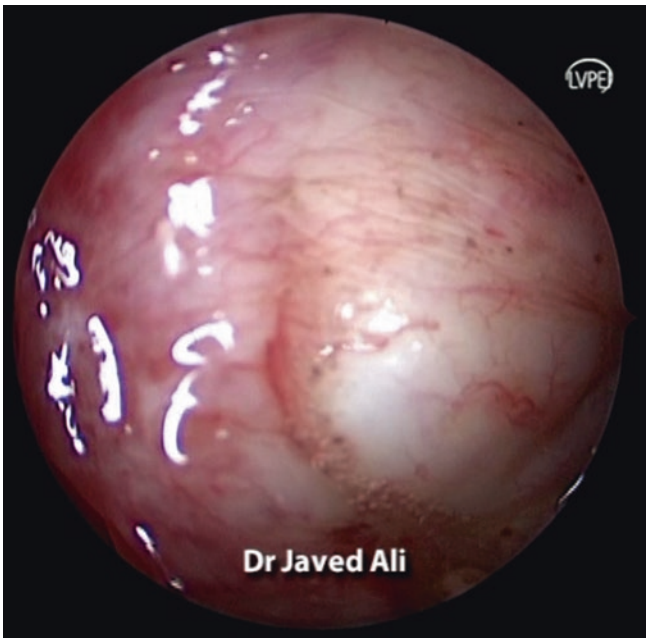


Fig. 30.11 Smooth mucosa of the diverticulum

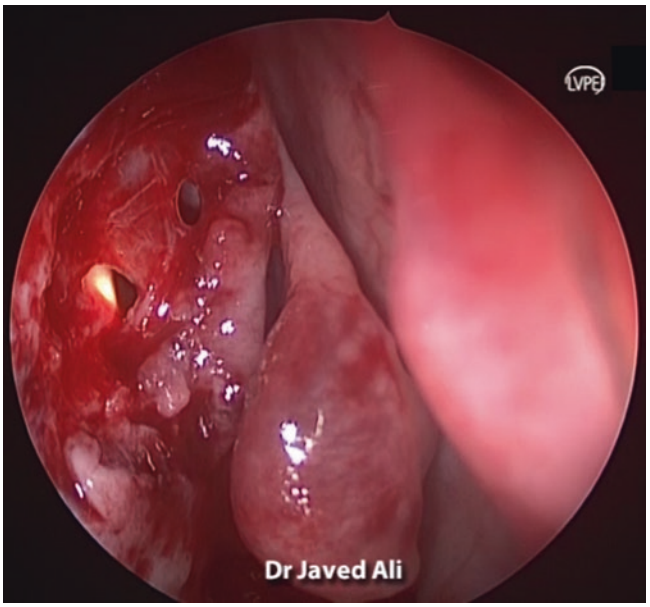


Fig. 30.13 Endoscopic view following partial removal of bulla ethmoidalis. Note the lacrimal light pipe beyond the mucosa of the bulla

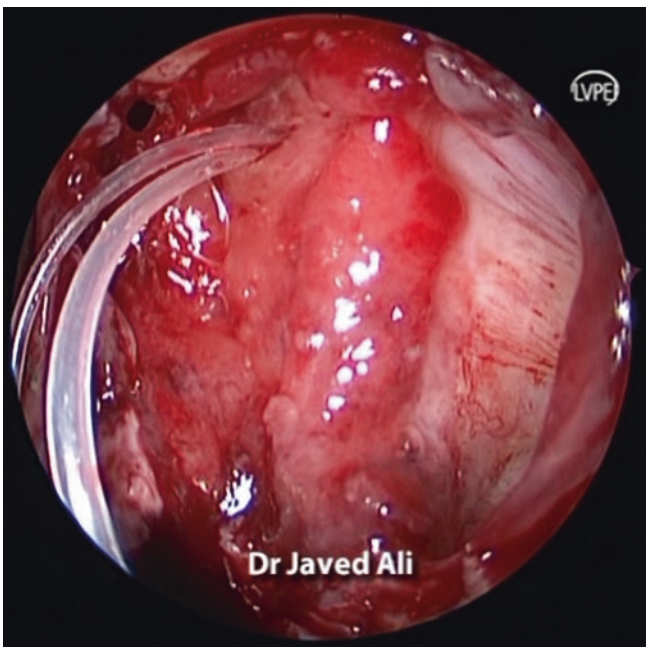


Fig. 30.12 A good mucosa to mucosa approximation of the anterior and posterior lacrimal flaps

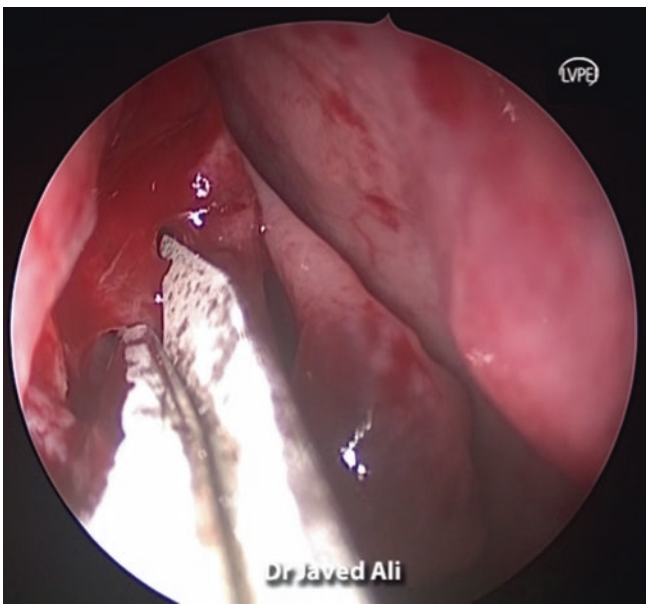


Fig. 30.14 Mucosal of the bulla completely excised to expose the lacrimal sac

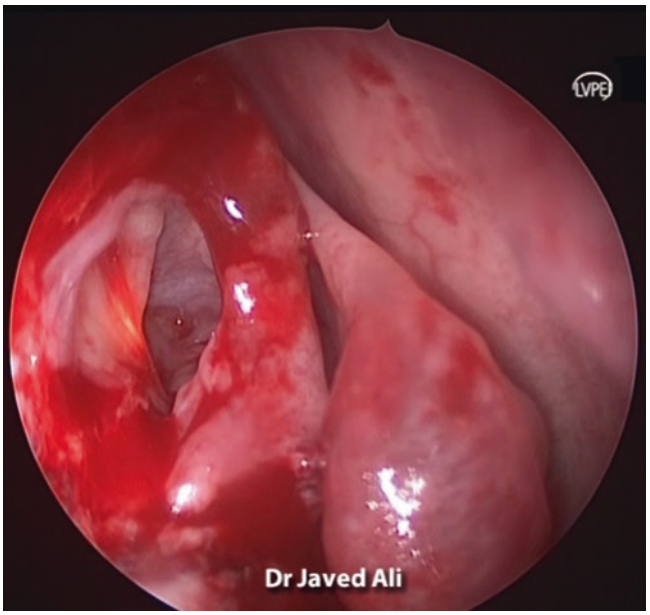


Fig. 30.15 The entire sac is at the level of middle ethmoids

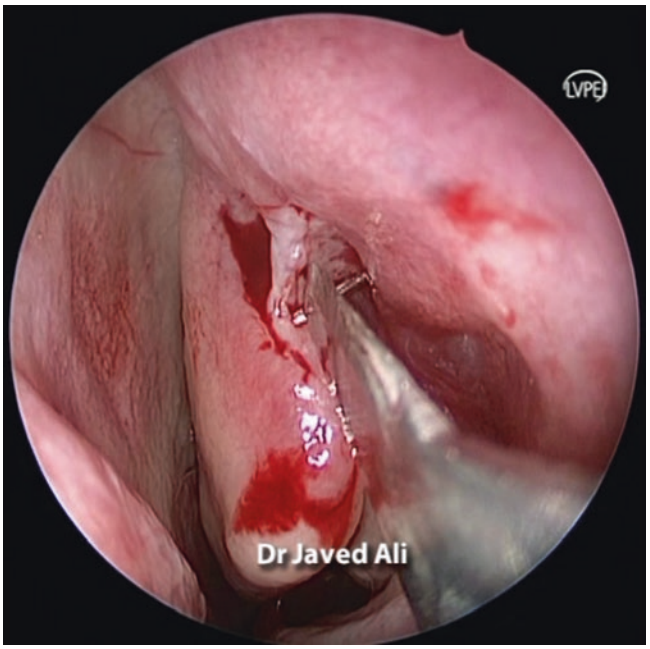


Fig. 30.17 Management of turbino-ostial synechiae: synechiolysis with a vertical motion of No. 15 blade

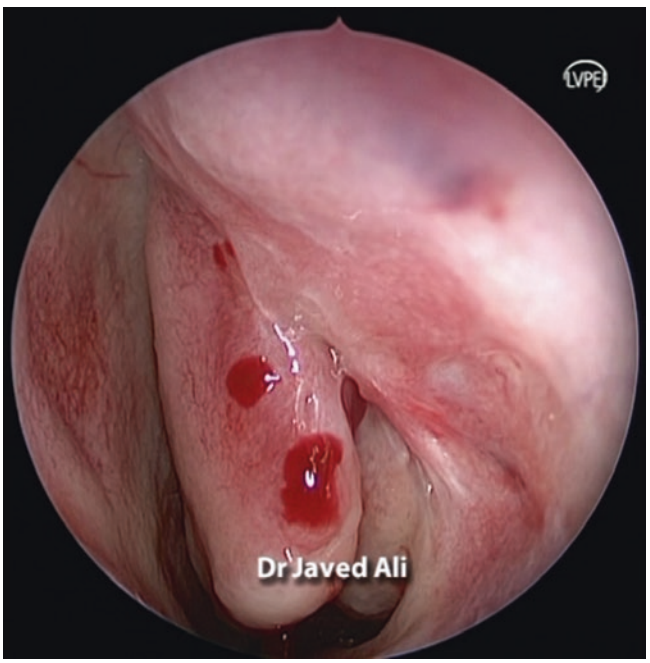


Fig. 30.16 Endoscopic view of a failed DCR showing a broad-based turbino-ostial synechiae

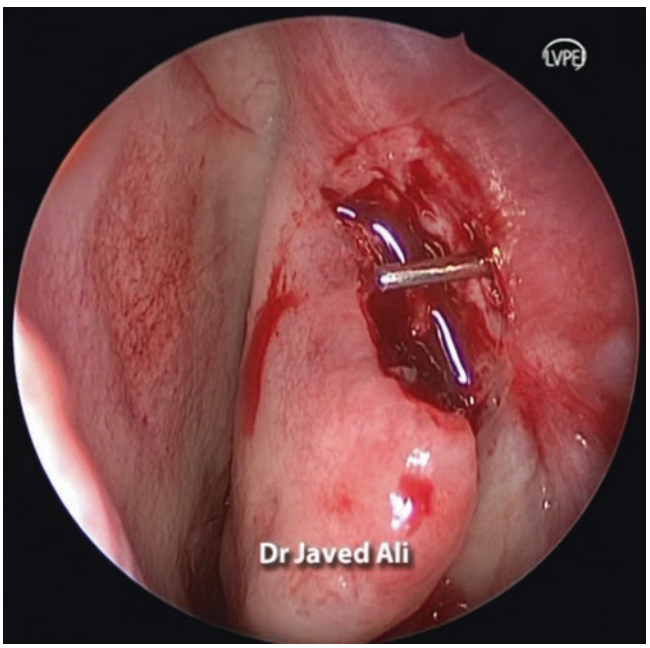


Fig. 30.18 Management of turbino-ostial synechiae: partial middle turbinoplasty to clear the area in front of the cicatrized ostium

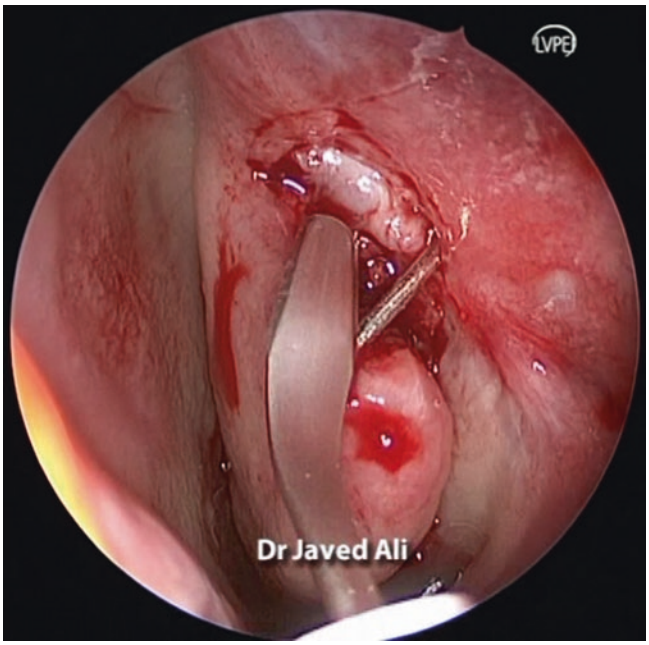


Fig. 30.19 Management of turbino-ostial synechiae: identifying and raising the lacrimal sac flaps

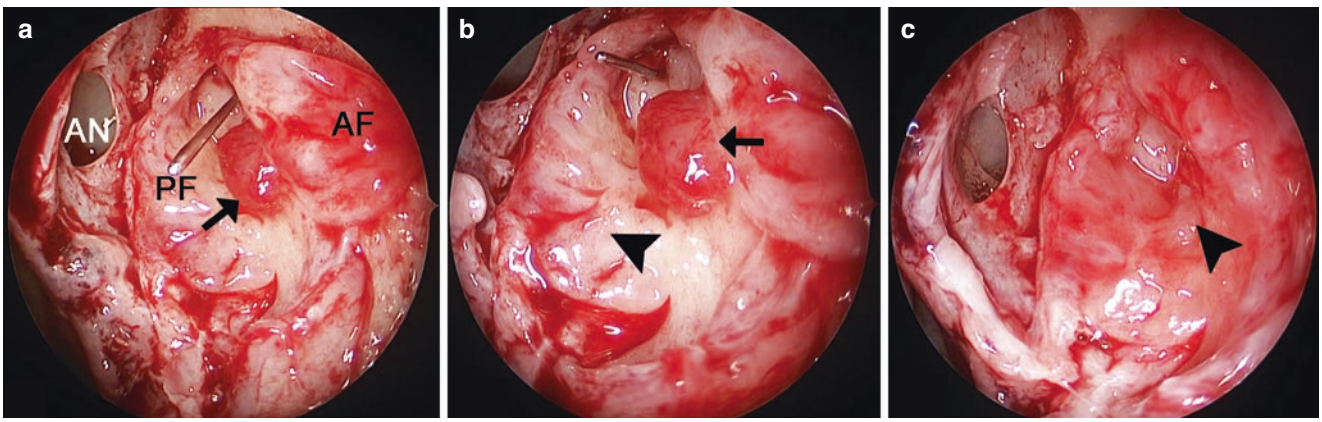


Fig. 30.20 Intrasaccal granuloma arising from the anterior wall (*arrow*). Note the anterior (AF) and posterior (PF) lacrimal sac flaps and the opened up agger nasi (AN) (**a**). Note its proximity to the internal common opening in panel (**b**) (denoted by the metallic probe) to the granuloma and also its broad-based nature. Panel (**c**) shows endoscopic features following the excision. Note the broad-based synechiae with areas of submucosal fibrosis. Also note that trauma was avoided to the underlying lacrimal sac mucosa

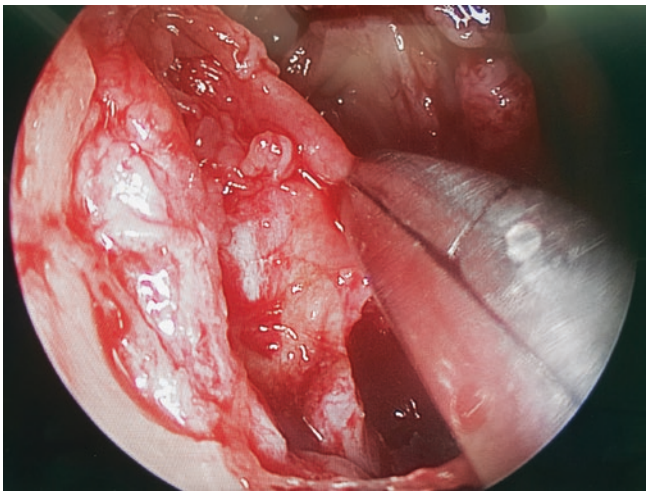


Fig. 30.21 Endoscopic features of the lacrimal sac in a case of lichen planus

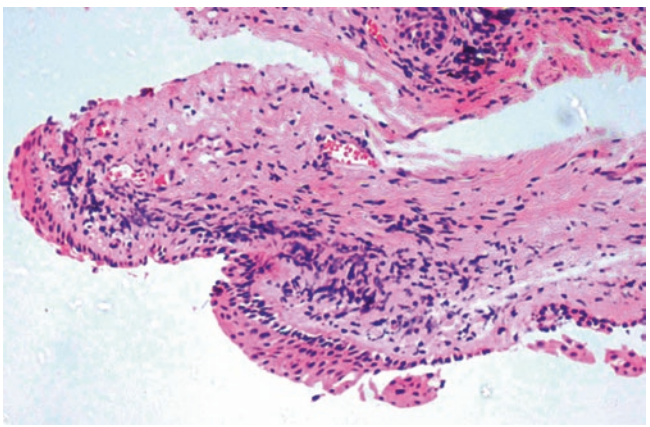


Fig. 30.22 Histopathological features of lacrimal sac in lichen planus. Note the dense stromal fibrosis and lymphocytic infiltrations

Fig. 30.23 Instrument fracture of the powered drill during an endoscopic DCR

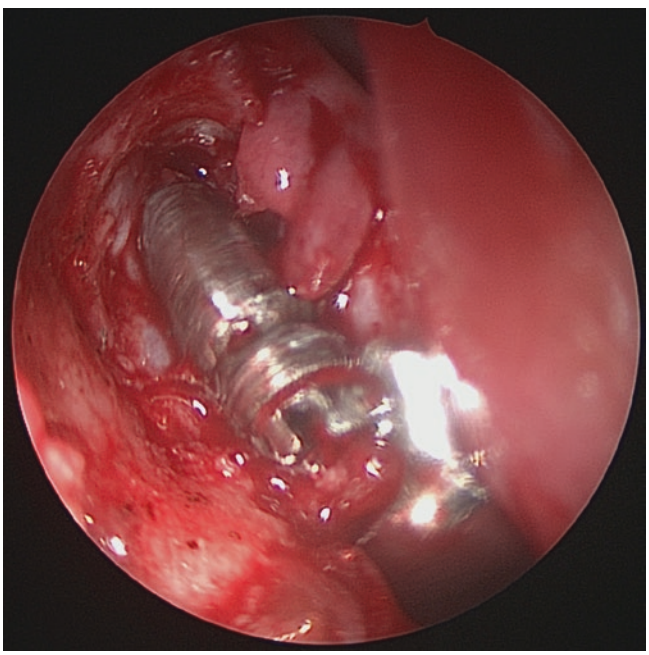


Fig. 30.24 Endoscopic picture showing retained tip of the drill soon after instrument fracture

Evaluation of a DCR Ostium and DOS Scoring

31

Mohammad Javed Ali, Alkis James Psaltis, and Peter John Wormald

Introduction

Dacryocystorhinostomy (DCR) is a common surgery employed for the management of nasolacrimal duct obstruction and chronic dacryocystitis with a high success rate [1–8]. However, the failure rates can occur from 4 to 13% [1, 9–11]. Many causes of failures can be attributed to ostium, the most common being scarring and cicatricial closure of the osteotomy site [9–12]. The other causes related to ostium include inadequate size, inappropriate location, intervening ethmoids, DCR to air cell, membranes over the internal common opening, granulomas, and sump syndrome [10, 12, 13]. Numerous studies in the past have focused on the size and measurement techniques of the ostium and patency tests [14–22]. It is amply evident that many finer physical and functional details of the ostium need to be evaluated postoperatively in an orderly manner to appreciate pathological behaviors early on and institute corrective measures toward prevention or treatment. This chapter presents a DCR ostium protocol for a detailed evaluation and also the DCR ostium or the DOS scoring to standardize the evaluation.

Evaluation of an Ostium

Defining an Ostium

The different parts of an ostium need to be defined before we start evaluating it. The ostium can be arbitrarily defined to have a base with four edges surrounding it, namely, anterior, posterior, superior, and inferior (Fig. 31.1).

Location of Ostium

The location of an ostium should be described in relation to the middle turbinate, which is the most prominent landmark in the vicinity. The most common location of the lacrimal sac is in front of the axilla of middle turbinate (MT) with two-thirds of the sac length above the insertion [23, 24]. Hence, most of the healed ostia should ideally be in front of the axilla of MT with some portion above it (Fig. 31.1). Occasionally it may be found behind the axilla of MT or completely above the axilla of MT owing to lacrimal sac's location (Fig. 31.2).

Shape of the Ostium

With a good primary intention healing, majority of the ostia are circular to oval (Figs. 31.1 and 31.3). The more important part of a shape is the depression of the base. The base is depressed but shallow in cases of good mucosa-to-mucosa approximation all across after a sufficient osteotomy to completely expose the sac (Fig. 31.4). Deep bases are also noted with good mucosal approximation but when the osteotomy is beyond what is sufficient (Fig. 31.3). Although ostia with deep bases are not a problem, the one with shallow bases should be strived for to be as natural as possible. Other shapes like crescentric or vertically narrow are seen in cases of irregular healing and inadequate, patchy cicatrization (Fig. 31.5).

Size of Ostium

Numerous studies have demonstrated multiple techniques of measuring an ostium (Fig. 31.6) [14–22]. The percentage of reduction from the original size subsequently is variable, and

M. Javed Ali, F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

A.J. Psaltis, F.R.A.C.S.
Department of Otolaryngology, Head Neck Surgery, The Queen Elizabeth Hospital, Adelaide, Australia

P.J. Wormald, F.R.A.C.S.
Department of Otolaryngology, Head Neck Surgery, The Queen Elizabeth Hospital, Adelaide, Australia

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_31

reasons are probably multifactorial. However, if mucosa-to-mucosa approximation is achieved all across and the healing completes with primary intention, the reduction in surface area is around 20% only [23]. Based on the literature and one of the author's (PJW) publication and detailed study of ostium, at 4-week evaluation, we propose to consider any ostium better than 8 × 5 mm as good (Figs. 31.1 and 31.3) and <4 × 3 mms as a mini-ostium (Fig. 31.7).

Evolution of an Ostium

Evolution of an ostium in the postoperative period is an important parameter to monitor (Figs. 31.8, 31.9, 31.10, 31.11, and 31.12). It helps in sequentially assessing the healing process and any deviant behaviors that demand intervention. Most of the ostium shrinkage happens in the first 4 weeks and very little if at all beyond that [19, 20]. Regular monitoring helps the surgeon also understand the response to the operative technique and if there is any need to modify step(s) of the surgery. Studying evolution of an ostium would perhaps be partly helpful in determining the benefits or harm of adjunctive procedures in DCR.

Ostium Cicatrix

Cicatrization is healing of the ostium with a scar tissue. The authors here describe a term "ostium pseudocicatix," where the ostium and its parameters are good, but much medially toward the septum, there is a vertical thin layer of scar tissue like a curtain (Fig. 31.13). It is important to differentiate this from true cicatrization.

The patient is asymptomatic. Functional endoscopic dye test (FEDT) and irrigation are patent. On endoscopy with a 2.7 mm telescope, there is usually a dehiscence, and visualizing from the edge and through it would make one visualize the normal ostium or FEDT flow (Fig. 31.13). Irregular healing can lead to incomplete cicatrization (Fig. 31.14) or a complete cicatricial closure (Fig. 31.15).

Ostial or Peri-ostial Synechiae

It is important to evaluate any synechiae involving the ostium in the early phases, and if found to be directly threatening the tear flow pathway, synechiolysis may be required. Early detection and management prevent consolidation of synechiae. Based on the anatomical location and threat, synechiae can be broadly divided into noninterfering and those interfering or likely to interfere with ostium functions (Fig. 31.16).

Internal Common Opening (ICO)

The ICO is the junction between the canaliculi and lacrimal sac and represents the distal end of the common canaliculus. The position of the ICO and its dynamicity should be evaluated. The most common location in an ideal ostium is at the base (Fig. 31.3). Occasionally it is in close relation to one of the four edges (Fig. 31.17) and uncommonly may be hidden by an overhanging edge (Fig. 31.18). ICO can be traced by simple visualization of an opening (Fig. 31.3), its movements, or using a dye test (Fig. 31.17). Beginners can also trace it with the help of silicone stent. While viewing the ICO, the patient is asked to blink, and the dynamic movements of ICO are studied with opening and closing of the eyelids. Presence of any obstructive tissues like membranes or rarely granulomas covering the ICO should be noted and appropriate measures like endocanaliculotomy initiated if warranted (Fig. 31.19).

Silicone Stent

Silicone stents and ostium's response to their presence should be carefully assessed. After clearing the discharge, the stent should be traceable from its distal cut end right up to the internal common opening (Figs. 31.8, 31.9, 31.10, and 31.11). The dynamicity of the ICO is transmitted to the stents, and it is common to observe the tubes moving with each blink. Hence, the stent movements are an indirect indicator of ICO dynamicity. It is important to assess any developing contact granulomas or stent entrapment within healing tissues. Entrapment may rarely occur if the tube is cut very short combined with an aggressive cicatrization.

Functional Endoscopic Dye Test (FEDT)

Functional endoscopic dye test is performed by placing 2% fluorescein drops in conjunctival cul-de-sac and assessing its natural flow into the ostium with normal blinking. In the presence of normal functioning lacrimal pump and patent passages, the dye is visualized in the ostium within few seconds (Fig. 31.1) and at maximum within a minute (Figs. 31.1, 31.5, and 31.17). The authors do not irrigate unless patient is symptomatic and FEDT is delayed or negative (no dye in ostium). If no spontaneous flow of dye is noted into the ostium, irrigation can occasionally show a fluorescein dye into the ostium reflecting lacrimal pump failure. No dye in the ostium on irrigation and reflux indicates a physical obstruction at ICO or proximal to it.

Ostial and Peri-ostial Granulomas

Ostial granulomas are occasionally encountered since a good endoscopic DCR with mucosa-to-mucosa approximation and primary intention healing prevents their occurrence. However, aggressive healing or contact granulomas secondary to stents may be noted (Fig. 31.20). Most of the granulomas resolve with topical ocular and nasal steroids. Granulomas threatening the ICO (Figs. 31.21 and 31.22) or entrapping a stent within them may require a careful surgical removal. Recently, 8 different types of ostial and peri-ostial granulomas have been described (Table 31.1), each with their characteristic features [25]. There has been an effort to standardize the management of each of these granulomas. Table 31.2 describes the management flowchart encompassing all the types.

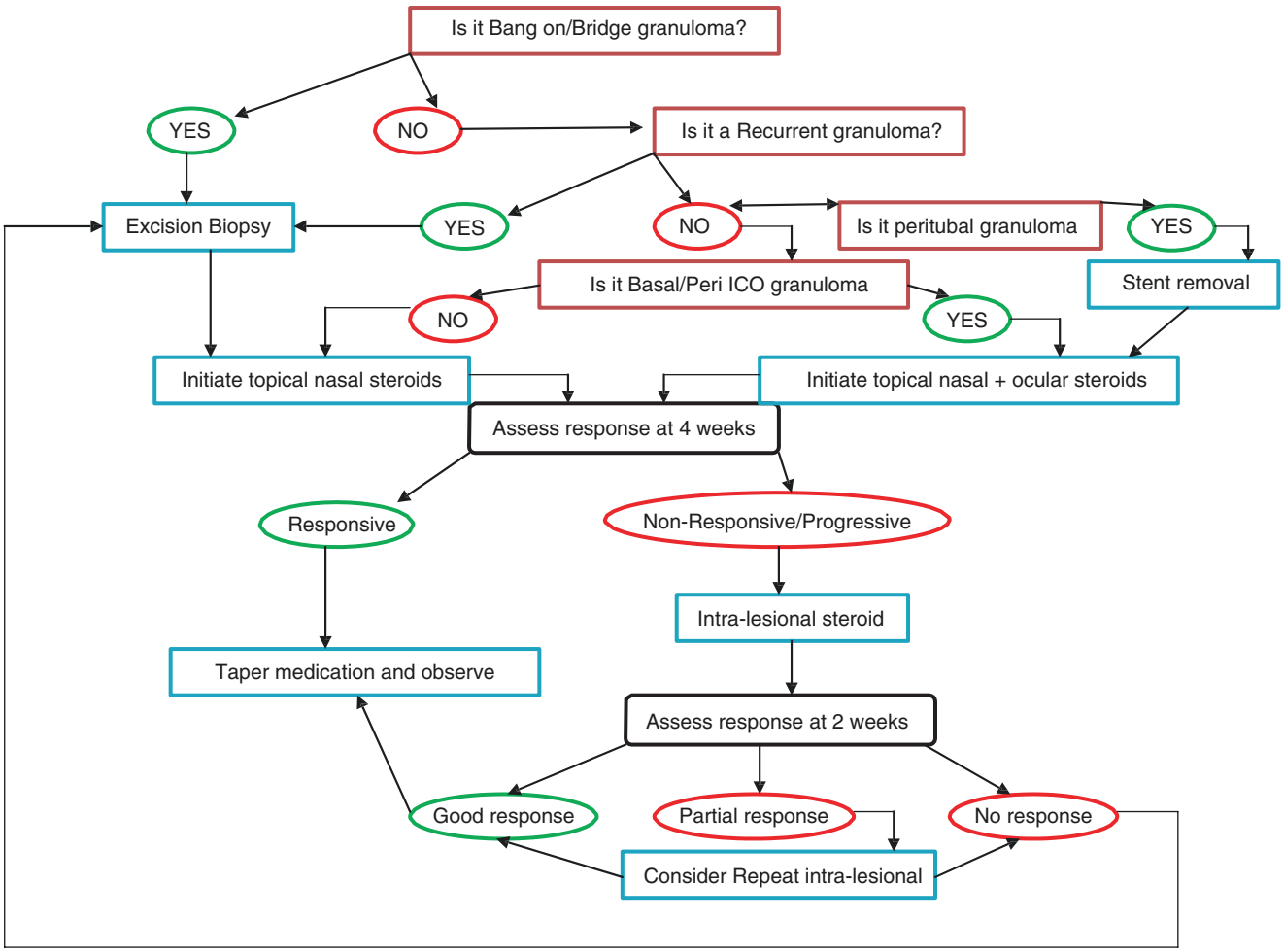
Table 31.1 Proposed classification of ostium granulomas

1. Edge granuloma
2. Basal granuloma
3. Peri-ICO granuloma
4. Bang on ICO granuloma
5. Peritubal granuloma
6. Edge to edge or bridge granuloma
7. Combined granuloma
8. Diffuse granuloma

Other Ostium Pathologies

There are numerous ostium pathologies or deviations from normal behaviors that need to be identified, monitored, and treated if indicated. Arbitrarily, they can be classed into major and minor. Major pathologies are rare and include soft tissue infection (Fig. 31.23) of the ostium, orbital breach and fat prolapsed toward the ostium, and organizing or obstructive tissues threatening the ICO. Minor pathologies can be diffuse ostium edema (Fig. 31.24), organizing discharge (Fig. 31.25) and ethmoid entry secondary to posterior location of sac (Fig. 31.26). There may be many more examples

Table 31.2 Proposed management guideline for ostium granulomas



of each category and should be classed based on the physical and functional threats to the ostium and outcome parameters.

DOS Scoring

The DCR ostium scoring or simply the DOS scoring system has been devised by the authors taking into consideration all the important parameters described in evaluation of an ostium. While giving different scores to each sub-parameter, current evidence-based understanding [14–22], author's past publications [6, 19, 23, 26–32], and clinical experience of ostium evaluation were taken into account. In spite of many details to note in each of the parameters, only the most significant have been included in the scoring to make it simple and easy to use.

The DOS scoring evaluates ten major parameters. Each major parameter is subdivided into four sub-parameters with a specific score for each in a descending order. Normal sub-parameter gets the highest score of 4 points, and the worst sub-parameter gets the lowest score of 1. The maximum points that can be achieved for an ostium evaluation is 40 and the minimum is 10. Based on the significance of each sub-parameter, overall ostia are graded as excellent (score of 36–40), good (31–35), fair (21–29), and poor (10–20). Table 31.3 depicts the DOS scoring.

Conclusion

Evaluation of the DCR ostium at regular intervals is crucial in achieving very high success rates. A better understanding of pathophysiology of healing and tissue response to operative techniques and adjunctive procedures can be additional advantages. Routine ostium evaluation helps the surgeon in early detection of pathologies and guides with indications for an appropriate intervention. The DOS scoring is an elaborate yet a simple scoring system that can be easily applied in routine clinical evaluation.

Table 31.3 The DCR ostium (DOS) scoring

PARAMETER	SUBPARAMETER WITH SCORES		PARAMETER	SUBPARAMETER WITH SCORES	
1.Location of Ostium:	In front and above axilla of MT	– 4	6. Internal Common Opening (ICO):	Uncovered by edge, Dynamic	--4
	Behind axilla of MT	-- 3		Overhanging edge, Dynamic	--3
	Any other location	-- 2		Partially obstructed / membrane	--2
	Not recognizable	-- 1		Not traceable with FEDT / irrigation	-1
2.Shape of the Ostium:	Circular / Oval with shallow base	– 4	7. Silicone Stents:	Course traced, moves with blink/Unintubated	-4
	Circular / Oval with deep base	-- 3		Intubated but lost/removed before 4 weeks	--3
	Crescentric / Vertical slit /others	– 2		Associated contact granuloma	--2
	Not recognizable	-- 1		Entrapped into ostial tissues	--1
3. Size of the Ostium: (Length x breadth)	> 8 x 5 mm	-- 4	8. FEDT:	Spontaneous and in < 1 minute	--4
	5 -9 x 3 –5 mm	-- 3		Spontaneous and in > 1 minute	--3
	1 – 4 x 1 –3 mm	-- 2		Not spontaneous but positive with irrigation	-2
	Obliterated	-- 1		Negative with irrigation	--1
4. Ostium Cicatrization:	None	-- 4	9. Ostium Granulomas :	None	--4
	Pseudocicatrix	-- 3		On one or more edges	--3
	Incomplete cicatricial closure	-- 2		Peri ICO / threatening ICO	--2
	Complete cicatricial closure	-- 1		Covering / obstructing ICO	--1
5. Synechiae:	None	-- 4	10. Other Ostium Pathologies :	None	--4
	Non-ostial / Non-interfering	-- 3		1 minor	-- 3
	Interfering Ostial	-- 2		> 1 minor	-- 2
	Complete synechial closure	-- 1		Major	-- 1

Maximum possible Score : 40

Minimum possible Score : 10

Ostium Grading Score : 36 – 40 = Excellent

30 – 35 = Good

21 – 29 = Fair

10 – 20 = Poor

Overall Ostium Score :

OSTIUM GRADE : EXCELLENT

GOOD

FAIR

POOR

References

1. Tarbet KJ, Custer PL. External dacryocystorhinostomy. Surgical success, patient satisfaction and economic costs. Ophthalmology. 1995;102:1065–70.
2. Turkcu FM, Oner V, Tas M, et al. Anastomosis of both posterior and anterior flaps or only anterior flaps in external dacryocystorhinostomy. Orbit. 2012;31:383–5.
3. Cokkeser Y, Evereklioglu C, Er H. Comparative external versus endonasal dacryocystorhinostomy: results in 115 patients. Otolaryngol Head Neck Surg. 2000;123:488–91.
4. Dolman PJ. Comparison of external dacryocystorhinostomy with non-laser endonasal dacryocystorhinostomy. Ophthalmology. 2003;110:78–84.
5. Hartikainen J, Grenman R, Puukka P, et al. Prospective randomized comparison of external dacryocystorhinostomy and endonasal laser dacryocystorhinostomy. Ophthalmology. 1998;105:1106–13.
6. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
7. Davies MJ, Lee S, Lemke S, et al. Predictors of anatomical patency following primary endonasal dacryocystorhinostomy: a pilot study. Orbit. 2011;30:49–53.
8. Codere F, Denton P, Corona J. Endonasal dacryocystorhinostomy: a modified technique with preservation of the nasal and lacrimal mucosa. Ophthal Plast Reconstr Surg. 2010;26:161–4.
9. Walland MJ, Rose GE. The effect of silicone intubation on failure and infection rates after dacryocystorhinostomy. Ophthalmic Surg. 1994;25:597–600.
10. McLachlan DL, Shannon GM, Flanagan JC. Results of dacryocystorhinostomy: analysis of the re-operation. Ophthalmic Surg. 1980;11:427–30.
11. Allen KM, Berlin AJ, Levine HL. Intranasal endoscopic analysis of dacryocystorhinostomy failure. Ophthal Plast Reconstr Surg. 1988;4:143–5.
12. Welham RA, Wulc AE. Management of unsuccessful lacrimal surgery. Br J Ophthalmol. 1987;71:152–7.
13. Konuk O, Kurtulmusoglu M, Knatova Z, et al. Unsuccessful lacrimal surgery: causative factors and results of surgical management in a tertiary referral center. Ophthalmologica. 2010;224:361–6.
14. Linberg JV, Anderson RL, Bumsted RM, Barreras R. Study of intranasal ostium at external dacryocystorhinostomy. Arch Ophthalmol. 1982;100:1758–62.
15. Ezra EJ, Restori M, Mannor GE, Rose GE. Ultrasonic assessment of rhinostomy size following external dacryocystorhinostomy. Br J Ophthalmol. 1998;82:786–9.
16. Ben Simon GJ, Brown C, McNab AA. Larger osteotomies results in larger ostia in external dacryocystorhinostomy. Arch Facial Plast Surg. 2012;14:127–31.
17. Argin A, Gorur K, Ozcan C, et al. The role of larger osteotomy in long term success in external dacryocystorhinostomy. J Plast Reconstr Aesthet Surg. 2008;61:615–9.
18. Baldeschi L, Nolst Trenite GJ, Hintschich C, et al. The intranasal ostium after external dacryocystorhinostomy and the internal opening of lacrimal canaliculi. Orbit. 2000;19:81–6.
19. Mann BS, Wormald PJ. Endoscopic assessment of the DCR ostium after endoscopic surgery. Laryngoscope. 2006;116:1172–4.
20. Chan W, Selva D. Ostium shrinkage after endoscopic dacryocystorhinostomy. Ophthalmology. 2013;120:1693–6.
21. Rootman D, DeAngelis D, Tucker N, et al. Cadaveric anatomical comparison of the lateral nasal wall after external and endonasal DCR. Ophthal Plast Reconstr Surg. 2012;28:149–53.
22. Yazici B, Yacizi Z. Final nasolacrimal ostium after external dacryocystorhinostomy. Arch Ophthalmol. 2003;121:76–80.
23. Wormald PJ, Kew J, Van Hasselt CA. The intranasal anatomy of the nasolacrimal sac in endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2000;123:307–10.
24. Rebeiz E, Shapshay S, Bowlds J, et al. Anatomic guidelines for dacryocystorhinostomy. Laryngoscope. 1992;102:1181–4.
25. Ali MJ, Wormald PJ, Psaltis AJ. The Dacryocystorhinostomy ostium granulomas: classification, indications for treatment, management modalities and outcomes. Orbit. 2015;34:146–51.
26. Kamal S, Ali MJ, Naik MN. Circumostial injection of MMC (COS MMC) in external and endoscopic dacryocystorhinostomy: efficacy, safety profiles and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
27. Lee A, Ali MJ, Li EY, et al. Balloon dacryoplasty in internal ostium stenosis following endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2014;30:7–10.
28. Ali MJ, Joshi DS, Naik MN, Honavar SG. Clinical profile and management outcomes of acute dacryocystitis: two decades of experience in a tertiary eye care center. Semin Ophthalmol. 2015;30:118–23.
29. Tsirbas A, Wormald PJ. Agger nasi cell mucosal autograft for lacrimal sac reconstruction during endonasal dacryocystorhinostomy. Orbit. 2004;23:105–10.
30. Roithmann R, Burman T, Wormald PJ. Endoscopic dacryocystorhinostomy. Braz J Otorhinolaryngol. 2012;78:113–21.
31. Tsirbas A, Davis G, Wormald PJ. Mechanical endonasal dacryocystorhinostomy versus external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2004;20:50–6.
32. Tsirbas A, Wormald PJ. Mechanical endonasal dacryocystorhinostomy with flaps. Br J Ophthalmol. 2003;87:43–7.

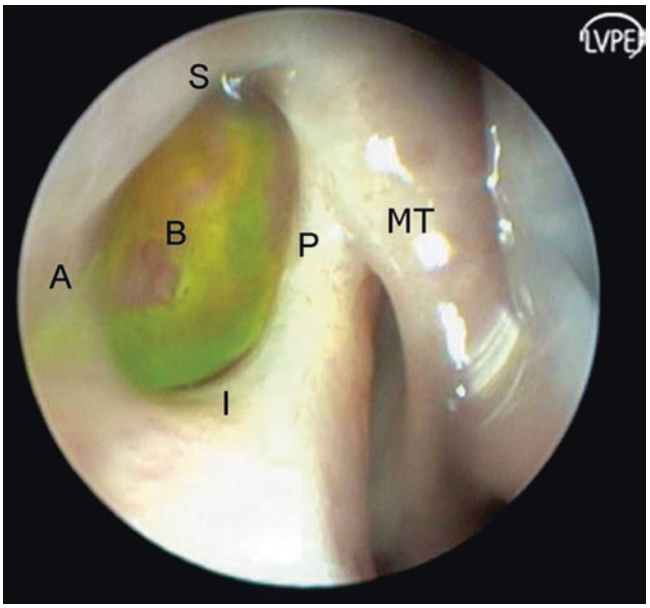


Fig. 31.1 Endoscopic view of an ostium with its named edges and base

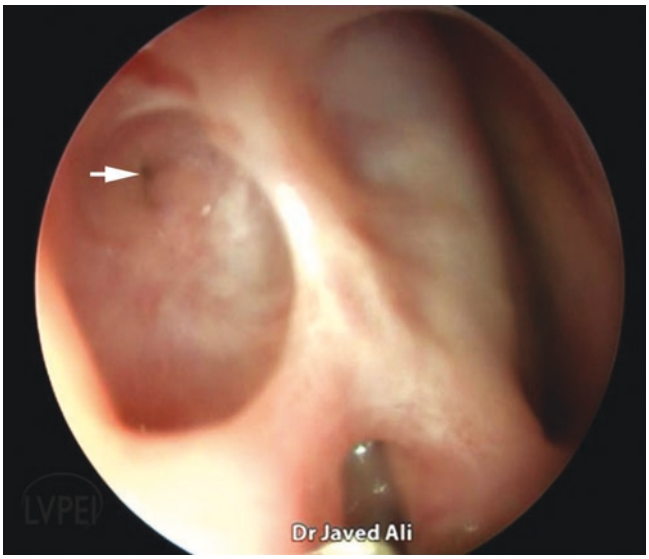


Fig. 31.3 Ostium with a deep base

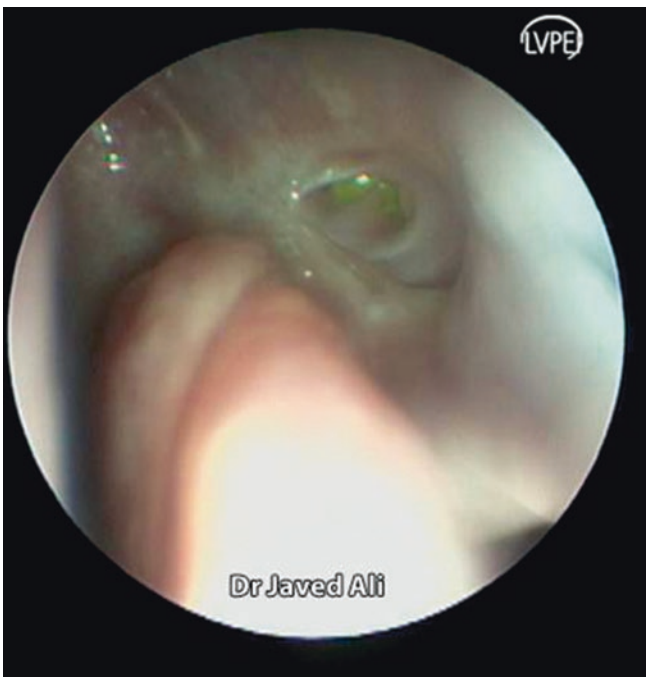


Fig. 31.2 Abnormal location: ostium above the axilla of middle turbinate

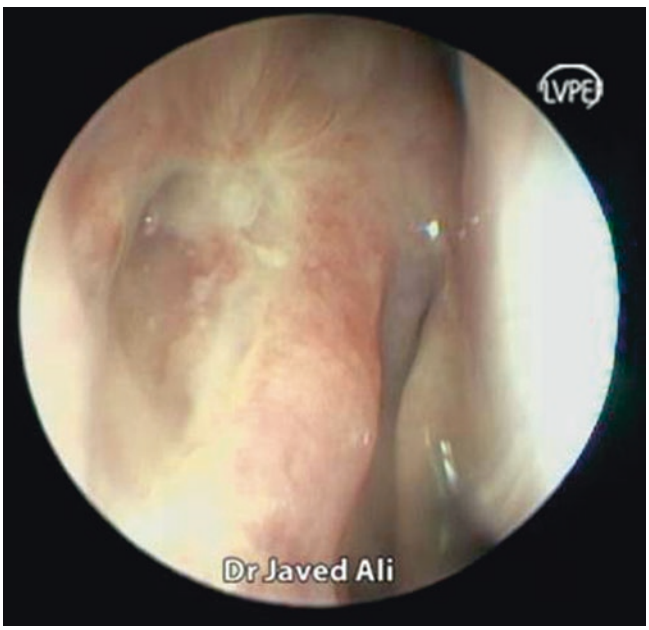


Fig. 31.4 Ostium with a shallow base

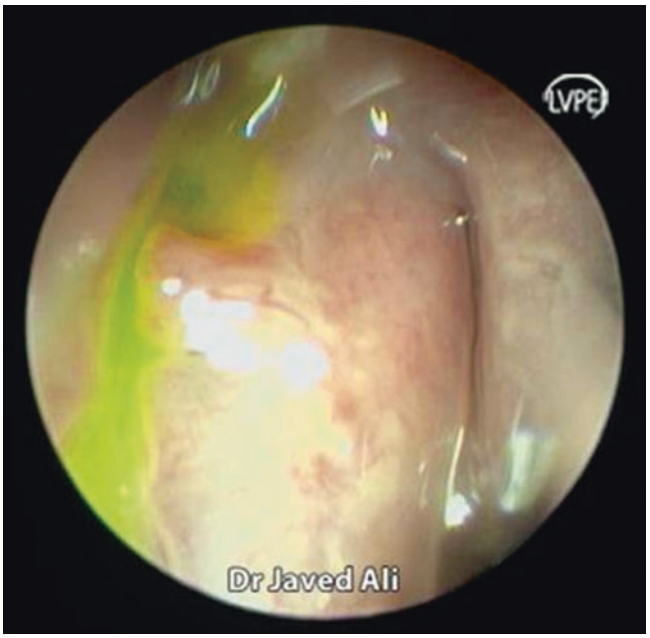


Fig. 31.5 Vertically narrow ostium

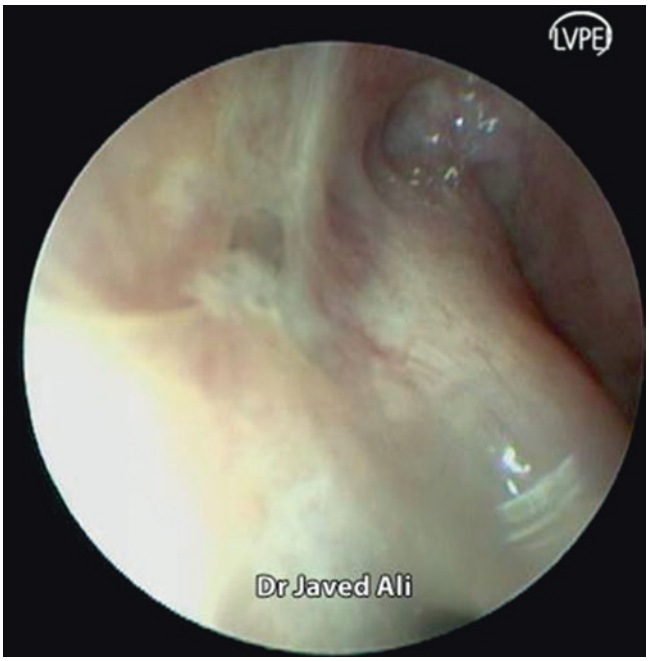


Fig. 31.7 A mini-ostium

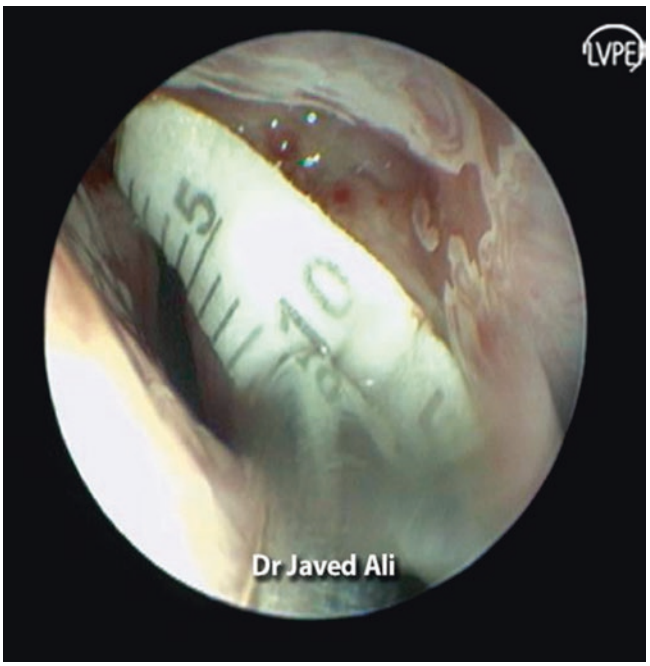


Fig. 31.6 Measuring an ostium

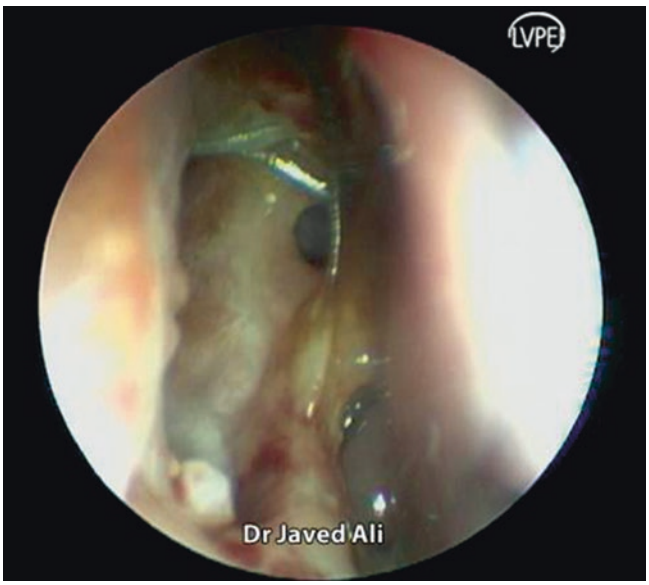


Fig. 31.8 Ostium at 1 week

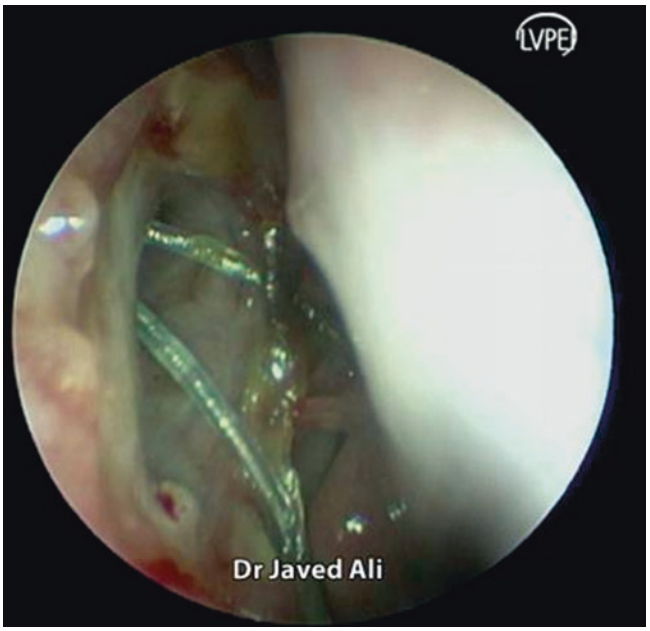


Fig. 31.9 Ostium at 2 weeks

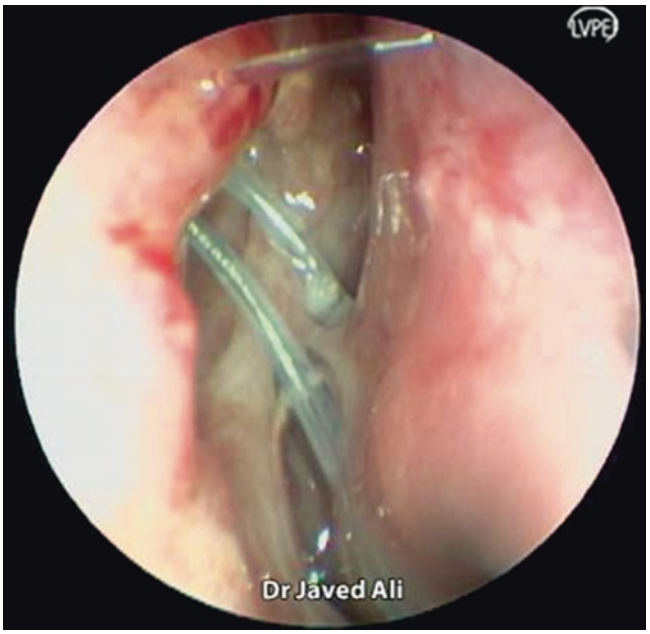


Fig. 31.11 Ostium at 4 weeks

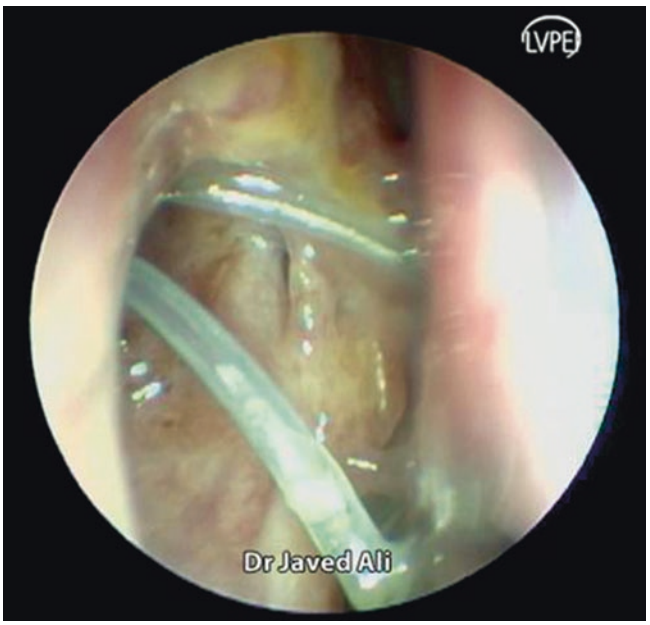


Fig. 31.10 Ostium at 3 weeks

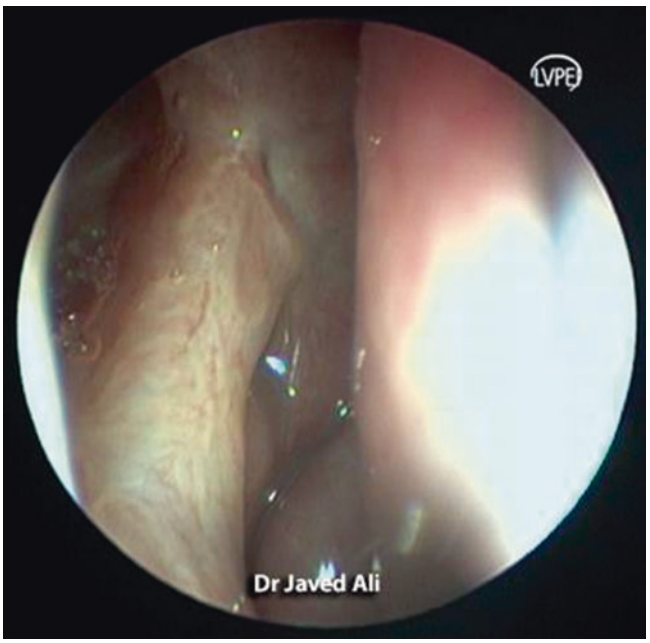


Fig. 31.12 Ostium at 6 weeks

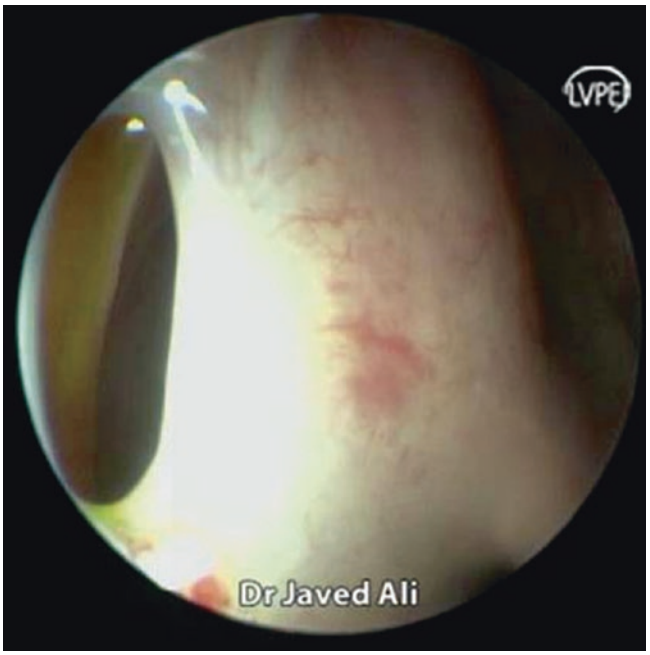


Fig. 31.13 Pseudocicatricial ostium

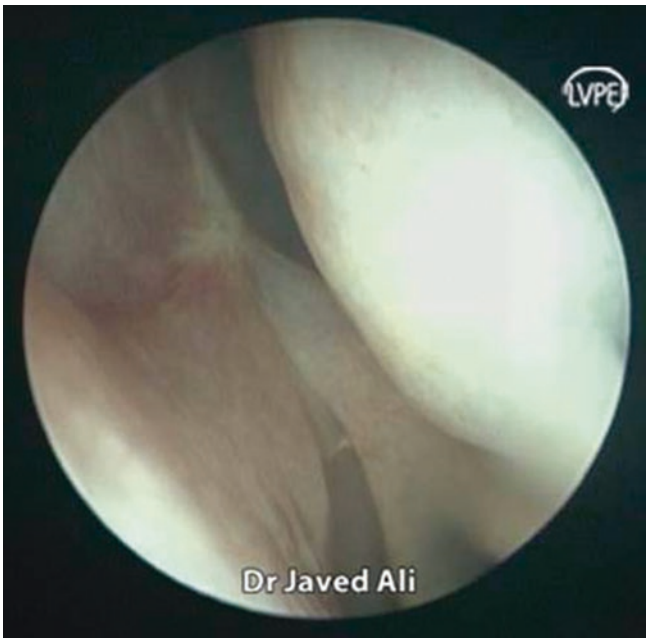


Fig. 31.15 Complete cicatricial closure

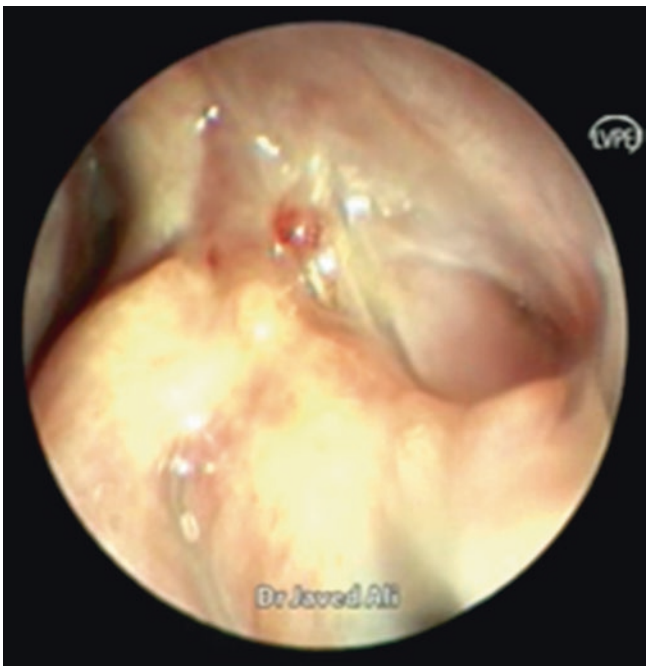


Fig. 31.14 Incomplete cicatrization

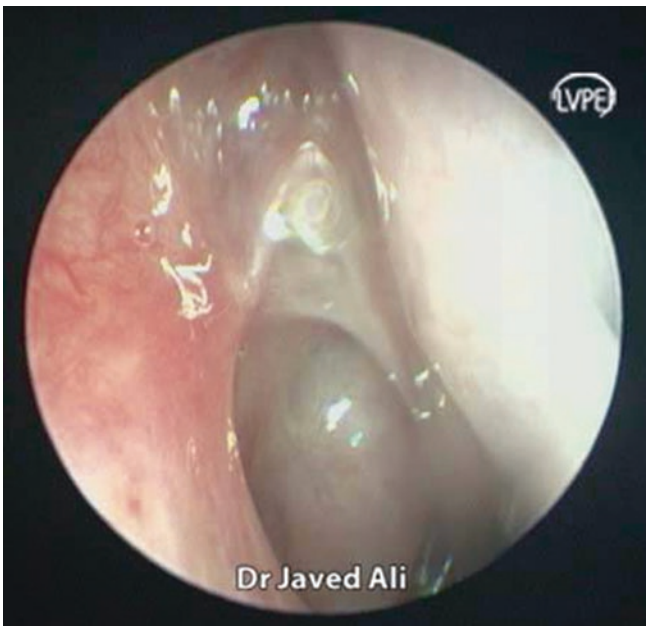


Fig. 31.16 Interfering ostio-septal synechiae

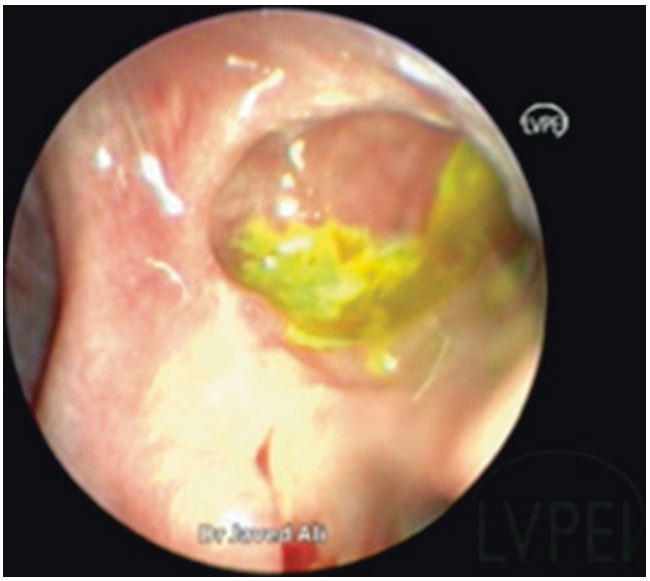


Fig. 31.17 Anterior edge ICO

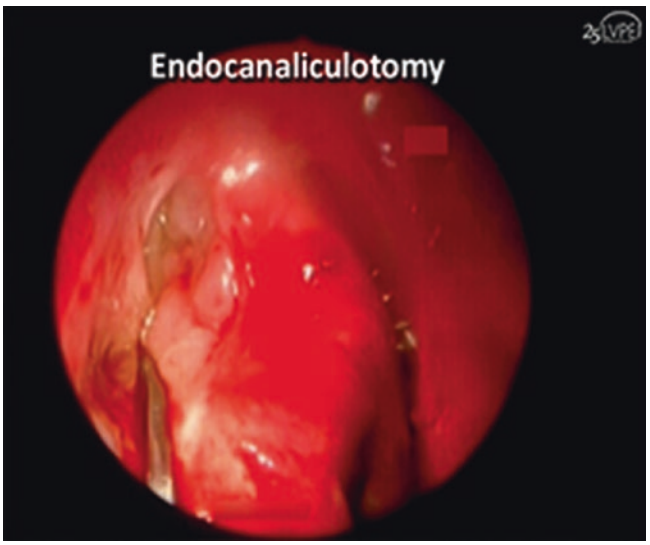


Fig. 31.19 Endocanaliculotomy

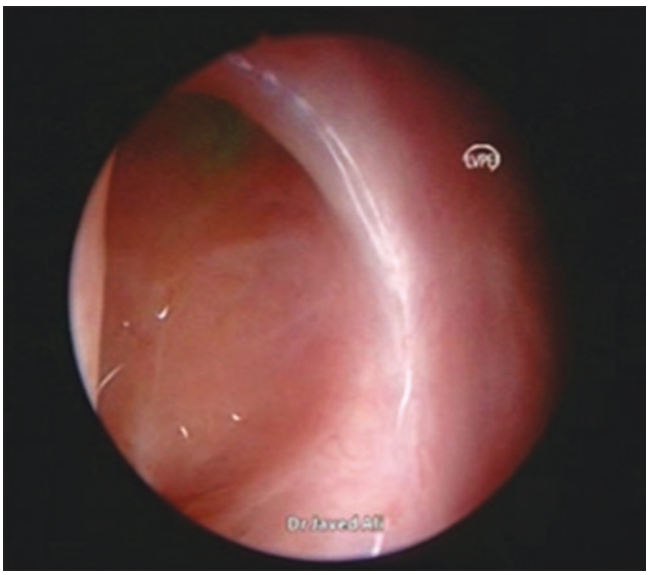


Fig. 31.18 ICO covered by an overhanging edge

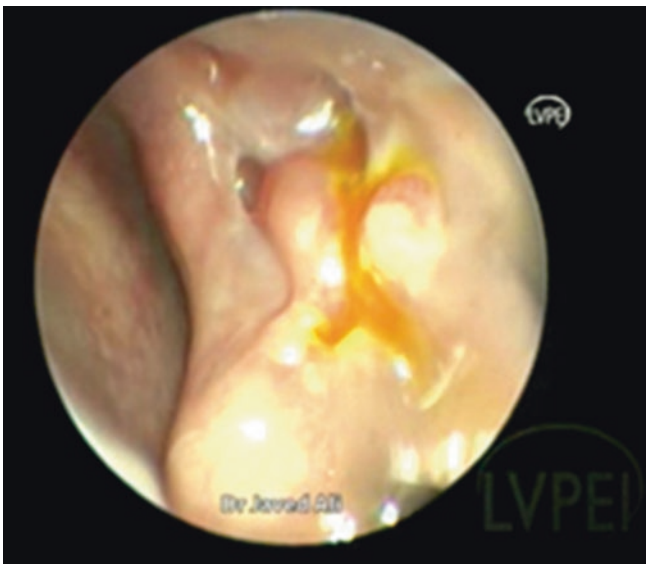


Fig. 31.20 A basal granuloma

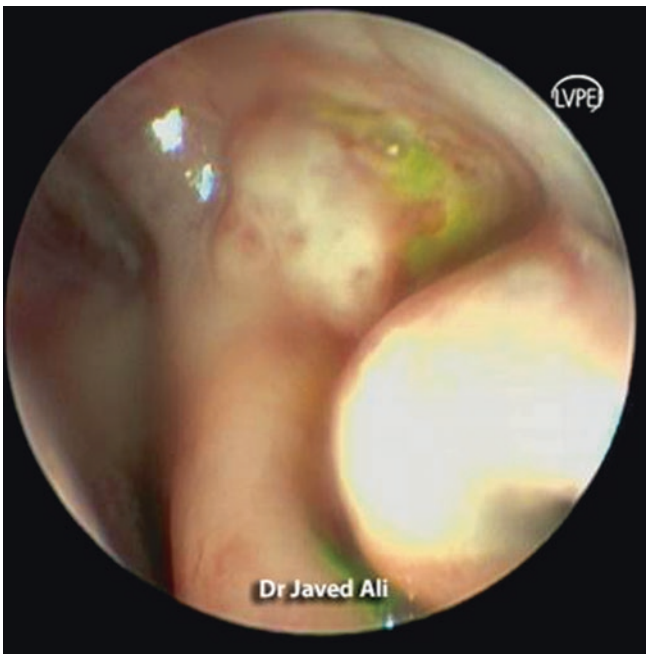


Fig. 31.21 ICO threatening granuloma

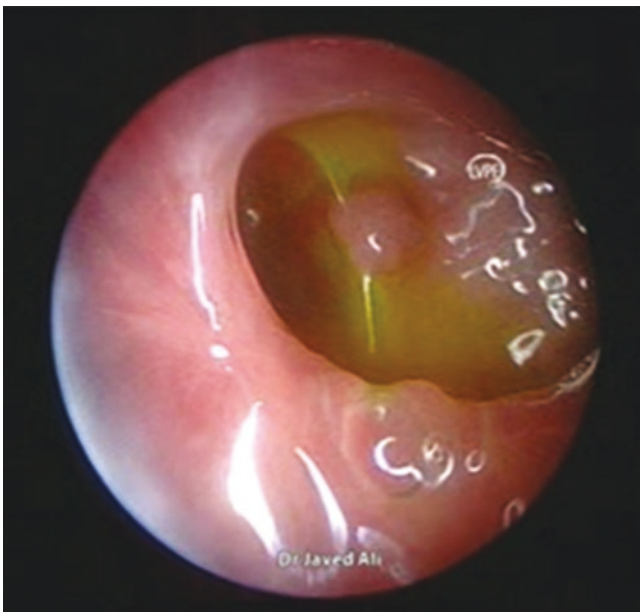


Fig. 31.22 Bang on ICO granuloma

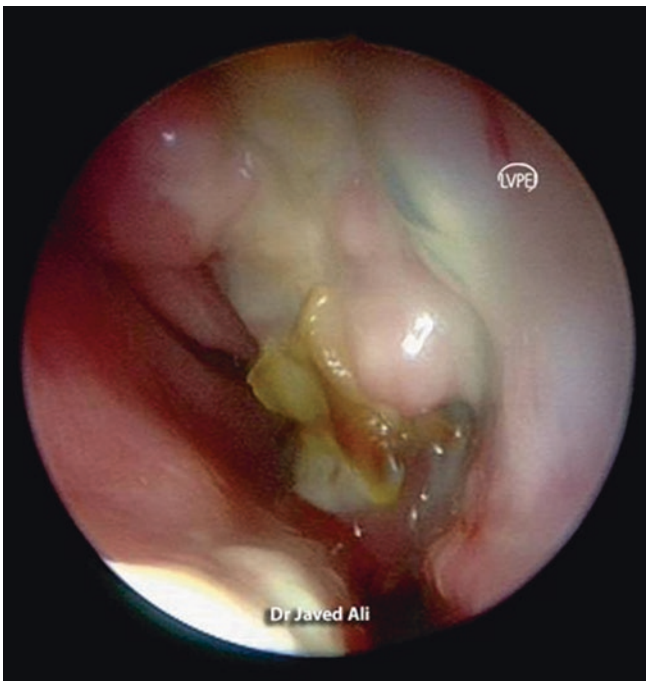


Fig. 31.23 Infected soft tissues of ostium

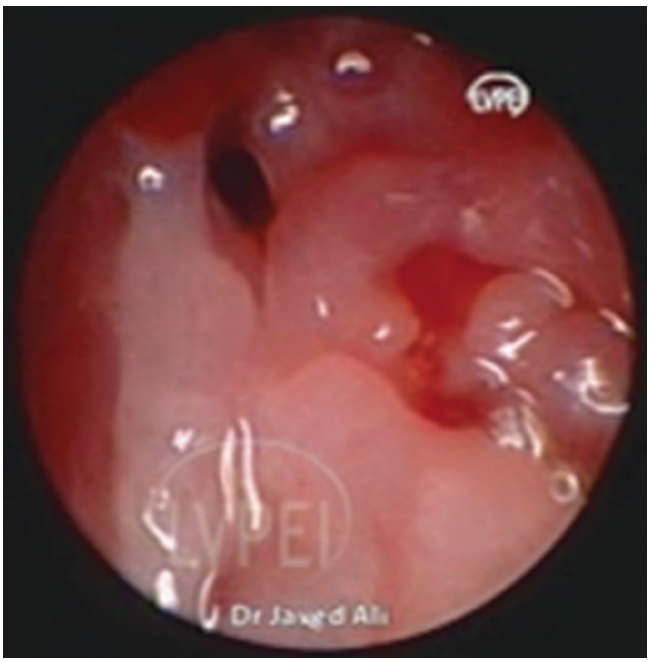


Fig. 31.24 Diffuse ostium edema

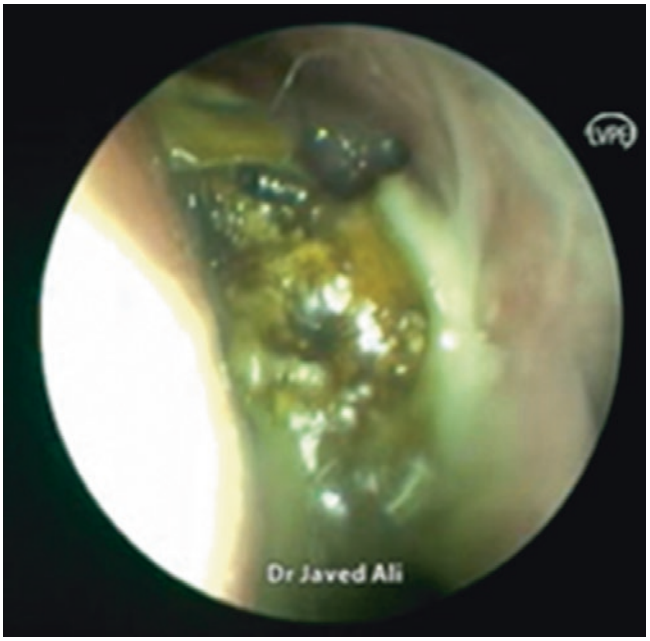


Fig. 31.25 Organizing discharge

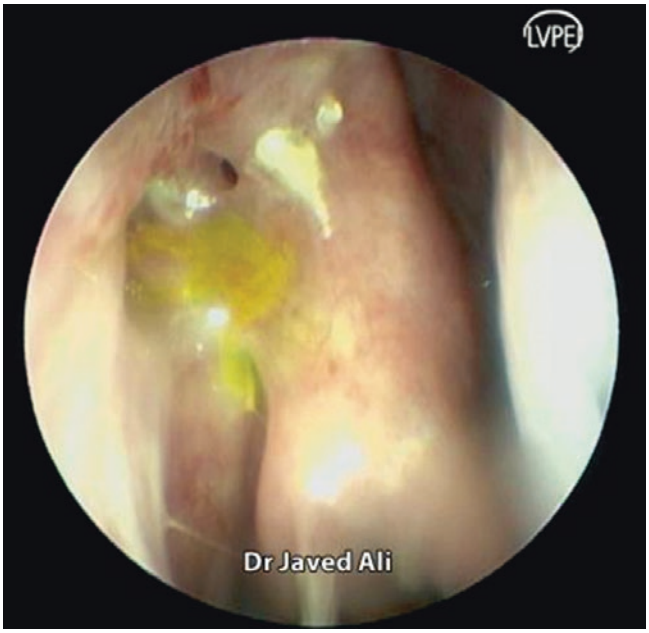


Fig. 31.26 Opened up ethmoids

Pediatric and Adult Balloon Dacryoplasty

32

David I. Silbert and Noelle S. Matta

Introduction

Over the past 15 years, balloon dacryoplasty has become a widely accepted treatment for nasolacrimal duct obstruction, for both primary treatment and as a secondary procedure following failed probing. In 1996 Becker et al. [1] reported on the efficacy of balloon catheter dilation in the treatment of congenital nasolacrimal duct obstruction (CNLDO) in children over 12 months of age and those children failing probing or silicone intubation. The commercial lacriCATH balloon was introduced shortly thereafter.

Classical treatment of CNLDO in children has included medical management consisting of lacrimal sac compression and topical antibiotics to control infection. Though this may increase rate of spontaneous resolution, there is no good data to prove this as the majority resolve spontaneously by 6–12 months of age. For those cases that do not resolve, typically nasolacrimal probing is performed either under general anesthesia or under topical anesthesia by 1 year of age. Classically, failure of probing has been treated with repeat probing with or without infracture of the turbinate; however, Pediatric Eye Disease Investigator Group (PEDIG) has shown that success rate of a repeat probing following initial probing failure was poor [2]. Following failure of probing, silicone intubation of the nasolacrimal system was the classical treatment followed by DCR for those patients failing intubation.

Surgical Technique

For children under 30 months, typically, a 2 mm balloon is recommended, while a 3 mm balloon is recommended for older children and adults. A larger balloon, however, can be used in younger children at the surgeon's discretion. Preoperatively, intravenous dexamethasone should be given. Antibiotics can also be administered, if there are signs of infection. The nares should be packed with cottonoids soaked in oxymetazoline beneath the inferior turbinates. A sterile prep of the face is not required for the procedure as the nose is inherently dirty. At this point the puncta are widely dilated (Fig. 32.1), and Bowman probes can be used to probe first (Figs. 32.2 and 32.3), though newer balloon probes can be passed without first passing Bowman probes with the help of hash marks (Fig. 32.4). At this point cottonoids are removed, and proper placement of the probe is confirmed beneath the inferior turbinate. Placement of the balloon is verified in the nose by direct inspection, use of an endoscope, or with direct metal on metal contact. Inspection with an endoscope however provides the most certainty of proper placement.

Once the balloon catheter is assembled with the manometer as per standard protocols (Fig. 32.5), the balloon is inserted into the nasolacrimal duct just like a probe under endoscopic guidance up to the opening in the inferior meatus (Fig. 32.6) and inflated with an inflation device using saline. Fluorescein can be used to color the saline making the balloon more visible during inflation in the nose (Fig. 32.7). The balloon is then inflated to 8 atmospheres of pressure for 1 min (Fig. 32.7), and deflated (Fig. 32.8), and repositioned higher in the duct, and the inflation is repeated for additional one to two times. Hash marks on the tube can help guide placement of the tube, but due to the variation in anatomy between younger and older patients, direct visualization is best to ensure that the balloon is across the valve of Hasner for the first dilation (Fig. 32.4). After that the balloon can be pulled back so the first hash mark is visible at the punctum, then reinflated for a minute, deflated, and pulled back to the second hash mark for a final inflation. The second hash mark typically corresponds to balloon placement in the nasolacrimal sac and proximal duct. A stopcock can be used in bilateral procedure to inflate both balloons simultaneously saving surgical time. At the end of the procedure, a dilated nasolacrimal duct opening is usually noted (Fig. 32.9).

D.I. Silbert, M.D., F.A.A.P. (✉) • N.S. Matta, C.O., C.R.C., C.O.T.
Family Eye Group, Lancaster, PA, USA
e-mail: DSilbert@familyeyegroup.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_32

Advantages of the balloon include the lack of an implant in the nasolacrimal system and the ability to dilate the system much larger than with typical lacrimal probes without traumatizing the canalicular system. Disadvantages of the balloon include their relative cost. However, balloon dacryoplasty is effective following failed probing as well as a primary procedure as per physician preference. Some surgeons prefer a balloon in older children; however, the PEDIG NLD1 study showed good results with primary probing even in older children [3, 4].

Postoperative care following balloon dacryoplasty is intended to prevent infection, scarring, and restenosis of the nasolacrimal system and should include topical, oral, and intranasal steroids and antibiotics as appropriate. For children it is advisable to use a steroid antibiotic drop such as tobramycin-loteprednol or tobramycin-dexamethasone, four times daily for a week. An oral antibiotic such as such as cephalexin can be given for 7 days. Finally oral prednisolone 5 mg/5 ml can be used in children at a dose of up to 2 mg/kg per day split in three doses for 3 days and then half the dose for an additional 3 days, while a prednisolone taper pack can be used in adults. Intranasal steroids can be added in older children and adults once daily for a few weeks.

Balloon Dacryoplasty and Complex CNLDO

Balloon dacryoplasty is particularly useful in cases of partial obstruction. These children typically present to the ophthalmologist at an older age with waxing and waning symptoms. They will have periods of relative normalcy followed by periods of apparent obstruction. Often the parents are frustrated with their primary care physician for not diagnosing the problem, but this is likely due to the intermittency of the problem. The symptoms are most likely related to a stenosed but patent nasolacrimal system, which intermittently becomes obstructed during periods of rhinitis, allergy, or upper respiratory infection. History taking is more important in diagnosing intermittent obstruction as symptoms during exam will vary widely and may not even be present. Balloon dacryoplasty is the preferred treatment for partial obstruction as it can enlarge the stenotic duct preventing intermittent obstruction.

Failure in balloon dacryoplasty as in probing and silicone intubation is typically due to complicated factors like creation of a false passage, bony anomalies, or infection and scarring following the procedure. Utilization of an endoscope can help verify proper placement and guide passage of the probe in more difficult cases. The surgeon can be deceived by apparent metal on metal since a probe can be passed into the nares through a false passage. Becker's higher success rate compared to other studies may relate to the use of an endoscope or direct visualization of the probe in most cases.

When utilizing an endoscope, a 2.7 mm pediatric endoscope should be used in children, while a 4 mm endoscope may be used in adults. The use of a 0° or a 30° endoscope is as per surgeon preference, though depending on the anatomy, a 30° may be more useful as it can be placed lower in the nose to look superiorly. The ophthalmologist who wishes to learn this skill can begin utilizing endoscopes in all nasolacrimal procedures to begin with, to understand the appearance of the normal nasal anatomy.

In patients with bony stenosis during initial probings, it is wise to document this in the operative note and inform the parents. Some of these children can benefit from an endoscopically guided balloon dacryoplasty; however, if the passage cannot be negotiated with the balloon probe, conversion to an endoscopic DCR would be a good option. Especially in secondary procedures, it is prudent to treat infection with oral antibiotics preoperatively and treat with systemic antibiotics and steroids postoperatively to prevent re-scarring of the NLD.

Results of Pediatric Balloon Dacryoplasty

Becker's prospective study was performed on 61 lacrimal systems in 51 patients from ages 13–73 months (average 26 months). 44% had no previous surgery, while 34% had one or more failed probing, and 21% had failed silicone intubation. Procedures were performed with the aid of a nasal endoscope to visualize the probe beneath the inferior turbinate before dilatation. In order to optimize results, infection was suppressed preoperatively with oral and topical antibiotics, which were continued for 10 days after surgery. Oral and topical steroids were added postoperatively for 5 days and 10 days, respectively, to suppress inflammation and prevent re-scarring of the nasolacrimal duct (NLD). Success was measured at 6 weeks postoperatively and was defined as the absence of tearing or discharge, a normal tear meniscus, and a normal dye disappearance test (DDT). In this tightly controlled study, success rate was 96% in those patients treated with the balloon as a primary procedure. In patients treated following failed probing or silicone intubation, 94% were successful at 6 weeks [1].

In Becker's original study, children were placed under general anesthesia [1]. The nares were packed with cottonoids soaked in cocaine 4% or 0.25% phenylephrine, and patients were given intravenous antibiotic and steroid. The puncta were then dilated, and the nasolacrimal system was probed. The probe was directly visualized in the nose beneath the inferior turbinate either with headlight and nasal speculum or endoscope in many cases and, in the other cases, was touched with a Bowman probe or mosquito hemostat, which is more typical of how most ophthalmologists currently perform the procedure. A balloon probe was then inserted, and

placement was similarly confirmed. 2 mm balloons were used for children 30 months of age or younger, while a 3 mm balloon was used for older children. The balloon was inflated to 8 atmospheres for 90 s, deflated, reinflated for 60 s and then deflated, moved more proximally to just beyond the common canaliculus and then inflated two additional times for 90 and 60 s, and then deflated and withdrawn from the system. In addition to postoperative oral and topical steroids and antibiotics postoperatively, children were also treated with oxymetazoline or phenylephrine intranasal drops for 5 days postoperatively. Of the three failures in Beckers study, 2 were anatomic failures, as the probe could not be visualized beneath the inferior turbinate. The third failure was a partial failure such that the child was symptomatic when allergic rhinitis was present but was asymptomatic with a patent nasolacrimal system at other times.

Becker postulated that chronic infection and fibrosis might account for failure of probing in certain children. He felt that nasolacrimal systems with fibrosis and constriction proximal to the valve of Hasner would not respond well to probing since a typical number 0 Bowman probe measures only 0.71 mm, but would respond to the balloon since the inflated balloon profile measures 2 or 3 mm. Elimination of infection prior to surgery and elimination of inflammation postoperatively were felt to be critical for success of the procedure.

Subsequent reports on balloon dacryoplasty in children have shown good results. Maheshwari et al. [5] showed an 87.5% (7 of 8) success rate in secondary balloon dacryoplasty following initial probing failures in children aged 2–6 years with complex obstructions [5]. Casady et al. [6] reported on a stepwise treatment of nasolacrimal duct obstruction in 127 patients ranging in age from 1 to 81 months [6]. Balloon dacryoplasty was performed after failure of initial probing. Of 39 probing failures, 32 were cured with balloon catheterization with a success rate of 82.1% [6]. Chen and Hsiao reported a success rate of 79% (57 of 72 children) for balloon dacryoplasty as primary treatment in a group of older children aged 18–112 months [7]. Tien and Young reported an 82% (32/39) success rate for secondary balloon dacryoplasty following failed probing in children aged 10–84 months and concluded that although the success rate might be lower than some published reports of silicone intubation, the simple and atraumatic nature of the balloon procedure makes it an attractive alternative to silicone intubation [8].

In the most definitive study, the NLD2 study, the Pediatric Eye Disease Investigator Group (PEDIG) prospectively enrolled patients into one of two groups following failed probing. The study included children 6 to <48 months of age following a failed probing. The patients were not randomized but were treated with silicone intubation, balloon dacryoplasty, or repeat probing as per choice of the investigator. Treatment success was defined as no epiphora, mucous discharge, or increased tear film at a follow-up visit 6 months following the procedure. In the balloon group, success was found to be 77%, while in the intubation group, it was found to be 84%. Repeat probing was successful only 56% of the time. Although the study was prospective, it is limited by the lack of randomization. The PEDIG group concluded that both procedures were successful in a similar proportion of patients [2].

Adult Balloon Dacryoplasty

Balloon dacryoplasty can also be used for adults with partial obstruction; however, results typically are not as good as for children. Couch et al. [9] reported on results of endoscopically assisted balloon dacryoplasty for treatment of partial NLDO in one hundred adult patients. While 90% of patients had improvement in their symptoms postoperatively, only 56% of patients experienced complete relief of their epiphora [9]. This is similar to the experience of few others [10]. While the procedure is most often successfully completed in adults, symptoms are often not completely eradicated to the patient's satisfaction, and long-term results are unknown.

Perry et al. reported on the combined use of balloon dacryoplasty and silicone intubation in 13 adults with partial NLDO [11]. The patency to irrigation at 6 months (tubes were removed at 2 months) was noted to be 73%, while 60% had a subjective reduction in epiphora. In the case of adults, the endoscope is invaluable as it can let the surgeon know whether the probe is passed properly or the presence of false passage. Also in the adult, the endoscope is far easier to use as compared to children, as the nares are larger. In the case of adults when a balloon dacryoplasty under general anesthesia is under consideration, consent can also be obtained for an endoscopic balloon-assisted DCR. After initial probing, if the system is felt to be too tight or if it is difficult to navigate the system with the probe, the procedure can be converted to an endoscopic balloon DCR. Patients appreciate this approach as it has a higher chance of success. Although complete NLDO in adults can be treated with balloon dacryoplasty under fluoroscopy, and it was possible to pass a balloon successfully through the nasolacrimal system, only 25% of patients were ultimately successfully treated [12].

Updates (2015–2016)

Subsequent to the publication of the chapter, a literature search revealed some new publications. A survey of members of the American Association of Pediatric Ophthalmology and Strabismus (AAPOS) was undertaken by Dotan and Nelson [13]. Questionnaires were sent electronically to 1495 mem-

bers of AAPOS with 127 responses received back. The authors found that 3% of pediatric ophthalmologists utilized balloon dacryoplasty when performing primary procedures in 12-month-olds for congenital nasolacrimal duct obstruction (CNLDO), while less than 1% combined silicone tubes and balloons in this age group, while 17% used silicone intubation as the primary procedure. At 24 months 21% performed primary balloon dacryoplasty, and an additional 3% performed balloon dacryoplasty combined with silicone intubation, while 29% utilized silicone tubes as the primary procedure. At 3 years of age, the numbers were 24%, 5%, and 38%, respectively. Of interest, probing was the first choice for children 2 years and under, but at age 3 silicone intubation was the most commonly performed primary procedure. Physicians practicing less than 10 years tended to prefer balloon dacryoplasty to silicone intubation. For secondary procedures following a failed probing, balloon dacryoplasty was used 23% of the time, while balloon and silicone intubation was performed 9% of the time and silicone intubation alone 51% of the time. The authors noted that the study shows a lack of consensus among pediatric ophthalmologists in the management of CNLDO. The study is limited by a response rate of less than 10% of AAPOS members.

The use of balloon dacryoplasty outside of the United States is likely much less prevalent. Nair and Kamal [14] surveyed members of the Oculoplastic Association of India (OPAI) via email. They had a 46% response rate with 124 of 267 members responding. For primary procedures, 33% utilized silicone intubation, while only 7% utilized a balloon. Of interest 50% of respondents reported using an endoscope for all of their probings. Only 3% of respondents used balloon dacryoplasty in cases of failed probing. The authors suggested that the higher cost was likely an issue affecting adoption in India.

Lin et al. [15] conducted a meta-analysis comparing treatments for CNLDO. The meta-analysis was conducted according to Cochrane collaboration and the quality of reporting of meta-analyses, the PRISMA guidelines. Studies were included in the analysis if they were randomized controlled trials or prospective trials. The authors found two studies comparing balloon dacryoplasty and silicone intubation that met the requirements. They found that 79.8% (83/104) of the patients in the balloon dacryocystoplasty group and 77.8% (87/112) of the patients in the intubation group were treated successfully. There was no significant difference between the two groups.

The use of balloon dacryoplasty is less prevalent in adults than in children. Success rates of balloon dacryoplasty have been quite variable. Ali et al. [10] report on the short-term results of endoscopic guided anterograde 3 mm balloon dacryoplasty combined with silicone intubation in adults with acquired partial nasolacrimal duct obstructions (4). Their study was retrospective in nature and included 21 eyes with partially obstructed nasolacrimal ducts in 12 patients. Patients with canalicular stenosis, partial canalicular obstructions, or post-traumatic obstruction were excluded from the study. The procedures were performed under general anesthesia. The authors noted anatomical success in 71% and a functional success rate of 62%. The use of silicon tubes in addition to the 3 mm balloon likely improved the success rate. The authors concluded that balloon dacryoplasty was minimally invasive and produced satisfactory results but were not sure of the long-term results. Further investigation of this approach is needed [10].

Conclusion

Balloon dacryoplasty has become a popular procedure over the past 15 years. It has shown itself to be successful in children as a secondary procedure following failed probing and as a primary procedure in select patients especially children with partial nasolacrimal obstruction or older children. Advantages of the balloon include the lack of a retained implant as in the case of stents and the relative ease of the procedure. The use of an endoscope may improve outcomes. Suppressing pre- and postoperative inflammation and infection likely improves outcomes. Although the results in adults with partial NLD obstructions are encouraging, long-term results are awaited to conclusively ascertain its role as an alternative to a dacryocystorhinostomy.

References

1. Becker BB, Berry FD, Koller H. Balloon catheter dilation for treatment of congenital nasolacrimal duct obstruction. Am J Ophthalmol. 1996;121:304–9.
2. Pediatric Eye Disease Investigator Group. Balloon catheter dilatation and nasolacrimal duct intubation for treatment of nasolacrimal duct obstruction following a failed probing. Arch Ophthalmol. 2009;127:633–9.
3. Pediatric Eye Disease Investigator Group. Primary treatment of nasolacrimal duct obstruction with probing in children less than four years old. Ophthalmology. 2008;115:577–84.
4. Ali MJ, Naik MN, Honavar SG. Balloon dacryoplasty: ushering a new and routine era in minimally invasive lacrimal surgeries. Int Ophthalmol. 2013;33:203–10.
5. Maheshwari RJ. Balloon catheter dilation for complex congenital nasolacrimal duct obstruction in older children. J Pediatr Ophthalmol Strabismus. 2009;46:215–7.
6. Casady DR, Meyer DR, Simon JW, et al. Stepwise treatment paradigm for congenital nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2006;22:243–7.
7. Chen PL, Hsiao CH. Balloon dacryocystoplasty as the primary treatment in older children with congenital nasolacrimal duct obstruction. J AAPOS. 2005;9:546–9.
8. Tien DR, Young DJ. Balloon dilation of the nasolacrimal duct. J AAPOS. 2005;9:465–7.
9. Couch SM, White WL. Endoscopically assisted balloon dacryoplasty treatment of incomplete nasolacrimal duct obstruction. Ophthalmology. 2004;111:585–9.

10. Ali MJ, Naik MN. Efficacy of endoscopic guided anterograde 3mm balloon dacryoplasty with silicone intubation in treatment of acquired partial nasolacrimal duct obstruction in adults. Saudi J Ophthalmol. 2014;28:40–3.
11. Perry JD, Maus M, Nowinski TS, et al. Balloon catheter dilation for treatment of adults with partial nasolacrimal duct obstruction: a preliminary report. Am J Ophthalmol. 1998;126:811–6.
12. Yazici Z, Yazici B, Parlak M, et al. Treatment of obstructive epiphora in adults by balloon dacryocystoplasty. Br J Ophthalmol. 1999;83:692–6.
13. Dotan G, Nelson LB. Congenital nasolacrimal duct obstruction: common management policies among pediatric ophthalmologists. J Pediatr Ophthalmol Strabismus. 2015;52:14–9.
14. Nair AG, Kamal S. Indian survey on practice patterns of lacrimal and eyelid disorders (iSUPPLE) report 1: congenital nasolacrimal duct obstruction. Int J Pediatr Otorhinolaryngol. 2016;88:7–12.
15. Lin AE, Chang YC, Lin MY, Tam KW, et al. Comparison of treatment for congenital nasolacrimal duct obstruction: a systematic review and meta-analysis. Can J Ophthalmol. 2016;51:34–40.

Fig. 32.1 Wide dilation of punctum

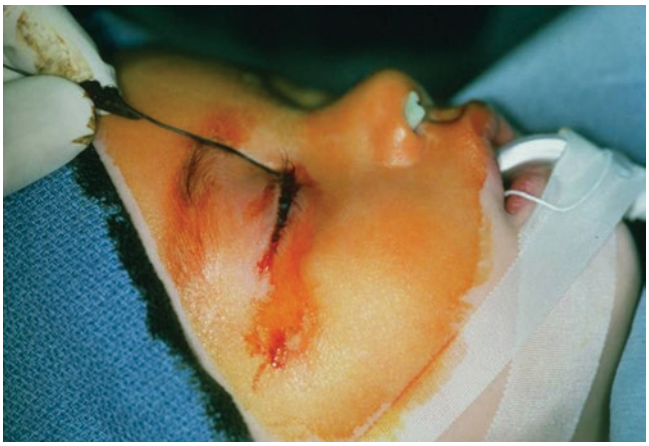


Fig. 32.3 Proper orientation to pass probe into the duct

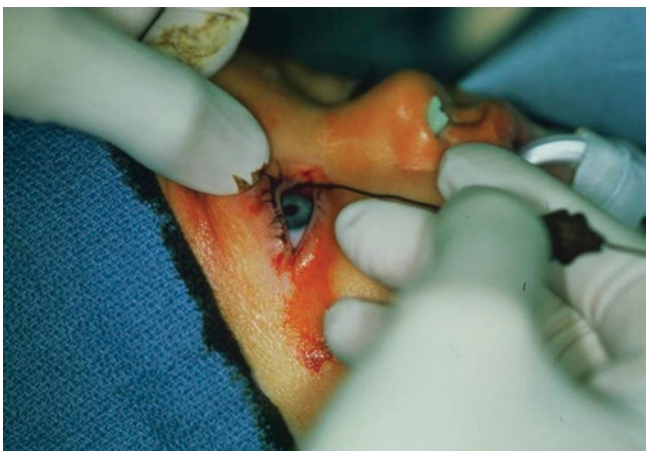


Fig. 32.2 Primary passage of Bowman probe or balloon probe into canaliculus

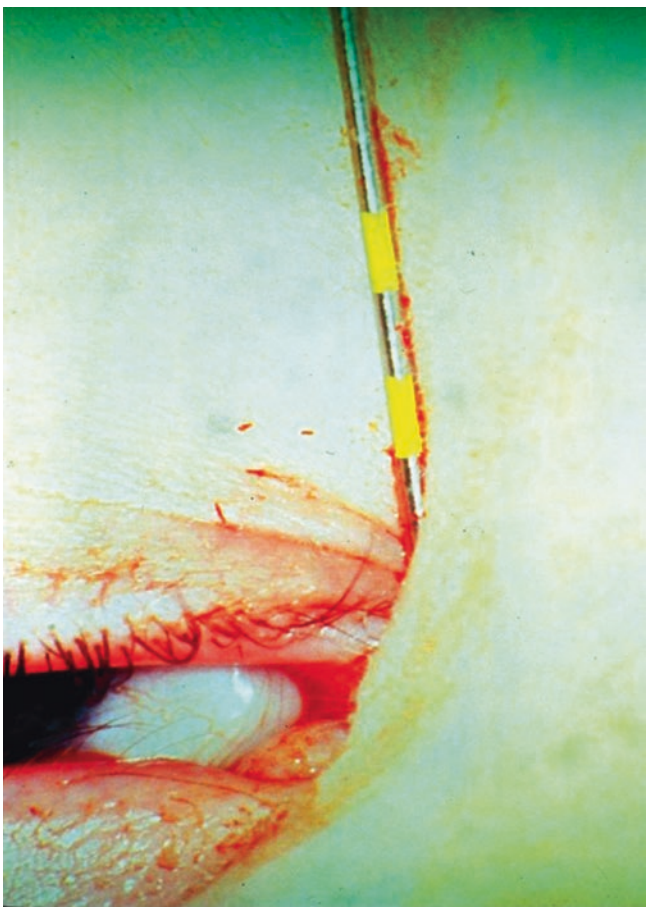


Fig. 32.4 Balloon probe in place showing hash marks

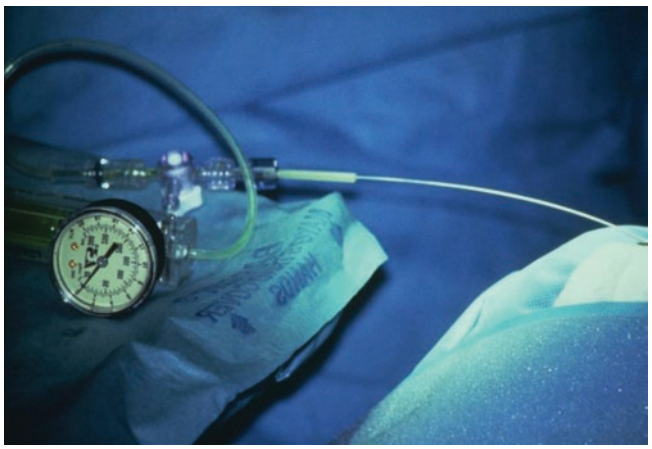


Fig. 32.5 Balloon probe attached to inflation device. Note flexibility of probe

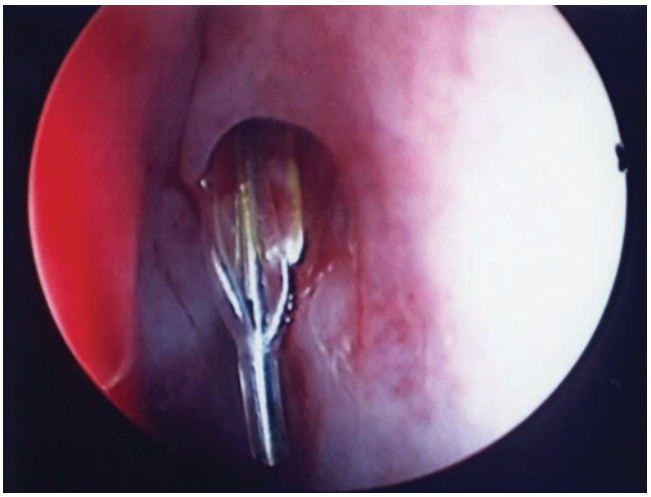


Fig. 32.8 Deflated balloon

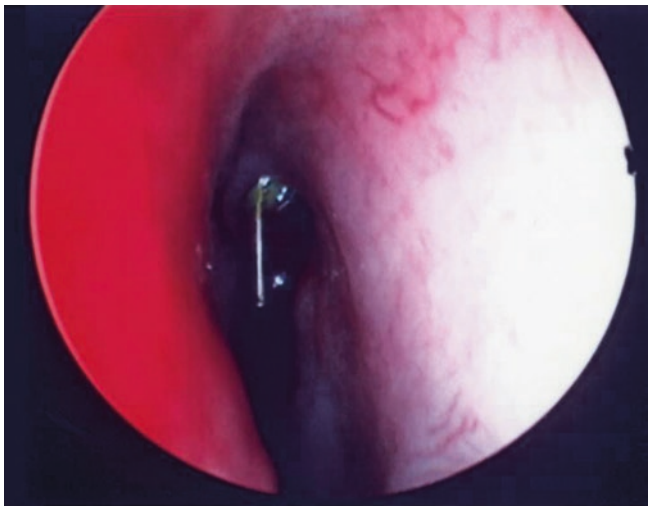


Fig. 32.6 Endoscopic view of deflated balloon ensuring proper placement through valve of Hasner

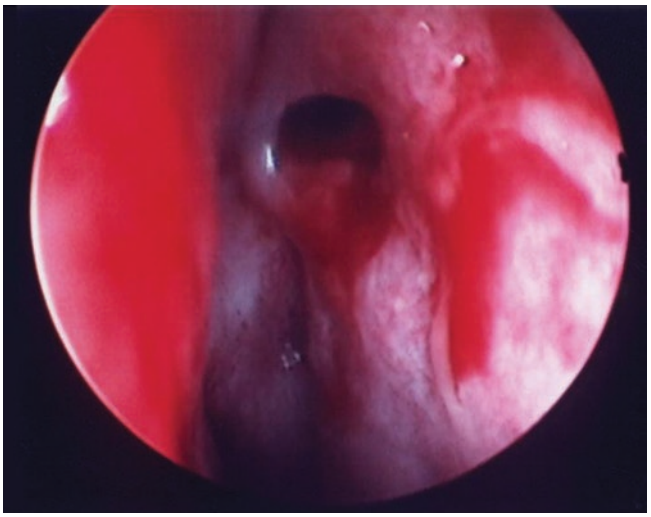


Fig. 32.9 Dilated opening of the nasolacrimal duct into inferior meatus following balloon removal

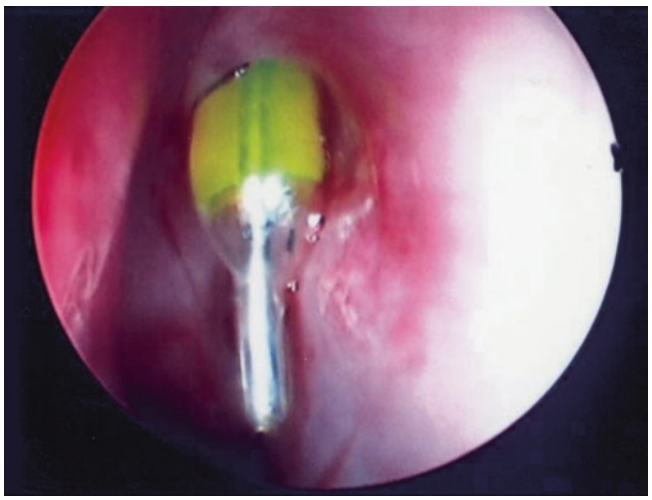


Fig. 32.7 Inflated balloon with fluorescein-tinged saline across valve of Hasner

Canalicular and Nasolacrimal Duct Recanalization

33

Mohammad Javed Ali

Introduction

Natural orifice transluminal endoscopic surgeries (NOTES) are evolving and upcoming minimally invasive modalities for managing luminal and extra-luminal disorders of mucosal-lined cavities. Canalicular obstructions and NLDO are therapeutic challenges. Most of the lacrimal obstructions are known to follow the common final pathway of inflammation and fibrosis, even if there is a wide range of etiological factors. Canalicular obstructions can occur following infections, inflammations like Stevens-Johnson syndrome and lichen planus, post-traumatic and post-topical ocular medications, and systemic chemotherapy [1–3]. Numerous modalities with variable success rates have been described for canalicular obstructions and include retrograde intubation dacryocystorhinostomy, membranectomy, endocanalicular laser surgery, canalicular trephination, and balloon canaliculoplasty [4–8]. For nasolacrimal duct obstructions (mostly partial), alternative options to a DCR described include therapeutic trephination and intubation, silicone intubation alone and anterograde balloon dacryoplasty, electrocauterization or diathermy-assisted recanalization of NLDO (RC-NLDO), radio-frequency recanalization, and microsurgical NLD rhinostomy with eversion technique [9–17].

Dacryoendoscopy is a procedure utilizing microendoscopic techniques to visualize the entire lacrimal system from the puncta to the inferior meatus [18–29]. It is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders thus having many diagnostic and potential therapeutic implications [18–29]. Till the late 1990s, the microendoscopic systems were not well developed; however with the advancement in other specialties like endoscopic retrograde cholangiopancreatography (ERCP), numerous microendoscopes with a good image quality were designed. Dacryoendoscopes used in the past include the Junemann probe and the vitroptic. Additional channels were added, for example, for laser delivery of KTP-YAG or Erbium-YAG laser for laser dacryoplasty and micropunches for sample collection [28]. The author performs it using a 0.6 mm microendoscope (Karl Storz, Tuttlingen, Germany) which was adapted and partly modified from the original sialoendoscope (Figs. 33.1 and 33.2). The current chapter will discuss the instruments, indications, and techniques of lacrimal passage recanalizations.

Instruments and Techniques

1. Dacryoendoscope
2. 1 ml syringe with saline
3. Camera head
4. Endoscopic viewing system
5. Antifog solutions (ex-diluted chlorhexidine)
6. Sisler's trephines
7. Huco trephines
8. Additional instruments based on the technique like microdrill or laser or balloon dacryoplasty

The dacryoendoscope has a thin, rigid fiber endoscope and a side port on the hand piece (Figs. 33.1 and 33.2). The rigid fiber endoscope is attached to the eyepiece through a fiber-optic cable (Fig. 33.1). The eyepiece of the dacryoendoscope is connected to the camera head and secured. The camera head is then connected to the endoscopic viewing system (Fig. 33.3), the tip of the scope is gently cleaned with antifog solution, and image quality is assessed.

The dacryoendoscopy can be performed in an anterograde or a retrograde manner. For the recanalizations procedures, the anterograde approach is used. It is important to know that illumination may need to vary in different parts of the lacrimal system especially when there are obstructions.

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_33

Indications

The indications for the recanalizations procedures are as follows:

1. Complete canalicular obstructions
2. Complete nasolacrimal duct (NLD) obstructions
3. Symptomatic partial obstructions
4. Patchy or multifocal canalicular or NLD strictures
5. Obstructive dacryolithiasis
6. Obstructive foreign bodies, for example, migrated punctal plugs
7. Membranous canalicular obstructions following a DCR

Contraindications

1. Acute canaliculitis
2. Acute dacryocystitis
3. Post-traumatic obstructions following gross fractures
4. Misaligned canaliculi
5. Acute infective rhinitis (for nasolacrimal recanalizations)

Techniques

1. Dacryoendoscopy-guided canalicular and NLD trephination
2. Laser dacryoplasty
3. Microdrill canaliculoplasty
4. Balloon canaliculoplasty
5. Diathermy based recanalizations

Canalicular Recanalization Techniques

Canalicular trephination can be carried out using laser, microdrills or balloons under dacryoendoscopic visualization or alternatively using trephines under similar guidance. Sisler's trephines were described in the year 1990 as specialized microtrephines designed for the canaliculi [4]. The trephine is 16 mm long and 0.81 mm wide with a plastic hub behind for a syringe or simply to hold during the boring movements. It is accompanied by an intraluminal stylet or guide (Fig. 33.4). Dacyroendoscope is used to assess the type of obstruction (partial or complete), its distance, and its appearance. It is important to differentiate stenosis from various degrees of obstructions (Figs. 33.5, 33.6, 33.7, and 33.8). Lubricated trephine is inserted to the point of obstruction with its accompanying stylet in place to minimize trauma to the proximal, patent canaliculus. The syringe is then affixed to trephine's luer lock hub, and trephination is carried out by gentle rotation of the assembly. After each mm boring, dacryoendoscope is used to assess the extent of clearance and assess further passage and obstruction. Bleeding is usual since the obstruction is a fibrovascular tissue, and it should be simultaneously cleared by irrigating the canaliculus with saline from the side port. The trephination is continued and when the sac is entered, the syringe will pop indicating achievement of the desired passage, and a plug of scar tissue is seen either within the lumen of trephine or barrel of the syringe (Fig. 33.9). Dacryoendoscope is inserted to ascertain complete recanalization (Fig. 33.10). This is followed by stenting of the new passage with mono or bicanalicular stents. Postoperatively a combination of topical antibiotic and steroid is continued in a tapering fashion for 4 weeks. The author retains the tubes for 3 months in recanalization cases.

Laser dacryoplasty is performed using Erbium-YAG laser or KTP-YAG laser [7, 28]. For this purpose, the dacryoendoscope needs to have an additional channel for the passage of laser fiber. Laser delivery using a sapphire fiber of 375 μm and energy of 50 mJ with 1–3 Hz frequencies have been described. The procedure is same as described above, but instead of a mechanical trephine, laser is used to lyse the fibrous tissues, followed by irrigation and intubation [7, 28].

Microdrill dacryoplasty was introduced by Busse. The additional channel on dacryoendoscope is designed to carry a battery-operated 0.3 mm stainless steel microdrill shaft. The frequency to begin was 50 Hz, but powerful drills up to 3000 Hz are available. The microdrill is best suited for partial obstructions, where the drill starts from the edge of the patent lumen to recanalize it further. It is very important to have a continuous irrigation and suction with a clear visualization and utmost control on the instruments, since the possibility of canalicular lacerations can be high if the shaft is not accurately positioned [25].

Balloon canaliculoplasty is sparsely reported in the literature [6]. It uses a 2 mm balloon for recanalizations following probing just like in balloon dacryoplasty. The inflation-deflation cycles at 8 atmospheres of pressure are followed by intubation. It was found to be more effective in common canalicular obstruction as compared to isolated canalicular obstructions.

Nasolacrimal Duct Recanalizations Techniques

Nasolacrimal duct obstructions are an enigma! Recanalization approaches used include dacryoendoscopic guided Huco trephination and intubation, anterograde balloon dacryoplasty, electricity-assisted recanalization of NLDO (RC-NLDO), and mechanical recanalizations under simultaneous guidance [9–15]. Trephination is usually done using the Huco trephine (Fig. 33.11). Lubricated trephine is inserted to the point of obstruction with its accompanying stylet in place to minimize trauma to the proximal structures. The trephination is carried out by gentle rotation of the assembly. After each mm boring,

dacryoendoscope is used to assess the extent of clearance, assess further passage and obstruction, modify the course, and confirm complete recanalizations (Figs. 33.12, 33.13, 33.14, and 33.15). Bleeding is usual since the obstruction is a fibrovascular tissue, and this needs to be cleared simultaneously with saline irrigation of the NLD from the irrigation port (Fig. 33.2). Crawford silicone intubation is performed and retrieved through the NLD and secured in the inferior meatus (Fig. 33.16), following the recanalization procedure.

Anterograde balloon dacryoplasty is usually used for recanalizing partially obstructed nasolacrimal ducts [9]. The ducts are initially probed and the probe confirmed with an endoscope in the inferior meatus. A 3 mm lubricated balloon is then passed into the distal portions of the nasolacrimal ducts and inflated to 8 Atmospheres for 90 s and deflated and reinflated to 8 Atmospheres for 60 s. The same procedure is repeated again for the proximal portion of the nasolacrimal duct. This is followed by stenting of ducts with Crawford bicanalicular tubes [9].

Electrocautery or diathermy-based NLD recanalizations have also been described and claimed to be effective. The electrocautery-based recanalizations with bicanalicular intubation (RC-BCI) have shown efficacy for overcoming both the canalicular obstructions and NLDO [8, 11]. The instrument consists of a lacrimal canaliser (Tonxing Co, Changyi, China), whose console can discharge current between 50 and 150 W at a frequency of 500 KHz. The handpiece is a high-frequency lacrimal probe made of copper-silver alloy with 2 mm blunt, smooth but naked tip for electrocauterization. Another variant of this in a more practical setting has been described by Agarwal et al. [14], where a 20 gague, 7 W, endodiathermy probe connected to phaco machine has been used and recommended this as an alternative to DCR.

Complications

1. Bleeding
2. Proximal healthy tissue trauma
3. Punctal trauma
4. Canalicular or NLD lacerations (rare)
5. False passage (rare)
6. Aggressive reocclusion
7. Tube-related complications

Prevention of Complications

1. Prior proximal dilatation
2. Lubrication of trephines
3. Good knowledge of anatomical course and variations
4. Avoid forceful entries
5. Periodic blood and debris clearance
6. Always perform under visualization

Advantages of Recanalization Procedures

1. Minimally invasive procedure
2. Major surgical interventions avoided
3. Sculptured passage creation
4. Smooth edges and less reclosures
5. Minimal trauma
6. Quick recovery
7. Early rehabilitation

Outcomes

Canalicular Recanalization

Nathoo et al. [5] studied canalicular trephination and intubation in 45 eyes of 43 patients, and at 1-year follow-up showed a success rate of 64%. Khoubian et al. [17] studied the effects of trephination and intubation based on the level of canalicular obstructions in 41 eyes and found that 80% of eyes had complete resolution from epiphora in lower distal canalicular obstructions, 66% in distal bicanalicular obstructions, and 59% in common canalicular obstruction. No cases of complete resolution were noted in the proximal group.

In the pilot study conducted by the author on ten patients treated with dacryoendoscopic guided recanalizations, 40% were mid and 60% were distal obstructions. 40% of these were partial, equally divided between the mid and distal groups. At 6 months follow-up, 50% of these were patent. The author found that dacryoendoscopy helped in avoiding false passages and accurate assessment of the obstructions as well as its complete clearance following trephination.

Laser dacryoplasty has been shown to be effective in 80% of the patients with regard to relief from epiphora at a mean follow-up of 20.4 months [7, 27]. The success rate in canalicular stenosis was 67%, whereas in isolated common canalicular stenosis the rate was as high as 86%. Microdrill dacryoplasty showed a success of 78% in reducing epiphora at 12 months follow-up [25]. Balloon dacryoplasty showed an immediate success rate of 82% was achieved, but long-term follow-up success is only 57% and not encouraging [6]. The outcomes of RC-BCI in canalicular obstructions in 32 eyes showed a complete resolution from epiphora in 81% at a mean follow-up of 21.5 months [8].

Nasolacrimal Duct Recanalization

Ali et al. [9] performed anterograde balloon dacryoplasty in 21 partially obstructed NLD, followed by silicone intubation for 3 months. At a minimum follow-up of 6 months after tube removal, anatomical success was noticed in 71% of the lacrimal passages. The use of silicone intubation along with a balloon

dacryoplasty is not clear. Kashkouli et al. [10] retrospectively compared balloon dilatation with intubation versus intubation alone and reported no statistical difference between the groups (61% vs 54%) in the outcomes at a mean follow-up of 14.60 months. However, it is important to note that this was not a randomized study. Bleyen et al. [13] conducted a similar study but was a randomized control trial. They also did not find a significant difference between the groups (52% vs 57%).

In a pilot study conducted by the author on ten partially obstructed NLD with dacryoendoscopy-guided recanalizations, although showed very good immediate success in all patients, however, the long-term outcomes were discouraging. There was a success rate of only 50% at 6 weeks follow-up, even though only partial obstructions were chosen for the procedures. 80% (4/5) of the failed NLD recanalization worsened symptomatically because of complete obstructions and needed dacryocystorhinostomy.

The outcomes of diathermy recanalization have been reported to be 92.7% at a 2-year follow-up. The surgical time taken was 21.3 ± 6.2 min with complications noted in 1.3% and include punctal cheese wiring [14]. Javate et al. [15] performed a comparative trial between endocanalicular lacrimal duct recanalization (ELDR) and a standard external DCR and found that the anatomical and functional success rates were 93% and 85%, respectively, as against 94% and 90% in external DCR, and concluded that both are equal in efficacy without the major complications of external DCR. Dacryoendoscopy-guided recanalization has shown good outcomes in pediatric patients with dacryoceles, congenital fistulas, and retained silicone stents from past interventions [18]. Dacryoendoscopy monitoring of the NLD recanalization was found to be useful before and after reduction of a bony NLD fracture [19].

Conclusion

In conclusion, for canalicular obstructions, the outcomes of various procedures are more convincing especially trephination and canaliculoplasty. Dacryoendoscopy-guided recanalization in the author's experience still needs evolution. The fundamental need to make recanalization a real alternative modality is accurate understanding of the etiopathogenesis, which is still elusive. Apart from this, modifications in instrumentation and techniques with a larger sample size and longer follow-up are required. Till then skepticism on NLD recanalizations is justified.

References

1. Liarakos VS, Boboridis KG, Mavrikakis E, et al. Management of canalicular obstructions. Curr Opin Ophthalmol. 2009;20:395–400.
2. Durrani OM, Verity DH, Meligonis G, et al. Bicanalicular obstruction in lichen planus: a new cause of lacrimal canalicular obstruction. Ophthalmology. 2008;115:386–9.
3. McCartney E, Valluri S, Rushing D, et al. Upper and lower system nasolacrimal duct stenosis secondary to paclitaxel. Ophthal Plast Reconstr Surg. 2007;23:170–1.
4. Sisler HA, Allarakhia L. New minitrephine makes lacrimal canalicular rehabilitation an office procedure. Ophthal Plast Reconstr Surg. 1990;6:203–6.
5. Nathoo NA, Rath S, Wan D, et al. Trephination for canalicular obstruction. Experience in 45 eyes. Orbit. 2013;32:281–4.
6. Yang SW, Park HY, Kikkawa DO. Balloon canaliculoplasty after canalicular trephination in monocanalicular and common canalicular obstruction. Jpn J Ophthalmol. 2008;52:444–9.
7. Steinhauer J, Norda A, Emmerich KH, et al. Laser canaliculoplasty. Ophthalmologe. 2000;97:692–5.
8. Chen D, Li N, Wan P, et al. A novel procedure to treat canalicular obstruction by recanaliculisation and bicanalicular intubation. Br J Ophthalmol. 2012;96:366–9.
9. Ali MJ, Naik MN. Efficacy of endoscopic guided anterograde 3 mm balloon dacryoplasty with silicone intubation in treatment of acquire partial nasolacrimal duct obstruction in adults. Saudi J Ophthalmol. 2014;28:40–3.
10. Kashkouli MB, Beigi B, Tarassoly K, et al. Endoscopically assisted balloon dacryoplasty and silicone intubation versus silicone intubation alone in adults. Eur J Ophthalmol. 2006;16:514–9.
11. Chen D, Ge J, Wang L, et al. A simple and evolutional approach proven to recanalize the nasolacrimal duct obstruction. Br J Ophthalmol. 2009;93:1438–43.
12. Tanaka Y, Hamamoto Y, Kogure T, et al. Microsurgical reconstruction of nasolacrimal duct obstruction using an eversion technique. Plast Reconstr Surg. 2012:e905–6.
13. Bleyen I, Willem A, Bosch VD, et al. Silicone intubation with or without balloon dacryoplasty in acquired partial nasolacrimal duct obstruction. Am J Ophthalmol. 2007;144:776–80.
14. Agarwal S, Gupta SK, Singh V, et al. A novel technique to recanalize the nasolacrimal duct with endodiathermy bipolar probe. Ind J Ophthalmol. 2013;61:718–21.
15. Javate R, Pamintuan FG, Cruz RT, et al. Efficacy of endoscopic lacrimal duct recanalization using microendoscope. Ophthal Plast Reconstr Surg. 2010;26:330–3.
16. Garcia EA, Machado MAC, Da Silva AF, et al. Recanalization of nasolacrimal duct with radiofrequency: a preliminary study. Arq Bras Oftalmol. 2012;75:412–4.
17. Khoubian JF, Kikkawa DO, Gonnering RS. Trephination and silicone stent intubation for the treatment of canalicular obstructions: effect of the level of obstruction. Ophthal Plast Reconstr Surg. 2006;22:248–52.
18. Heichel J, Bredehorn-Mayr T, Struck HG. Endoscopy of the lacrimal duct system in children. Klin Monatsbl Augenheilkd. 2015;232:881–5.
19. Maruyama N, Katori N, Sumiya N. Intraoperative use of the lacrimal endoscope for accurate reduction of bony nasolacrimal duct fracture. Plast Reconstr Surg. 2015;130:e761–2.
20. Sasaki T, Miyashita H, Miyanaga T, et al. Dacryoendoscopic observation and incidence of canalicular obstruction or stenosis associated withS-1, an oral anticancer drug. Jpn J Ophthalmol. 2012;56:214–8.
21. Kakizaki H, Takahashi Y, Sa HS, et al. Congenital dacryocystocele: comparative findings of dacryoendoscopy and histopathology in a patient. Ophthal Plast Reconstr Surg. 2012;28:e85–6.
22. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal dacryorhinotomy: part II. Inferior meatal dacryorhinotomy. Am J Ophthalmol. 2005;140:1070–4.
23. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal dacryorhinotomy. Part I:positional diagnosis of primary nasolacrimal

duct obstruction with dacryoendoscope. Am J Ophthalmol. 2005;140:1065–9.
24. Küstner M, Clemens S, Tost F. Minimally invasive endoscopic surgery of the lacrimal drainage system--two case reports. Klin Monatsbl Augenheilkd. 2005;222:928–32.
25. Maier M, Schmidt T, Schmidt M. Endoscopically controlled surgery with the micro-drill and intubation of the lacrimal ducts. Ophthalmologe. 2000;97:870–3.
26. Emmerich KH, Steinhauer J, Meyer-Rüsenberg HW, et al. Dacryoendoscopy—current status. Ophthalmologe. 1998;95:820–2.
27. Emmerich KH, Lüchtenberg M, Meyer-Rüsenberg HW, et al. Dacryoendoscopy and laser dacryoplasty: technique and results. Klin Monatsbl Augenheilkd. 1997;211:375–9.
28. Emmerich KH, Meyer-Rüsenberg HW, Simko P. [Endoscopy of the lacrimal ducts]. Ophthalmologe. 1997;94:732–5. Klin Monatsbl Augenheilkd. 1997;94:732–5.
29. Haefliger IO, Piffaretti JM. Lacrimal drainage system endoscopic examination and surgery through the lacrimal punctum. Klin Monatsbl Augenheilkd. 2001;218:384–7.

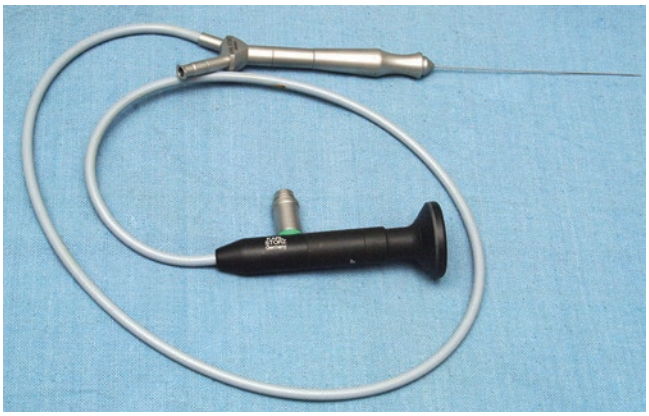


Fig. 33.1 Dacryoendoscope with rigid telescope and *black* eyepiece

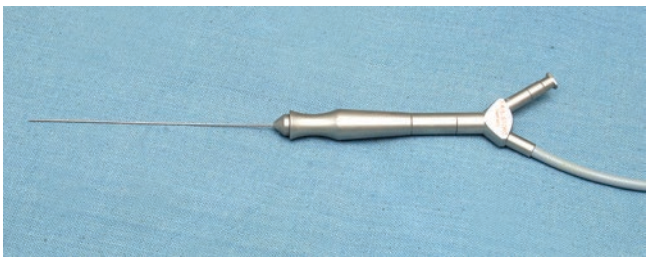


Fig. 33.2 A closer view of side port

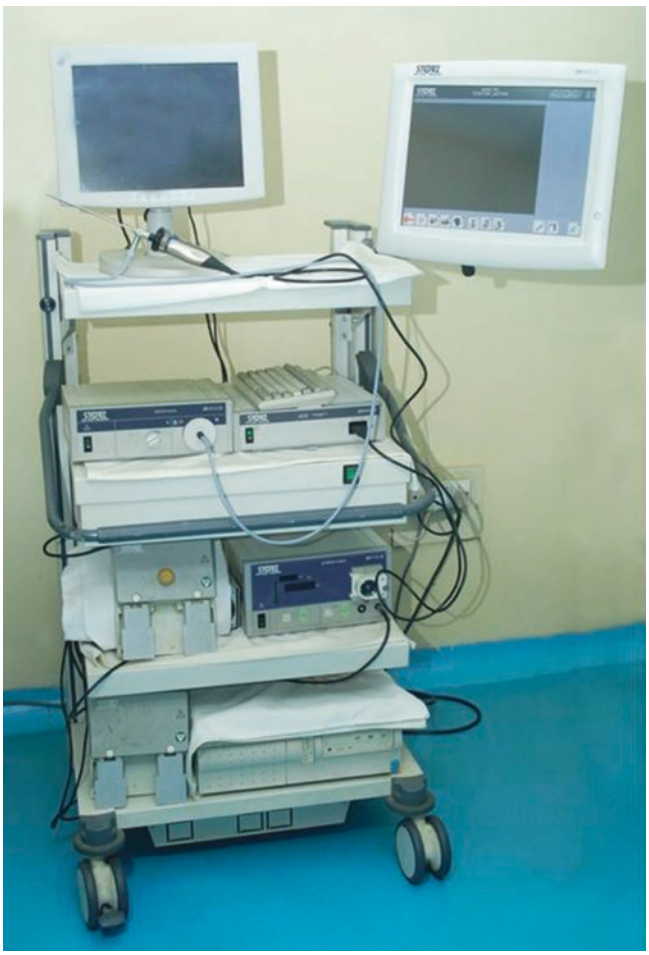


Fig. 33.3 Endoscopic viewing system

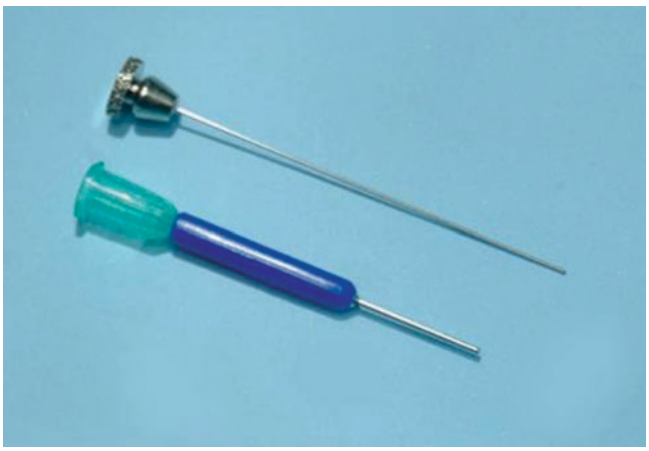


Fig. 33.4 Sisler's canalicular trephine with intraluminal stylet

Fig. 33.5 Canalicular stenosis

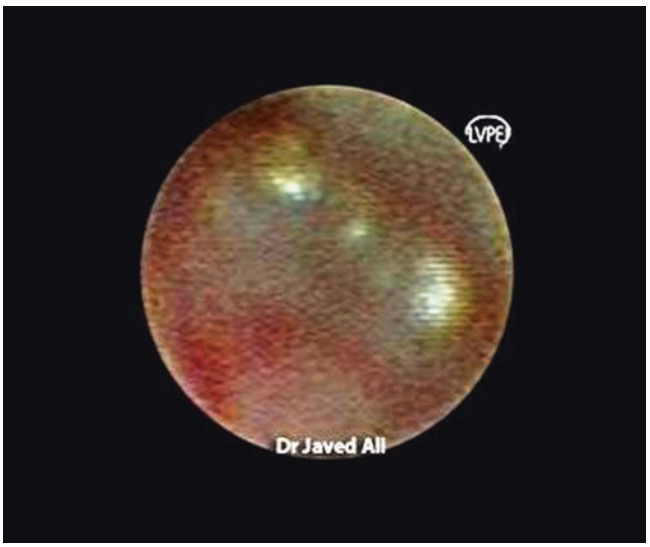


Fig. 33.7 Complete canalicular obstruction

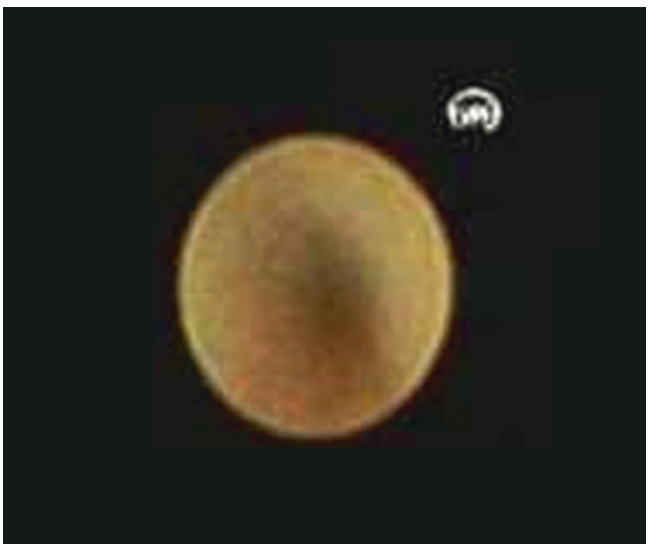


Fig. 33.6 Partial canalicular obstruction

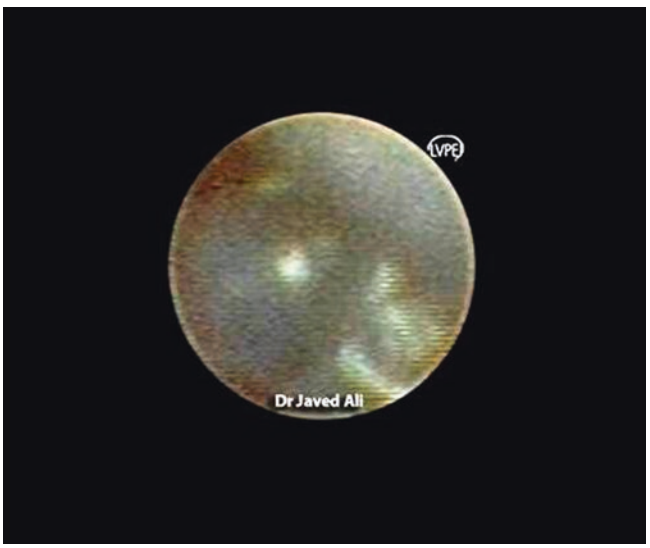


Fig. 33.8 Complete canalicular obstruction

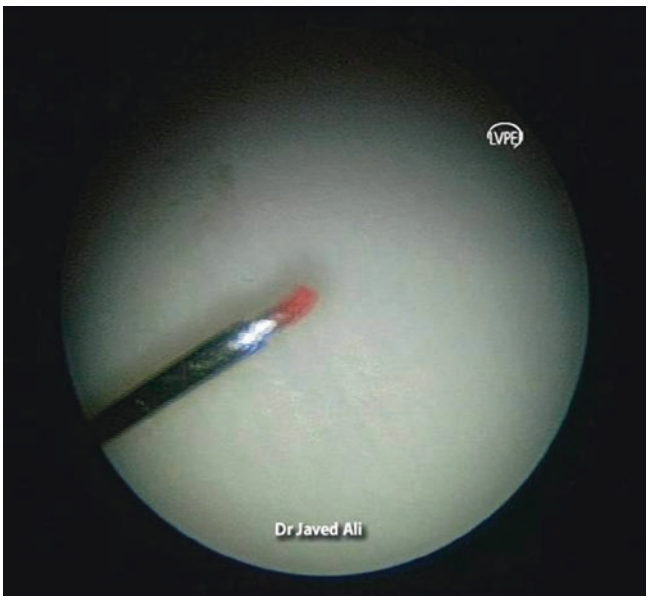


Fig. 33.9 Obstructed sculpted segment in trephine barrel

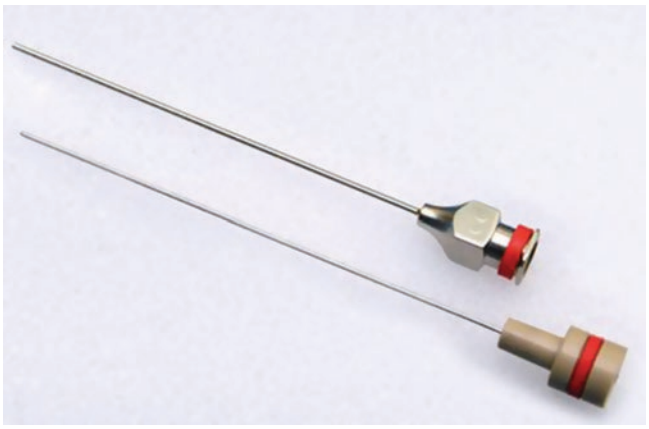


Fig. 33.11 Huco trephine

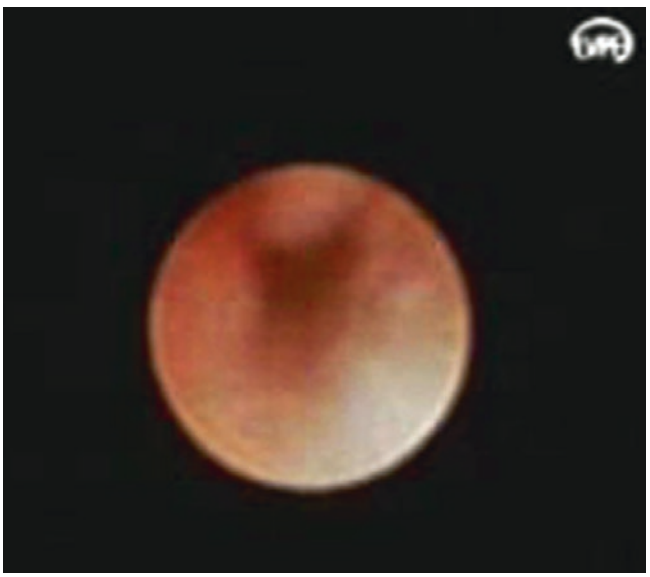


Fig. 33.10 Complete canalicular recanalization

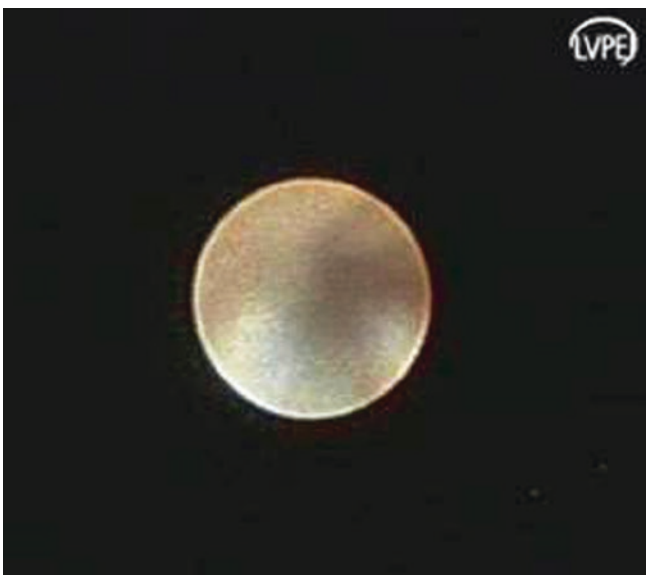


Fig. 33.12 Obstructed nasolacrimal duct

Fig. 33.13 Following early trephination

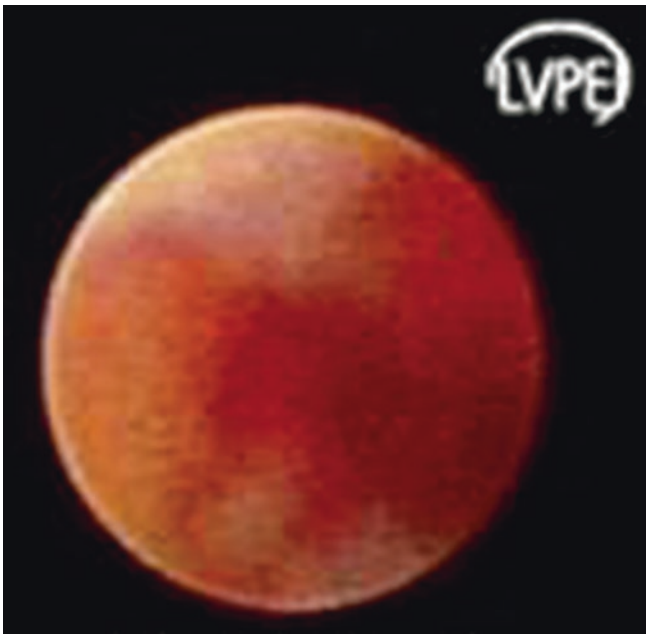


Fig. 33.15 Complete recanalization

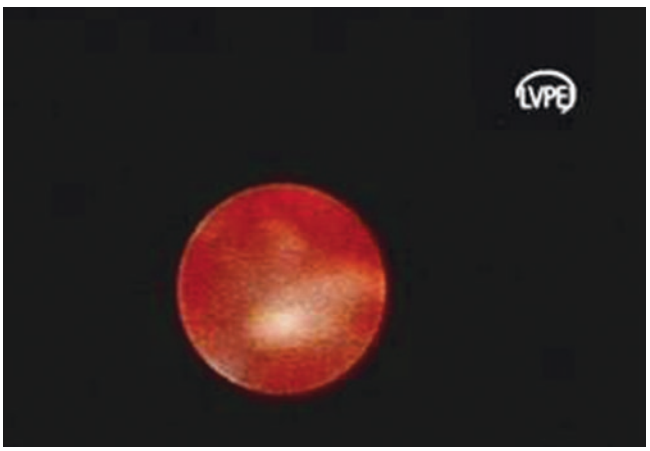


Fig. 33.14 Residual tissue in lumen following recanalization

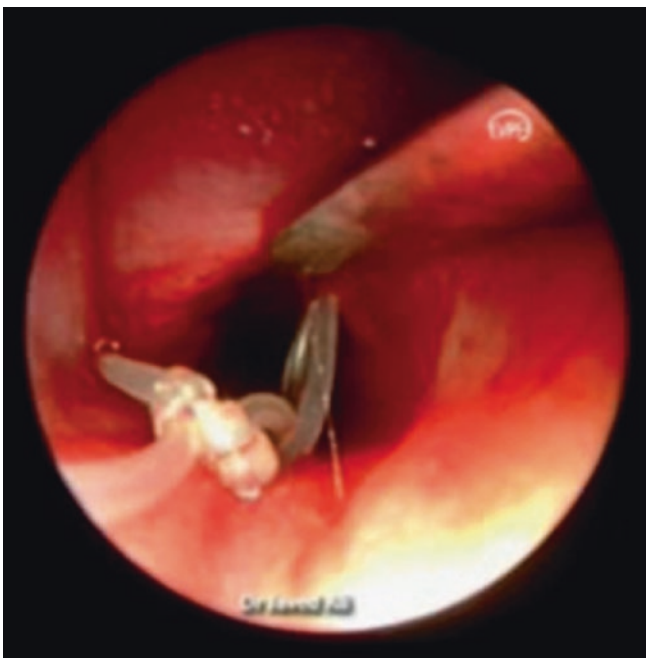


Fig. 33.16 Crawford intubation secured in inferior meatus

Diagnostic and Therapeutic Interventional Radiology of the Lacrimal System

34

Ulrich Lachmund and Kai Wilhelm

Introduction

Radiologists are more often involved in the diagnostic workup for patients, who suffer from epiphora or a teary eye. Epiphora is a common disease [1–3] and is diagnosed in up to 3% in an outpatient office [1]. Epiphora is classified according to the Munk scale from grades 0 to IV (grade 0 no tearing, grade I < 2 times per day, grade II < 2–4 times per day, grade III = 5–10 times per day, grade IV tearing >10 times per day) [4]. Obstructions of the lacrimal system are one of the most common reasons for epiphora [2, 5]. The complete diagnostic workup of the lacrimal system is fast becoming of more interest to the combined team of radiologist and ophthalmologist, who are using different new techniques to treat the lacrimal system disorders. Radiological interventions to treat the lacrimal system and other new techniques used by ophthalmologists are now well established for treatments in selected cases [6, 7]. To identify patients suitable for interventional therapy, the exact cause for epiphora has to be determined. In this chapter we will photographically decipher various lacrimal stenosis and obstructions for the readers with the help of Figs. 34.1–34.29.

Radiological Diagnostic Imaging

Anatomically, the lacrimal system consists of the pre-saccal system that starts with the lower and upper puncta lacrimalia, from where the lacrimal fluid enters the inferior and superior canaliculus. They usually join to form the common canaliculus (Figs. 34.1 and 34.2). The pre-saccal system is followed by the saccal system that consists of the lacrimal sac. The final part of the lacrimal system is constituted by the post-saccal system, the nasolacrimal duct. The post-saccal system can be further divided into the upper part, the middle part, and the distal part.

From the valvular aspects, the most important structure in the upper part of lacrimal system is the valve of Rosenmüller, at the entry of the common canaliculus to the lacrimal sac, then the valve of Krause, which is directly at the end of the lacrimal sac. The major post-saccal occlusions can be located at the level of the valve of Krause. The middle portion is often where we find membranous valves (Arlt's sinus, Krause's or Bérauld's valve, spiral valve of Hyrtl, and Taillefer's valve). This portion often suffers from membranous occlusions, inflammatory changes of the lacrimal system, and irregularities of the wall (Fig. 34.3). The major anatomical structure in the distal part is the valve of Hasner. Very often stenoses or occlusions are noted at the level of the valve of Hasner, whereas dacryoliths are usually seen just above the valve (Figs. 34.3, 34.4, 34.5, and 34.6). Valves are believed to facilitate unidirectional passage of fluids and prevent reflux from the nasal cavity to the lacrimal system, and the valves of Hasner and Rosenmüller are likely to play major roles.

To diagnose pathology of the lacrimal system, one can perform a basic clinical irrigation and probing, endoscopy, and when needed certain radiological investigations. Dacryocystography (DCG) or digital subtraction dacryocystography (DSD) of the lacrimal system is one of the least invasive ways to examine the lacrimal system. DSD is performed to demonstrate pathologic changes like obstructions of the lacrimal drainage system. DSD is capable of determining the patency of the canaliculi, lacrimal sac, and nasolacrimal duct. When disease is present, the site and degree of obstruction or stenosis can be evaluated well. Since the original description of Ewing [8], many radiographic techniques for dacryocystography (DCG) have been described. Digital

U. Lachmund (✉)
Institute of Neuroradiology, University Hospital of Zurich, Zurich, Switzerland
e-mail: Ulrich.lachmund@hotmail.com

K. Wilhelm
Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_34

subtraction dacryocystography (DSD), which combines the technique of dacryocystography and digital subtraction fluoroscopic capabilities, has become the gold standard. DSD is able to render high-resolution images of the complete nasolacrimal duct system. In addition, assessment of the rate of flow of contrast material yields important information regarding flow dynamics [6, 9]. A DSD is, in contrast to other diagnostic procedures, a dynamic procedure that is able to detect pathologies by modifying the contrast flow to bring out early- and late-stage pathologies with good distinction. The DSD is a true dynamic examination, in contrary to CT-DCG, MRI DCG, or cone beam CT-DCG which are more of static examinations.

Techniques

To perform a DSD, a digital subtraction angiography (DSA) is performed.

Patients are prepared by instilling a short-acting topical anesthetic into the conjunctival sac (e.g., Novesine® 0.4, CIBA Vision Ophthalmics, Germering, Germany). Then, contrast medium (CM) is injected through a dacryocystography catheter. Every small polyvinylchloride tubing catheter can be used as a dacryocystography catheter. We routinely prefer a 22-G polyvinylchloride tubing catheter (dacryocystography catheter, COOK®, Queensland, Australia). Water-soluble, nonionic liquid contrast media (CM) (iomeprol, IMERON®300, Bracco Imaging Deutschland GmbH, Konstanz, Germany) are injected manually during acquisition (e.g., frame rate, 2 per second; a higher frame rate up of 5 per second up to 10 per second can be used to detect fistulas). In the early phase of injection, reflux can be minimized by an initial slow injection rate. Subsequently, the rate can be increased to achieve greater sac distension or to overcome resistance by partial obstruction. The advantage of the use of flushing controlled by real-time imaging is for avoiding false passages that may occur with a forceful blind irrigation. The site of obstruction is described according to anatomical landmarks.

Normally, CM flows freely down the lacrimal system into the nose (Fig. 34.2a–c). In patients with stenosis, early reflux through the punctum with a residual flow of contrast material to the nasal cavity is seen (Figs. 34.2d and 34.7a). In occlusion (complete obstruction) no CM reaches the nasal cavity (Figs. 34.7b and 34.8). Furthermore, three-dimensional (3D) rotational angiography (3DRA) or cone beam CT (Fig. 34.9) techniques provide valuable additional information regarding the site and degree of stenotic lesions and the adjacent anatomic structures [10, 11].

In the majority of cases with obstructions, the cause of the epiphora was found in the post-saccal or saccal part of the lacrimal system [12]. To distinguish obstructions caused by osseous changes like in fractures or soft tissue alterations caused by inflammations or tumors, a computer tomography (CT) of the head and neck with i.v. contrast can be performed (Fig. 34.10) [13–16]. At the same time, CT-dacryocystography with injection of CM into the lacrimal duct can also be performed.

To better examine and diagnose additional soft tissue changes, a magnetic resonance imaging (MRI) scan with gadolinium contrast given i.v. and also in the lacrimal duct, if needed (MRI-dacryocystography), can be performed. A MRI is indicated to delineate lacrimal systems in tumors or complex postoperative situations (Fig. 34.11) [17].

In a retrospective analysis [18] of 355 diagnostic dacryocystographies in 281 patients suffering from epiphora, 71% had a tear duct obstructions, in about one third a stenosis (Figs. 34.4–34.7, 34.15, 34.19, 34.20, 34.23, 34.27, and 34.28), and a complete obstruction in the remaining (Figs. 34.7, 34.8, 34.12, 34.13, 34.18, and 34.21). The stenosis was localized at the junction of sac and nasolacrimal duct in 31 (38%) cases, post-saccal in 26 (32%) cases, in the common canaliculus in 24 (29%) cases, and in 1 case at the lower canaliculus. The site of complete obstructions was the junction of sac and nasolacrimal duct in 99 (59%) and the common canaliculus in 29 (17%) cases, immediate post-saccal in 27 (16%) cases, and lower canaliculus in 14 (8%) cases.

Dacryoliths were found in about 7% of cases, and the major location was post-saccal just before Hasner's valve, followed by the sac and the pre-saccal system (Figs. 34.3–34.6, 34.26–34.28). In the pre-saccal system they appear in combination with the bacterium *Actinomyces israelii*. Fistulas that were usually noted in the pre-saccal system, more in the inferior and common canaliculus, can be blind ending or communicating with the canalicular system (Figs. 34.14 and 34.15). Very often a fistula depicts a gross stenosis at its distal end (Fig. 34.15). With DSD, even fistulas of 0.5 length can be diagnosed. Their length is often no longer then 1–2 mm. Blind-ending fistulas tend to become dilated.

Diverticula are also commonly detected with radiological investigations although they may be clinically obscured. Diverticulum is a protrusion of the lacrimal wall that can be arisen from random locations. Very often they are seen at the tip of the sac and in the region the valve of Krause. They are often protrusions without any pathology of the lacrimal duct. If they are multiple, often an obstruction exists, or there could be a chronic recurrent inflammation of the lacrimal system. In the case of associated obstructions (Fig. 34.16), they are a sign of pathology and need to be treated. Their size can also vary depending upon the extent of obstructions. For example, they can be larger with more dense obstructions. After treatment of the causative factor, they disappear and hence can be monitored for additional evidence of success.

Lacrimal sump syndrome can occur after dacryocystorhinostomy (DCR) following improper lacrimal sac marsupial-

ization. In a study by Faye et al. [19], it appeared in 1.2% of failed DCR cases. The DSD is a good tool in this situation to diagnose the blind sac syndrome and aid decision making for the next surgical or interventional step. Dacryoplasty is also one alternative technique to treat this situation.

Radiologically Guided Treatment with Balloon Dilation

The most minimally invasive method to treat the lacrimal system is the balloon dilatation. Especially in the case of incomplete obstructions or stenosis of the lacrimal system, balloon dilation has become an alternative to surgical procedures in many cases [7, 20–26]. In addition, dacryoliths of the lacrimal system, which may result from lacrimal flow obstruction, may be removed or flushed out during the intervention [27].

Lacrimal balloon dilatation was first described by Becker and Berry [28] in 1989, followed by Munk [4] in 1990. Becker and Berry introduced a 3–4 mm coronary angioplasty catheter through the canaliculus in an anterograde approach, whereas Munk introduced a 3–4 mm tibial angioplasty catheter through the inferior opening of the nasolacrimal duct in a retrograde approach. Meanwhile several special dacryocystoplasty catheters have been designed since then, allowing safe balloon dilation using the transcanalicular access [24–26, 29, 30]. Therefore, no further nasal manipulation is necessary resulting in greater patient comfort and acceptance of the procedure (Fig. 34.16). We prefer to use a 2 mm diameter balloon for obstructions of the canaliculi (Figs. 34.19–34.21) and 3 mm for obstructions of the nasolacrimal duct and sac (Figs. 34.20, 34.23, 34.24, 34.27, and 34.28). The size of the balloon depends on the width of the nasolacrimal duct, the pathology, and the age of the patient. For occlusions in elderly patients, we use a large balloon size since tissues have higher laxity.

The inflation pressure routinely applied to reach complete balloon inflation is about 10 bars. The duration of inflation of the balloon catheter ranges from 15 to 45 s [7]. We additionally have increased the time of dilation up to 60 s, again depending on the pathology, that is, occlusions, or elderly patients. But in general we emphasize that the balloon catheter should be inflated for a short time, to prevent severe damage to the lacrimal drainage system and the surrounding structures, especially the venous plexus [27].

Techniques

In contrast to most surgical procedures, balloon dilation can be performed as an outpatient procedure under local anesthesia; even in children we can perform this method but only under low radiation with only fluoroscopic guidance and last image hold technique [31]. In children, depending of the age and their behavior, we often use mild sedation monitored by an anesthetist. The basic interventional procedure consists of the following steps: after local anesthesia of the conjunctival sac by repeated application of 2–4 drops of oxybuprocaine hydrochloride 0.4% (Novesine® 0.4, CIBA Vision Ophthalmics, Germering, Germany), the canaliculi are irrigated with 1–2 ml of the local anesthetic. In addition, anesthesia of the nasal mucosa with oxybuprocaine hydrochloride 1% (Novesine® Wander 1%, Wander Pharma, Nürnberg, Germany) may be necessary. Additionally we perform very often subcutaneous anesthesia by nerve blocks (infratrochlear nerve, infraorbital nerve), infiltration of the inner lid margins and sac, and anesthesia of the periosteum of the sac and if needed of the area of the inferior turbinate. Anesthesia is done with a combination of lidocaine 20 mg/ml with epinephrine 5 μg/ml.

Under fluoroscopic guidance, a flexible 0.014 in. guide wire (e.g., ChoICE™, Extra Support Guidewire with Hydrophilic Coating, Boston Scientific, Marlborough, MA, USA) is introduced through the superior punctum or inferior punctum across the obstruction into the inferior meatus of the nasal cavity. To introduce the guide wire, we often use the Lachmund dacryoplasty cannula (Fig. 34.17). The deflated balloon dacryocystoplasty catheter (Coyote™, Monorail™ PTA Balloon Dilatation Catheter, Boston Scientific, Marlborough, MA, USA) is then advanced in an anterograde manner over the wire (Fig. 34.18) and positioned across the obstruction (Figs. 34.19c, 34.20b, 34.21b, 34.23b, 34.24b, 34.25c, and 34.26d). Dilation is performed by inflating the balloon with water-soluble contrast medium (Figs. 34.19c, 34.20b, 34.21b, 34.23b, 34.24b, 34.25c, and 34.26d). The technical result of dilation is visible under fluoroscopic control immediately. Sufficient widening of the obstruction is achieved only if the balloon fully opens during inflation. In the case of residual obstruction, the balloon will not completely enfold, and fluoroscopy shows a residual hour-glass deformity (Fig. 34.23). To avoid damage to the lacrimal drainage system after the dilatation, first the guide wire is removed superiorly, followed by removal of the deflated balloon catheter.

Mild bleeding may occur, as is blood-tinged nasal discharge after the procedure. Dacryocystography followed by forced irrigation is performed immediately after the procedure to access the patency of the nasolacrimal duct system. Depending on the pathology, we insert a stent, Masterka (FCI S1.1610 Masterka 40 m, FCI, Paris, France) or Nunchaku-style tube [32] (FCI, Nunchaku self-retaining bicanalicular nasal intubation S1-1371 Nunchaku 105 mm, FCI, Paris, France). The stents are extubated after 2–3 months.

Postoperatively, the patients are treated with decongestant eye drops (e.g., xylometazoline hydrochloride; Otriven®,

Zyma GmbH, München, Germany) for at least 1 week (one–two drops, twice a day). Additionally TobraDex® eye drops (1 ml = 3 mg tobramycin, 1 mg dexamethasone, Alcon Switzerland SA, Risch, Switzerland) are used routinely as topical prophylactic antibiotic and anti-inflammatory therapy for 3–4 weeks. We do not recommend routine prophylactic oral antibiotics prior to dacryocystoplasty; however, there are surgeon preferences otherwise.

Results

Since initial reports by Becker and Berry [28], several large series have been attested the efficacy of lacrimal balloon dilatation. Technical success rates of 89–95% have been reported. According to the experiences of Lee [21] with 430 eyes of 350 patients, the technical success rate and the overall initial improvement rate were 95% and 57%, respectively. The 2-month, 1-year, and 5-year improvement rates were 48%, 39%, and 37%, respectively. The technical failure rate and re-obstruction rate are higher in patients with posttraumatic or postsurgical obstructions than in those with idiopathic obstructions. Nevertheless, no major complications were reported and patient compliance was good.

The most important indication for balloon dilation is the pre-saccal pathology (Figs. 34.7, 34.19–34.21). This region cannot be reached by the Dacryocystorhinostomy (DCR) performed external or internal. To introduce the guide wire, we often use the Lachmund dacryoplasty cannula (Fig. 34.17). Also, good success rate of up to 80% can be achieved with pre-saccal and post-saccal occlusion (Figs. 34.19–34.24). We now see also good results in occlusion of the anastomosis in failed DCR. In this case we reopen the anastomosis with the Lachmund dacryoplasty cannula and the balloon with a clinical success rate of about 75% (Fig. 34.25). In all these cases, a silicone tube intubation must be performed. These techniques have also shown promise in canalicular obstructions. In addition, dacryoliths and lacrimal sump syndromes can be treated in a simple and non-invasive manner (Fig. 34.26). After the removal and dilation of the distally located stenosis, we have a very high success rate (Figs. 34.27 and 34.28).

Stent Placement

Stent placement can be performed on an outpatient basis under local anesthesia. It is indicated in patients who suffer from epiphora caused by a severe stenosis or partial to near total obstructions of the nasolacrimal drainage system and who refuse surgical procedures or are not suitable to general anesthesia. Stent implantation is done in a retrograde fashion using special nasolacrimal duct polyurethane stents.

Song et al. [33] first described fluoroscopically guided insertion of plastic stents (so-called mushroom stents) into the nasolacrimal duct as an alternative to surgical procedures. The primary result with these techniques seemed promising [22–34]. Nevertheless, lacrimal stents can be occluded, and in contrast to the excellent technical success rates, the long-time patency rate decreases to 19.2% after follow-up of 5 years [7]. The main problem of the procedure is the tendency toward obstruction of the stent by granulation tissue or mucoid material in the proximal portion of the mushroom stent [35]. To overcome the limitations of the conventional polyurethane stent designed by Song, we designed a new stent type with alterations made in material and stent design (Dacryocystoplasty-Endostent (Ref: 8089006S), SiKa-Med, Wiehl, Germany). This soft polyurethane stent is 5.9 F in diameter and 34 mm in length. It has a slightly S-shaped configuration and a tapered ending without ballooned portion [36]. The set consists of a dilator, a stent pusher, a 0.47 mm angled atraumatic nitinol guide wire with a 7 cm hydrophilic radiopaque flexible tip, and a dacryocystography catheter. For diagnostic purposes and to plan the intervention, dacryocystography is performed in anterior and lateral views. Digital subtraction dacryocystography is performed before stent implantation to demonstrate the side of obstruction and to exclude anatomical irregularities and variants. In contrast to the mushroom stents, the method for implanting the Dacryocystoplasty-Endostent was simplified to improve the procedure and to advance patient comfort (Fig. 34.29). No additional sheath for introducing the stent is necessary thanks to its well-tapered stent ending. The first step of the procedure is to probe the nasolacrimal duct system with a dacryocystography catheter. Then a flexible angled nitinol guide wire is introduced via the catheter into the nasolacrimal duct system. Under fluoroscopic guidance the guide wire is gently pushed forward into the inferior meatus of the nasal cavity until protruding from the external naris.

Before stent implantation the specially designed tapered dacryocystography catheter from the stent set has to be advanced anterogradely over the guide wire until leaving the nostril as well. From distal the stent is threaded on the guide wire directly followed by a stent pusher. Next step the stent and the stent pusher have to be retrogradely advanced over the guide wire until having contact with the dacryocystography catheter. Carefully fixing the anastomosis of dacryocystography catheter (proximal), stent, and stent pusher (distal) to the guide wire, the stent is now brought into position under fluoroscopic control. After having reached correct stent position, the guide wire is pulled back while firmly holding in place the stent pusher to avoid dislocation of the stent. Then, the dacryocystography catheter and the stent pusher are retracted leaving the stent in its target position. Dacryocystography followed by irrigation is performed

immediately after the procedure to access correct stent position and stent patency. Postoperative treatment protocol is as we described earlier.

Clinical follow-up examinations should be performed at intervals of 1 week and at monthly intervals thereafter. Reasons for stent occlusion are usually granulation tissue as well as mucoid impactions in the stent. Two months after implantation, the stent should be removed by grasping it transnasally with a hook or forceps. Rarely, it has to be removed endoscopically when it cannot be grasped or when tight granulation tissue holds it in place.

During stent implantation mild pain sensation might occur, as is blood-tinged nasal discharge after the procedure. Commonly the patients report from a foreign body sensation at the medial canthal region for a few days which spontaneously disappears. Apart from one patient with acute blindness due to an infection after stent implantation, no major complications have been reported in the literature, and patient compliance is high.

Many authors agree on the attractiveness of a polyurethane stent used as an alternative to conventional dacryocystorhinostomy because it offers an easy, effective, safe, and reversible way to manage lacrimal drainage problems [35–39].

However, this method has not yet gained widespread acceptance among ophthalmologists and interventional radiologists. This is due to the long-term results which to date are less than favorable. Even Song decided not to recommend nasolacrimal duct stents as a first-line therapeutic option [33, 37, 40, 41] although having achieved excellent initial clinical results. Yazici [42] came to the same conclusion stating that the success rate of nasolacrimal stent implantation decreases as follow-up increases. Other studies are more optimistic, with a multicentric study recruiting more than 400 patients showing a primary patency rate of 59% after 5 years [43]. It is highly interesting, however, that despite of these rather discouraging results regarding long-term stent patency, many authors still do not directly advocate discontinuation of polyurethane stents. The group of Schaudig and Maas [35], for example, admit that the overall success rate is lower than that reported after conventional dacryocystorhinostomy, yet they draw the conclusion that refinement of the surface and stent design may improve results in the future.

The short-term observation after implantation of the newly designed hydrophilic-coated TearLeader stent has already shown a clear tendency toward more favorable results. This also includes the good feasibility and greater patient comfort during the implantation procedure as it is shown in our studies [44] and in the first long-term clinical results reported by Ferrer-Puchol [45]. However, longer follow-up periods will be required to define the role and recommend guidelines.

Conclusion

Lacrimal duct surgery has dramatically improved over the years, but there is still a need for the external or internal DCR approach. However, in major cases of epiphora that are due to lacrimal obstructions, minimal invasive techniques have found their place in the routine treatment in lacrimal duct treatments. This is due to DCP being easily and safely performed under local anesthesia and causing no facial scars, fewer bleeding complications, and less postoperative complications with high patient compliance.

Fluoroscopically guided balloon dacryocystoplasty is one of the most minimal invasive techniques that is established in the lacrimal duct treatment. Only local anesthesia is needed, the normal anatomy is preserved, and the patient is able to go to work the next day. Because of being the least invasive therapy in nasolacrimal duct pathology, it has the potential to be used as the first-line therapy. However, stent placement should be selected with caution as a first-line therapeutic option in patients who refuse surgical procedures or are not suitable for general anesthesia procedures. Although the initial results of stent placement are good, long-term results have to be improved.

References

1. Linberg JV, McCormick SA. Primary acquired nasolacrimal duct obstruction: a clinicopathologic report and biopsy technique. Ophthalmology. 1986;93:1055–63.
2. Kanski JJ, Spitznas M. Lehrbuch der klinischen ophthalmologie, 2. Auflage. New York, NY: Thieme; 1996. p. 57–66.
3. Traquair HM. Chronic dacryocystitis: It's causation and treatment. Arch Ophthalmol. 1941;26:165–80.
4. Munk PL, Lin DTC, Morris DC. Epiphora: treatment by means of dacryocystoplasty with balloon dilatation of the nasolacrimal drainage apparatus. Radiology. 1990;177:687–90.
5. Wilhelm HJ, Schätzle W. Zur Diagnostik und Therapie von Tränenwegserkrankungen. In: Glanz H, Schätzle W, editors. HNO Praxis heute, vol. 3. Berlin: Springer; 1983. p. 65–76.
6. Wilhelm K. Interventional radiology. In: Weber RK, Keerl R, Schaefer SD, Della Rocca RC, editors. Atlas of lacrimal surgery. Springer: Berlin; 2007. p. 143–54.
7. Song HY, Lee DH, Ahn H, et al. Intervention in the lacrimal drainage system. Cardiovasc Intervent Radiol. 2002;25:165–70.
8. Ewing AE. Roentgen ray demonstration of the lacrimal abscess cavity. Am J Ophthalmol. 1989;26:1–4.
9. Kassel EE, Schatz CJ. Lacrimal apparatus. In Head and neck imaging Som PM, Curtin HD (eds) 3rd edn. Mosby, St Louis 1995 pp 1129–1183.
10. Lüchtenberg M, Kuhli C, du Mesnil de Rochemont R, et al. Three-dimensional rotational dacryocystography for imaging of the lacrimal drainage system and adjacent anatomical structures. Ophthalmologica. 2005;219:136–41.
11. Wilhelm KE, Rudorf H, Greschus S, et al. Cone-beam computed tomography (CBCT) dacryocystography for imaging of the nasolacrimal duct system. Klin Neuroradiol. 2009;19:283–91.

12. Pereira L, Dammann F, Duda SH, et al. Stellenwert der dakryozystographie in der lokalisations diagnostik der tränenwegs stenosen. Fortschr Röntgenstr. 1997;166:498–501.
13. Goldberg RA, Heinz GW, Chiu L. Gadolinium magnetic resonance imaging dacryocystography. Am J Ophthalmol. 1993;115:738–41.
14. Hähnel von S, Jansen O, Zake S, et al. Der wert der spiral-CT zur diagnose von stenosen der ableitenden tränenwege. Fortschr Röntgenstr. 1995;163:210–4.
15. Manfre L, Maria de M, Todaro E, et al. MR dacryocystography: comparison with dacryocystography and CT dacryocystography. Am J Neuroradiol. 2000;21:1145–50.
16. Zinreich SJ, Miller NR, Freeman LE, et al. Computed tomographic dacryocystography using topical contrast media for lacrimal system visualization. Orbit. 1990;9:79–87.
17. Kirchhoff K, Hahnel S, Jansen O, et al. Gadolinium-enhanced magnetic resonance dacryocystography in patients with epiphora. J Comput Assist Tomogr. 2000;24:327–31.
18. Hofer U, Wilhelm K, Schild H. Diagnostische dacryozystographie: Durchführung, auswertekreterien, häufigkeit und lokalisation von pathologischen befunden. Fortschr Röntgenstr. 2000;172(Suppl 1):S152.
19. Faye B, Racy E, Assouline M. Complications of standardized endonasal dacryocystorhinostomy with unciformectomy. Ophthalmology. 2004;111:837–45.
20. Janssen AG, Mansour K, Rabbe GJ. Dacryocystoplasty: treatment of epiphora by means of balloon dilation of the obstructed nasolacrimal duct system. Radiology. 1994;193:453–6.
21. Lee JM, Song HY, Han YM, et al. Balloon dacryocystoplasty: results in the treatment of complete and partial obstructions of the nasolacrimal system. Radiology. 1994;192:503–8.
22. Song HY, Jin YH, Kim JH, et al. Non-surgical placement of a nasolacrimal polyurethane stent: long-term effectiveness. Radiology. 1996;200:759–63.
23. Wilhelm K, Textor J, Hofer U, et al. Nasolacrimal duct obstructions: treatment with balloon dilation and stent implantation. Fortschr Röntgenstr. 1997;167:486–90.
24. Lachmund U, Ammann-Rauch D, Forrer A, et al. Therapie von canaliculus-communis-Stenosen mittels ballonkatheter dilatation. Ophthalmologe. 2005;102:369–74.
25. Lachmund U, Ammann-Rauch D, Forrer A, et al. Minimal invasive therapie der epiphora durch ballon catheter dilatation und Stent implantation. Ophthalmologe. 2005;102:375–86.
26. Lachmund U, Wilhelm K, Remonda L, et al. Interventionelle radiologische therapie der tränenwege. Klin Neuroradiol. 2005;15(Nr. 1):50–61.
27. Wilhelm K, Hofer U, Textor J, et al. Nonsurgical fluoroscopically guided treatment of dacryoliths during dacrycystoplasty. Radiology. 1999;212:365–70.
28. Becker BB, Berry FD. Balloon catheter dilatation in lacrimal surgery. Ophthalmic Surg. 1989;20:193–8.
29. Wilhelm KE, Hofer U, Textor J, et al. Antegrade transcanalicular dacryozystoplasty of nasolacrimal duct obstructions. Radiology. 2000;217:324.
30. Wilhelm K, Hofer U, Textor HJ. Nonsurgical fluoroscopically guided dacryocystoplasty of common canalicular obstructions. Cardiovasc Intervent Radiol. 2000;23:1–8.
31. Hünerbein R, Grass F, Leber M, et al. Balloon dacryocystoplasty: interventional radiological therapy of congenital dacryostenosis. Rofo. 2005;177:1387–93.
32. Inatani M, Yamauchi T, Fukuchi M, et al. Direct silicone intubation using Nunchaku-style tube (NST-DSI) to treat lacrimal passage obstruction. Acta Ophthalmol Scand. 2000;78:689–93.
33. Song HY, Jin HY, Kim JH, et al. Nasolacrimal duct obstruction treated non-surgically with use of plastic stents. Radiology. 1994;190:535–9.
34. Perena MF, Castillo J, Medrano J, et al. Nasolacrimal polyurethane stent placement: preliminary results. Eur J Ophthalmol. 2001;11:25–30.
35. Schaudig U, Maas R. The polyurethane nasolacrimal duct stent for lower tear duct obstruction: long-term success rate and complications. Graefes Arch Clin Exp Ophthalmol. 2000;238:733–7.
36. Wilhelm K, Loeffler K, Urbach H, et al. Complete tear duct obstruction: treatment with lacrimal polyurethane stent implantation. Cardiovasc Intervent Radiol. 2002;25:S149.
37. Kang SG, Song HY, Lee DH, et al. Non-surgically placed nasolacrimal stents for epiphora: long-term results and factors favouring stent patency. J Vasc Interv Radiol. 2002;13:293–300.
38. Pinto I, Paul L, Grande C, De la Cal MA. Nasolacrimal polyurethane stent placement for epiphora: technical long-term results. J Vasc Interv Radiol. 2001;12:67–71.
39. Lanciego C, De Miguel S, Perea M, et al. Nasolacrimal stents in the management of epiphora: medium-term results of a multicenter prospective study. J Vasc Interv Radiol. 2001;12:701–10.
40. Song HY, Jin YH, Kim JH, et al. Non-surgical placement of a nasolacrimal polyurethane stent. Radiology. 1995;194:233–7.
41. Ko GY, Song HY, et al. Obstruction of the lacrimal system: treatment with a covered, retrievable, expandable nitinol stent versus a lacrimal polyurethane stent. Radiology. 2003;227:270–6.
42. Yazici Z, Yazici B, Parlak M, Tuncel E, et al. Treatment of nasolacrimal duct obstruction with polyurethane stent placement: long-term results. Am J Radiol. 2002;179:491–4.
43. Lanciego C, Toledano N, Di Miguel S, et al. Resolution of epiphora with nasolacrimal stents : results of long-term follow-up in a multicenter prospective study. J Vasc Interv Radiol. 2003;14:1417–25.
44. Wilhelm K, Loeffler K, Urbach H, et al. Behandlung von tränenwegsverschlüssen mit dem PBN Wilhelm Tear Leader Stent–Erste Ergebnisse. Fortschr Röntgenstr. 2003;175(S1):152–3.
45. Ferrer-Puchol M, Esteban-Hernández E, Jornet-Frayos J, et al. Obstruction of the lacrimal system. Treatment and long term results with polyurethane song stent versus tear leader-stent. Annual meeting and postgraduate course of the cardiovascular and interventional radiological society of Europe, 2005, Poster 30, pp 164.

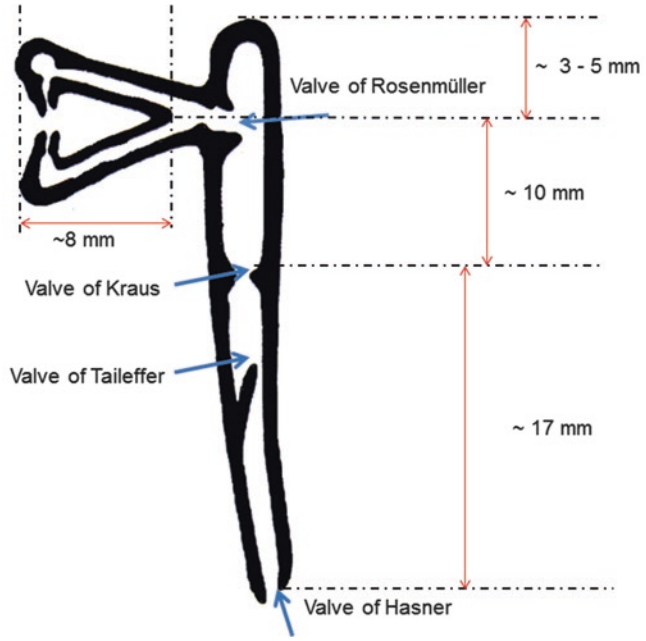


Fig. 34.1 Lacrimal apparatus—right eye. Normal anatomy with valves of the lacrimal system

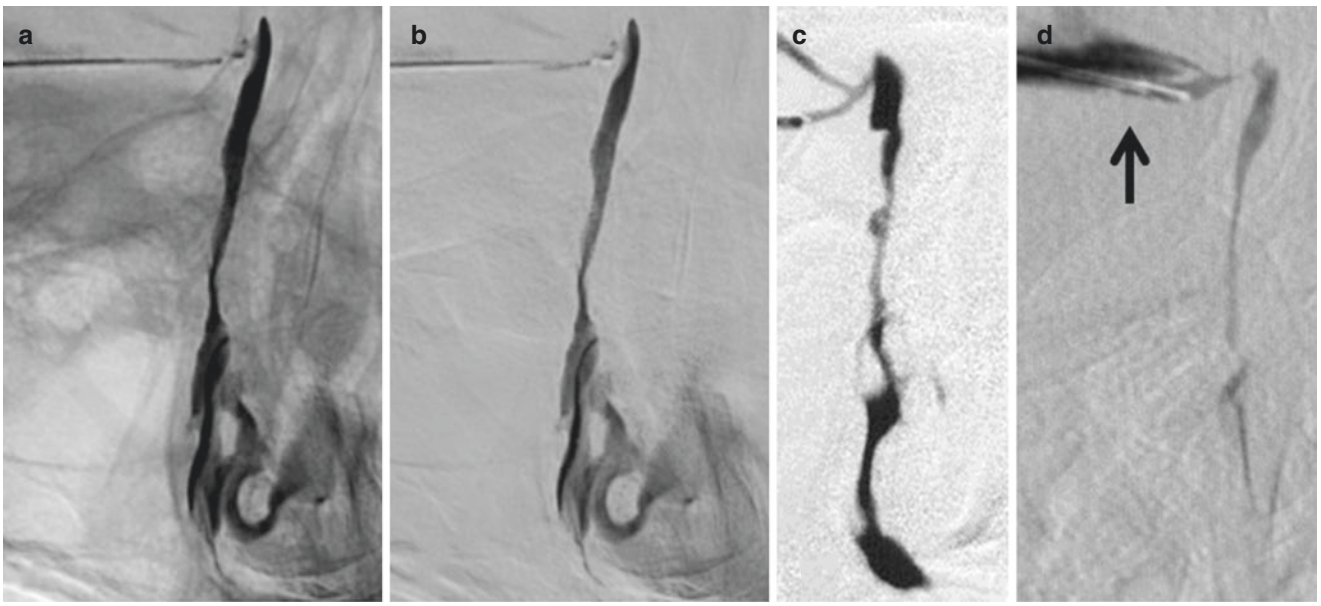


Fig. 34.2 Normal versus pathological lacrimal system in dacryocystography (DCG) demonstrated in two different patients. Normal in (**a**), (**b**), and (**c**) and pathological in (**d**). (**a**) Normal right DCG, frontal view, with cannula in the inferior canaliculus. (**b**) Same patient as shown in (**a**) with digital subtraction dacryocystography (DSD) demonstrates patency of the canaliculi, lacrimal sac, and nasolacrimal duct. No reflux of contrast medium to the eyelid is seen. (**c**) Normal DSD with no reflux of another patient. (**d**) Pathological lacrimal system with reflux shown due to an obstruction

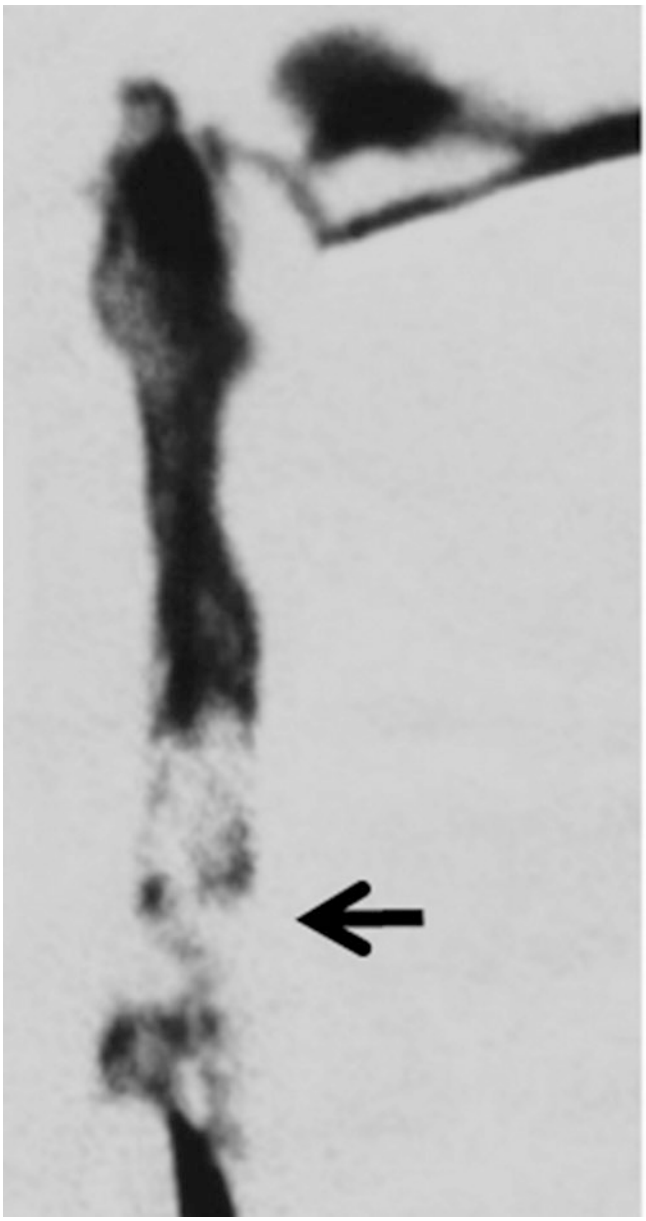


Fig. 34.3 Chronic recurrent inflammation and dacryolith with post-saccal distal stenosis: The digital subtraction dacryocystography (DSD) shows distal filling defect because of dacryolith and blunt, hazy borders of the lacrimal duct. Distal minor stenosis at the level of Hasner's valve. The proximal areas show reflux due to obstruction

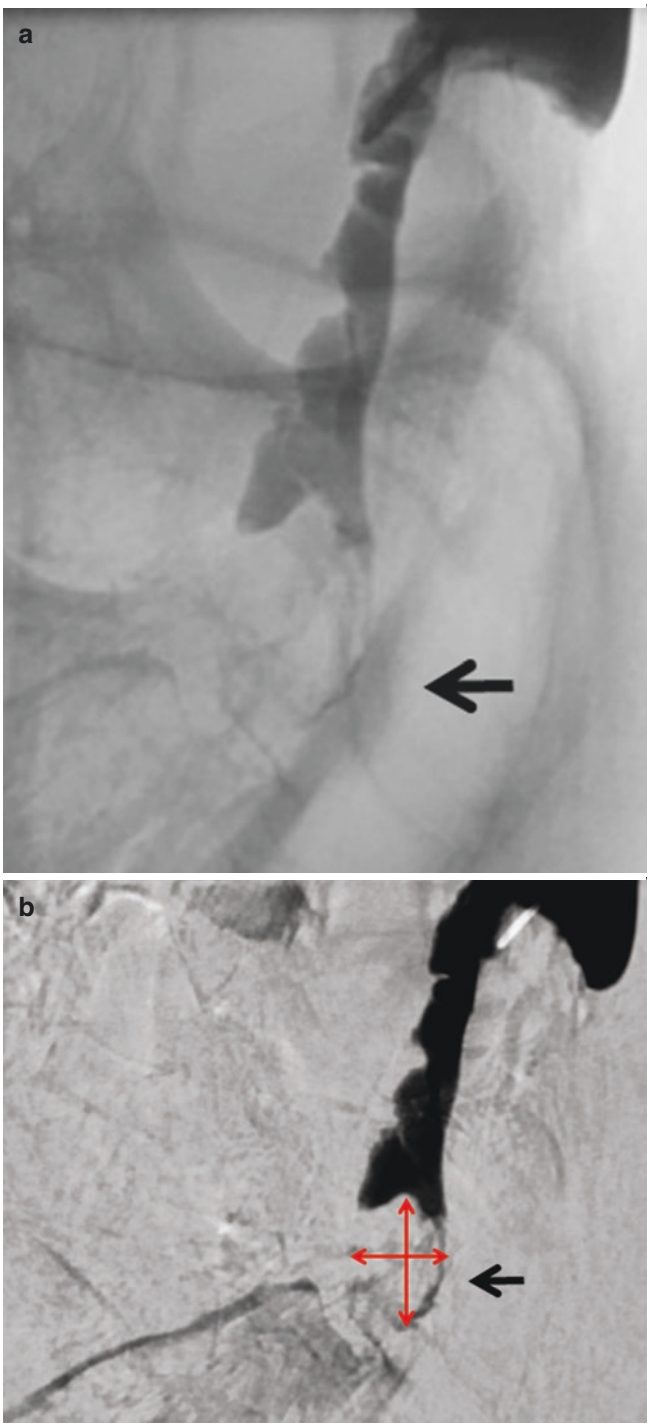


Fig. 34.4 (**a**, **b**) Dacryolith: DCG (**a**) and DSD (**b**) lateral view of the right eye shows the presence of a huge dacryolith (8 mm height × 7 mm width as shown with *red arrows*) before post-saccal distal stenosis at the level of Hasner's valve

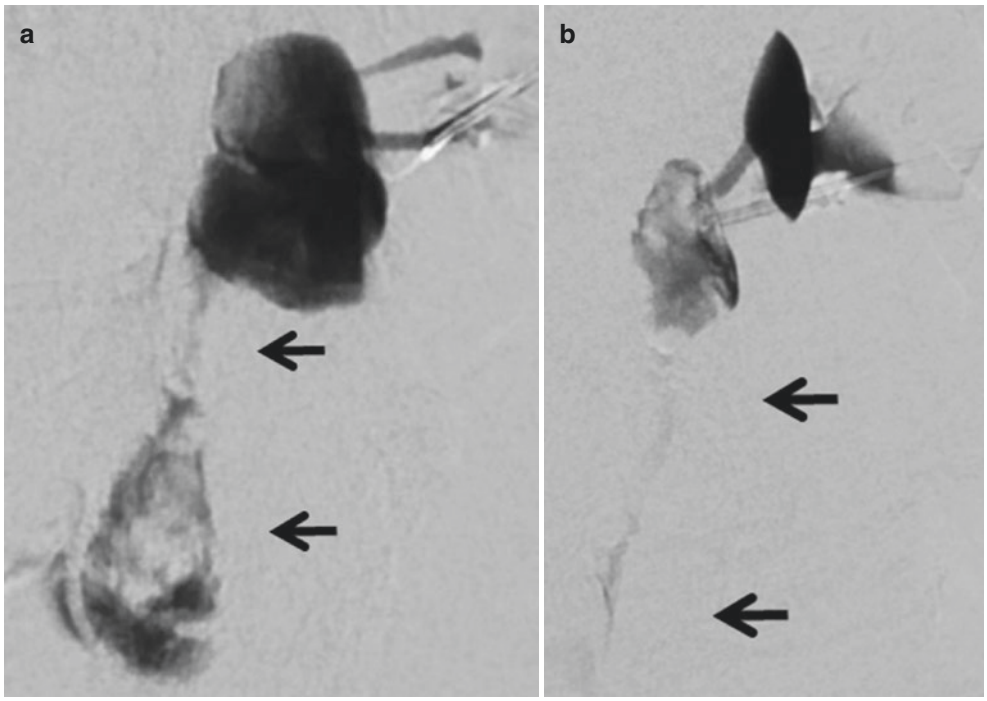


Fig. 34.5 (**a**, **b**) Dacryolith in two different patients shown in digital subtraction dacryocystography (DSD). Left eye lateral view demonstrates a post-saccal stenosis at the level of Hasner's valve and a filling defect before Hasner's valve due to the presence of dacryolith. Hence, reflux is due to dacryolith obstruction

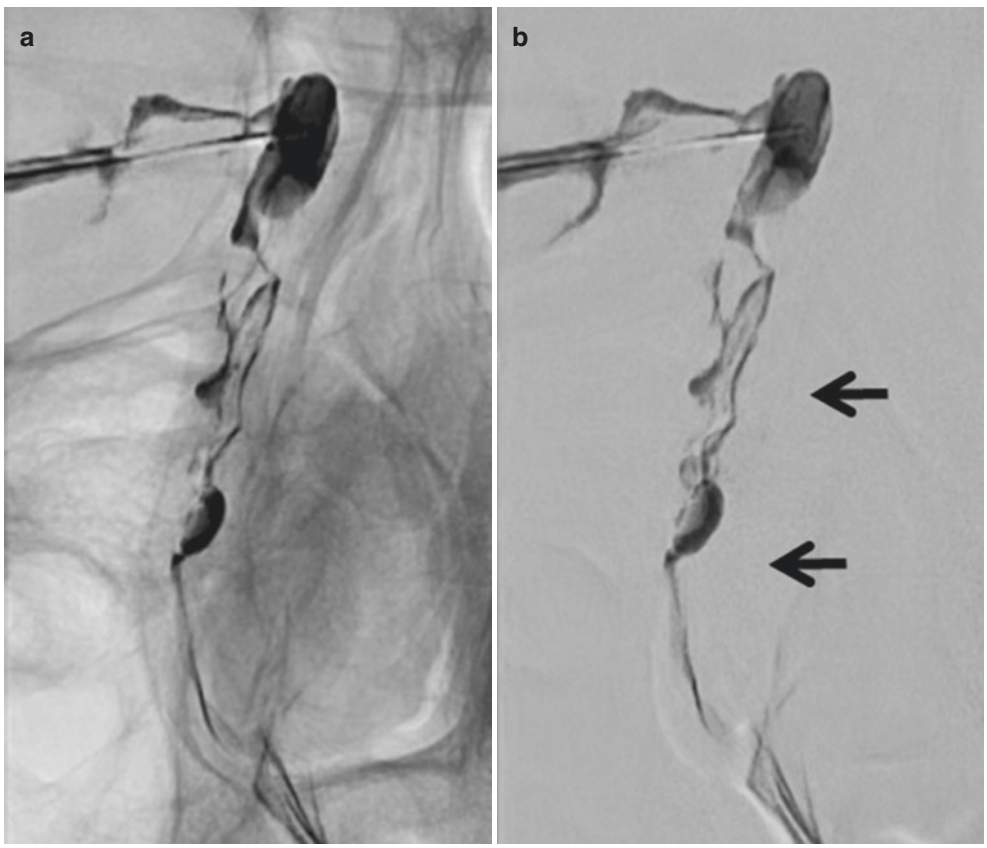


Fig. 34.6 (**a**, **b**) Dacryolith and post-saccal distal stenosis: dacryocystography (DCG) (**a**) and digital subtraction dacryocystography (DSD) (**b**) of the right eye. Frontal view demonstrates the obstruction of the NLD with reduced contrast medium passage to the nasal cavity (see *arrow*) and contrast medium reflux toward the eyelid. A post-saccal distal stenosis of the nasolacrimal duct at the level of Hasner's valve exists and just proximal to this is a large filling defect caused by the dacryolith. Additionally, the nasolacrimal duct is scarred down with multiple irregularities

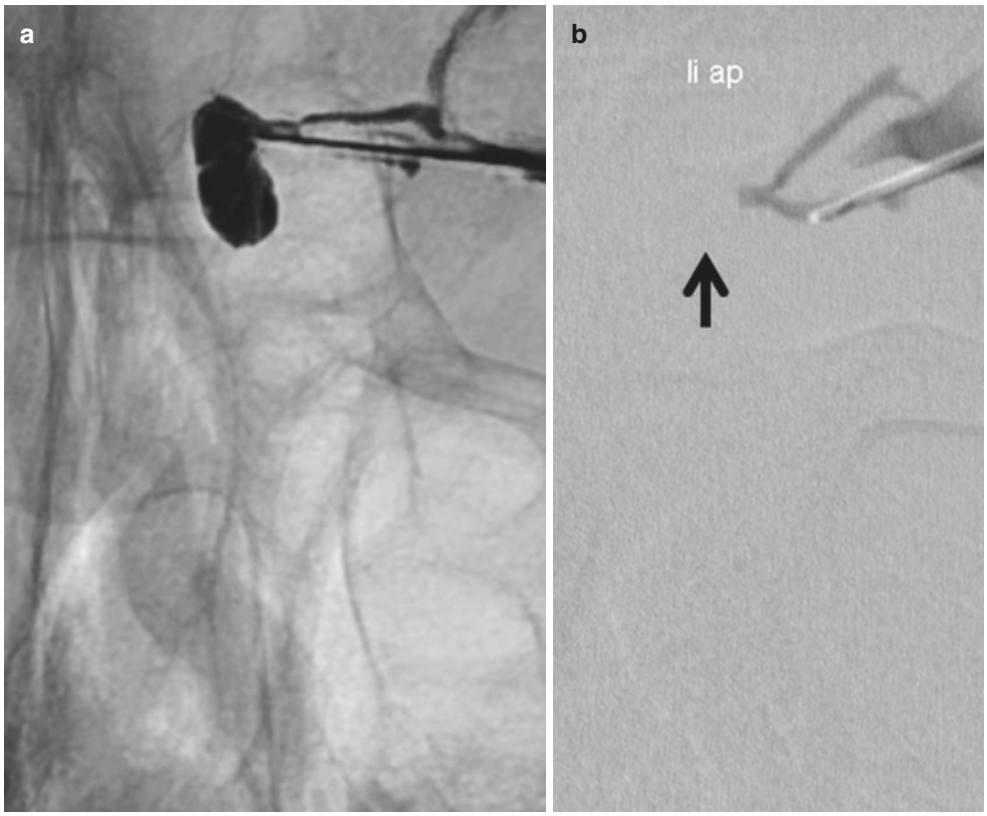


Fig. 34.7 (**a**, **b**) Pre-saccal stenosis or occlusion: digital subtraction dacryocystography (DSD) demonstrates (**a**) high-grade pre-saccal stenosis of the common canaliculus (see *arrow*) of the right eye with massive reflux and (**b**) pre-saccal occlusion of the common canaliculus (see *arrow*) of the left eye with massive reflux

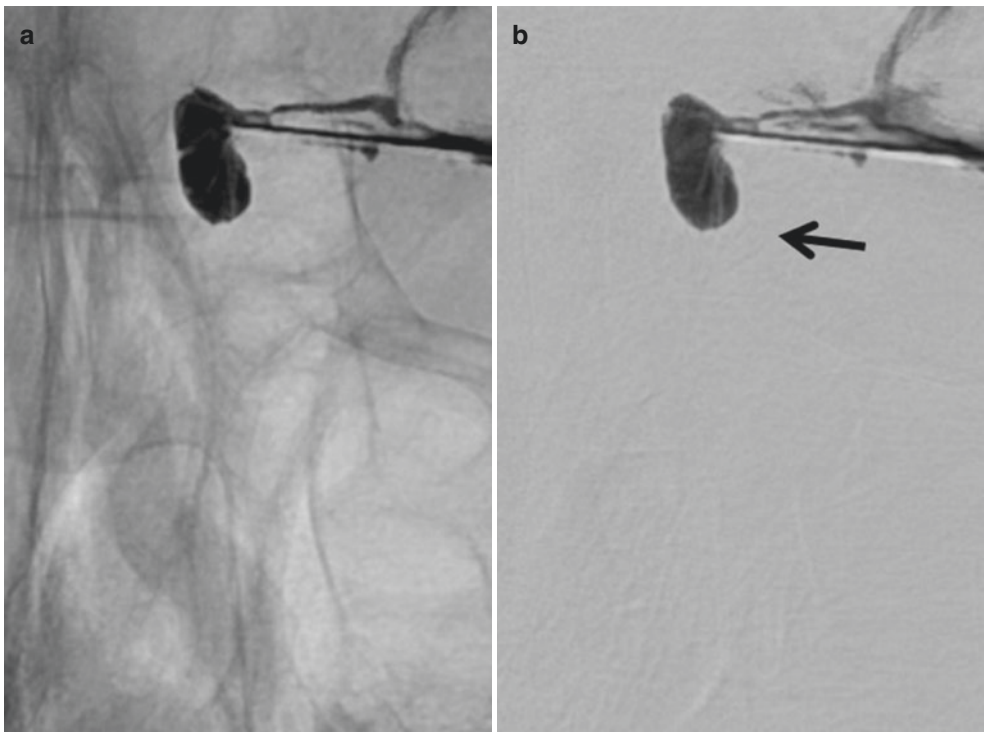


Fig. 34.8 (**a**, **b**) Post-saccal occlusion: dacryocystography (DCG) (**a**) and digital subtraction dacryocystography (DSD) (**b**) of left eye frontal view demonstrate a proximal occlusion of the NLD (see *arrow*) at the junction between the lacrimal sac and nasolacrimal duct

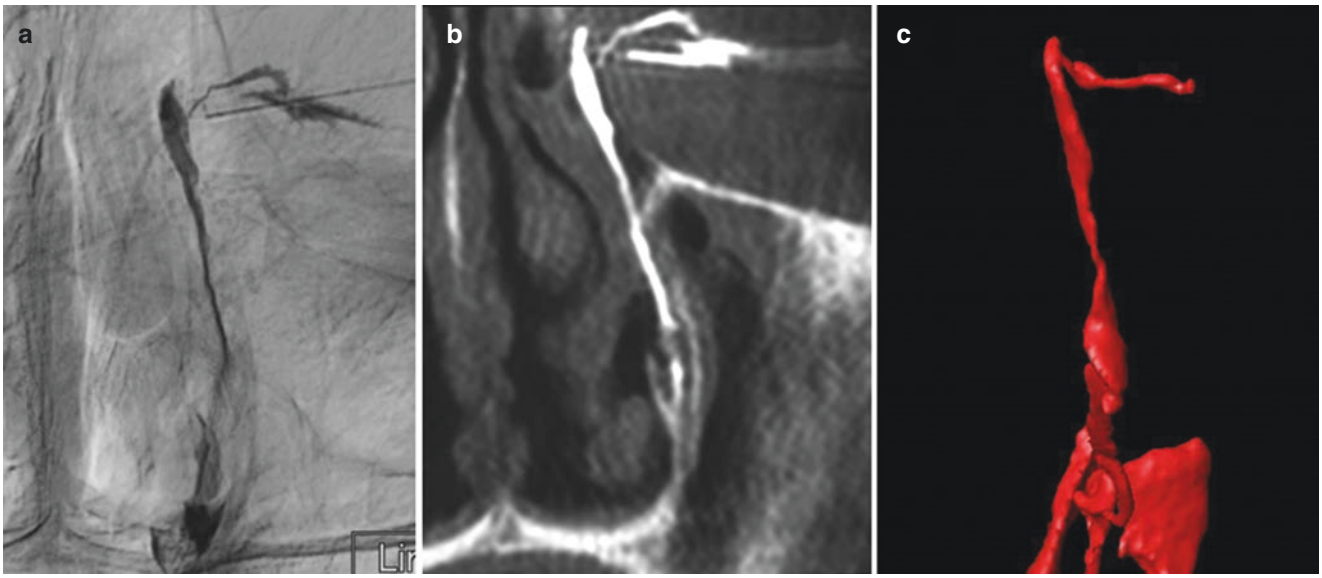


Fig. 34.9 Cone beam CT-DCG: (**a**) is left eye frontal view of DCG; (**b**) is the coronal cut of a cone beam computer tomography dacryocystography (CBCT-DCG); (**c**) is a 3D surface-shaded display (3D-SSD) showing reconstruction of the lacrimal system offering superb anatomic details

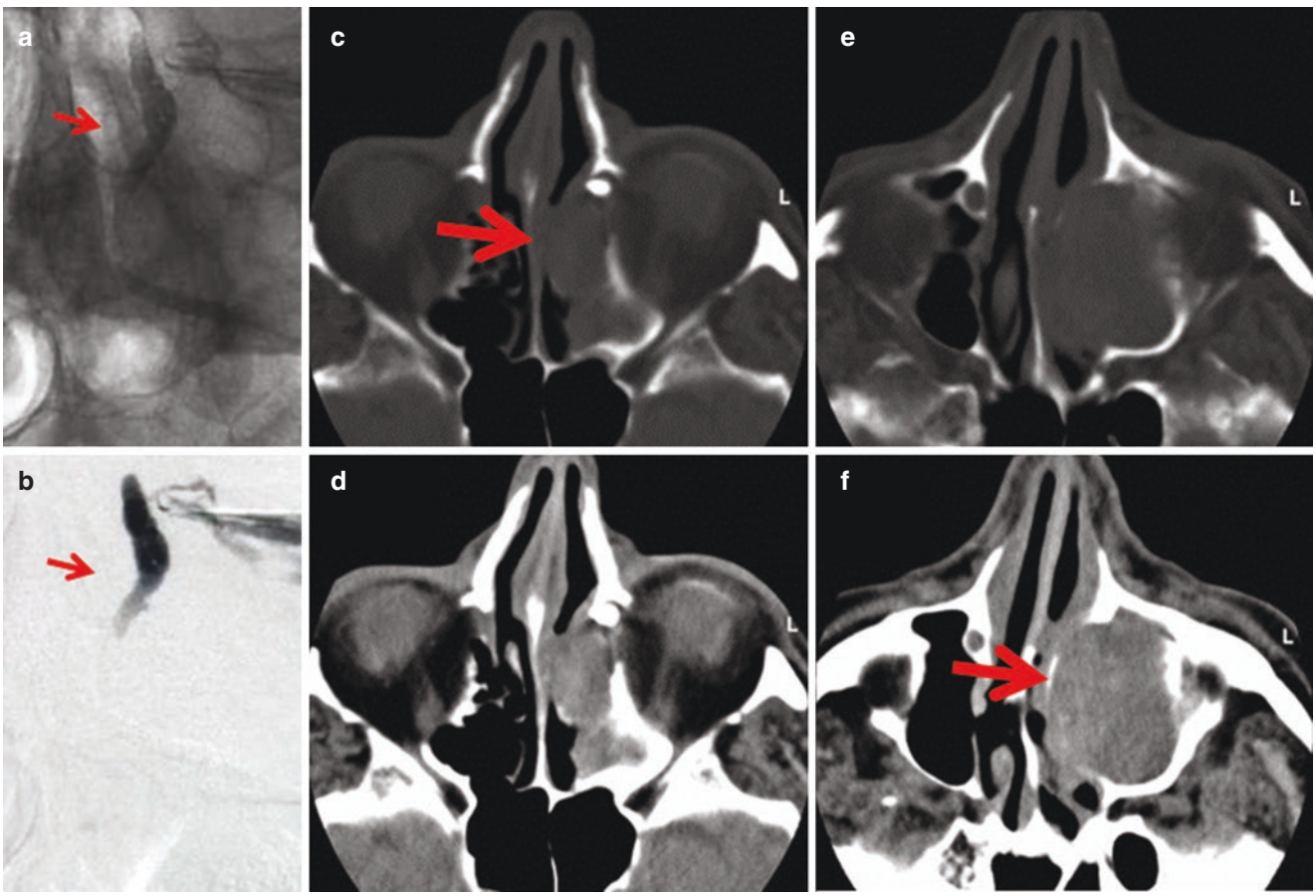


Fig. 34.10 Inverted papilloma: (**a**) dacryocystography (DCG), (**b**) digital subtraction dacryocystography (DSD), and (**c**–**f**) computed tomography (CT) showing the nasolacrimal duct is deviated by a mass growing from the maxillary sinus into the nasal cavity and displacing the nasolacrimal duct to the lateral side

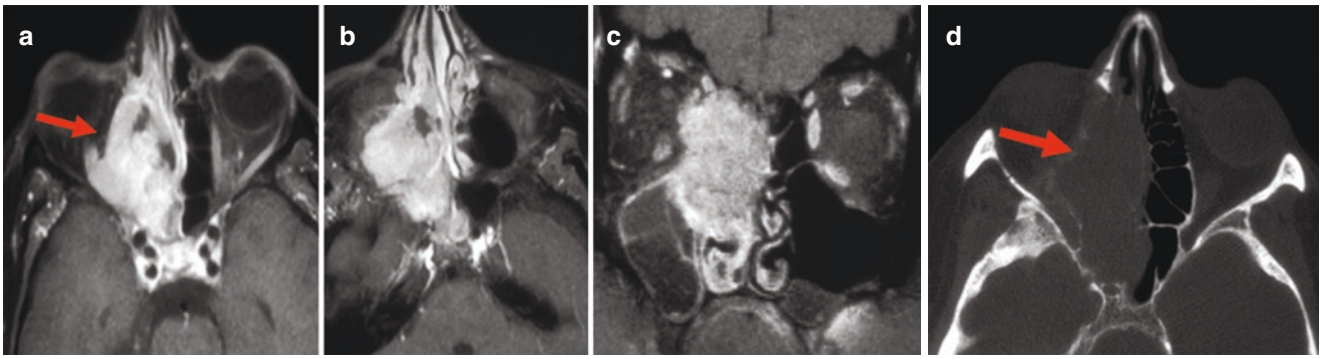
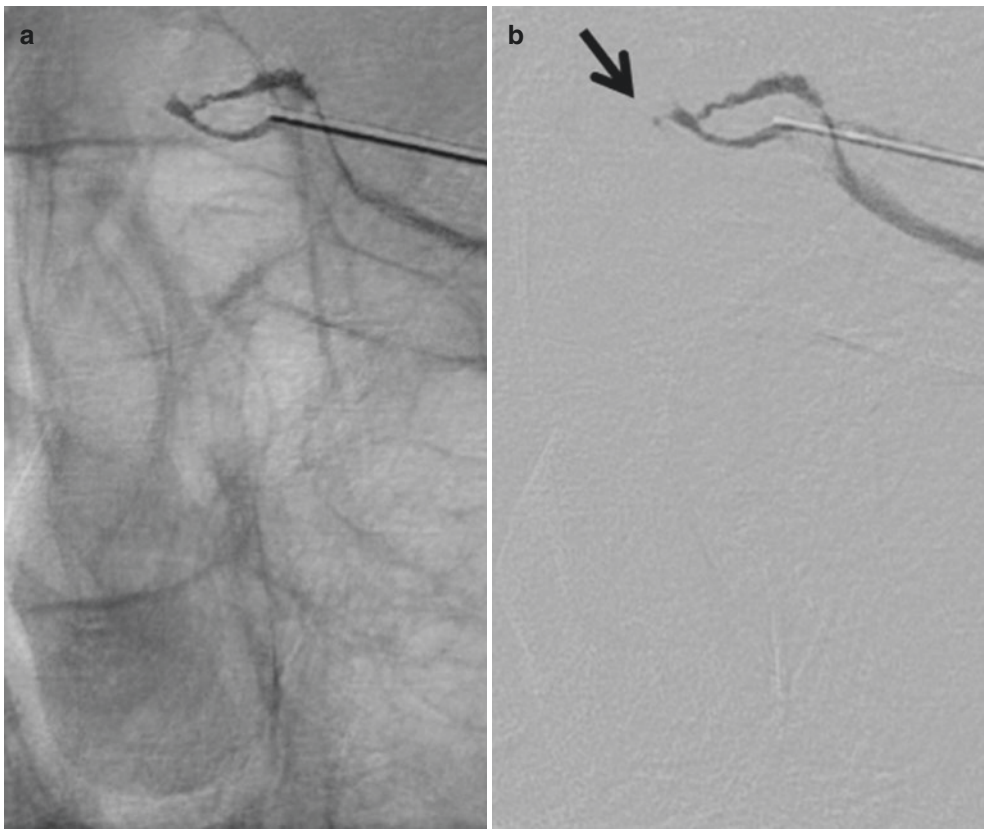


Fig. 34.11 Squamous cell carcinoma involving the lacrimal system. Magnetic resonance imaging (MRI) with T1 and IV gadolinium shown in panels (**a**–**c**). Computed tomography (CT), bone window, and axial cuts shown in panel (**d**). Large infiltrating tumor of paranasal sinuses involving the ethmoid, lacrimal system, and orbit



Figs 34.12 (**a**, **b**) Pre-saccal or saccal occlusion: (**a**) dacryocystography (DCG) and (**b**) digital subtraction dacryocystography (DSD) of the left eye, frontal view, demonstrating a pre-saccal/proximal most saccal occlusion (complete obstruction) at the level of the common canaliculus

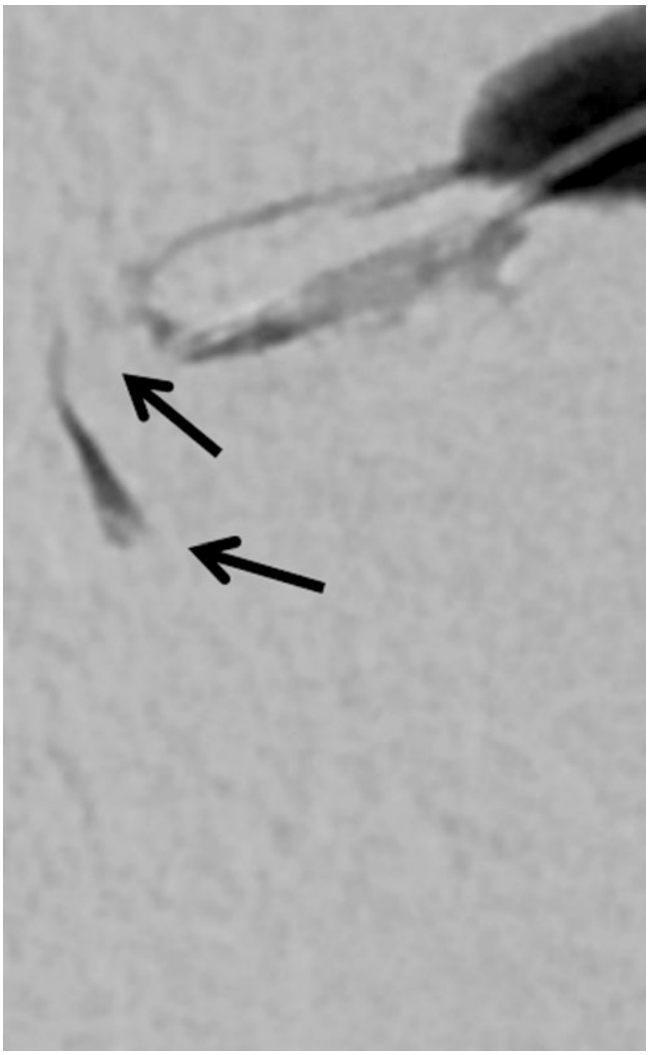


Fig. 34.13 Coexisting pre-saccal stenosis and post-saccal occlusion: radiographic anatomy from digital subtraction dacryocystography (DSD) demonstrates high-grade pre-saccal stenosis of the common canaliculus and post-saccal proximal occlusion

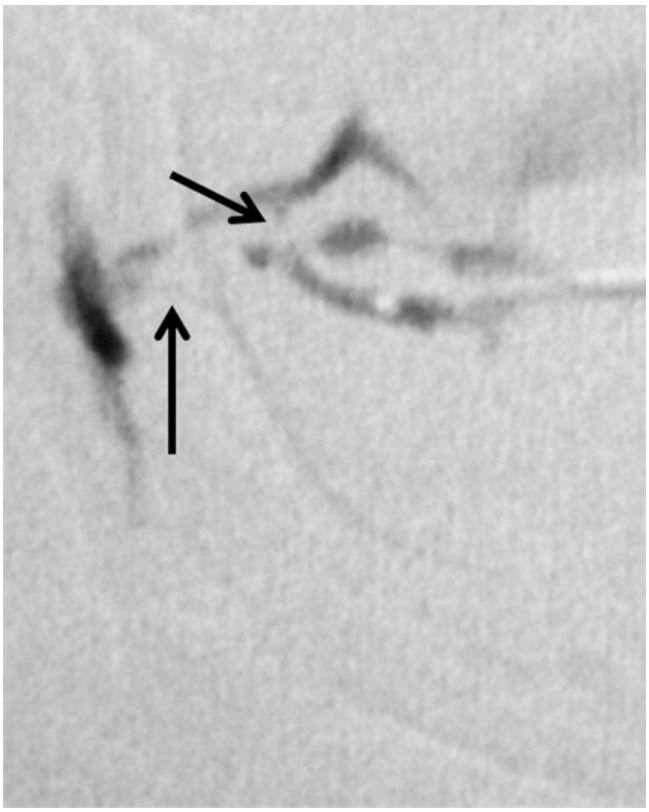


Fig. 34.14 Pre-saccal fistula shown in DSD left eye frontal view

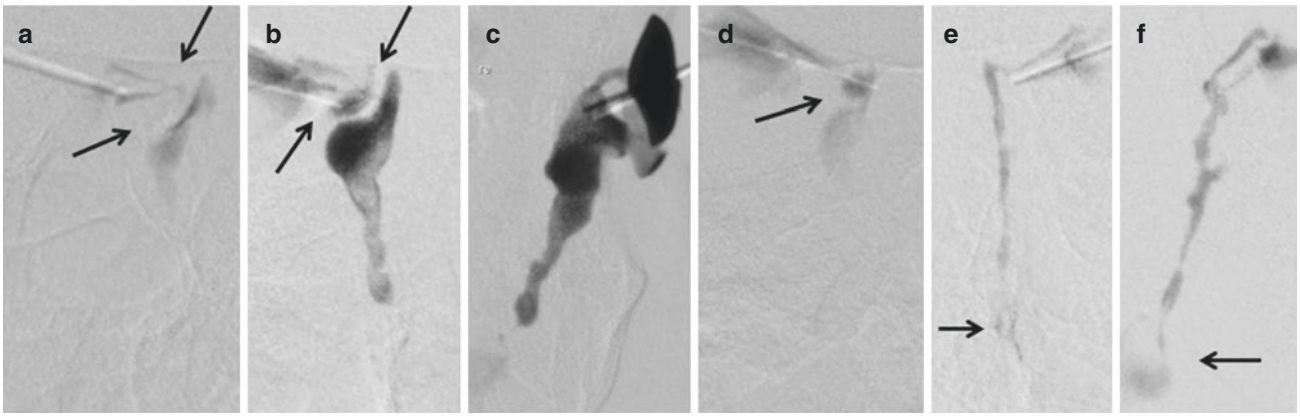


Fig. 34.15 Pre-saccal fistula with pre- and post-saccal stenosis right eye and post-saccal stenosis left eye: DSD showing a blind-ending fistula on a right eye frontal view (panels **a** and **b**) and lateral view (panel **c**). In (**a**) the pre-saccal stenosis can be seen. At one end of this fistula, a high-grade pre-saccal stenosis of the common canaliculus can be appreciated (panels **a** and **b**). Also a distal post-saccal high-grade stenosis at the level of Hasner's valve is seen (panel **c**). DSD left eye (AP and lateral view) (panels **e** and **f**) of the same patient presents a distal post-saccal stenosis at the level of Hasner's valve

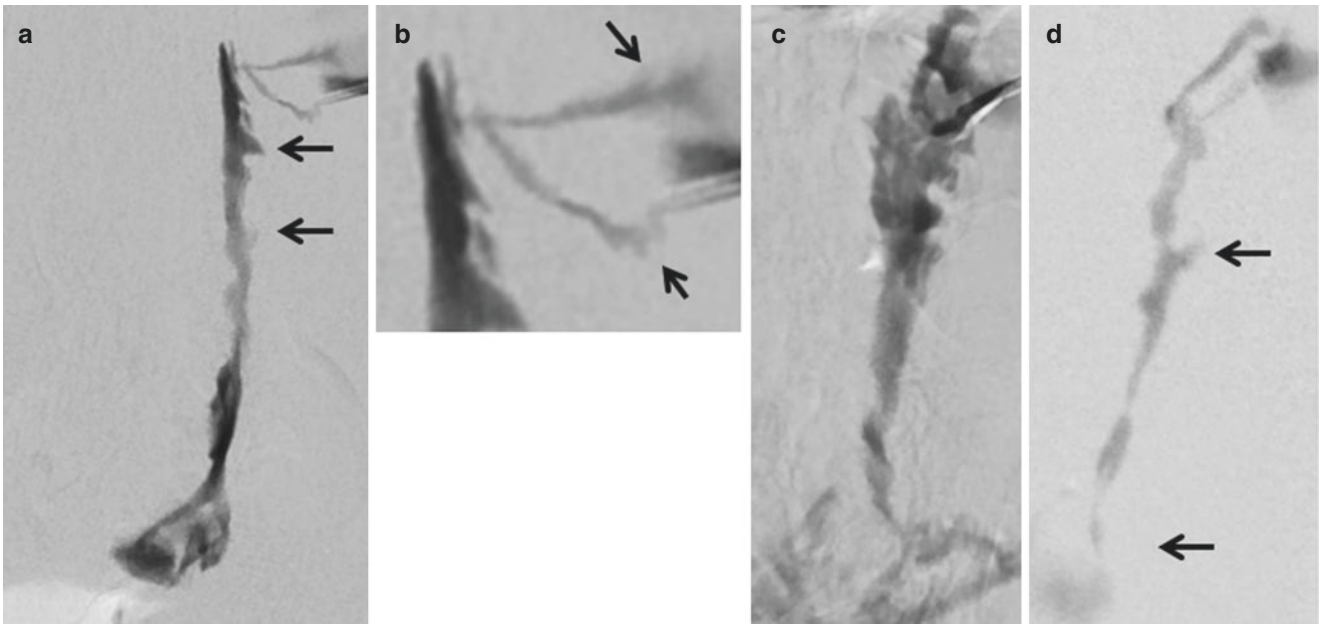


Fig. 34.16 Diverticula with post-saccal stenosis: DSD frontal view of the left eye in (**a**) and magnified pre-saccal system in (**b**) show multiple small diverticles of the whole lacrimal system. Panel (**c**) is lateral view of the same patient which shows a distal post-saccal stenosis at the level of Hasner's valve. Panel d is a different patient, lateral view, showing diverticula at the upper third and middle third, some at the level of the valves of Krause and Taillefer. In addition a distal stenosis can be noted at the level of Hasner's valve

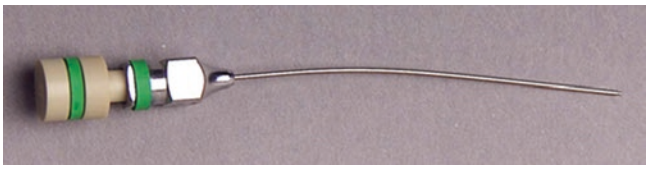


Fig. 34.17 Lachmund dacryoplasty cannula

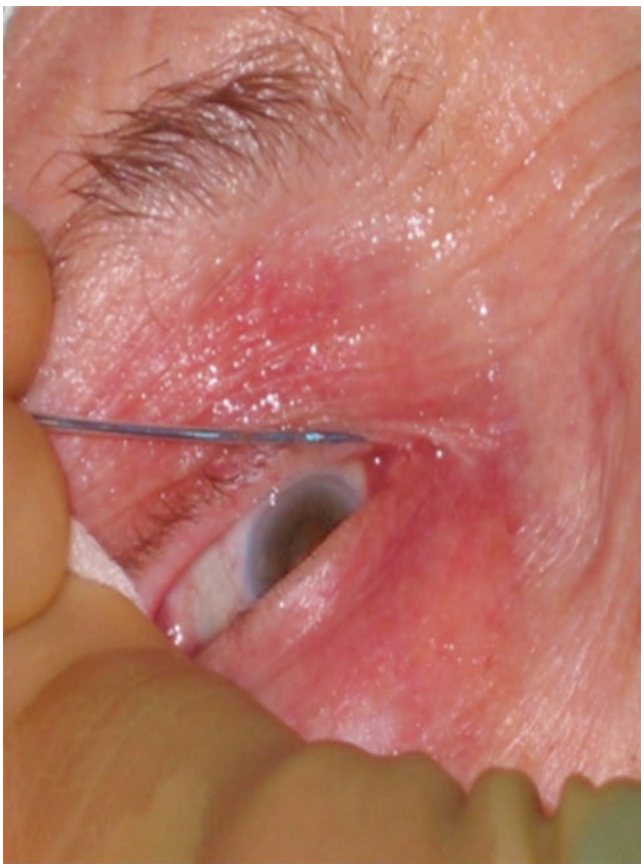


Fig. 34.18 Introducing the balloon catheter by Seldinger's technique over the guide wire

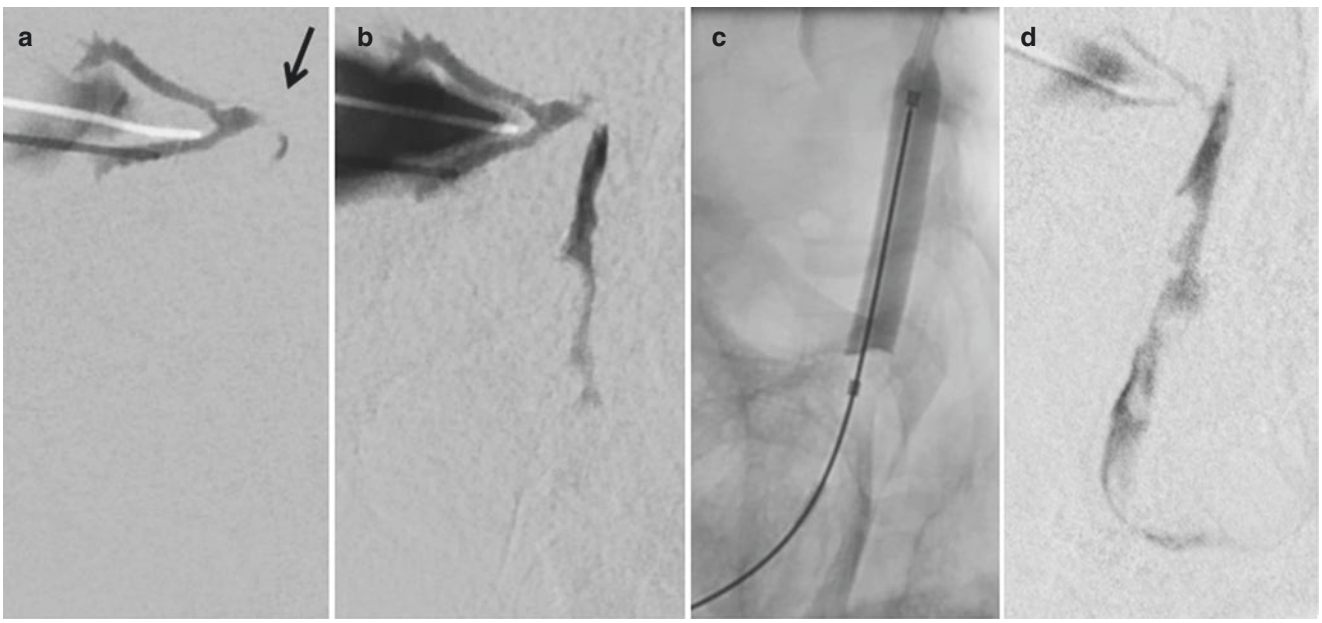


Fig. 34.19 Before, during, and after dacryoplasty in pre-saccal stenosis: Panels (**a** and **b**) showing a DSD (right eye, frontal view) with a high-grade pre-saccal stenosis of the common canaliculus. Panel (**c**) is a DCG which shows balloon dilation. Panel (**d**) is a DSD after balloon dilation which demonstrates a normal lacrimal system with minimal reflux

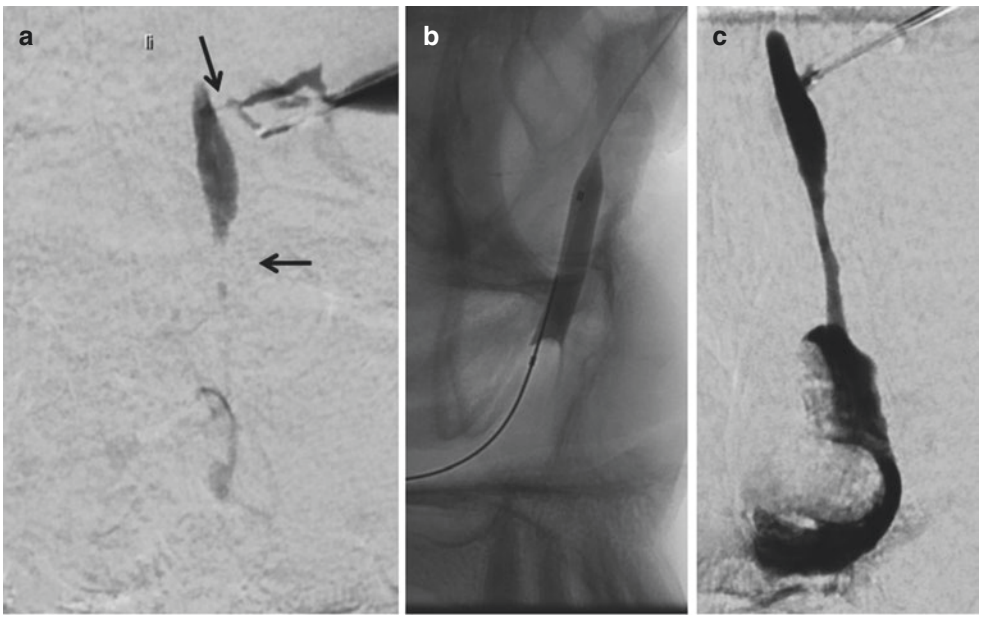


Fig. 34.20 Before and after dacryoplasty in pre-saccal and post-saccal stenosis: Panels (**a** and **b**) are DSD (right eye, frontal view) showing high-grade pre-saccal stenosis of the common canaliculus and a post-saccal proximal stenosis at the level of the end of the sac. Panel (**c**) is DSD after balloon dilation demonstrating a normal lacrimal system with minimal reflux

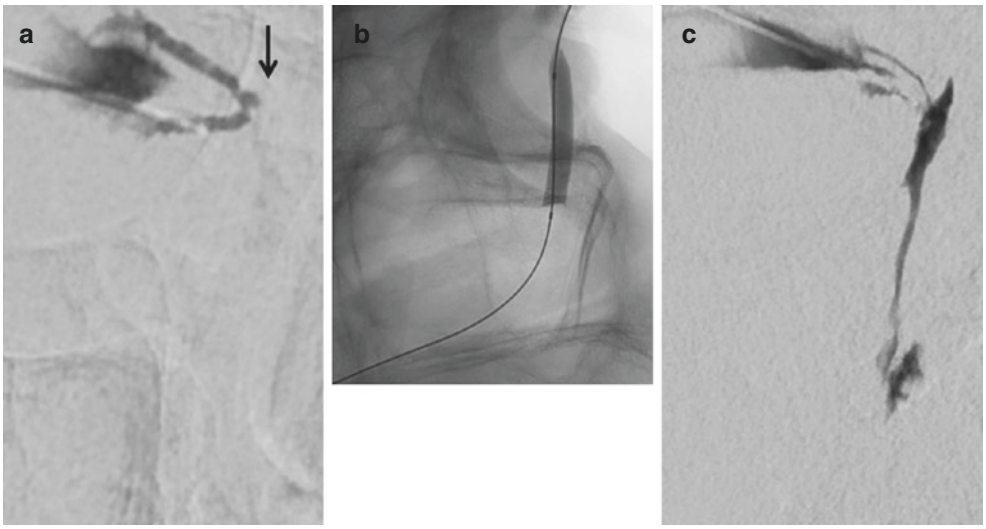


Fig. 34.21 Before and after dacryoplasty in pre-saccal occlusion: Panel (**a**) is a DSD (right eye, frontal view) showing a pre-saccal proximal occlusion of the common canaliculus. Panel (**b**) showing balloon dilation and panel (**c**) is a DSD after balloon dilation demonstrating a normal lacrimal system with minimal reflux

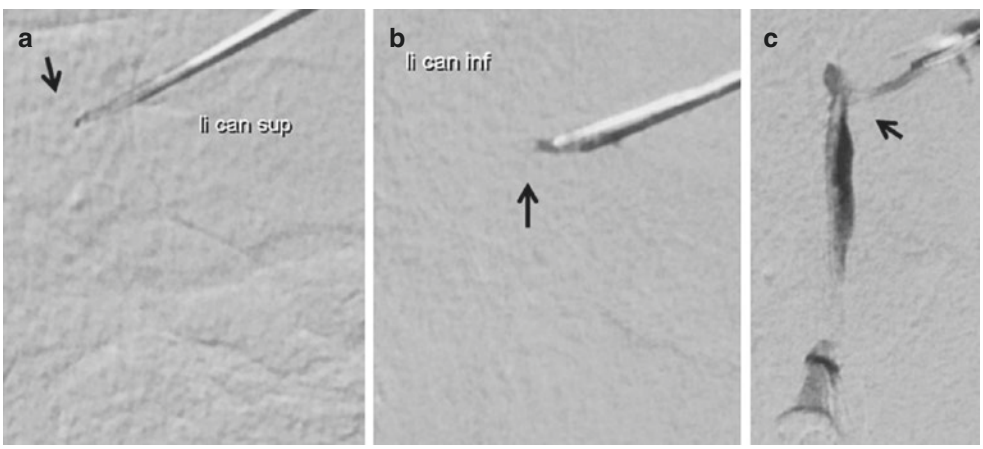


Fig. 34.22 Before and after dacryoplasty in complete pre-saccal occlusion: Panels (**a** and **b**), left eye showing partial obstruction of the inferior and superior canaliculus. Panel (**c**) is at 6-month follow-up. Silicon tube is still in superior canaliculus, and a normal inferior canaliculus without silicone tube can be appreciated

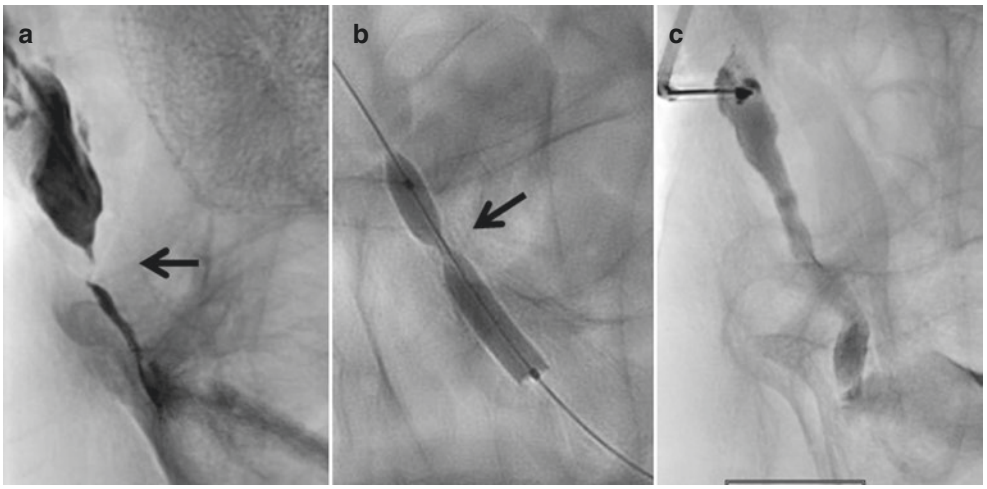


Fig. 34.23 Before, during, and after dacryoplasty in high-grade post-saccal proximal stenosis: dacryocystography (right eye, lateral view (panel **a**) shows incomplete obstruction of the nasolacrimal duct with a stenosis at the junction between the lacrimal sac and NLD. Panel (**b**) is a lateral view obtained during balloon inflation (3 mm balloon) showing inflation of the balloon at the level of the obstruction. Panel (**c**) is dacryocystography after balloon dilation demonstrating improvement of contrast medium passage through the nasolacrimal duct system without reflux

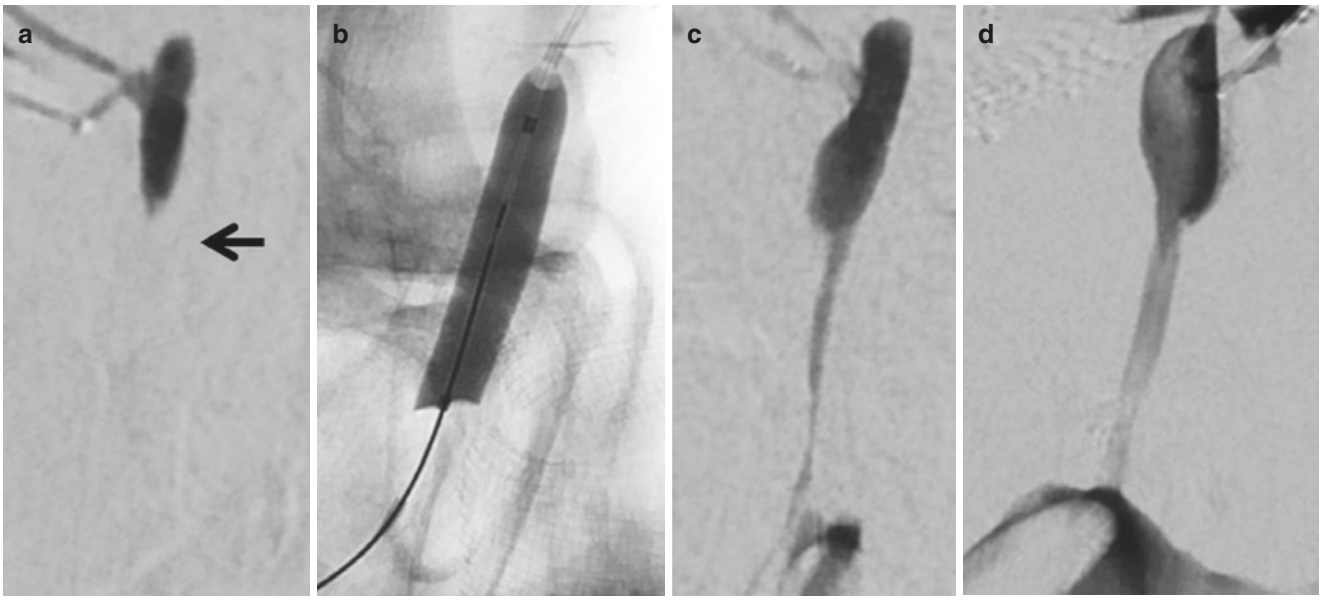


Fig. 34.24 Before and after dacryoplasty in post-saccal occlusion: Panel (**a**) is a DSD (right eye, frontal view) showing a post-saccal proximal occlusion of the nasolacrimal system. Panel (**b**) is lateral view obtained during balloon inflation (3.5 mm balloon) showing inflation of the balloon at the level of the obstruction. Panels (**c** and **d**) are DSD at 6-month follow-up demonstrating a normal nasolacrimal system without any reflux

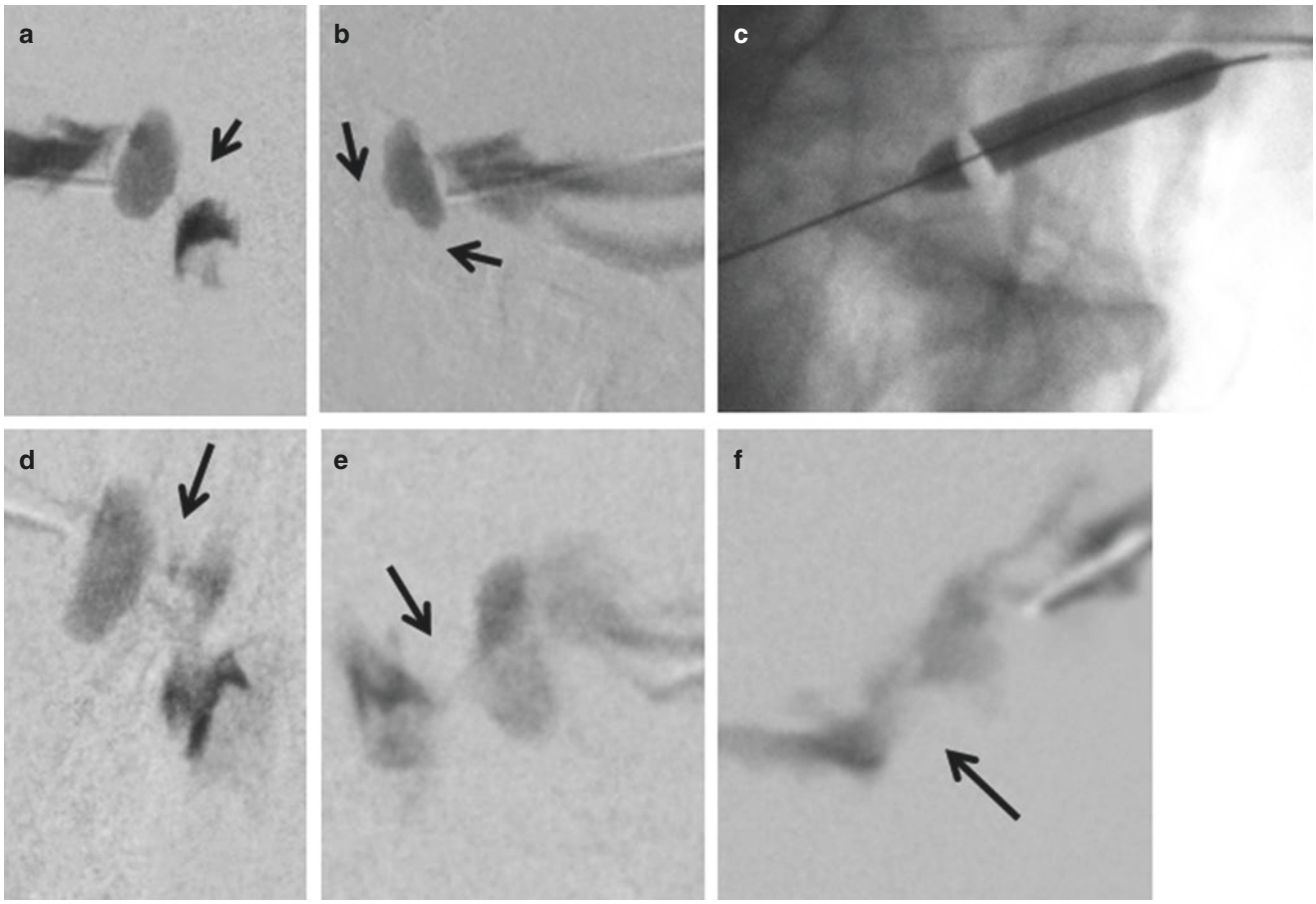


Fig. 34.25 Before and after dacryoplasty for a twice-failed DCR in both eyes: (**a**) Right eye shows a high-grade stenosis of the anastomosis created by DCR, post-saccal occlusion. (**b**) Left eye shows occlusion of the anastomosis and post-saccal occlusion. (**c**) Dacryoplasty performed with balloon dilation with 3.5 mm balloon. (**d**) Right eye, 1 year after dacryoplasty showing patency with no reflux. (**e**, **f**) Left eye, frontal and lateral view, 1 year after dacryoplasty showing patency and no reflux

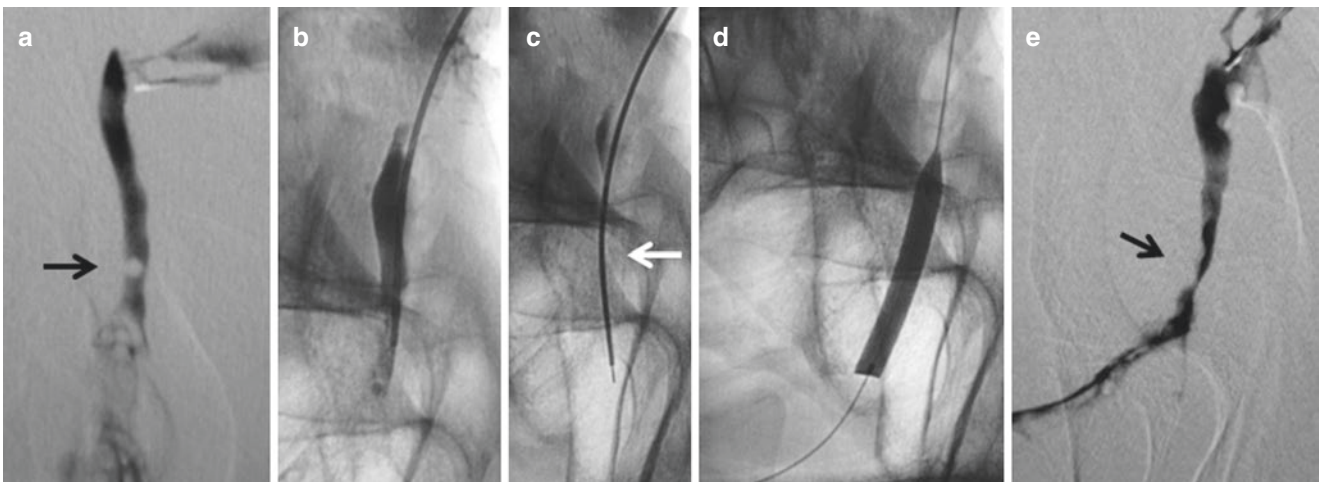


Fig. 34.26 Before and after dacryolith removal with Lachmund dacryoplasty cannula. (**a**) The nasolacrimal duct is obstructed and dilated caused by the dacryolith and the stenosis at the level of Hasner's valve. (**b**, **c**) Removal of the dacryolith with the Lachmund dacryoplasty cannula. (**d**) Dilation of the stenosis. (**e**) After dacryoplasty the diameter of the nasolacrimal duct returned to normal

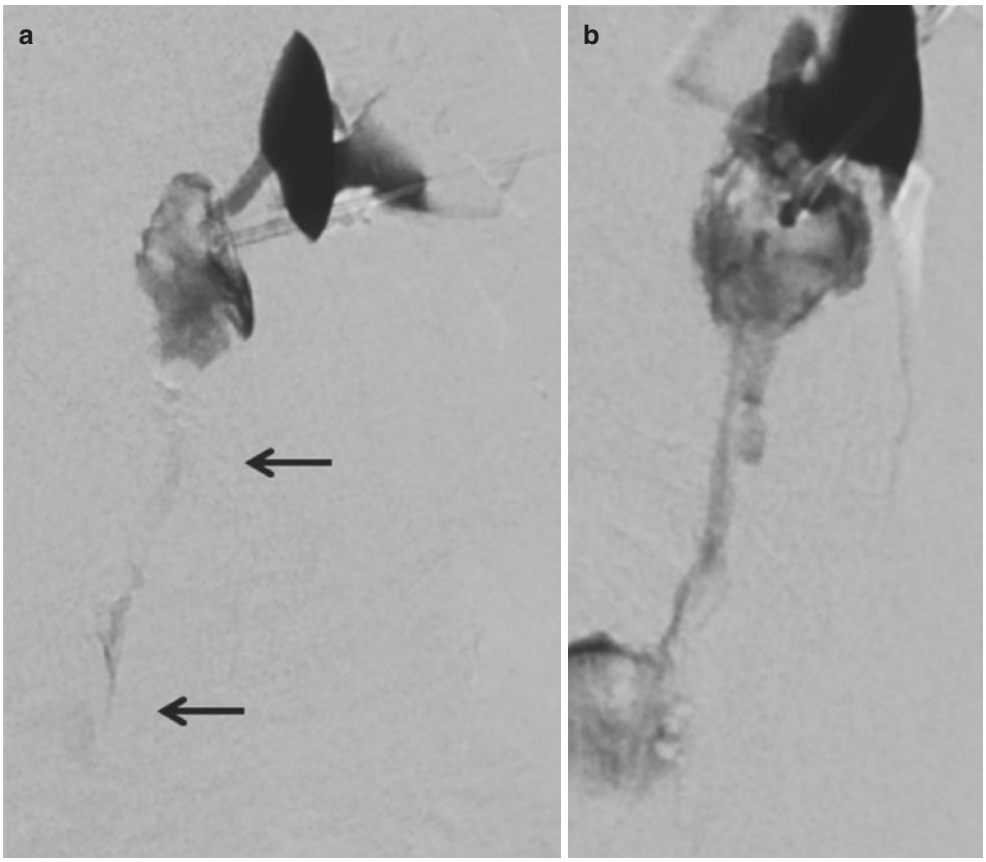


Fig. 34.27 (**a**, **b**) Before and after DCP in post-saccal stenosis with dacryolith. (**a**) DSD of the left eye, lateral view, demonstrating a post-saccal long-distance filling defect caused by a dacryolith and a stenosis at the level of the valve of Hasner. (**b**) After DCP, the dacryolith is not there and the nasolacrim al duct is normal

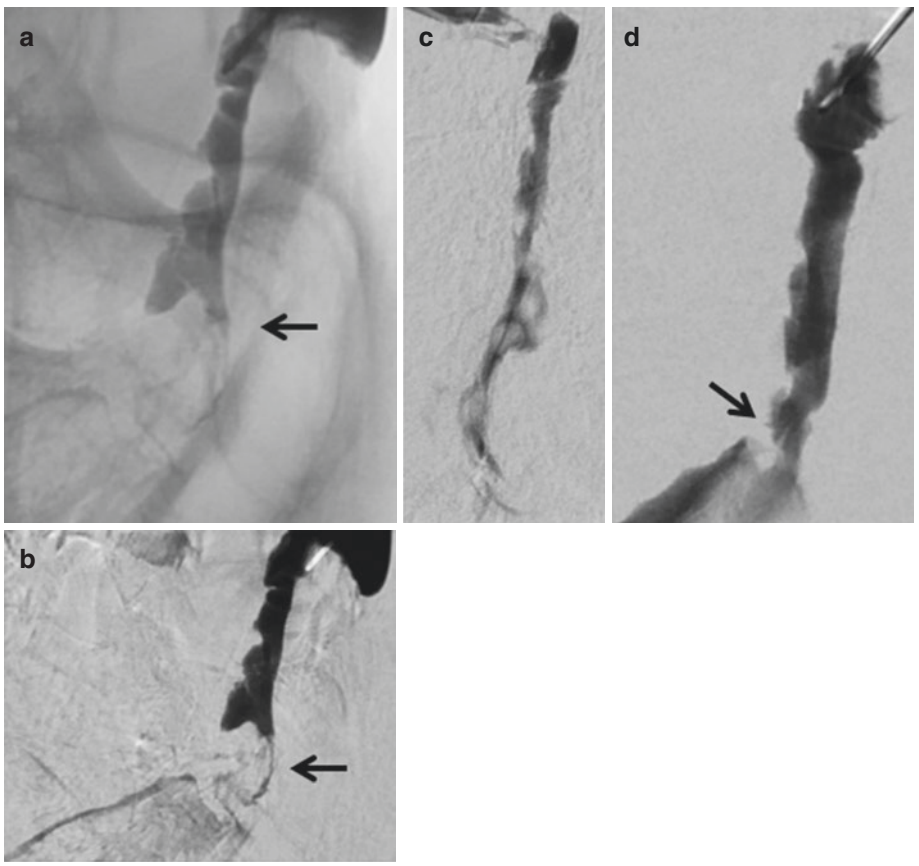


Fig. 34.28 Before and after DCP in post-saccal stenosis with dacryolith. (Panels **a**, **b**) Before DCP. A DSD lateral view of the right eye. Patient with huge dacryolith (8 mm × 7 mm). (Panels **c**, **d**) After DCP, 6 months later, frontal and lateral view. No dacryolith and DSD shows normal lacrimal duct

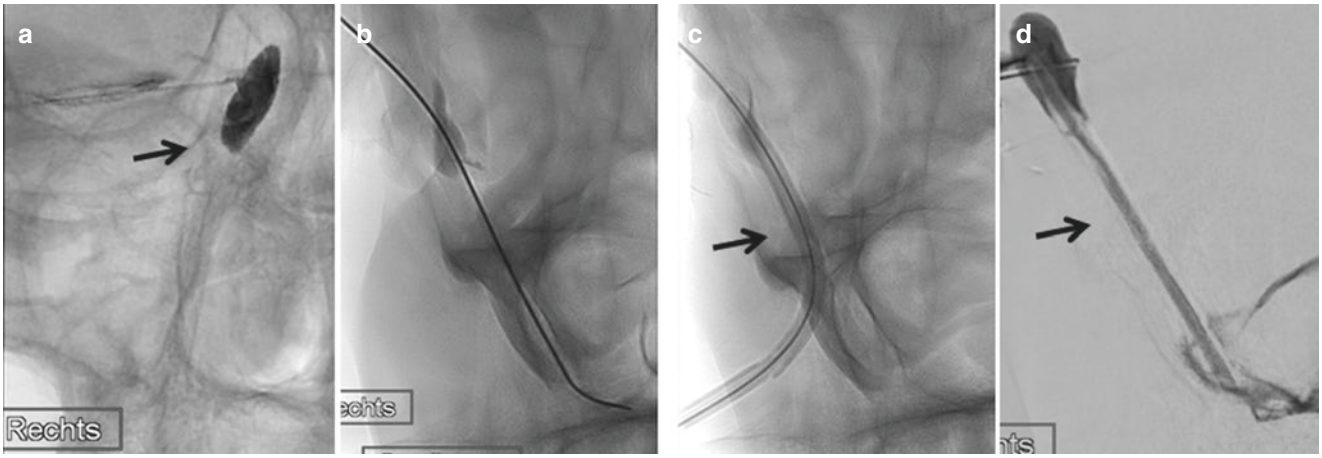


Fig. 34.29 Before and after stent placement in post-saccal occlusion. (**a**) Dacryocystography (right eye, frontal view shows complete obstruction of the left nasolacrimal duct system. (**b**) DSD, lateral view obtained after recanalization of the obstruction, demonstrates the guide wire which is introduced into the nasolacrimal duct system and gently advanced until reaching the inferior meatus of the nasal cavity. (**c**) Stent implantation (lateral view): From distal the stent is retrogradely advanced over the guide wire until the correct position of the stent is achieved. (**d**) Dacryocystography (lateral view) after stent implantation shows a patent stent with contrast medium passage through the stent into the inferior meatus of the nasal cavity

Lacrimal Trauma and Its Management

35

Gangadhara Sundar

Introduction

> Laughter and tears are both responses to frustration and exhaustion. I myself prefer to laugh, since there is less cleaning up to do afterward.—Kurt Vonnegut

Injury of the lacrimal drainage apparatus, usually in the form of canalicular lacerations, is relatively common in periorbital and facial trauma [1, 2]. This is most frequently encountered in otherwise young healthy males, although it may be seen in young children, the women, and the elderly [3, 4]. Less frequently encountered is injury of the nasolacrimal duct, usually in midfacial and naso-orbital-ethmoid (NOE) fractures [5]. The incidence of lacrimal system injuries has been reported to vary from 7% to 20% depending upon the mechanism of the injury and reporting [2]. Failure to recognize and manage lacrimal injuries is one of the common complications of eyelid/midfacial injuries. I shall herewith outline the predisposing factors and evaluation of the patient and discuss details of principles and mechanisms of management including long-term follow-up.

Etiopathogenesis

The lacrimal drainage system lies at the base of a bony "funnel," which redirects projectiles toward the canaliculi [7]. In addition, paucity of surrounding connective tissue renders it vulnerable to avulsion from shearing forces [8]. While most injuries arise from mechanical trauma, from either direct or indirect injuries, including avulsions, other forms of trauma include thermal (industrial or domestic fires), chemical (industrial or domestic vitriolage), drug-induced (chemotherapeutic agents: 5-fluorouracil, paclitaxel, docetaxel, etc.), and radiation trauma (external beam radiation for head and neck tumors), including beta irradiation (in the past, for pterygium surgery) (Table 35.1) [6, 7]. Canalicular lacerations in children may result either from broken spectacle lenses (Fig. 35.1), from blouse hooks (developing nations), or not infrequently from animal bites (dogs) [9–11]. Most young adults are affected either as blunt high-impact injuries (industrial, motor vehicle accident, assaults) when they are usually associated with varying degrees of naso-orbital-ethmoid (NOE) fractures (Fig. 35.2) [5]. In general, the lower canaliculus is more likely to be injured either related to the location or the ability to be avulsed by hooks and similar objects. Fractures of the midface (NOE, Le Fort II and III) also may involve the lacrimal sac fossa and nasolacrimal duct resulting in bony and occasionally soft tissue nasolacrimal duct disruption (Fig. 35.3) [5]. While most patients remain asymptomatic, late obstructions of the canaliculus or the nasolacrimal duct are not uncommon and quite challenging to manage as well [5].

Classification

Lacrimal system trauma may be classified based on anatomical structures involved or the mechanisms of injury. Based on the anatomic structures, it is further classified as bony or soft tissue trauma. Injuries may involve the lacrimal puncta at the eyelid margins; the vertical or more commonly the horizontal component of the canaliculi, usually the lower or the common canaliculus (most frequent); the lacrimal sac; and lastly the bony nasolacrimal canal and nasolacrimal duct (second most frequent). Table 35.1 reflects Wulc and Jordan's classification of lacrimal drainage system trauma [6, 7].

Clinical Features

As stated above, the frequency of involvement of the lacrimal drainage apparatus structures from most frequent to least frequent is as follows: canaliculus (lower, upper, and

G. Sundar, F.R.C.S.Ed.
Head, Orbit and Oculofacial Surgery, National University of Singapore, Singapore, Singapore
e-mail: gsundar1@yahoo.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_35

Table 35.1 Etiology of lacrimal drainage system trauma (Wulc [6], Jordan [7])

1. Mechanical
(a) Penetrating
• Direct: lacerations from sharp objects
• Indirect: lacerations from high-impact blunt objects: punch, hard balls and objects, blunt weapons, etc.
(b) Avulsions
2. Thermal
3. Chemical
(a) Vitriolage, domestic, or industrial accidents
(b) Chemotherapeutic agents: 5FU, paclitaxel, docetaxel, etc.
4. Radiation
(a) External beam radiotherapy, IMRT
(b) Beta irradiation (historical)
5. Iatrogenic: multifactorial
(a) Accidental
• Mechanical (direct (cuts) or indirect (avulsions (aggressive retraction during orbital surgery), false passage, mucosa tear with traumatic probing)
• Thermal (electrocautery, lasers, etc.)
• Chemical (3b)
• Radiation (4a, b)
(b) Intentional, e.g., punctal or canalicular thermal cautery or surgical closure for dry eye management

bicanalicular), nasolacrimal duct, lacrimal sac, and finally lacrimal puncta.

Most patients are diagnosed based on a high degree of suspicion [12–17]. The general principle of eyelid lacerations is that all eyelid lacerations medial to the puncta involve the canaliculus (canaliculi) until proven otherwise (Fig. 35.4). Thus, the onus is upon the trauma physician or ophthalmologist to diagnose and plan the management accordingly. Likewise, in all patients with facio-maxillary trauma, an evaluation of the CT scan for evidence of bony nasolacrimal duct disruption (Figs. 35.5, 35.6, and 35.7) should prompt the ophthalmologist to consider lacrimal irrigation to confirm patency of the drainage system, either immediately before facial fracture repair or after reduction of the NOE fragments but before plating of the involved bones. In the acutely traumatized patient, tearing and fluorescein dye disappearance test are generally unhelpful and unreliable owing to the false-positive results from edema resulting in drainage dysfunction [12–17].

After stabilization of the patient to rule out polytrauma, intracranial injury, cervical spine stabilization, and underlying globe injury, a preliminary examination of the medial upper and lower eyelids under magnification/handheld slit lamp and medial canthal region without infiltrative anesthesia is recommended, partly to confirm the diagnosis and also to help identify distal cut end of the canaliculus.

Gentle probing under topical anesthesia is usually well tolerated (Fig. 35.8). The classic clinical "calamari ring" sign (Fig. 35.9), a white collagenous ring surrounded by bloodstained soft tissue, is obvious once local hemostasis is secured with ice packs and analgesia prior to examination. This helps counsel patients accordingly and plan treatment. Inexperienced ophthalmologists may also diagnose a canalicular laceration upon lacrimal irrigation through the puncta (upper and lower separately) when extravasations of the irrigant fluid are visualized, prompting an exploration in the operating room under either local or general anesthesia.

Nasolacrimal duct injuries may be either bony duct fractures alone with intact soft tissue duct or obvious disruptions of both (Figs. 35.2, 35.3, 35.6, and 35.7) [5, 18–22]. Following a radiological examination of fine-cut CT from the lacrimal sac fossa down to the inferior turbinate, lacrimal irrigation may be attempted on the operating table after nasal decongestion to confirm the same. Direct visualization of fluorescein either under the inferior meatus or site of disruption is usually aided by a rigid nasal endoscope.

A late diagnosis of disruption of the lacrimal system is made on an asymptomatic patient based on the clinical history, delayed fluorescein dye disappearance test, or lacrimal irrigation and probing under topical anesthesia (Fig. 35.8) to confirm the presence of either a soft stop (canalicular obstruction) or hard stop (nasolacrimal duct obstruction). Symptomatic patients often present with a wet, teary eye with or without epiphora (overflow) with the constant need to wipe their tears to clear their vision. A Bowman probe or straight lacrimal cannula usually helps confirm the extent and location of the canalicular obstruction. Regurgitation of either clear fluid or mucus with a hard stop usually helps confirm a nasolacrimal duct obstruction. Occasionally mucocele or acute dacryocystitis may be noted late in the course (Figs. 35.10 and 35.11). Not infrequently an obvious scar involving the eyelid margin medial to the punctum and medial canthal area and lateral displacement of the upper or lower puncta are telltale signs of canalicular obstruction.

Diagnostic Evaluation

Apart from clinical examination either at the bedside or at the slit lamp, the following investigations may be indicated based on the presentation. As mentioned earlier, review of CT scans of the face (fine cuts) for evidence of NOE fracture, disruption of the lacrimal sac fossa, and bony nasolacrimal duct down to the inferior meatus is warranted, emphasizing the need for a CT with three-dimensional reconstruction of the whole face in most orbital fractures [5, 18–22]. The radiological findings of lacrimal crest avulsion, a bone fragment in the lacrimal sac fossa, a bone fragment in the nasolacrimal canal, greater than 50% compression of the canal, or marked nasomaxillary buttress displacement have been significantly associated with the development of epiphora or dacryocystitis [23]. Hence, the presence of any of these find-

ings on CT should alert the facial trauma surgeon to the potential for lacrimal outflow obstruction symptoms.

MRI is contraindicated in the acutely traumatized patient unless magnetizable foreign bodies have been ruled out, for example, gunshot pellets (Fig. 35.12). A CT scan is also useful in patients presenting late with tearing with or without discharge to diagnose the underlying bony deformities including diastasis, nonhealing fractures, and hyperostosis or not infrequently to confirm the location of the metallic plates and screws (Figs. 35.13 and 35.14) which may confound lacrimal bypass surgery. Rarely, a DCG or a CT dacryocystography (CT-DCG) may also be indicated to confirm the site of obstruction and alternative drainage path as well (Fig. 35.15).

Management

Canalicular Lacerations

The driving principle behind managing canalicular lacerations is that wound healing by primary intention (early primary repair) is always better than secondary intention or late repair [12–17]. While in the past, the indication for intervention of a monocanalicular laceration was controversial, it is now well recognized by most orbitofacial surgeons that all canalicular lacerations warrant primary repair, whether they are upper or lower. Reports have found canalicular dominance varies both between individuals and between the eyes. Hence repair of all canaliculi is universally recommended when possible, as a single functional canaliculus may not adequately siphon reflex tears in up to 50% of patients [24, 25].

Canalicular laceration repairs are not true emergencies and may be optimally performed in a controlled environment within 24–48 h, although on rare occasions a successful repair may be done as late as 4–5 days, with the outcome of surgery not seeming to be affected by the delay [26]. Adequate anesthesia, magnification, and illumination are essential. Most patients with bicanalicular injury (Figs. 35.16 and 35.17) or avulsion injuries (Fig. 35.18) require bicanalicular intubation and thus better performed under general anesthesia. Local anesthetic infiltration in the medial canthal area may distort or disrupt surgical anatomy and may interfere with identification and repair [27]. It may be considered only in simple direct canalicular lacerations or when general anesthetic is either contraindicated or unavailable. Magnification may be either with surgical operating loupes or the operating microscope. The author prefers the operating loupes as they are versatile and adaptable to eyelid, lacrimal, orbital, and facial reconstruction with angulated viewing when necessary, especially in the medial canthal area or within the nasal cavity. The ENT or neurosurgical microscope is often more useful than a vertically oriented ophthalmological microscope for the same reason. Illumination may be either in the form of "headlights" or from the operating microscope.

Intubation Systems in Lacrimal Trauma

The intubation systems in lacrimal trauma can be broadly divided into bicanalicular and monocanalicular ones. The advantages and disadvantages of each are summarized in Table 35.2.

Bicanalicular Intubation Systems

The following intubation systems are currently available and used based on availability and surgeons' preference:

- Crawford bicanalicular intubation system with olive tip and Crawford hook (Fig. 35.19).
- Ritleng bicanalicular intubation system with hook (Fig. 35.20).
- Large-diameter STENTube (Figs. 35.21 and 35.22).
- Others: Quickert-Dryden tube, Guibor tube, and Jackson intubation systems.
- Beyer's modified pigtail probe: This has a French eye at the tip (as opposed to the fishhook-ended Worst pigtail probe that is not recommended) (Fig. 35.23).
- Two separate monocanalicular stents: Mini-Monoka or Crawford-Monoka [28].

Table 35.2 Comparison of bicanalicular and monocanalicular stents

	Advantages	Disadvantages
Bicanalicular stent	Familiarity of surgeon Ease of use Ready availability Less expensive Medical canthal approximation Bicanalicular repair possible Prolapsed tube doesn't result in tube/stent loss Intubates lower lacrimal system	Requirement for general anesthesia Potential injury to unaffected canaliculus Removal requires training/experience
Monocanalicular stent	Simpler to use Can be performed under local anesthesia Easy removal Performed even in patients with single punctum/canaliculus	Poor medial canthal approximation Poor anchoring with large, dilated puncta Easily removed and lost when not secure More expensive

Monocanalicular Intubation Systems

- Historical (Veirs rods, modified Venflon catheters, etc.): Generally not recommended
- Monocanalicular stents: Monoka, Mini-Monoka, and Crawford-Monoka (Fig. 35.24)

Steps in the Surgical Management of Lacrimal Canalicular Lacerations

1. Stabilization of the medical status of patients and evaluation for any serious vital organ injury.
2. Optimization and fitness for anesthesia; general anesthesia if possible.
3. Apply ice packs to the medial canthal area to minimize bleeding and edema and for pain relief.
4. Nasal decongestion is preferable.
5. Attempts should be made overall to minimize iatrogenic trauma, dissection, and cautery and to prevent any further disruption of the medial canthal area.
6. Tips to identify cut end of canaliculus: In most cases, direct visualization under magnification, illumination, and gentle retraction of the wound with approximation of the lateral eyelid margin to the medial canthal area will guide the surgeon toward localizing the cut end of the canaliculus (Fig. 35.25). The "calamari ring" sign (Fig. 35.9) is a very reliable clinical sign in most patients, better seen several hours after the initial injury when active bleeding has stopped. As the lacrimal punctum is the narrowest part of the drainage system, the canaliculi are usually large and easily visible to the experienced surgeon unless the primary team has traumatized them by performing cautery or surgery in that region. Once identified, a Bowman probe is gently passed into its lumen to confirm a "hard stop."

   Alternative technique includes the use of an atraumatic pigtail probe (Fig. 35.23) through the other punctum, canaliculus, and proximal common canaliculus [29, 30], especially in some circumstances when the severed deep ends of the laceration are difficult to identify [8]. It is to be remembered that rarely the common canaliculus may not be present, and hence the canaliculi enter the sac independently and thus make this technique unfeasible [16]. Even in experienced hands, the pigtail probe is sometimes difficult to use and hence may cause iatrogenic injury to the lacrimal system. Thus, this technique is indicated in patients where general anesthesia is not possible and intubation of the upper lacrimal system alone is desired. It is not advisable in inexperienced hands and with involvement of the lower lacrimal system.

   Injecting viscoelastic "milk," air, fluorescein, methylene blue, etc. has also been reported but often not used owing to the variability of results and dense staining of the entire wound with the latter. The author believes that the cut ends of the canaliculus can almost always be identified, the only exception being severe blast injuries of involving the medial canthal region and face.
7. Once the cut end is identified, probing is performed gently to ascertain the patency of the tract (Fig. 35.26) followed by cannulation of the upper and lower canalicular system delivered endonasally from the inferior meatus either by tactile retrieval or preferably by direct visualization (Figs. 35.27 and 35.28). The medial canthal tendon is gently approximated with 4-0 Vicryl sutures to ensure better approximation of the cut ends of the canaliculus. One of the various techniques of pericanalicular suturing may be employed [31, 32]. The author prefers a double horizontal pericanalicular mattress suture (Fig. 35.29), a modification of the "single-stitch" technique with delayed absorbable sutures (PDS) (6-0 for proximal and 5-0 for distal) followed by tightening of the medial canthus before repairing the eyelid margin using the standard technique [17]. Better approximation is facilitated by gentle traction on the bicanalicular stents while tying the pericanalicular suture knots, a distinct advantage over monocanalicular and annular ring intubation.
8. *Securing the silicone stents*: Most bicanalicular stents are secured, under gentle traction, below the inferior meatus. A small, single, secure knot is essential if removal of the tube is to be performed by rotation of the knot through the canaliculi and puncta in the office under topical anesthesia. This is possible even in young children in an outpatient office setting without sedation or anesthesia. When multiple knots are placed, the tube may be removed only through the nasal cavity either by nasal speculum examination or nasal endoscopy, thus precluding the procedure in the office in children and uncooperative adults.

   When annular ring intubation is performed, the Prolene or nylon suture is tied within the lumen of the silicone stent and rotated into the lacrimal sac (Figs. 35.30 and 35.31).

   When Mini-Monoka or Crawford-Monoka stents are used, the nubbin at the proximal end secures its position at the vertical part of the canaliculus and the tip lying flat against the eyelid margin.
9. *Duration of stenting*: In general, while the wound healing occurs by primary intention, pericanalicular wound continues to mature, and wound contraction continues for a few weeks. For this reason, the author generally leaves both monocanalicular and bicanalicular stents for up to 12 weeks, unless the patient is very symptomatic or there is a premature tube prolapse.

10. *Postoperative management*: Most patients will require a tapering antibiotic-steroid eye drop in the initial 3–4 weeks postoperatively. Intraocular pressure may need monitoring for steroid response. Nasal decongestion may be prescribed for the first few weeks. Topical antibiotic creams are indicated for eyelid lacerations and continued for a week after suture removal. Systemic antibiotics are indicated based on the nature of the injury, e.g., animal bite, human bite, surgical knife, or industrial equipment [33].
11. *Silicone stent removal*: The author's preferred technique when no knots are placed is to simply pull the stent through the canaliculus not involved by the laceration (Fig. 35.32). When multiple knots are placed, the distal end is first visualized after nasal decongestion below the inferior meatus, the visualized loop cut at the medial canthal area, and the nasal ends of the tube removed under direct visualization (Fig. 35.33). Annular ring extubation is performed by rotating the suture knot into the medial canthal area and then cut and the silicone-suture segment removed under topical anesthesia. Monoka stents are usually removed under direct visualization and topical anesthesia by removing it just like a punctal plug.
12. A fluorescein dye disappearance test with confirmation of fluorescein on nasal endoscopy and if necessary gentle probing and irrigation through the repaired canaliculus may be performed to confirm functional and anatomical patency (Fig. 35.34).
13. *Follow-up*: The author reviews the patient at 6 weeks, 3 months, 6 months, and then annually for 2–3 years when possible.
14. *Management of epiphora post-intubation*: Epiphora post-intubation may be related to the following reasons:
    (a) Edema in the perioperative period, which usually resolves within a few days.
    (b) Tearing secondary to the occlusion of the luminal cavity especially with large-diameter stents that usually resolve after removal of the tube.
    (c) Persistent tearing and discharge in patients with a tight canaliculus (hypertrophic scarring, wound contraction, or healing by secondary intention). These may not resolve even upon removal of the tube and may warrant secondary procedures including balloon canaliculoplasty, canaliculo-DCR, or even conjunctivo-DCR when indicated.
15. *Management of tube-related complications*: (a) Prolapsed bicanalicular stents may be successfully reposited either by gentle repositioning into the lacrimal sac by reinsertion or through the nasal cavity and securing the knot. On rare occasions, if either of the above is not possible, the stent may have to be removed (if more than several weeks post-injury) or restented under local or general anesthesia (if early on) as indicated. Cheese wiring of puncta, canaliculi, and pyogenic granuloma (Fig. 35.35) may occur either because of a stiff, poor medical grade silicone, or tightly secured stents. In such cases early removal of the stents may be indicated to prevent migration of the stent in the lacrimal sac and prevent a dacryocystitis.

Nasolacrimal Duct Injuries

Bony fractures of the nasolacrimal duct are seen in 7–15% of all facial traumas, and a small proportion of that result in soft tissue duct injury (Figs. 16.4–16.66). Most authorities initially prefer a wait-and-watch approach and later consider a definitive surgery like a dacryocystorhinostomy at a later stage [5, 17–21]. While infrequently, performing a DCR or C-DCR in these patients is fraught with complications including high rates of failure, postoperative morbidity of chronic dacryocystitis, hyperostosis of the lacrimal sac fossa/bony nasolacrimal duct, and interference with surgery by the orbital/midfacial reconstruction plates/screws possibly warranting removal of the hardware prior to the DCR itself. Such situations may propel the surgeon to consider primary repair or intubation of the nasolacrimal duct. In the author's extensive practice of orbital and midfacial trauma, all patients have evaluation of the bony and soft tissue ducts. When clear patency is established and minimal disruption or mobilization of the lacrimal fragments is expected, conservative management is a practice.

In gross disruption of the lacrimal sac fossa/lacrimal duct or when major reduction and manipulations are expected, prophylactic bicanalicular intubation with the Crawford tubes is performed atraumatically. The tubes are left loose until all midfacial reconstruction is performed and finally tied below the inferior meatus by the standard technique. The tubes are left in place for 3–6 months before removal. Follow-up is as per canalicular lacerations as mentioned above. Ali et al. [5] studied the nasolacrimal duct obstructions exclusively in patients with NOE fractures. They found that majority of the fractures were NOE type II (64.2%) and most were repaired by open reduction and internal fixation prior to lacrimal surgery. The mean duration from trauma to presentation was 19.5 months with all patients having epiphora and half of them presenting additionally with a swelling below the medial canthus. All patients underwent a dacryocystorhinostomy (DCR) with mitomycin C and intubation with a success rate of 92.8% at 6 months' follow-up after tube removal. In the absence of canalicular injury, DCR appears to be an effective modality of management in such cases, and delayed DCR does not appear to alter the outcomes.

In summary, injuries either of the proximal or distal lacrimal drainage system are common yet frequently undiag-

nosed or mismanaged. A complete evaluation, preoperative counselling, and sound surgical technique with stenting with the appropriate silicone tube intubation with repair, with long-term follow-up, go a long way in the management and rehabilitation of these patients.

Updates (2015–2016)

Canalicular Trauma

Identifying the distal end of the canaliculus in lacerations especially deep in the medial canthus or complex lacerations has always been a challenge. Previously recommended and widely practiced techniques to identify the cut end of canaliculus in order of decreasing practice include direct examination and observation for the distal end under high magnification (operating microscope or surgical loupes) with minimal manipulation, pigtail probe through the opposite punctum/canaliculus, air insufflations under a bed of normal saline, gentle probing of suspected canaliculi, injecting viscoelastic through the proximal cut end, and injecting milk/dye through the opposite punctum/canaliculus. Orge and Dar [34] have published on a modified technique [1] to help identify and repair a canalicular laceration in a retrospective series of pediatric canalicular lacerations (n = 17) over a 7-year period. They advocate the use of direct delivery of viscoelastic into the wound area which they claim helps spread tissues out, minimize ooze from smaller blood vessels, magnify tissues within the region, and lubricate the drainage pathway for subsequent intubation. The authors however fail to mention the specific viscoelastic used and had not performed a comparative study to study its benefits with controls.

Tavakoli et al. [35] have published their experience on the use of Masterka^{R}, a relatively new "pushed" lacrimal intubation system, in monocanalicular lacerations. Fayet et al. [36] had previously published in 2014 their experience with the "pushed" monocanalicular stent in congenital nasolacrimal duct obstruction which was also the manufacturer's recommendation. In their series Tavakoli et al. [35] used the Masterka^{R} in 48 patients with monocanalicular lacerations, with all patients undergoing surgery under general anesthesia with careful identification of the cut ends, pushed intubation, pericanalicular sutures with 7-0 Vicryl and fixing the stent at the lacrimal punctum similar to punctal plugs. At a follow-up of 6 months, they reported an anatomical success of 87% and a functional success of 100%. Three patients had an extrusion of the tube, and three others had canalicular stenosis despite the presence of the tube. The main difference and possible advantage of this tube is the active "pushing" that is possible with this tube as opposed to passive placement of other conventional monocanalicular (mini-Monoka) stents which will pose difficulties, if the distal end of the stent is not well aligned with the cut end of the canaliculus or in presence of severe stenosis.

Erickson et al. [8] had published a single case report demonstrating the use of a newly designed irrigating clockwise and counterclockwise pigtail probe cannula in an 89-year-old patient with deep medial canthal eyelid laceration with canalicular disruption. Their proposed advantages with this probe include a novel modification of a previously available surgical tool, relative ease in identifying distal cut end if and when a common canaliculus is patent, and a lumen for irrigation in difficult intraoperative localization of the cut end, followed by annular or doughnut ring intubation. They do however caution that in patients with individual canaliculi without common canaliculus or surgeons unfamiliar with pigtail probes, this procedure may not be possible, and other forms of canalicular repair may have to be employed.

Liu et al. [37] had published on a novel technique of monocanalicular and bicanalicular intubation [5] using an improvised soft probe technique. They reduced the flexibility of the catheters by introducing a stainless steel acupuncture needle through it. Once both the catheters are passed into the canaliculus and nasolacrimal ducts, they are tied in a circular fashion in the nose and pulled up in a way that the circular portion fits into the canaliculus like any bicanalicular intubation. This is essentially a type of pushed intubation. They did not report any iatrogenic trauma.

The Gaskins [38] had published a single case report of an unusual complication following an attempted Crawford intubation technique in a patient with a complex medial eyelid laceration by a plastic surgery team. Performed under general anesthesia, while attempted intubation of the lower canaliculus at the medial canthal tendon was performed, without endoscopic guidance, the long metal probe was "lost" and detached from the silicone tube. Intraoperative imaging revealed the probe to be lodged within the middle cranial fossa via the superior orbital fissure, adjacent to the vital structures. Subsequently this had to be cautiously removed via transorbital route under neurosurgical monitoring. This publication highlights several important points. The Crawford tube should only be used and cautiously passed after proper identification of the medial cut end of the canaliculus and also only when a "distinct hard stop" of the lacrimal sac fossa is felt. In patients who have a comminuted fracture, with poor bony support and with blind, careless force against the probe, it is likely to take a path of least resistance, through the orbital soft tissues and possibly into the intracranial cavity potentially causing significant neurological damage and morbidity.

Two landmark and informative papers by Murchison and Bilyk deserve special attention and reading [4, 27]. In their first publication on all canalicular lacerations managed over a 10-year period involving 137 canaliculi, they highlighted

that over 70% of canalicular lacerations were associated with other injuries including ocular injuries, facial lacerations, and fractures. They had addressed several important aspects of canalicular lacerations including indications for canalicular laceration repair, techniques, monocanalicular versus bicanalicular intubation, specific factors determining outcomes including surgeon experience, operating environment, type of anesthesia, and potential medicolegal implications. Based on their study and previous publications, they suggested that ideally all canalicular lacerations should be repaired. Although the vast majority of cases in their series were monocanalicular intubations, they proposed a few disadvantages of these monocanalicular stents including absence of medial canthal tension with avulsion of the medial canthal tendon and potential kinking of canaliculus especially in medial canalicular lacerations. Factors determining higher success rates include a surgeon with experience and seniority, general anesthesia, and a formal operating theater environment compared to the minor procedure room and possibly bicanalicular intubation, especially in medial canalicular lacerations.

In their second related publication on their 10-year review of 38 pediatric canalicular lacerations, this subgroup comprised 27.7% of all (137) lacerations. With a mean age of 10.8 years, the majority were males with the largest group from dog bites, followed by other accidents (fingers or toys against the eyelid), sports injuries, falls, and finally altercations. Their study highlighted a few interesting points. Once again, patients with the intubation and repair performed in the operating room had a statistically significant higher success rate compared to procedure performed in the minor procedure room. Also, among the various intubation systems, the functional success was higher among the Crawford (bicanalicular intubation system) group (100%) compared to the mini-Monoka (monocanalicular intubation system) group (93.5%). Interestingly, 12 patients or their parents were unhappy with the postoperative appearance (scar) with half of them bothered by the epiphora as well.

Chowdhury et al. [26] shared their Moorfields' experience and followed up results in 65 canalicular lacerations (61 patients) over a 10-year period. Interestingly, the main predisposing factors in their study were injuries from punches, falls, kicks, and from broken glass. All patients had undergone monocanalicular intubations with the mini-Monoka stent. They were also the first to classify the location of canalicular lacerations to the lateral segment (9%), central segment (43%), and the medial segment (48%). Significantly, in their study which included only monocanalicular stents, 22% of the stents were lost (15% presumed from failed follow up), and 7% reported within the first month after surgery. Despite this, they reported a functional success rate of 92% with the highest risk factor for failure being injuries from broken glass.

Ejstrup et al. [39], in a retrospective review of 11 patients who had bicanalicular lacerations repaired by six different techniques over a 10-year period followed by telephone surveys/questionnaires, failed to demonstrate the distinct benefit of any one particular technique. These techniques included two monocanalicular stents (two patients with one persistent symptomatic patient); one monocanalicular stent with inability to identify, cannulate, and intubate the other (persistent symptoms); two monostents into the nose, both of whom remained asymptomatic; and two annular stents both of whom were either lost to follow-up or deceased. Seven patients had bicanalicular intubation, of whom only one was asymptomatic, with the others either having been lost to follow-up or having persistent epiphora. One patient of the bicanalicular group subsequently required a DCR, and another had revision DCR after a failed primary. They do however claim the benefit of monocanalicular intubations including the ease, need for less experience, and possible reduction of damage to the lacrimal puncta compared to bicanalicular stents. Their results reflect the challenge of achieving a high anatomical and functional success rates highlighting the role of experience, surgical skill, patience in identifying the cut ends, and meticulous technique to achieve the best possible outcome.

Nasolacrimal Duct Injuries

Imre et al. [40] shared their retrospective review of 12 patients who underwent an endoscopic endonasal medial maxillectomy (EMM) for sinonasal tumors and had a transection of the nasolacrimal duct. They, despite not adopting any specific measures to preserve patency of the lacrimal sac drainage system, showed that none of their patients complained of epiphora postoperatively. In addition subsequent Fluorescein dye disappearance test showed no stasis in any of their patients. They suggested that no special measures or interventions are necessary to preserve patency of the lacrimal drainage system. However, neither did they elucidate on the term "simple transaction of the nasolacrimal duct" nor were lacrimal systems in their patients completely evaluated. It is also possible that patients with gross systemic morbidity as in this series would not prioritize epiphora as a major symptom. Nonetheless the author and editor of this text believe in the rehabilitation of such patients at the time of surgery if NLD transaction can be clearly demonstrated.

Uzun et al. [41] from Turkey have published their experience on 40 eyes of 35 patients with post-traumatic nasolacrimal duct obstruction. They highlighted common post-traumatic and iatrogenic etiologies of lacrimal instruction including midfacial fractures; surgeries as in the orbital, lacrimal, paranasal sinus, and nasal; and craniofacial surgeries. Modes of surgical rehabilitation included conventional

external DCR, conjunctivo-DCR, endonasal DCR, and laser-assisted DCR. While they quote an overall functional and anatomical success rate of 92.5%, no specific breakdown is presented based on the outcomes of each technique.

Image-guided lacrimal surgery was initially described by Day et al. [42] in 2008 in a patient with complex endonasal anatomy from cocaine abuse. Ali and Naik [43] have published regarding their preliminary experience with image-guided dacryolocalization (IGDL) in three cases of complex traumatic nasolacrimal duct obstruction [15] and in another series [44] demonstrated the use of CT-DCG-guided stereotactic surgeries. These techniques are needed only in complex trauma situations and highlight the value of intraoperative navigation in identifying pathological anatomy thereby avoiding damage to the vital structures including the orbit and the skull base.

Acknowledgment Dr. Stephanie Young for proofreading, updating, and suggesting changes.

References

1. Herzum H, Holle P, Hintschich C. Eyelid injuries: epidemiological aspects. Ophthalmologe. 2001;98:1079–82.
2. Almousa R, Amrith S, Mani AH, et al. Radiological signs of periorbital trauma – the Singapore experience. Orbit. 2010;29:307–12.
3. Kennedy RH, May J, Daily J, et al. Canalicular laceration: an 11-year epidemiologic and clinical study. Ophthal Plast Reconstr Surg. 1990;6:46–53.
4. Murchison AP, Bilyk JR. Pediatric canalicular lacerations: epidemiology and variables affecting repair success. J Pediatr Ophthalmol Strabismus. 2014;51:242–8.
5. Ali MJ, Gupta H, Honavar SG, et al. Acquired nasolacrimal duct obstructions secondary to naso-orbito-ethmoid fractures: patterns and outcomes. Ophthal Plast Reconstr Surg. 2012;28:242–5.
6. Wulc AE, Arterberry JF. The pathogenesis of canalicular laceration. Ophthalmology. 1991;98:1243–9.
7. Jordan DR, Ziai S, Gilberg SM, et al. Pathogenesis of canalicular lacerations. Ophthal Plast Reconstr Surg. 2008;24:394–8.
8. Erickson BP, Ko AC, Lee WW. Novel pigtail canula for a canalicular-involving eyelid laceration. Ophthal Plast Reconstr Surg. 2016;32:e45–7.
9. Naik MN, Kelapure A, Rath S, et al. Management of canalicular lacerations. Epidemiological aspects and experience with mini-Monoka canalicular stents. Am J Ophthalmol. 2008;145:375–80.
10. Savar A, Kirszrot J, Rubin PA. Canalicular involvement in dog bite related eyelid lacerations. Ophthal Plast Reconstr Surg. 2008;24:296–8.
11. Sadiq MA, Corkin F, Mantagos IS. Eyelid lacerations due to dog bite in children. J Pediatr Ophthalmol Strabismus. 2015;9:1–4.
12. Hawes M, Dotzbach R. Trauma of the lacrimal drainage system. In: Linberg J, editor. Lacrimal surgery. New York, NY: Churchill Livingstone; 1988. p. 241–62.
13. Canavan YM, Archer DB. Long term review of injuries to the lacrimal drainage apparatus. Trans Ophthalmol Soc U K. 1979;99:201–4.
14. Reifler DM. Management of canalicular lacerations. Surv Ophthalmol. 1991;36:113–32.
15. Ho T, Lee V. National survey on management of canalicular injury in the United Kingdom. Clin Experiment Ophthalmol. 2006;34:39–43.
16. Duke-Elder S. The anatomy of the visual system. In: Duke-Elder S, editor. System of ophthalmology. St. Louis, MO: Mosby; 1971. p. 570.
17. Kersten RC, Kulwin DR. 'One-stitch' canalicular repair. A simplified approach for repair of canalicular laceration. Ophthalmology. 1996;103:785–9.
18. Dingman RD, Grabb WC, Oneal RM. Management of injuries of the naso-orbital complex. Arch Surg. 1969;98:566–71.
19. Mathog RH, Baner W. Post-traumatic pseudohypertelorism (telecanthus). Arch Otolaryngol. 1979;105:81–5.
20. Merville LC, Real JP. Fronto-orbito nasal dislocations: initial total reconstruction. Scand J Plast Reconstr Surg. 1981;15:287–97.
21. Harris GH, Fuerste FH. Lacrimal intubation in the primary repair of midfacial fractures. Ophthalmology. 1987;94:242–7.
22. Gruss JS. Naso-ethmoid-orbital fractures: classification and role of primary bone grafting. Plast Reconstr Surg. 1985;75:303–17.
23. Garg RK, Hartman MJ, Lucarelli MJ, et al. Nasolacrimal system fractures: a description of radiologic findings and associated outcomes. Ann Plast Surg. 2015;75:407–13.
24. Kalin-Hajdu E, Cadet N, Boulos PR. Controversies of the lacrimal system. Surv Ophthalmol. 2016;61:309–13.
25. Reed S, Lissner G. Clinical study on the effectiveness of tear drainage with a single canalicular system under environmental stress. Ophthal Plast Reconstr Surg. 1993;9:27–31.
26. Chowdhury HR, Rose GE, Ezra DG. Long-term outcomes of monocanalicular repair of canalicular lacerations. Ophthalmology. 2014;121:1665–6.
27. Murchison AP, Bilyk JR. Canalicular laceration repair: an analysis of variables affecting success. Ophthal Plast Reconstr Surg. 2014;30:410–4.
28. Naik MN, Gupta R, Honavar SG. Bicanalicular laceration managed with two mini-monoka monocanalicular stents. Orbit. 2008;27:135–7.
29. Jordan DR, Nerad JA, Tse DT. The pigtail probe revisited. Ophthalmology. 1990;97:512–9.
30. Jordan DR, Gilberg S, Mawn LA. The round tipped, eyed pigtail probe for canalicular intubation. A review of 228 patients. Ophthal Plast Reconstr Surg. 2008;24:176–80.
31. Fountain TR. Management of canalicular trauma. In: Levine MR, editor. Manual of oculoplastic Surgery. 4th ed. Thorofare, NJ: SLACK Incorporated; 2010. p. 33–8.
32. Tao H, Wang P, Han C, et al. One-stitch anastomosis through the skin with bicanalicular intubation: a modified approach for repair of bicanalicular laceration. Int J Ophthalmol. 2013;6:656–8.
33. Chhabra S, Chhabra N, Gaba S. Maxillofacial injuries due to animal bites. J Maxillofac Oral Surg. 2015;14:142–53.
34. Orge FH, Dar SA. Canalicular laceration repair using a viscoelastic injection to locate and dilated the proximal torn edge. J AAPOS. 2015;19:217–9.
35. Tavakoli M, Karimi S, Behdad B, et al. Traumatic canalicular laceration repair with a new monocanalicular silicone tube. Ophthal Plast Reconstr Surg. 2017;33:27–30.
36. Fayet B, Katowitz WR, Racy E, et al. Pushed monocanalicular intubation: an alternative stenting system for the management of congenital nasolacrimal duct obstructions. J AAPOS. 2012;165:468–72.
37. Liu Z, Sha X, Liang X, et al. Use of silicone tubes to repair canalicular lacerations via a novel method. Eye Sci. 2013;28:195–200.
38. Fan Gaskin J, Gaskin BJ. An unusual complication of Crawford tube insertion. Ophthal Plast Reconstr Surg. 2015;31:e11–3.
39. Ejstrup R, Weincke AK, Toft PB. Outcome after repair of concurrent upper and lower canalicular lacerations. Orbit. 2014;33:169–72.

40. Imre A, Imre SS, Pinar E, et al. Transection of nasolacrimal duct in endoscopic medial maxillectomy: implication on epiphora. J Craniofac Surg. 2015;26:e616–9.
41. Uzun F, Karaca EE, Konuk O. Surgical management of traumatic nasolacrimal duct obstruction. Eur J Ophthalmol. 2016;26:517–9.
42. Day S, Hwang TN, Pletcher SD, et al. Interactive image-guided dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2008;28:338–40.
43. Ali MJ, Naik MN. Image guided dacryolocalisation (IGDL) in traumatic secondary acquired lacrimal drainage obstructions (SALDO). Ophthal Plast Reconstr Surg. 2015;31:406–9.
44. Ali MJ, Singh S, Naik MN, et al. Interactive navigation-guided ophthalmic plastic surgery: the utility of 3D CT-DCG guided dacryolocalization in secondary acquired lacrimal duct obstructions. Clin Ophthalmol. 2016;11:127–33.

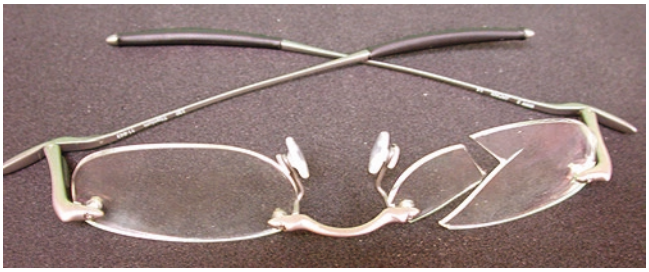


Fig. 35.1 Broken glasses in lacrimal trauma

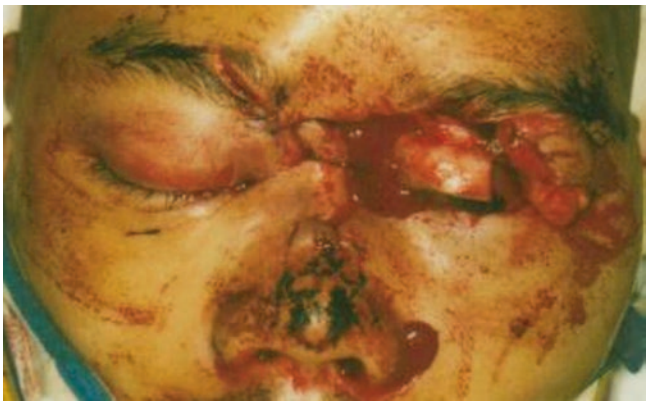


Fig. 35.2 Eyelid and canthal lacerations with underlying NOE fracture

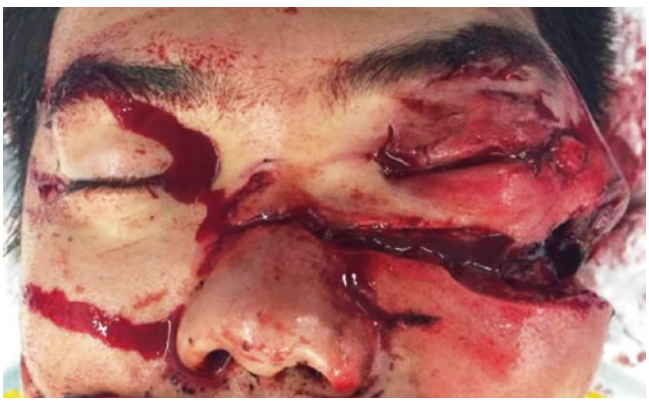


Fig. 35.3 A midface soft tissue and bony trauma

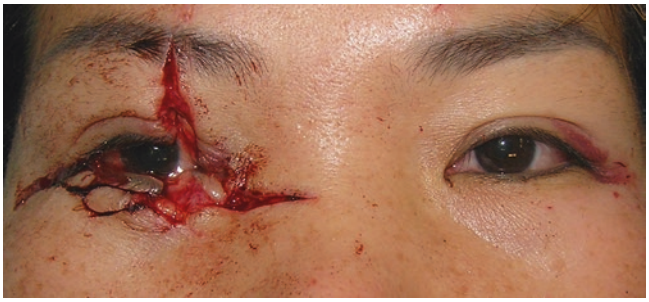


Fig. 35.4 Upper and lower eyelid with medical canthal lacerations

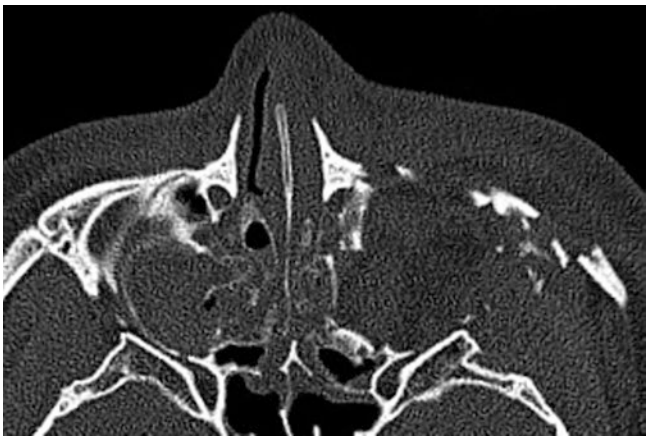


Fig. 35.5 CT scan, axial cut, bony window, showing a left bony NLD fracture

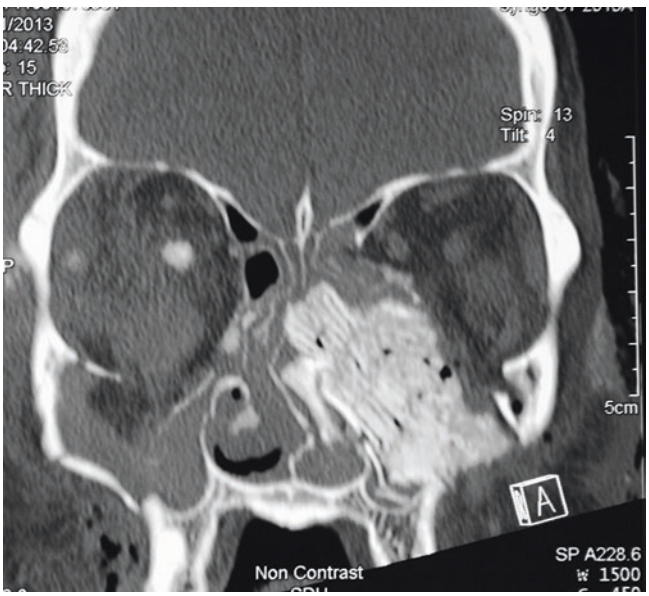


Fig. 35.6 CT scan, coronal cut showing bony and soft tissue NLD disruption following a blast injury

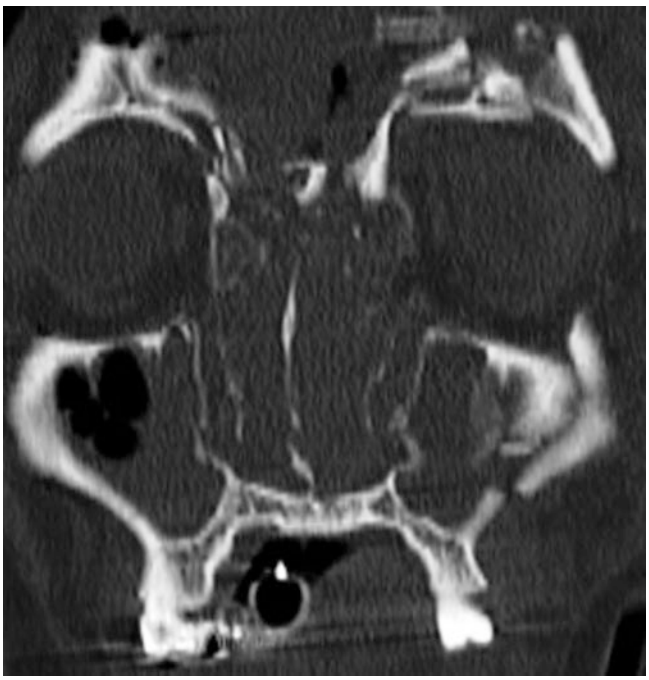


Fig. 35.7 CT scan, coronal cut, bony window, showing bilateral bony NLD fracture

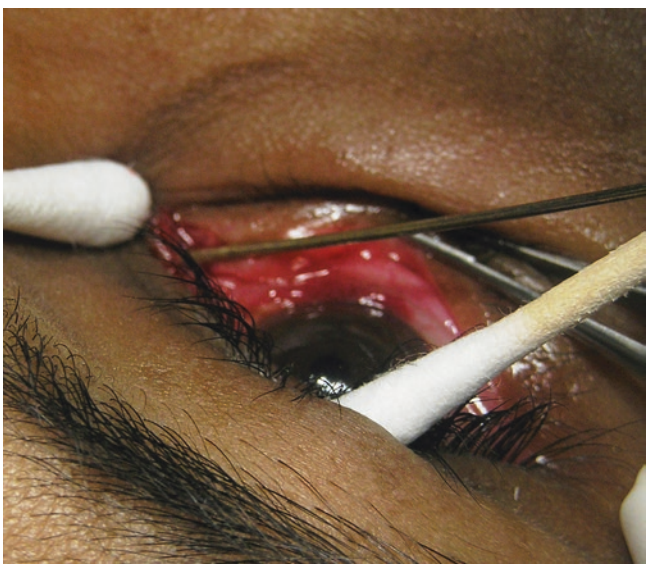


Fig. 35.8 Probing the distal cut end

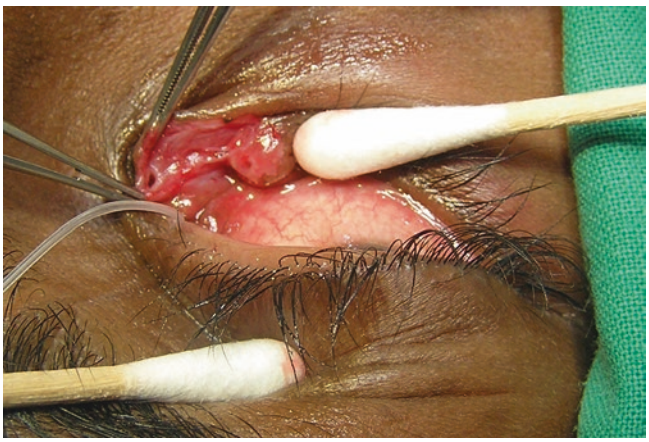


Fig. 35.9 Calamari sign

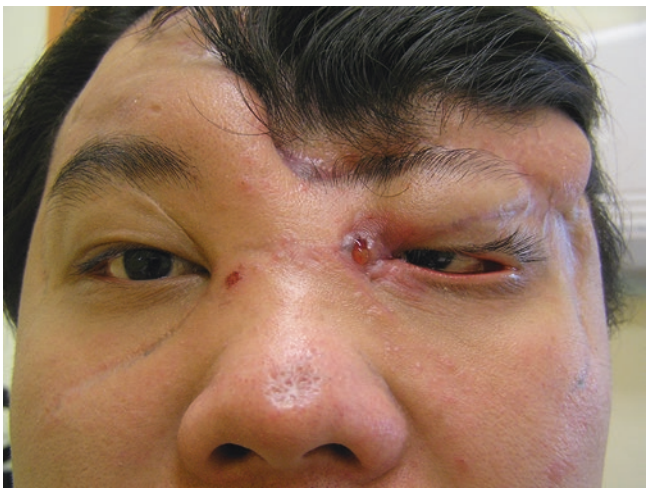


Fig. 35.10 NOE fracture with acute dacryocystitis and spontaneous lacrimal fistula

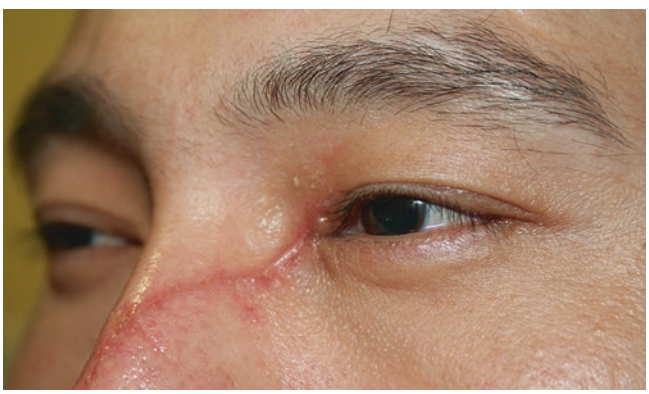


Fig. 35.11 Acute dacryocystitis following NOE fracture

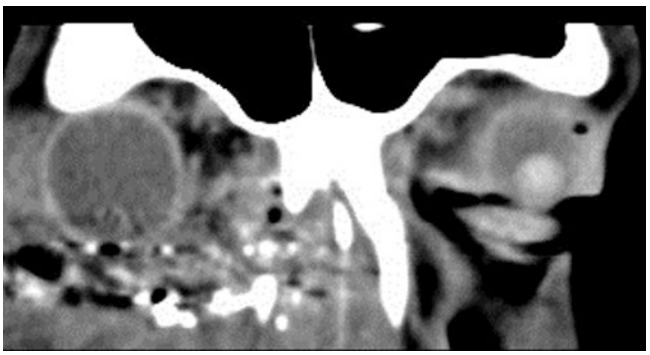


Fig. 35.12 CT scan, coronal cut showing numerous gun pellets and disruption of NLD

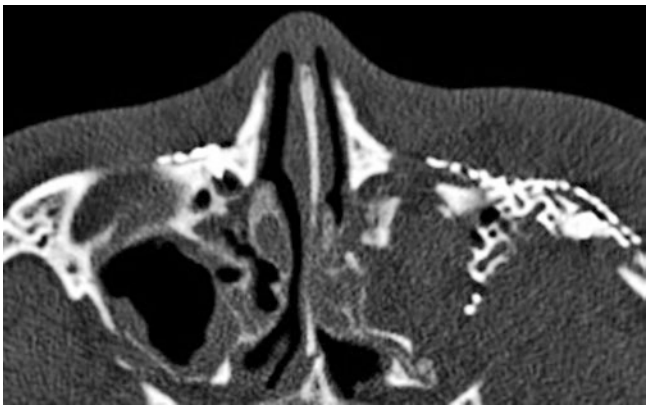


Fig. 35.13 CT scan, axial cut, bony window, showing titanium screws near NLD

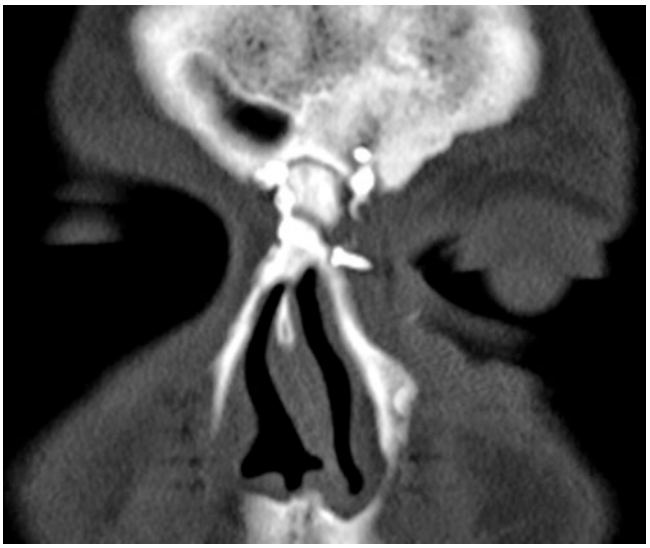


Fig. 35.14 CT scan, coronal cut showing a titanium screw at the medial canthus

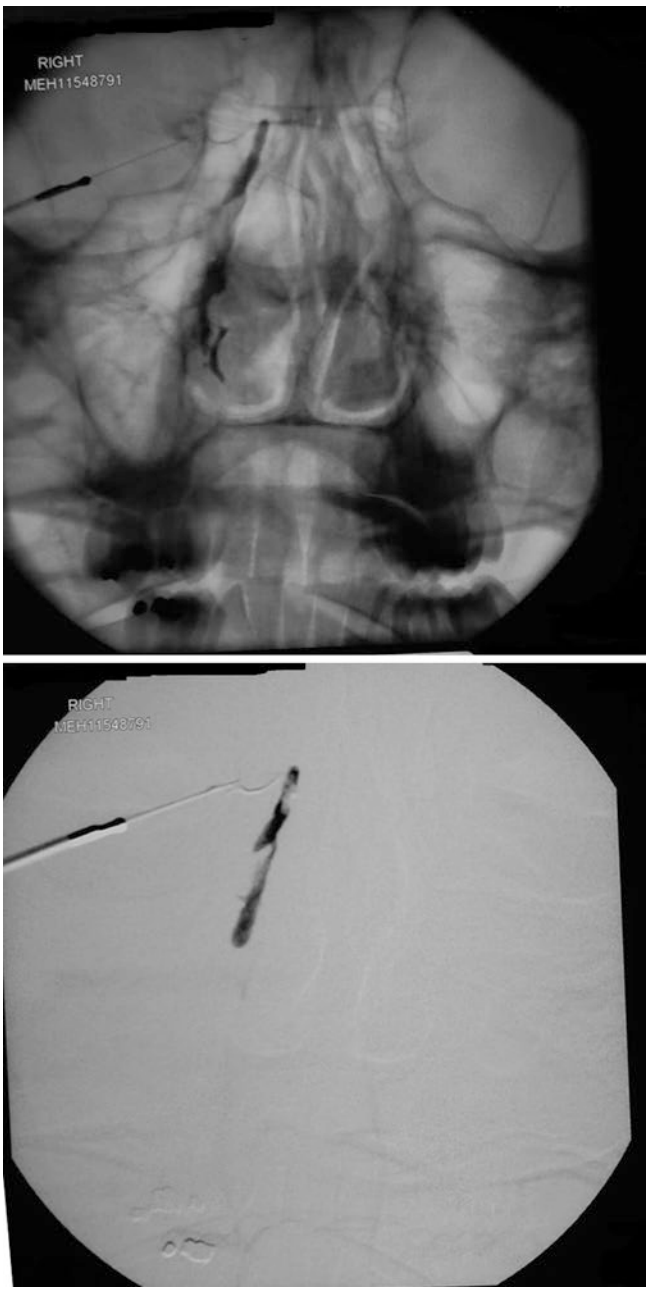


Fig. 35.15 DCG showing a right distal NLD obstruction

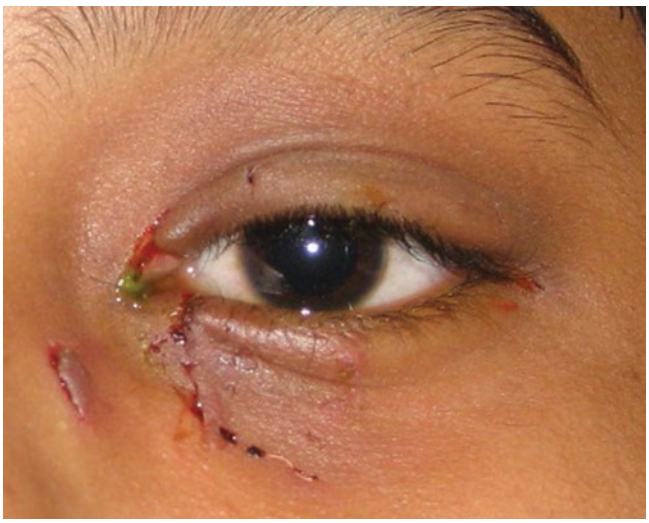


Fig. 35.16 Bicanalicular laceration

Fig. 35.18 Avulsion injury. It is important to rule out underlying fractures

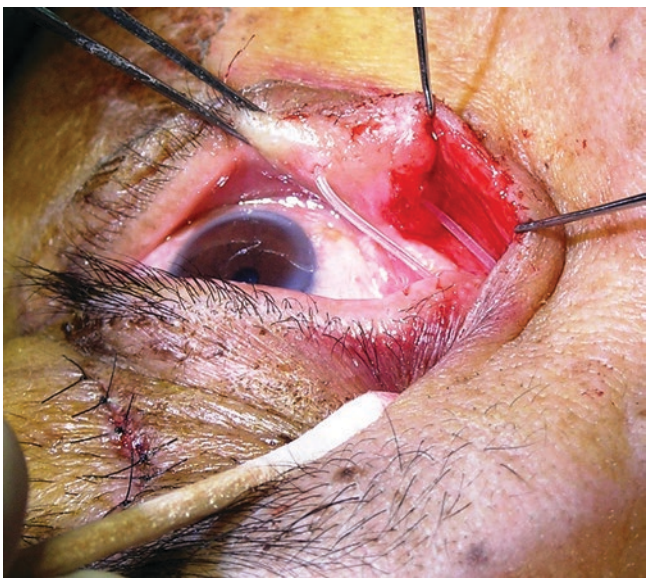


Fig. 35.17 Upper and lower canalicular injury being repaired

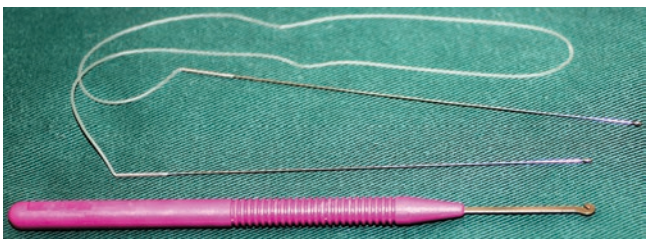


Fig. 35.19 Crawford stents with retrieval device

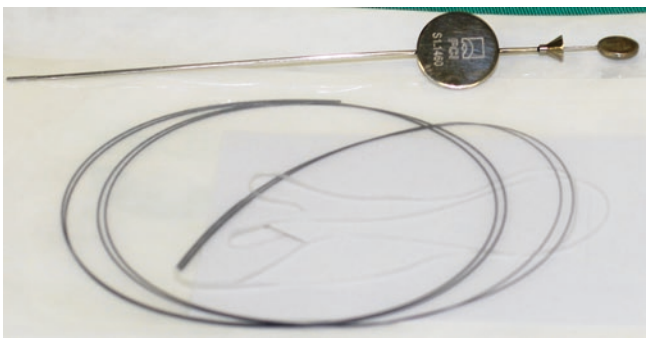


Fig. 35.20 Ritleng intubation

Fig. 35.21 Large-diameter stent tubes

Fig. 35.22 Extubated large-diameter stent tube

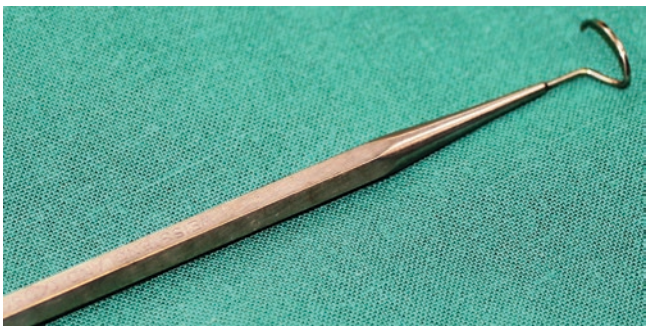


Fig. 35.23 Pig tail probe

Fig. 35.24 Mini-Monoka stent

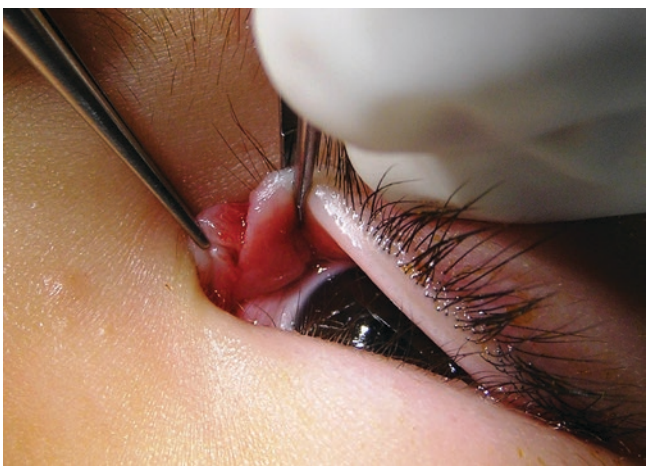


Fig. 35.25 Approximation of eyelid margins in efforts to locate canalicular cut ends

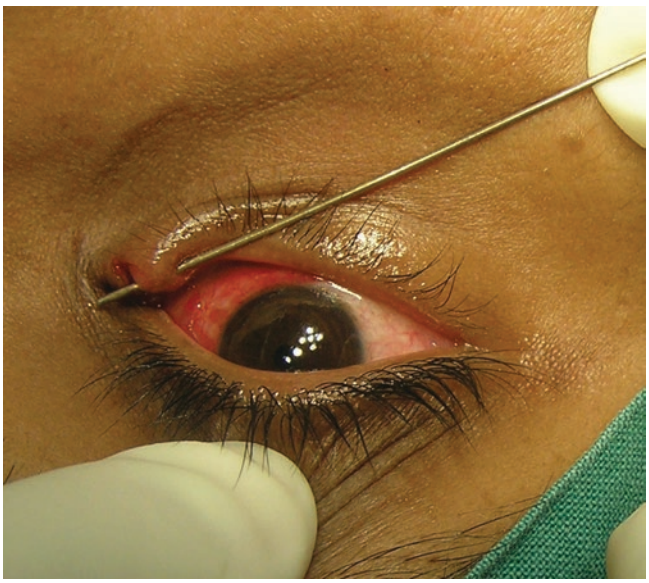


Fig. 35.26 Probing the proximal canaliculus

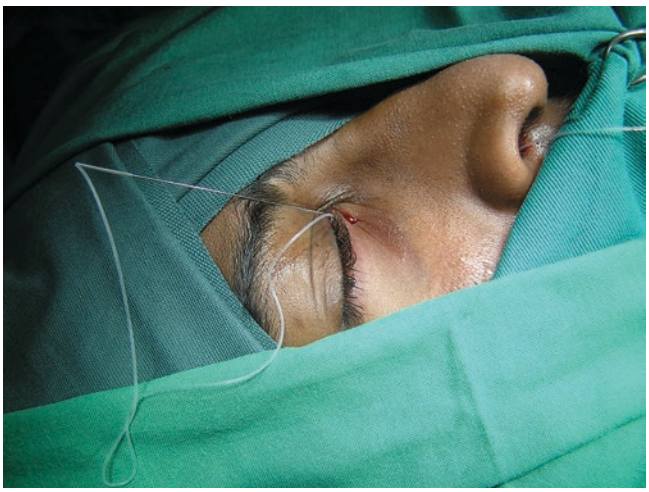


Fig. 35.27 Bicanalicular intubation being retrieved from the nose

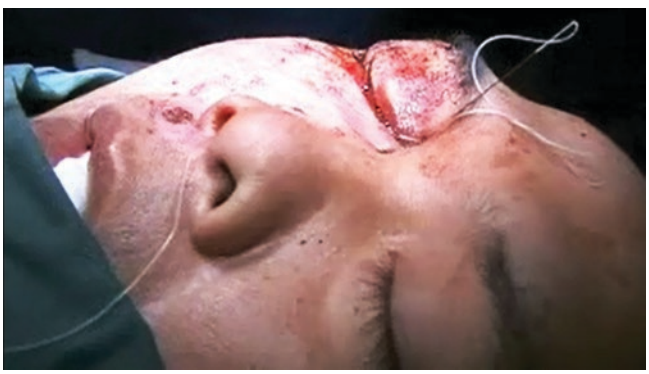


Fig. 35.28 Bicanalicular intubation in lacrimal trauma

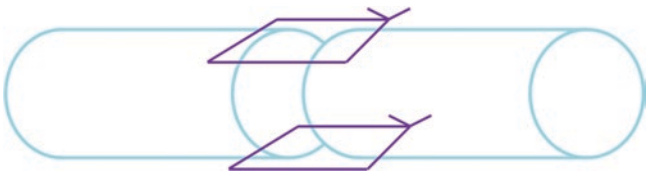


Fig. 35.29 Pericanalicular horizontal mattress sutures

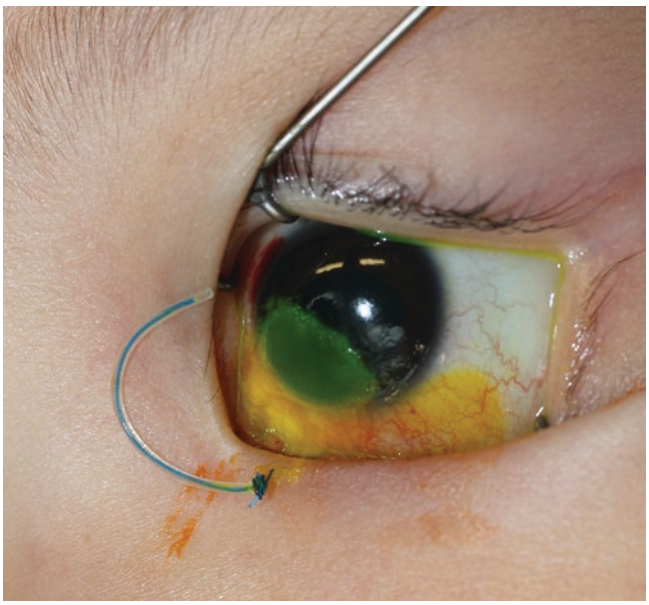


Fig. 35.30 Annular ring intubation with corneal abrasion

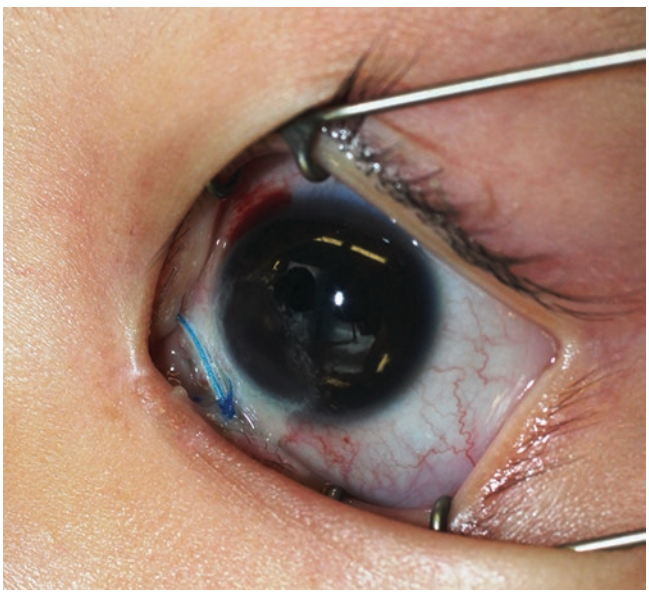


Fig. 35.31 Annular ring intubation with corneal abrasion

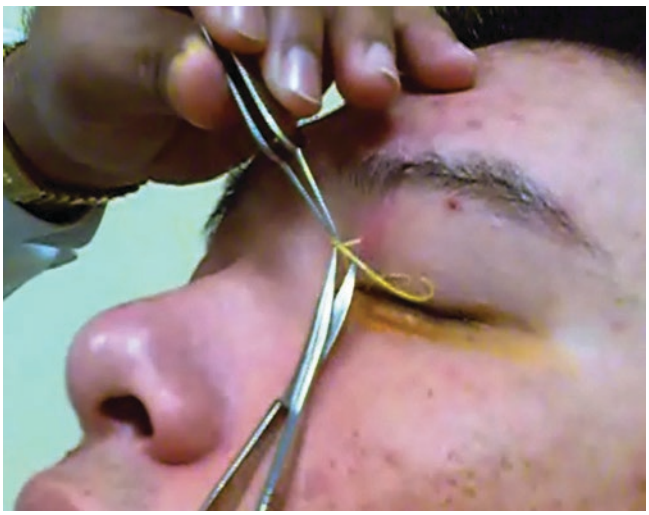


Fig. 35.32 Trans-ocular stent removal

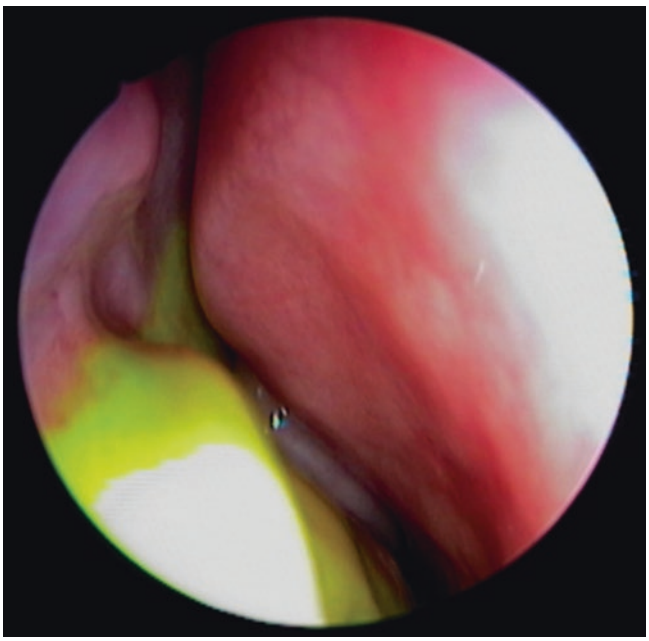


Fig. 35.34 Fluorescein dye test

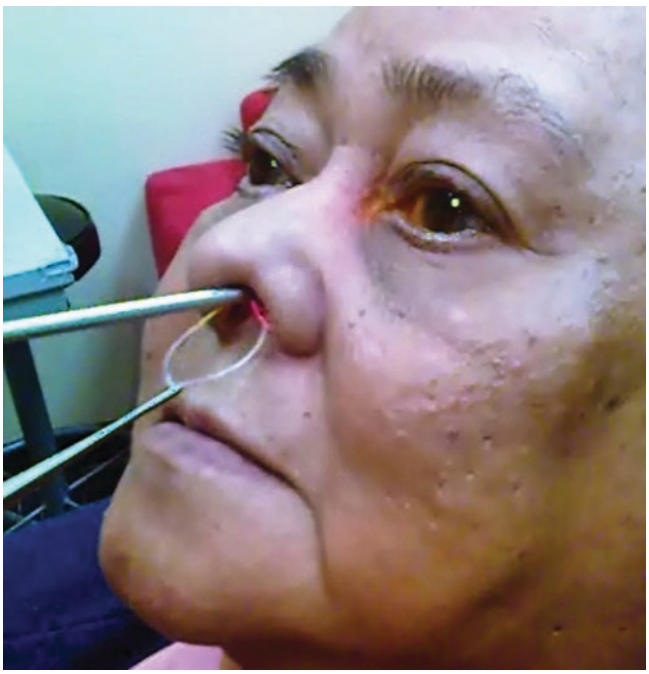


Fig. 35.33 Trans-nasal stent removal

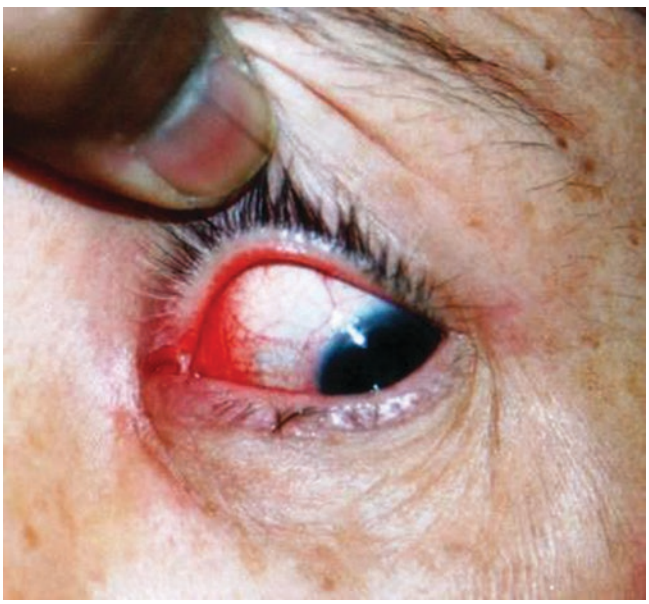


Fig. 35.35 Early pyogenic granuloma secondary to intubation

Image-Guided Dacryolocalization and Stereotactic Lacrimal Surgeries

36

Mohammad Javed Ali

Introduction

Accuracy and precision in surgery are most desired by any surgeon to have better outcomes. Stereotactic technology helps exactly to achieve this goal. Image guidance is reasonably well established in neurosurgery, spinal surgeries, and endoscopic skull base procedures [1–3]. However, the literature with regards to lacrimal surgery is very sparse with only few reports [4–11]. The term "image-guided dacryolocalization" or IGDL was proposed by Ali et al. [4] to encompass the use of stereotactic navigation for lacrimal disorders. The current chapter would discuss the technology, indications, techniques, and outcomes of stereotactic lacrimal surgeries.

The Navigation System

Numerous systems are available for navigation guidance and include ISG viewing wand^{R} (Cedara technologies, Ontario, Canada), Fusion System^{R} (Medtronic Inc., Minneapolis, USA), Nav PICO^{R} systems (Karl Storz, Tuttlingen, Germany), and the latest generation StealthStation7^{R} (Medtronic Inc., Minneapolis, USA). There are two modes of performing navigation, the electromagnetic mode and the optical mode. The electromagnetic systems utilize a field magnetic generator which is in very close vicinity to the surgical area and the setup includes a head-mounted marker coil that needs to be wrapped around the patient's forehead (Fig. 36.1). The optical mode utilizes the infrared rays for navigation, and it does not need an elaborate headbands; hence, the setup is much easier. However, the optical mode has a problem with "line of sight" interference, and this can be a potential limiting factor while operating with assistance in the periorbital area. It should also be kept in mind that systems utilizing electromagnetic navigation may interfere with communications of an implantable device or patient monitoring systems. The author prefers StealthStation S7^{R} which provides both the options of optical navigation mode and the AxiEM™ electromagnetic mode (Fig. 36.2). It also has the ability to interface and work simultaneously with numerous imaging modalities like computed tomography (CT), magnetic resonance imaging (MRI), CT and MRI angiographies, 2-arm fluoroscopy, and the C-arm imaging systems.

Techniques

For intraoperative navigation, contiguous CT scans of 1 mm thickness are performed from the superior aspect of the horizontal portion of mandible to the vertex as per the image-guidance acquisition protocols or the manufacturer's recommendations. The imaging data is uploaded into the software, and the patient location is then registered using multiple points to set up the machine ready for navigation. In context of complex lacrimal surgeries, two techniques need detailed mention: three-dimensional (3D) CT-dacryocystography and navigation enabling of endoscopes.

3D CT-DCG for Navigation

Dacryocystography is performed using the nonionic, water-soluble contrast medium (Iohexol, 755 mg/ml). The contrast is diluted 50:50 with normal saline and injected slowly into the lacrimal drainage system with the help of lacrimal cannula mounted on a 1 cc syringe. The images are acquired immediately after dye irrigation. Once CT-DCG images are acquired, the slices are reconstructed to sub 1 mm thickness, and 3D reconstruction is performed on the CT workstation after adjusting the Hounsfield values to detect the contrast density (Fig. 36.3). Various CT-DCG scans are then uploaded to the navigation system and merged using the StealthStation

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_36

Merger software to create a 3D model of the lacrimal drainage system for real-time tracking. The patient location is then registered, and the navigation system can accurately demonstrate the location of an anatomical point radiologically in all the three CT-DCG planes (Fig. 36.4).

Navigation Enabling of Endoscopes

The AxiEM™ electromagnetic navigation stylet is a flexible tracker with a length of 23 mm and diameter of 1.2 mm (Fig. 36.5). It has unique miniaturized electromagnetic coils near its tip that allows for accurate and real-time tracking. The routinely used 4 mm, 0^0 endoscopes (Hopkins^R, Karl Storz, Tuttlingen, Germany) are employed for navigation enabling (Fig. 36.5). The stylet is anchored securely to the surface of the endoscope with the help of multiple adhesive dressings (Fig. 36.6). The tip of the stylet is in line with the edge of the telescope mirror (Fig. 36.6). The patient locations are then registered, and software with the "look ahead" features is utilized. This unique software has the ability to show the anatomical structures that would be encountered at defined points in the trajectory of the navigation-enabled endoscope. A typical "look ahead" screen would have four windows showing axial or coronal cuts of CT scans (Fig. 36.7). The first window shows the current location of the tip of the stylet or in this mode, the tip of the endoscope. The subsequent three windows show anatomical structures at 5 mm, 10 mm, and 15 mm, respectively, from the current location trajectory. Hence, the surgeon would have a very good idea of what lies ahead of his endoscope at those defined points.

Outcomes

The outcomes of image-guided surgery are very encouraging in secondary acquired lacrimal duct obstructions, a major chunk of which are post-traumatic cases. The first image-guided lacrimal procedure was described by Day et al. [5] in 2008, where they reported an endoscopic DCR for a bilateral nasolacrimal duct obstruction in a patient with a history of cocaine abuse. The endoscopic anatomy was altered with septal perforation, oronasal fistula and contracted turbinates with obliterated meati. Morley et al. [8] described a patient with chronic left-sided epiphora and status post left rhinectomy and hemi-maxillectomy for a sino-nasal carcinoma. In the absence of the left nasal cavity, a 24 mm Lester-Jones tube placement into the contra lateral side was performed under the image guidance. The tracking probe was used to identify the trajectory of the tube, and this route was adhered to when passing the trephines and the K-wire. The tubes were successfully placed as planned with free drainage and good endoscopic positioning.

Image-guided powered endoscopic dacryocystorhinostomy was possible in cases with grossly distorted endoscopic anatomy (Fig. 36.8), malpositioned lacrimal sacs, breached periorbital, encephalocele in the vicinity, and post-maxillectomy cases. Stereotaxis allowed accurate localization of lacrimal sac in all these cases. Useful clues were obtained with regards to the need for modification of any step during the surgery. Ali et al. [11] used 3D CT-DCG to localize lacrimal sacs in three complex SALDO patients, and in spite of completely misaligned endoscopic anatomy, geometric intraoperative orientation could be maintained all through the surgery resulting in successful outcomes in all the three cases. A case of unilateral arhinia with an ipsilateral mucocele was treated with contralateral dacryocystorhinostomy utilizing septal mucosa for the DCR ostium creation [9]. The path of the DCR was carefully preplanned on an image-guided platform and was adhered to during the surgery with constant stereotactic guidance (Figs. 36.9 and 36.10).

The advantages of a navigation-enabled telescope include eliminating the need for multiple localizing instruments, uninterrupted radiological orientation, and sustained navigation guidance throughout the surgery [10]. Since this can be performed only with the help of "look ahead" protocol software, numerous advantages of this technology as elucidated earlier gets added to the surgery. However, there are few limitations of using navigation-enabled telescopes as compared to the routine navigation. The front end of the telescope cannot touch the tissues as this would entail the risk of mucosal burns and tissue trauma. But, this limitation is negated to a large extent with the use of "look ahead" techniques. Another major limitation for any navigation surgery is the cost-benefit ratio. Hence, navigation can be avoided in routine cases and should be reserve for extremely challenging surgical scenarios.

References

1. Desai B, Hobbs J, Hartung G, et al. Image-guided technology and the surgical resection of spinal column tumors. J Neurooncol. 2016;131(3):425–35. (Epub)
2. Iqbal H, Pan Q. Image guided surgery in the management of head and neck cancer. Oral Oncol. 2016;57:32–9.
3. Kim TT, Johnson JP, Pashman R, et al. Minimally invasive spinal surgery with intraoperative image guided navigation. Biomed Res Int. 2016;2016:5716235.
4. Ali MJ, Naik MN. Image-guided dacryolocalization (IGDL) in traumatic secondary acquired lacrimal drainage obstructions (SALDO). Ophthal Plast Reconstr Surg. 2015;31:406–9.
5. Day S, Hwang TN, Pletcher SD, et al. Interactive image-guided dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2008;28:338–40.
6. Mostovych NK, Rabinowitz MR, Bilyk JR, et al. Endoscopic ultrasonic dacryocystorhinostomy for recurrent dacryocystitis following rhinoplasty. Aesthet Surg J. 2014;34:520–5.
7. Murchinson AP, Pribitkin EA, Rosen MR, et al. The ultrasonic bone aspirator in transnasal endoscopic dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:25–9.

8. Morley AM, Collyer J, Malhotra R, et al. Use of an image-guided navigation system for insertion of a Lester-Jones tube in a patient with disturbed orbito-nasal anatomy. Orbit. 2009;28:439–41.
9. Ali MJ, Singh S, Naik MN. Image-guided lacrimal drainage surgery in congenital arhinia-microphthalmia syndrome. Orbit. 2017;36(3):137–43. (Epub)
10. Ali MJ, Singh S, Naik MN, et al. Interactive navigation-guided ophthalmic plastic surgery: navigation enabling of endoscopes and their use in endoscopic lacrimal surgeries. Clin Ophthalmol. 2016;10:2319–24.
11. Ali MJ, Singh S, Naik MN, et al. Interactive navigation-guided ophthalmic plastic surgery: the utility of 3D-CT DCG guided dacryolocalization in secondary acquired lacrimal duct obstructions. Clin Ophthalmol. 2017;11:127–33.

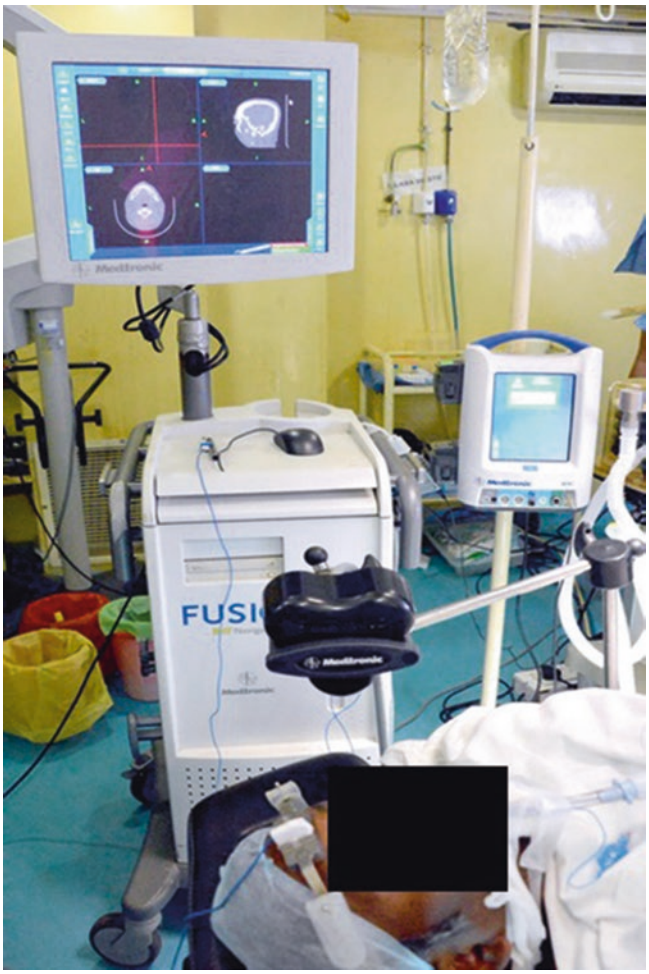


Fig. 36.1 The electromagnetic navigation system. Note the headband on the patient

Fig. 36.2 A modern lacrimal operating room with the StealthStation7^{R} system

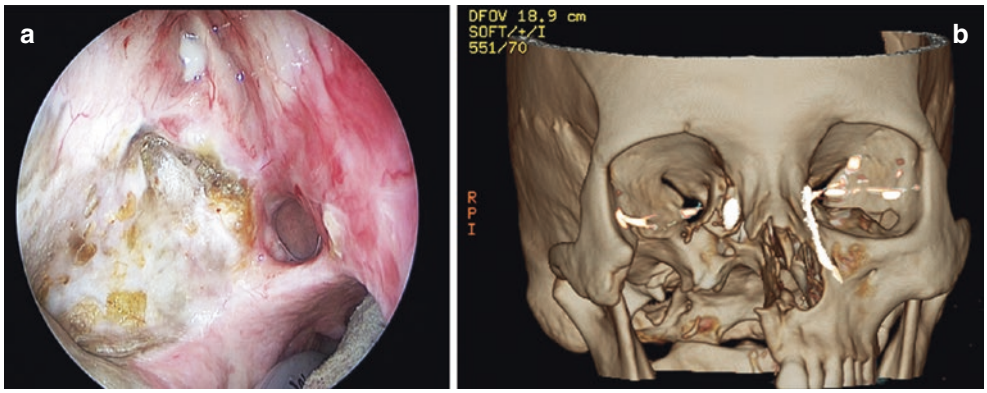


Fig. 36.3 Panel **a** shows endoscopic view in a patient with SALDO. Note the absence of lateral wall structures secondary to maxillectomy. Also note the large palatal perforation. Panel **b** shows a 3D CT-DCG. Note the absence of sac-duct junction and the nasolacrimal ducts. The lacrimal sac is displaced posteroinferiorly

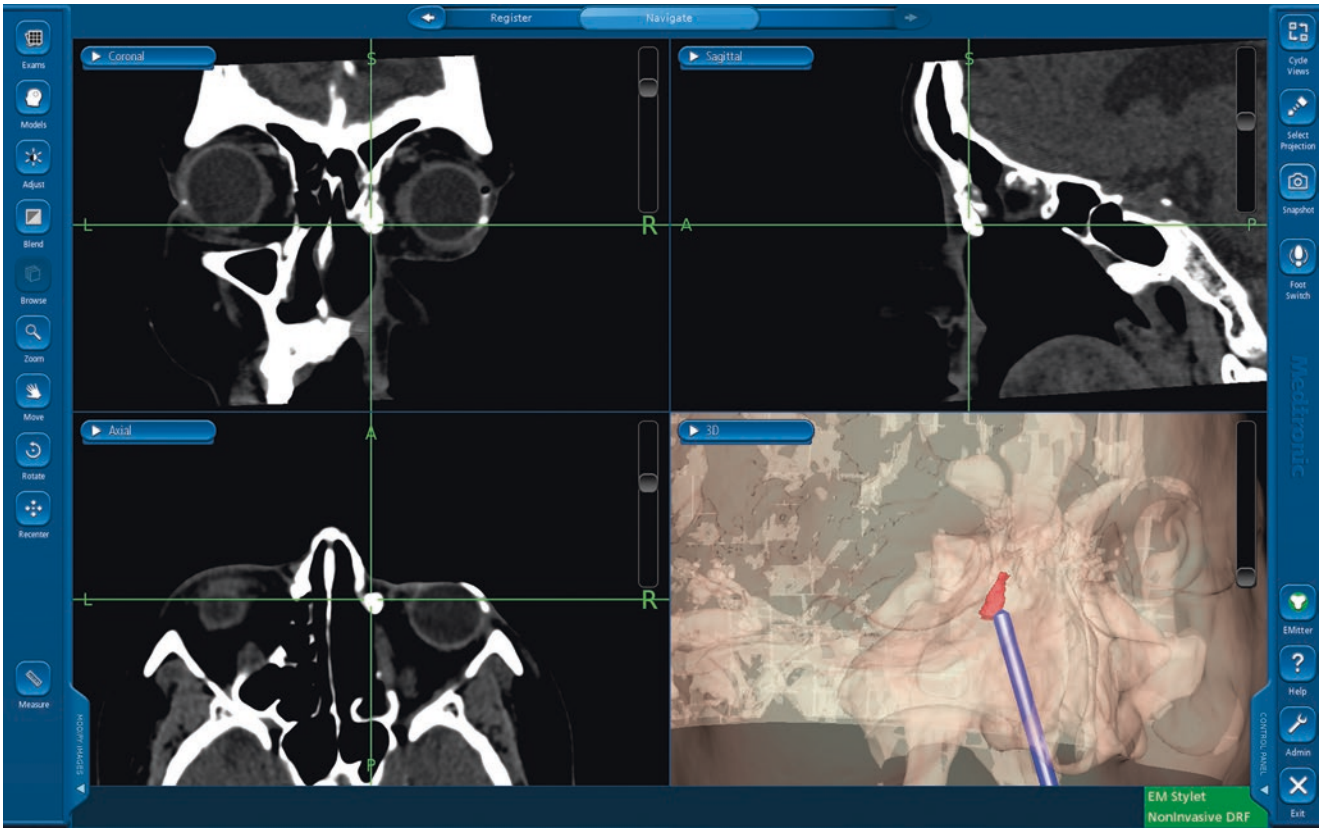


Fig. 36.4 Intraoperative image guidance with the help of CT-DCG. CT scans in coronal (*upper left*), sagittal (*upper right*), and axial (*lower left*) cuts clearly delineating the dye filled lacrimal sac. *Lower right panel* shows the 3D reconstruction of the navigation system and its tracking of lacrimal sac in three dimensions. The *blue* is the navigation tracker

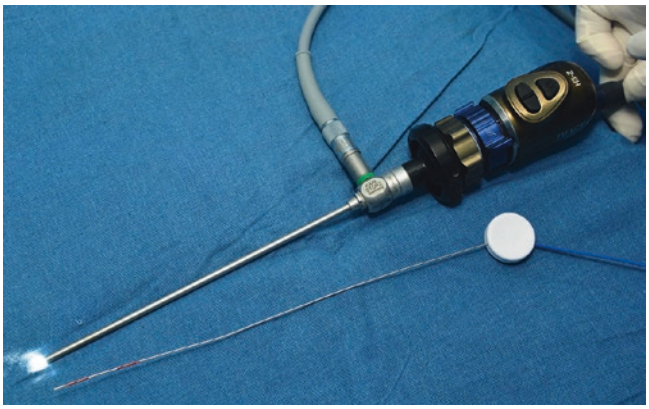


Fig. 36.5 The Hopkins endoscope and the navigation tracking stylet

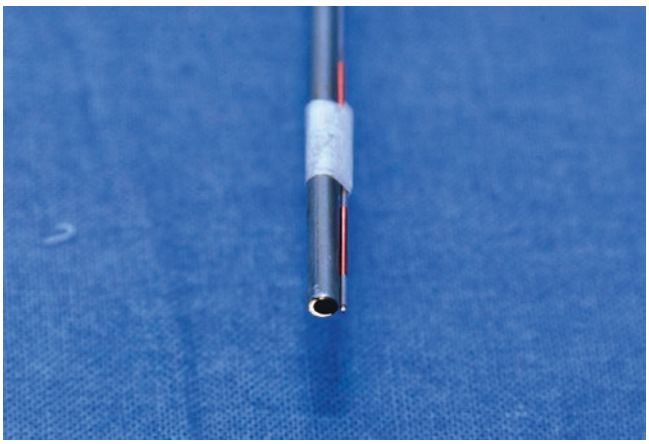


Fig. 36.6 The securing of the navigation stylet to the endoscopes to make them navigation enabled too

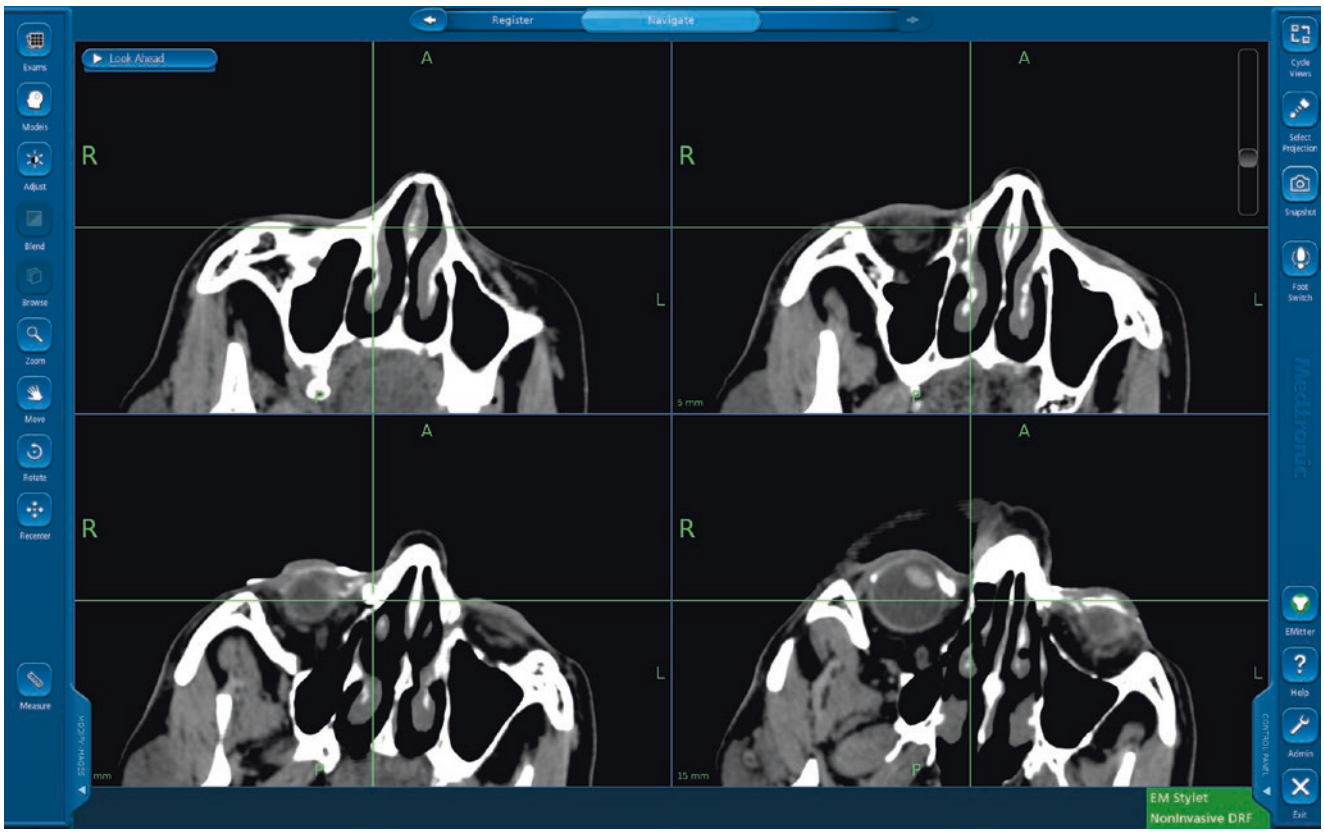


Fig. 36.7 Navigation with look ahead protocol. Note the top left CT scan; axial cut is at the location of the endoscope. The top right is the structures at 5 mm ahead in the straight trajectory of the endoscope. Note the just faint appearance of the lacrimal dye here. The *left lower panel* is 10 mm ahead from the endoscope. Note the green cross hairs are just behind the lacrimal sac. This means that the lacrimal sac lies between 5 mm and 10 mm from the current location of the endoscope. The *right lower panel* shows structures at 15 mm form the current location of endoscope

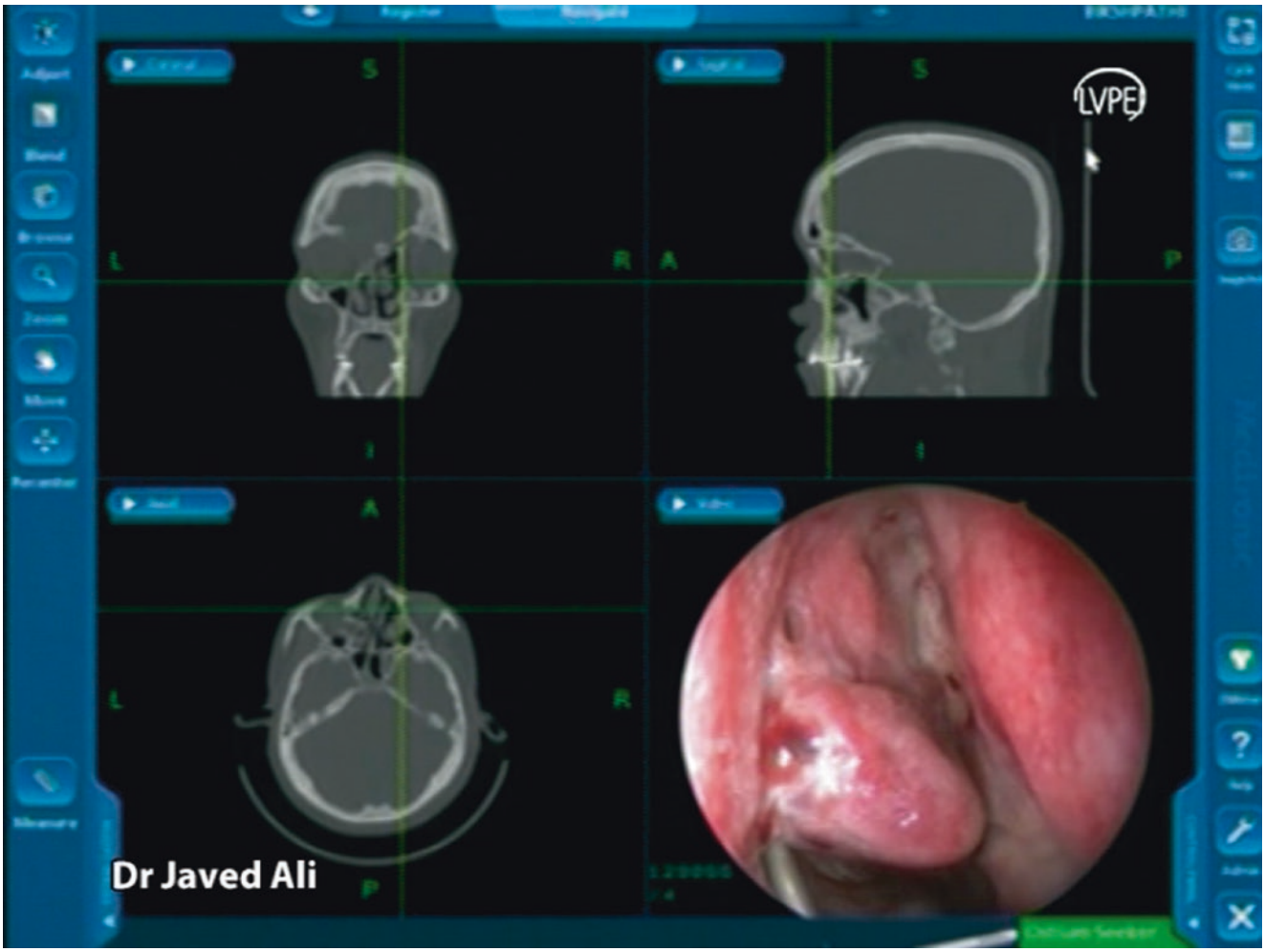


Fig. 36.8 Intraoperative navigation in a post-trauma setting. Note the grossly distorted lateral wall and the fractured middle turbinate

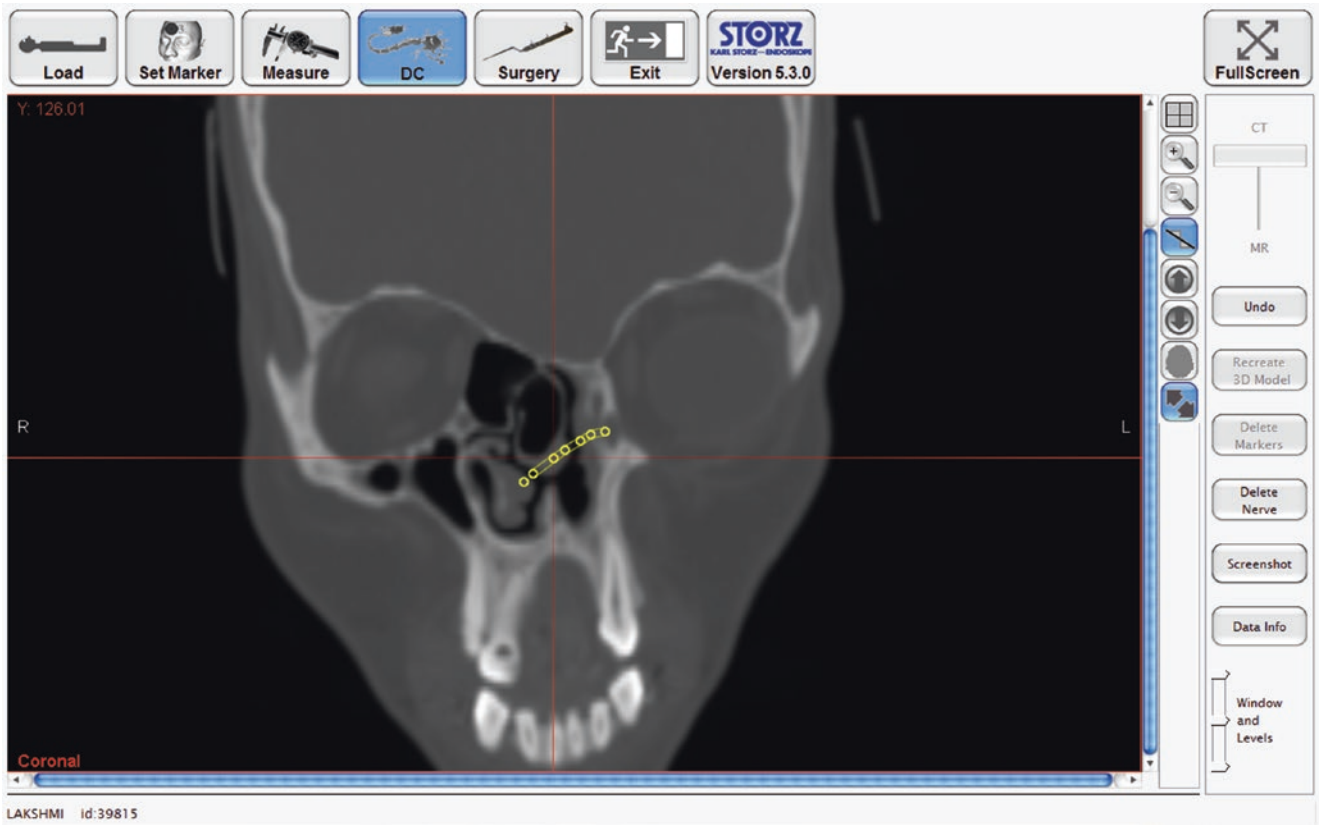


Fig. 36.9 Computer designation of a path of DCR in this patient with partial arhinia. Note the start of it (*yellow chain*) from the lacrimal sac of the left side across the septum onto a hypertrophied middle turbinate on the opposite side

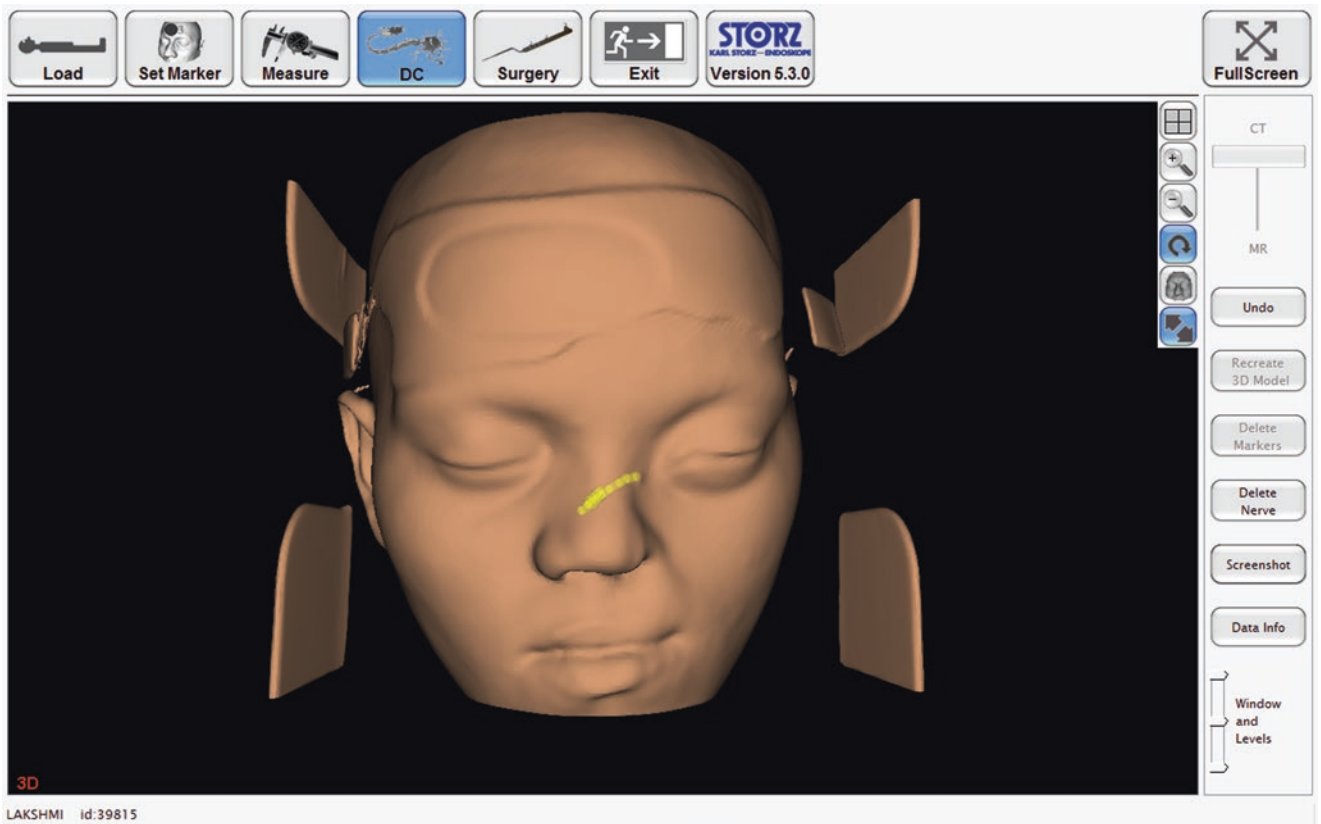


Fig. 36.10 The computer designation in 3D for a better understanding for the surgeon

Intubation in Lacrimal Surgery: Devices and Techniques

37

Tarjani Vivek Dave and Mohammad Javed Ali

Introduction

Lacrimal drainage obstructions causing epiphora is a common lacrimal disorder. Depending on the age of the patient and the pathophysiology of the condition, the disorder can either be relieved by simple probing or by a dacryocystorhinostomy (DCR). In certain conditions, the success rates of the treatment can be improved by intubating the lacrimal system. Canalicular intubation is also indicated in the management of lacerated canaliculus. Intubation is achieved commonly by placing a silicone stent in the lacrimal passages. The silicone stent maintains the passages where it is present and is also believed to allow tissue healing around itself thus maintaining lacrimal patency.

Historical Aspects

The first usage of a canalicular stent was by Graue who used a silver wire and passed it through the lower punctum into the nose [1]. The first description of polyethylene tubing for treatment of canalicular strictures was published in 1950 by Henderson [2]. Huggert was the first to describe bicanalicular intubation in 1959 using polyethylene tubing, with tubes being secured in the nose and bridging the gap between upper and lower puncta [3]. The first reported use of silicone tube stent was in 1968 by Keith [4]. Various probes for silicone intubation were subsequently popularized by Quickert and Dryden [5]. In 1977, Crawford introduced the Crawford lacrimal intubation set for bicanalicular intubation [6]. He subsequently made a series of technique modifications [7–11] in the 1980s. To facilitate the retrieval of the Crawford probe, other workers proposed a modification, known as the groove director, in 1983 and 2001 [12, 13]. In 1989, Fayet and associates [14] introduced the monocanalicular intubation system known as Monoka and Mini-Monoka. It was further modified by Ruban and associates in 1995 [15]. In 1998, another bicanalicular intubation system—the Ritleng lacrimal intubation set—was introduced [16]. Subsequently many others like the Nanchaku^{R} and the Masterka^{R} were introduced and currently used.

Indications

There are numerous indications for intubation and varies among surgeons. Its use in pediatric age group is for cases of failed probing, demonstrable nasolacrimal duct (NLD) narrowing, complex CNLDO, or as adjuncts following balloon dacryoplasty. Lacrimal intubation is preferred in pediatric DCRs. In the pediatric population, aggressive healing response of the tissues often causes failure of patency of the created passage [10]. In such cases, intubation provides a stent around which healing can occur thus helping maintain patency. It is useful adjunct when there are partial or complete canalicular obstructions. DCRs with poor flaps, membrane at common internal opening, and revision DCRs may probably benefit from intubation. Traumatic canalicular tears, posttraumatic canalicular strictures, and congenital/acquired canalicular/punctal stenosis may also merit intubation during surgery. Intubation may not be preferred in acute dacryocystitis or canaliculitis where it may spread the infection across planes and so also in cases of suspected false passages to minimize further trauma.

The Ideal Stent

An ideal stent should have a few desirable properties. It should be soft and pliable so as to minimize tissue trauma during its passage. It should be inert and not incite inflammatory response by the host tissue. The stent tube should be retained safely in tissues for a long time.

T.V. Dave, M.D. (✉)
Govindram Seksaria Institute of Dacryology,
L.V. Prasad Eye Institute, Hyderabad, India
e-mail: tvdeye@gmail.com

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_37

Stent Materials

The various stent materials used over the years can be classified as organic, metal composites, and synthetic. The initial stents used were organic material like hair and catgut [17]. The organic materials on expected lines incited inflammation and lead to post-procedure strictures. The metal stents used were initially composed of silver [18]. Later the Veirs' rod, which was a malleable metal rod 1 cm in length with 4-0 braided silk attached to one end, was introduced [19]. Various synthetic materials used over the years for intubation have been nylon, polyethylene, supramid, silicone, and Teflon. In view of its relative flexibility, durability, inertness, and tolerability, silicone has so far been proven to be close to the ideal intubation material [20].

Types of Intubation Devices

Generically, the lacrimal intubation tubes are classified as monocanalicular and bicanalicular. A monocanalicular stent passes the site of pathology (tear or stricture) in a particular canaliculus but does not traverse the fellow canaliculus. On the other hand, a bicanalicular stent occupies both canaliculi and thus is a "closed loop" system. Monocanalicular intubation is either monocanalicular simple or monocanalicular annular [21]. Bicanalicular intubation could be either annular or nasal in configuration (Table 37.1) [21]. The common monocanalicular stents used are Monoka stents, Mini-Monoka stents, Monoka-Crawford stents, and Masterka stents. The common bicanalicular stents used are Crawford stents, Ritleng tubes, ring intubation system, and self-retaining tubes.

Monocanalicular Intubation

Simple Monocanalicular Intubation

Here the medial portion of the stent extends variably into the lacrimal sac and the nasolacrimal duct. The lateral portion lies at the punctum or within the canaliculus or deeper eyelid tissue (Fig. 37.1). It may also lie on the conjunctiva, skin, or eyelid margin. The stability of a monocanalicular stent depends on a snug fit into the punctum or fixation to the eyelid margin by sutures. Traditionally an angiocath silicone glide was used for intubation of a lacerated canaliculus. Improvement was achieved by a manufactured coupling of a punctal plug (as popularized by Freeman) and a silicone rod used for lacrimal intubation (Long & Fayet), available as the Monoka and Mini-Monoka devices (FCI Ophthalmics, Massachusetts, USA) [22].

The Mini-Monoka Device

The Mini-Monoka is a silicone stent that can be securely anchored at the punctum with no need for sutures. It is threaded through the punctum into the lacrimal system. As the Mini-Monoka does not feed all the way through the nasolacrimal system, it eliminates possible injury to the normal canaliculus and nasolacrimal duct.

This device consists of three components: (1) A silicone rod, which is a hollow tube 0.64 mm in external diameter and 27 cm long. (2) A superior fixation device (SFD), which allows for a secure seating of the punctal plug part of the device in the ampulla. (3) A seating instrument which can either be a metallic or a plastic probe point to push the plug securely into the punctum.

The superior fixation device has a collaret, which is wider than the lacrimal meatus to prevent burying or migration of the Monoka into the canaliculus. It is the only part of the device, which is visible once the Monoka has been properly placed in the lacrimal duct. It permits postoperative evaluation and simple removal when appropriate. Three sizes of collarets are available. These are fused to a bulb, which forms the inferior part of the SFD. When the Monoka is in place, the bulb is securely fixed in the ampulla. Its bulbous shape prevents the spontaneous extrusion of the SFD. Yet its size is not so wide that it would prevent simple removal when desired. The silicone tubing is fused together with the bulb, forming a right angle (Fig. 37.2). The Mini-Monoka device does not require a probe to be inserted into the nasolacrimal duct as it has a solid silicone rod. Placement of this device requires gentle punctal dilation. The proximal part of the punctum and canaliculus is intubated with the free silicone rod part of the device, which is brought out via the wound. Then a smooth pulling of the free silicone part of the Mini-Monoka allows the SFD to set into the punctum. The punctal plug seating delivery device may sometimes be needed. The

Table 37.1 Classification of canalicular intubation systems

Lacrimal intubation			
Monocanalicular intubation Traverses only the involved canaliculus		Bicanalicular intubation Traverses both the canaliculi	
Monocanalicular annular intubation	Monocanalicular simple intubation	Bicanalicular annular intubation	Bicanalicular nasal intubation
Stent brought out to skin through a dacryocystostomy	Lateral stent fixation to lid margin, skin, conjunctiva, or within punctum	Greaves' technique or pigtail probe method	Modified Quickert-Dryden method of nasolacrimal intubation

end of the rod is then shortened sufficiently to pass into the distal canalicular wound and the lacrimal sac. Since these are commonly used for canalicular lacerations, sutures are carefully placed to close the canalicular wound and to reconstruct the canthal tendon by standard techniques (Figs 37.3a–l). The average duration of intubation following trauma is 3 months [23]. However, the current trends are for shorter durations as would be described in subsequent chapter on "intubation dilemma." Removal of the stent is simple and is accomplished by pulling out the collaret with a forceps.

Self-Threading Monoka over a Ritleng Probe

The self-threading Monoka (Ritleng style) tube (Fig. 37.4) is attached to a thin thread guide, which is fed through a Ritleng probe (Fig. 37.5) and gently brought out through the nose. The probe is then removed, and the thread guide is pulled along with the silicone tubing into proper position in the nasolacrimal duct. The tube is securely anchored at the punctum by the SFD. Intubation can be a complicated process in infants and small children, as the nasal passages are compact with narrow anatomical confines. The removal of a thin suture or thread guide from the nose is easier and less traumatic than traditional metallic probes, facilitating canalicular procedures in young children.

Monoka-Crawford

The Monoka-Crawford (Fig. 37.6) can be used for monocanalicular repairs, DCR with monocanalicular agenesis or proximal obstruction, pre-saccal stenosis, or partial nasolacrimal duct obstructions. This stent feeds all the way down into the nasolacrimal duct, unlike the Mini-Monoka, and is anchored at the punctum by the SFD.

The Masterka^{R} Device

Designed by an oculoplastic surgeon Bruno Fayet, the Masterka^{R} offers a safer and faster intubation of tear ducts as it does not require the frequently difficult step of recovery inside the nasal cavity [24]. Unlike the traditional "pulled" technique in which the stent is advanced through the nasolacrimal system and retrieved through the nose by pulling on the guide probe or thread, the Masterka^{R} has no metallic probe or suture attached to it and, therefore, it is not pulled out of the nose. Instead, the Masterka is pushed into the nasolacrimal duct and anchored in place at the punctum by a plug-like fixation head similar to Monoka stents. A pushed intubation is more similar to a simple probing than a pulled intubation and significantly reduces time for the intubation procedure. The Masterka device consists of a silicone tube molded to a fixation head and pre-mounted on an introducer to facilitate insertion (Figs. 37.7 and 37.8). The introducer is easily and completely removed once the intubation of the lacrimal passages has been completed. The Masterka comes in three different lengths of 30, 35, or 40 mm.

Monocanalicular Annular Intubation

In a monocanalicular-annular stent placement, the lacrimal stent is passed through the length of the involved canaliculus only and into the lacrimal sac. The stent is then exteriorized to the skin through the wall of the sac, and the medial end of the stent may be tied to the laterally protruding end in the form of a "sling" (Fig. 37.9) [21]. In addition to silk, various materials used for these monocanalicular-annular stents included chromic gut, nylon suture, and polyethylene tubing. However, with the advent of Mini-Monoka, the annular technique of monocanalicular stenting has taken a backseat.

Bicanalicular Intubation

In this "closed loop" system, it is possible to expose only a short segment of the stent between the superior and inferior puncta or canaliculostomy and is therefore to a certain extent protected from extrusions [21].

Bicanalicular Annular Stent

In bicanalicular annular stent, both the canaliculi are occupied as a part of a continuous loop. The lateral portion of the loop lies between the lacrimal puncta and the medial portion is united to itself in the common canaliculus or the lacrimal sac (Figs. 37.10 and 37.11). Stallard cited Greaves' technique of bicanalicular annular stenting using a nylon suture over a lacrimal cannula [25]. Pig tail probes have also been used for annular stent placement [26]. The ends of the stent can be secured with a suture or a sleeve. The flexibility of silicone allows it to be tied to itself in a knot between the punctae [26]. Alternatively, the ends of the tubing may be tied and fixated away from the eye to the skin of the canthus [27, 28]. Murube recommended placing a nylon thread within the lumen of the silicone tube along its entire length and then tying the nylon [17]. The united ends of the tube can then be rotated into the canaliculus (Figs. 37.10 and 37.11). Self-retaining stents are another example of bicanalicular annular intubation.

Self-Retaining Stent and the Nunchaku Stents

Self-retaining stents made of silicone are a recent development (Fig. 37.12). They consist of a silicone tube in three different lengths (25 mm, 30 mm, and 35 mm) to cover for patient anatomical variations and two flexible anchoring ends designed to stabilize the stent into the common canaliculus. The outer diameter of the silicone tube is 0.64 mm. It has a central reference marking that offers control over proper positioning. Each end has two flexible flaps that fold inward during insertion through the punctum. Flaps open at the lacrimal sac for secure fixation. The flaps fold backward upon removal of the stent. Nunchaku is also a type of self-retaining stents that are

mounted on two nunchaku style metallic inserters for each of the canaliculus (Fig. 37.13).

Bicanalicular Nasal Stent

In a bicanalicular nasal stent both the canaliculi are occupied as a part of a continuous loop. The lateral portion of the loop lies between the lacrimal puncta and the medial portions of the stent together pass down the nasolacrimal duct to be fixated within the naris (Fig. 37.14). Passing one arm of the stent from the superior canaliculus to the nose and the other arm from the inferior canaliculus to the nose does this.

The Crawford Bicanalicular Nasal Intubation System

The Crawford bicanalicular intubation attaches to a metallic glide with an olive tip that is fed through the system and retrieved below the inferior turbinate using a Crawford hook (Fig. 37.15). This is a simple procedure designed by the Crawford, which speeds up the process of inserting a lacrimal stent with less trauma and tearing of the nasal floor. The Crawford intubation set comprises of two flexible stainless steel wires 0.40 mm diameter and a hollow silicone tube with an outside diameter of 0.64 mm and a 0.30 mm lumen. The stainless steel wires have olive-shaped tips for grasping with a special retrieval hook and permit ease of extraction from the inferior meatus of the nose (Fig. 37.15).

The Ritleng Bicanalicular Nasal Intubation System

The Ritleng device provides a technique for bicanalicular nasal intubation without the need for retrieval of the metal probes from the inferior meatus. This system consists of a (1) Ritleng tubular probe that is hollow and (2) two prolene or other monofilament guide threads that have a silicone tube securely fastened between their ends (Figs. 37.5 and 37.16). In this technique the nasolacrimal system is probed with the Ritleng probes as a part of the routine surgical procedure. The probe opens into the inferior meatus of the nose. With the probe in place, the prolene monofilament guide thread is introduced through the slit in the probe. In the inferior meatus of the nose, the prolene is easier to locate than the metal probes because the prolene material spreads out widely as it exits the Ritleng probe and also because prolene is blue in color. As the prolene is pulled out of the nose, the silicone tube comes into the nasolacrimal duct and can then be secured to the nose by standard techniques.

A tabulated comparison of commonly used Crawford and Ritleng tubes is as described in Tables 37.2, 37.3, and 37.4.

The Bika Bicanalicular Nasal Intubation System

The Bika is similar to the Crawford intubation system except that the metal bodkins have straight tip as against the olive

Table 37.2 Specifications of the Crawford and Ritleng bicanalicular nasal intubation devices

Crawford bicanalicular nasal intubation device	Ritleng bicanalicular nasal intubation device
• Crawford probe Stainless steel Olive tip 1 mm in diameter Probe diameter 0.4 mm • Silicone tube 0.64 mm in external diameter and a lumen of 0.30 mm attached to two flexible Crawford probes also known as "BODKINS" The Crawford II intubation system is available with wider diameter of silicone tube—0.93 mm • Retrieval device—hook	• Ritleng probe Stainless steel Funnel shaped end with a disc for orientation Inferior blunt end with a lateral outlet opening 5 mm above tip Narrow slit, 0.3 mm wide, that runs the length of the probe from the funnel-shaped entrance to the outlet opening dimensions: Probe diameter: 1 mm Probe length: Length 105 mm • Prolene monofilament: Thicker dark blue initial portion, 0.4 mm in diameter followed by a thinner light blue portion, 0.2 mm in diameter • Silicone tube: attached to Prolene monofilament guide at each end outer diameter 0.64 length 300 mm

Table 37.3 Techniques of canalicular intubation with Crawford and Ritleng devices

Technique of bicanalicular nasal intubation with Crawford device	Technique of bicanalicular nasal intubation with Ritleng device
• GA vs. LA • Punctum dilatation • Probe—Canaliculus, NLD • Upper-lower punctum • Deliver below inferior turbinate • Crawford hook device with endoscope • Traction over silicone tubes with hemostat forceps • Square knot • Allow knot to retract	• GA vs. LA • Punctum dilatation and probing • Ritleng introducer with stillette • Retrieve through nose • Remove stillette • Feed polypropylene • Repeat through other punctum • Position silicone tube • Traction over silicone tubes with hemostat forceps • Tight square knot • Allow knot to retract

Table 37.4 Advantages and disadvantages of the Crawford and Ritleng bicanalicular nasal intubation systems

Intubation device	Advantages	Disadvantages
Crawford bicanalicular nasal intubation device	• Olive tip Reduced false passage Decreased trauma • Easy retrieval • Flexible • "Tactile" feedback • Non-endoscopic • Easy to use	• Availability • Cost • Potential damage to narrow canaliculi • Difficult to introduce through punctum and common canaliculus due to olive tip • Tight obstructions difficult to overcome • Risk to both canaliculi in case of single canalicular pathology
Ritleng bicanalicular nasal intubation device	• Technique same as probing • Reusable hardware • Spontaneous prolene prolapse	• Stiff probe • False passage • May need endoscope • Risk to both canaliculi in case of single canalicular pathology

tip (Fig. 37.17). It comes in two varieties; adult Bika and infant Bika having different lengths.

Intubation Dynamics in FNLDO

Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description of a functional nasolacrimal duct obstruction or FNLDO. There is an increasing evidence of benefits of silicone intubation (SI) in FNLDO patients [30–32]. Moscato et al. [30] studied 44 eyes of 30 patients diagnosed as FNLDO, who underwent SI for a mean duration of 4 (±4.1) months. They were followed for a mean of 2.6 (±2.0) years from the time of intubation. The overall success for resolution of symptoms was seen in 77%. Extrapolating the data showed success at 50% between 5 and 6 years. They concluded that SI has good long-term success in cases of FNLDO.

Multiple mechanisms have been postulated to explain the benefit seen with SI in FNLDO [30–34]. Stent placement increases the volume and hence reduces resistance to outflow. Poiseuille's law states that resistance to flow is inversely proportional to fourth power of the radius. Hence the stents by increasing the diameter of the lumen reduces resistance to flow (Fig. 37.18). In addition Moscato et al. [30] proposed the riverbed phenomenon where an increased outflow following reduced resistance helps to maintain the enlarged passage. In addition, the stents may straighten up acute curves impeding outflow as well as help tear outflow by capillary action.

Complications

- Intraoperative
  - False passage
  - Tube separation from bodkins
  - Inability to complete procedure (anatomy vs. technique)
- Postoperative
  - Tube or stent prolapse (Fig. 37.19)
  - Erosion/cheese wiring (Fig. 37.20): material, too tight
  - Pyogenic granuloma (Fig. 37.21): punctal, nasal
  - Lost tubes: external vs. internal
  - Tube incarceration in the cicatrix

Management of Complications

- Tube prolapse: Minimal prolapsed can be observed; however, others need repositioning either through the canalicular push technique or the nasal pull technique. Tube prolapse can be minimized by the use of clips, suture to the lateral wall just within the vestibule (Fig. 37.22), or endoscopic self-linking of stents (Fig. 37.23) [29].
- Erosion/granuloma: Surgical excision of granuloma.
- Lost tubes: Can reintubate if early on in postoperative period. The medical versus legal implications of a lost tube should be kept in mind.

Conclusion

It is imperative to understand the anatomy and anatomical variations of the lacrimal system well**.** In a lacerated canaliculus, monocanalicular intubation significantly improves the surgical outcome. In patients undergoing dacryocystorhinostomy with a compromised common canaliculus or lacrimal sac or nasal mucosal flaps, bicanalicular nasal intubation is perhaps a useful adjunct. However, it is to be borne in mind that intubation in a DCR should not be viewed as a rescue device for a poorly performed surgery. The type of device to be used depends on the indication for repair and surgeons comfort. Appropriate use of technology helps in improving the surgical outcome and patient satisfaction.

References

1. Graue G. An Soc mex de oftal y otorinolaryng. 1932;9:114.
2. Henderson JW. Management of strictures of the lacrimal canaliculi with polyethylene tubes. Arch Ophthalmol. 1950;44:198–203.
3. Huggert A. The treatment of stenosis of the lacrimal canaliculi. Acta Ophthalmol. 1959;37:355–9.
4. Keith CG. Intubation of the lacrimal passage. Am J Ophthalmol. 1968;68:70–4.
5. Quickert MH, Dryden M. Probes for intubation in lacrimal drainage. Trans Am Acad Ophthalmol Otolaryngol. 1970;74:431–3.
6. Crawford JS. Intubation of obstruction in the lacrimal system. Can J Ophthalmol. 1977;12:289–92.
7. Kraft SP, Crawford JS. Silicone tube intubation in disorders of the lacrimal system in children. Am J Ophthalmol. 1982;94:290–9.
8. Rutherford S, Crawford JS, Hurwitz JJ. Silicone tubing used in intubating the lacrimal system: joining the ends for easy removal. Ophthalmology. 1984;91:963–5.
9. Crawford JS. Lacrimal intubation set with suture in the lumen. Ophthal Plast Reconstr Surg. 1988;4:249–50.
10. Crawford JS. Intubation of the lacrimal system. Ophthal Plast Reconstr Surg. 1989;5:261–5.
11. Crawford JS. Intubation of the lacrimal system. Ophthal Plast Reconstr Surg. 1990;18:318.
12. Tse DT, Anderson RL. A new modification of the standard lacrimal groove director for nasolacrimal intubation. Arch Ophthalmol. 1983;101:1938–9.
13. Anderson RL, Yen MT, Hwang IP, et al. A new groove director for simplified nasolacrimal intubation. Arch Ophthalmol. 2001;119:1368–40.
14. Fayet B, Bernard JA, Pouliquen Y. Repair of recent canalicular wounds using a monocanalicular stent. Bull Soc Ophthalmol Fr. 1989;89:819–25.
15. Ruban JM, Guigon B, Boyrivent V. Analysis of the efficacy of the large mono-canalicular intubation stent in the treatment of lacrimation caused by congenital obstruction of the lacrimal ducts in infants. J Fr Ophthalmol. 1995;18:377–83.
16. Pe MR, Langford JD, Linberg JV, et al. Ritleng intubation system for treatment of congenital nasolacrimal duct obstruction. Arch Ophthalmol. 1998;116:387–91.
17. Murube JL. Intubation bicanaliculaire annulaire dans les sections des canalicules lacrymaux. Bull Mem Soc Franc Ophthalmol. 1973;86:222–32.
18. Spaeth EB. In ‘the principles and practice of ophthalmic surgery’. Philadelphia: Lea & Febiger; 1994. p. 98–9.
19. Veirs ER. Malleable metal rods for immediate repair of the traumatically severed lacrimal canaliculus. Trans Am Acad Ophthalmol Otolaryngol. 1962;66:263–4.
20. Patrinely JR, Anderson RL. A review of lacrimal drainage surgery. Ophthal Plast Reconstr Surg. 1986;2:97–102.
21. Rifler DM. Management of canalicular laceration. Surv Ophthalmol. 1991;36:113–32.
22. Fayet B, Racy E, Renard G. Pushed monocanalicular intubation: a preliminary report. J Fr Ophtalmol. 2010;33:145–51.
23. Conlon MR, Smith KD, Cadera W, et al. An animal model studying reconstruction techniques and histopathological changes in repair of canalicular lacerations. Can J Ophthalmol. 1994;29:3–8.
24. Fayet B, Katowitz WR, Racy E, et al. Pushed monocanalicular intubation: An alternative stenting system for the management of congenital nasolacrimal duct obstructions. J AAPOS. 2012;16:468–72.
25. Stallard HB. In: Stallard HB, editor. Eye Surgery. Bristol, UK: John Wright and Sons Ltd.; 1965. p. 277–340.
26. Worst JGF. Method for reconstructing torn lacrimal canaliculus. Am J Ophthalmol. 1962;53:520–2.
27. Simons JN. Useful instrument for the repair of lacerated lacrimal canaliculus. Plast Reconstr Surg. 1969;43:78–80.
28. Zolli CL. Microsurgical repair of lacrimal canaliculus in medial canthal trauma. In: Hornblass A, editor. Oculoplastic, orbital and reconstructive surgery, vol. 1. Baltimore: Williams & Wilkins; 1988. p. 426–32.
29. Ali MJ, Gupta H, Naik MN, et al. Endoscopic guided-single self-linked stent in pediatric external dacryocystorhinostomy. Minim Invasive Ther Allied Technol. 2013;22:266–70.
30. Moscato EE, Dolmetsch AM, Silkiss RZ, Seiff SR. Silicone intubation for the treatment of epiphora in adults with presumed functional nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2012;28:35–9.
31. Fulcher T, O’Connor M, Moriarty P. Nasolacrimal intubation in adults. Br J Ophthalmol. 1998;82:1039–41.
32. Connell PP, Fulcher TP, Chacko E, et al. Long term follow up of nasolacrimal intubation in adults. Br J Ophthalmol. 2006;90:435–6.
33. Tucker SM, Linberg JV. Measurement of the resistance to fluid flow. Ophthalmology. 1995;102:1639–45.
34. Demirci H, Elner VM. Double silicone intubation for management of partial lacrimal system obstruction. Ophthalmology. 2008;115:383–5.

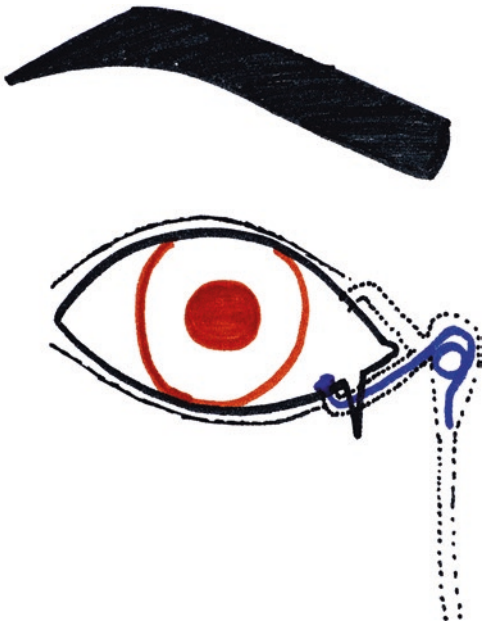


Fig. 37.1 Schematic diagram representing a simple monocanalicular intubation

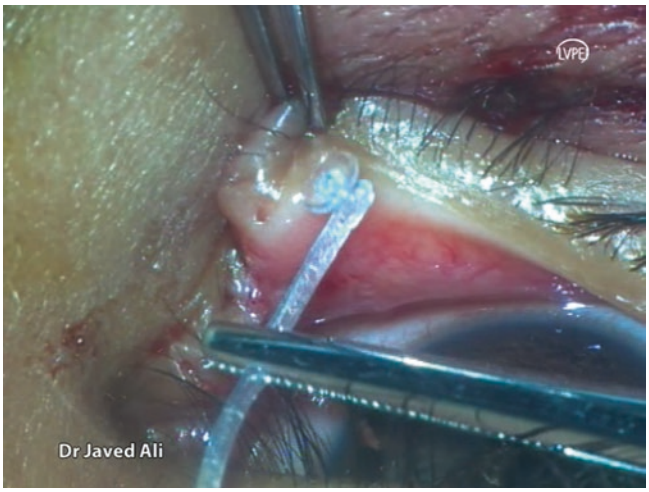


Fig. 37.2 The Mini-Monoka stent

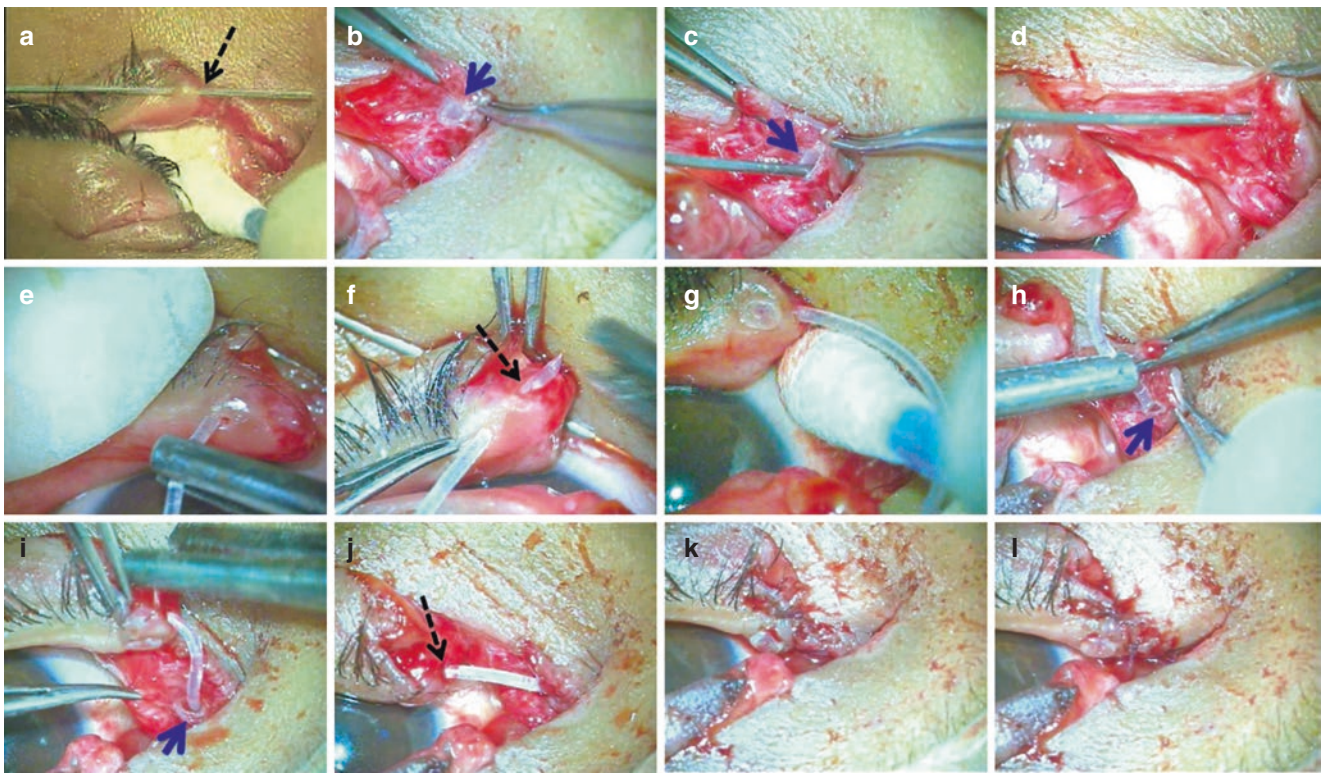


Fig. 37.3 Technique of insertion of a Mini-Monoka stent for lower canalicular laceration. Identification of the lateral cut end of the canaliculus (**a**). Identification of the medial cut end (**b**). Probe through the medial cut end (**c**). Confirming hard stop with the probe (**d**). Mini-Monoka pass through the punctum (**e**). Retrieval through the lateral cut end (**f**). Securing the SFD at the punctum (**g**). The pass of Mini-Monoka through the medial cut end (**h**). Approximating the two cut ends of the eyelid (**i**, **j**). Securing with a suture (**k**). The completed lid repair with a snugly fitting Monoka (**l**)

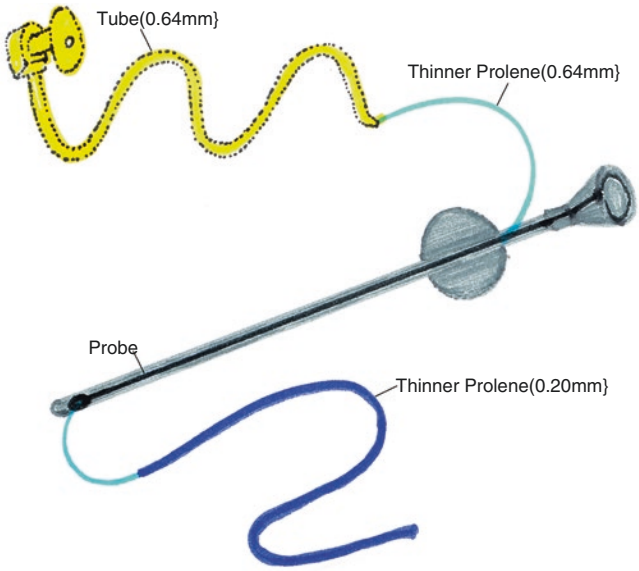


Fig. 37.4 Monoka over a Ritleng probe

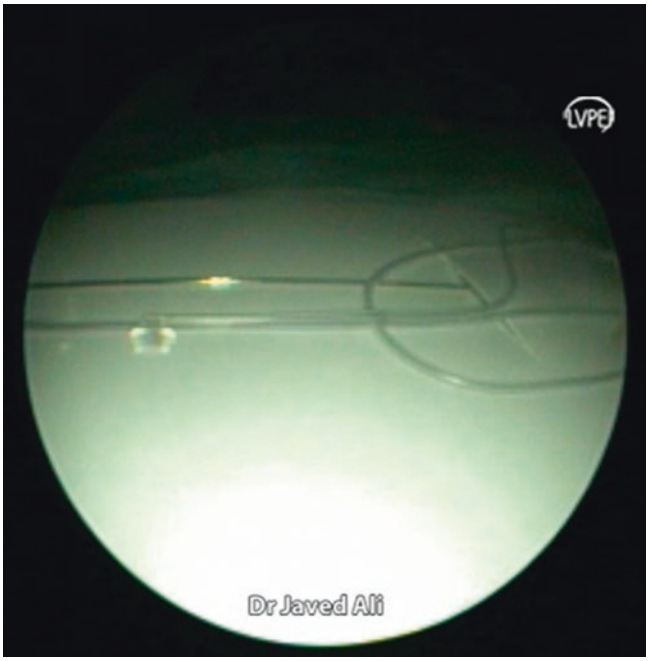


Fig. 37.6 Monoka-Crawford intubation set

Fig. 37.5 Metallic Ritleng probe

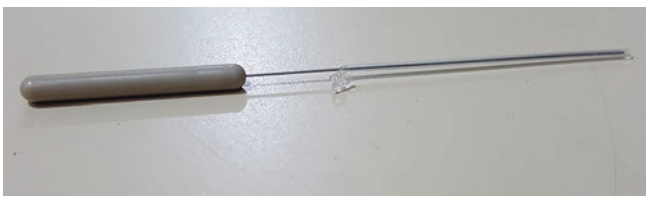


Fig. 37.7 The Masterka^{R} Device mounted on the inserter

Fig. 37.8 Schematic details of the Masterka^{R} device

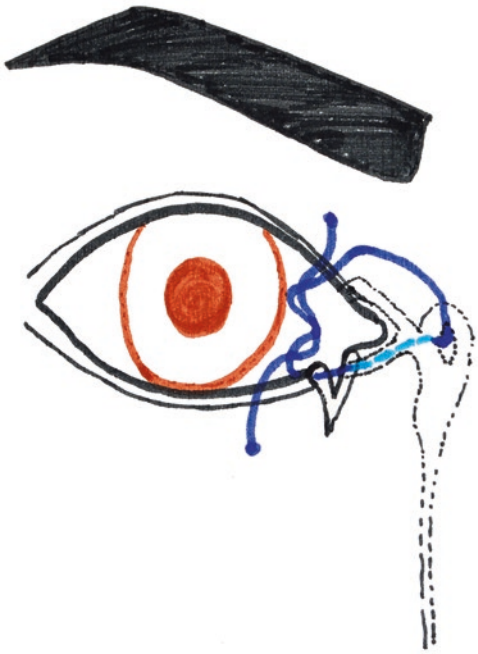


Fig. 37.9 Monocanalicular annular intubation

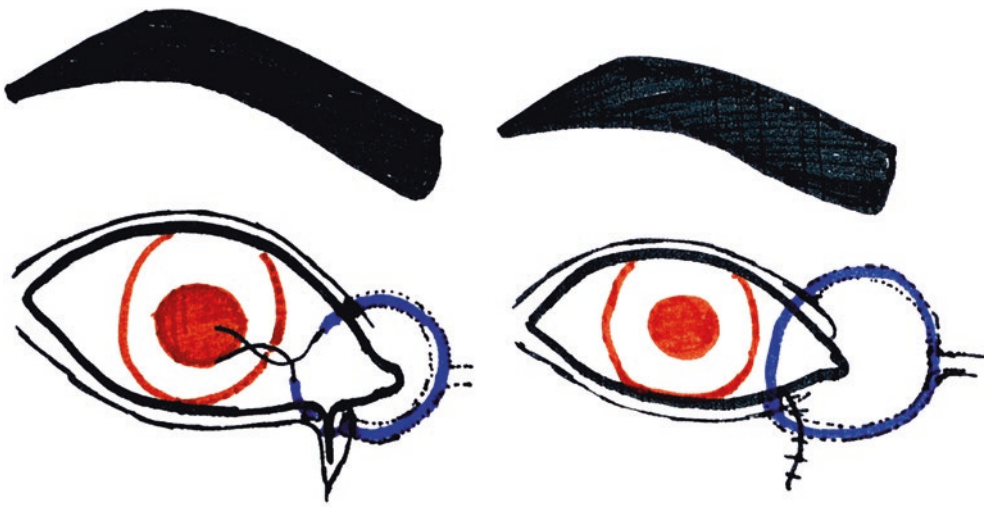


Fig. 37.10 Bicanalicular annular intubation

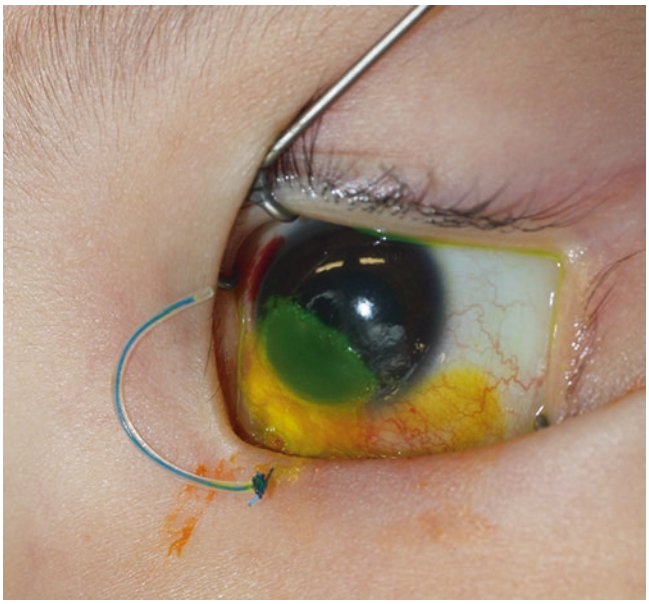


Fig. 37.11 A patient with bicanalicular annular intubation. (Photo courtesy: Dr. Gangadhar Sundar, Singapore)

Fig. 37.12 Self-retaining stents

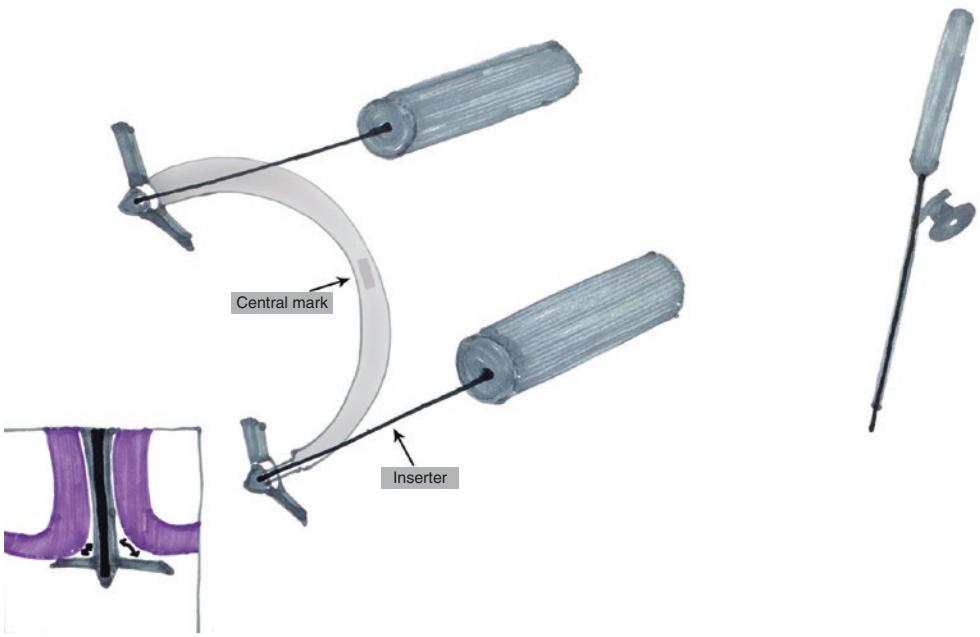


Fig. 37.13 Schematic details of the Nunchaku[R] stent

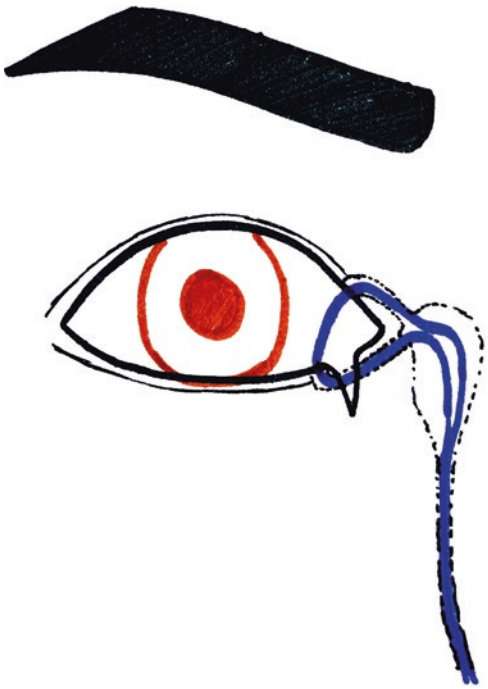


Fig. 37.14 Schematic diagram of bicanalicular nasal intubation

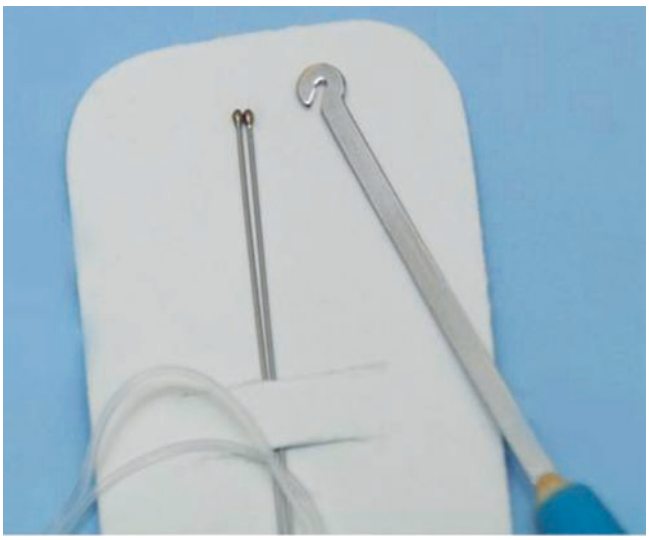


Fig. 37.15 The Crawford bicanalicular nasal stent with the retrieval device

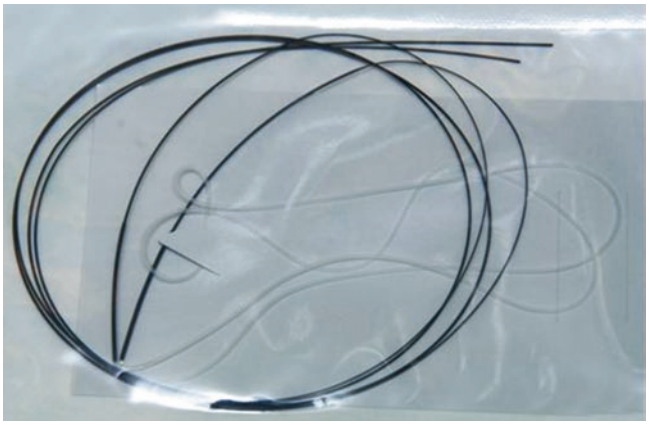


Fig. 37.16 The Ritleng threads with attached silicone tubes

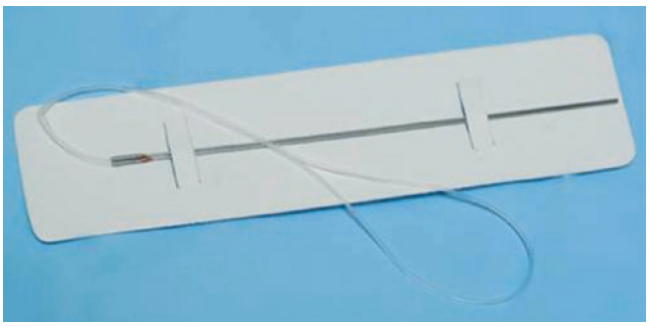


Fig. 37.17 The Bika bicanalicular nasal intubation device

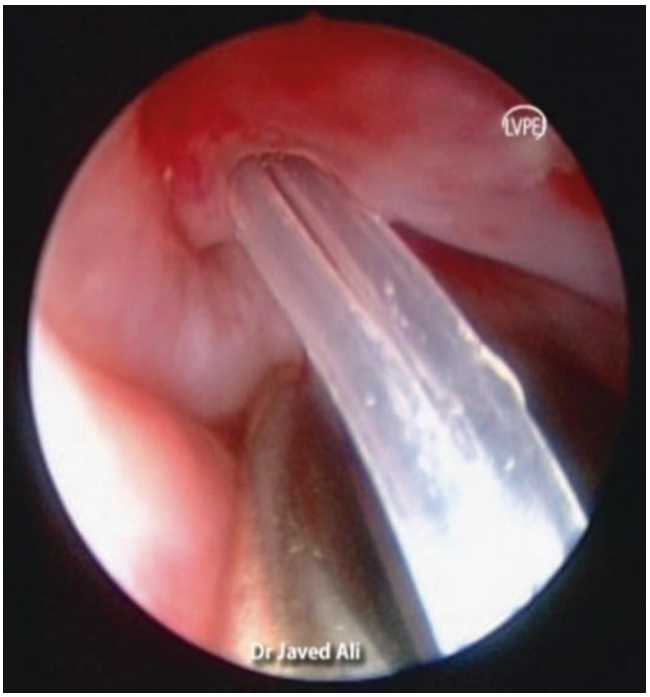


Fig. 37.18 Endoscopic view of the two arms of intubation tube coming through the NLD opening in inferior meatus. Note the dilatation of the opening

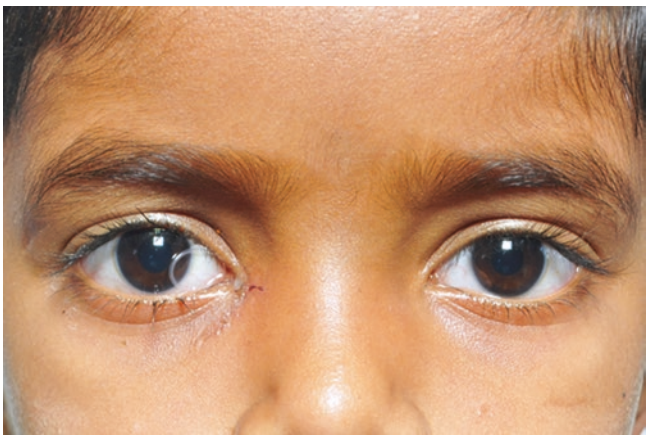


Fig. 37.19 Stent prolapsed

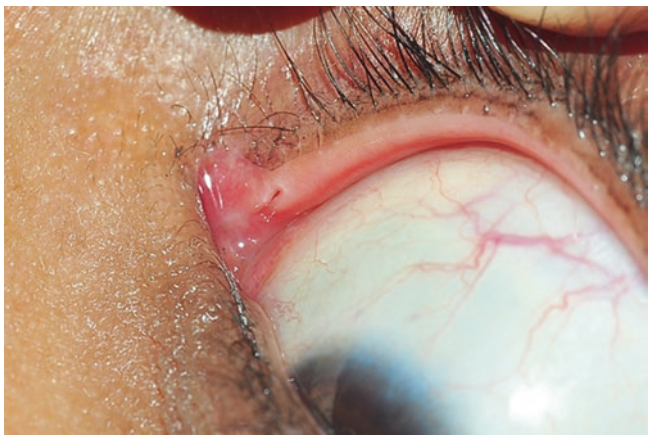


Fig. 37.20 Punctal and canalicular cheese wiring

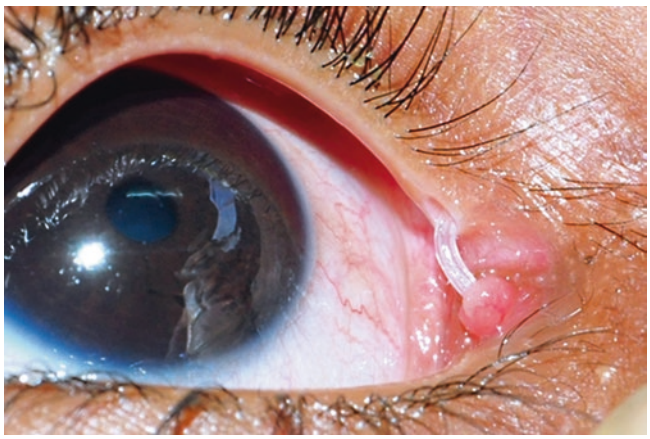


Fig. 37.21 Peritubal granuloma

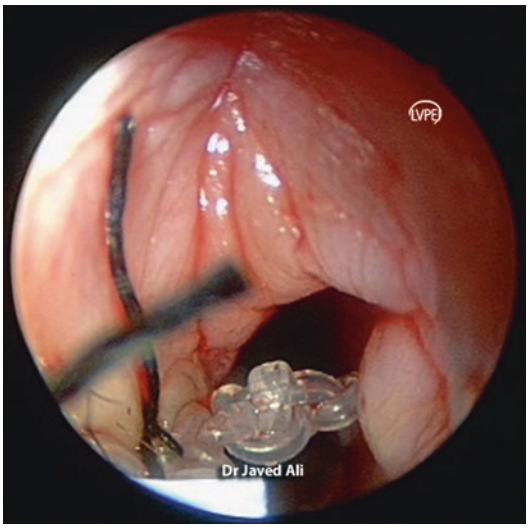


Fig. 37.22 Securing the stents by a suture at just within the vestibule

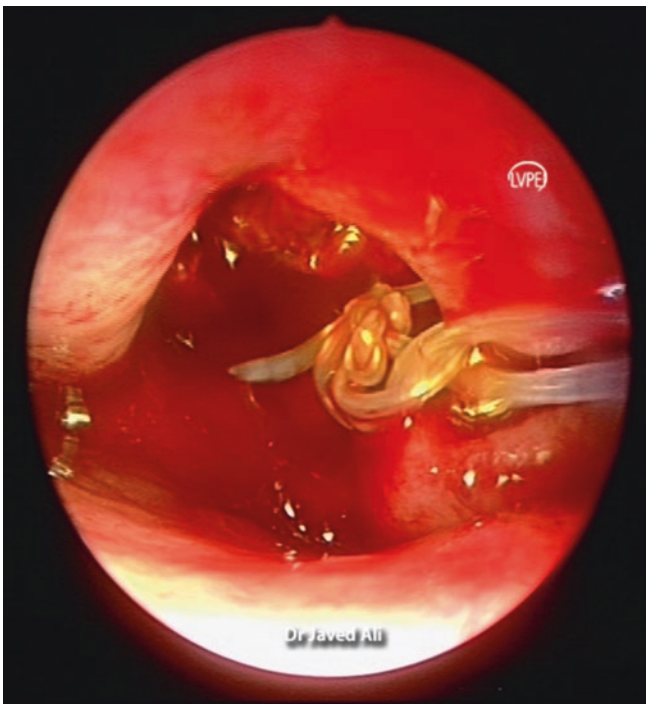


Fig. 37.23 Endoscopic self-linked stent

Tumors of the Lacrimal Drainage System

38

Gangadhara Sundar

The tears of the angels form a river where you can wash your pain, and even in the middle of the thunder, don't forget the love inside the rain.

—David Bailey

Introduction

The lacrimal drainage apparatus are paired structures that commence from the mucocutaneous junction at the medial end of the upper and lower eyelid margins as the lacrimal puncta. They then course through the lid margins of medial end of the eyelid and through the anterior limbs of the medical canthal tendon as the upper and lower canaliculi, which in most individuals merge into a common lacrimal canaliculus. The common canaliculus enters the lacrimal sac at its lateral wall with the fundus above and the body below, which then courses along the medial wall of the maxilla to open into the inferior nasal meatus with a mucosal valve (valve of Hasner) under the inferior turbinate. In general, tumors arising from the upper lacrimal drainage system are uncommon and when they do occur, are usually benign, especially at the punctal orifices. Tumors of the lacrimal sac and the nasolacrimal duct are extremely rare, and when suspected, all efforts should be ensured to rule out malignancy [1–23].

Tumors of the proximal lacrimal drainage system especially of the lacrimal puncta are not infrequently encountered as they are visibly obvious. Most of these are benign nevi which may be pigmented or nonpigmented. These are minimally symptomatic except for the concern and appearance (Fig. 38.1).

Lacrimal sac tumors are only rarely encountered by ophthalmologists and constitute only a minority of head and neck tumors [1–5]. At their early stages, they are neither suspected nor diagnosed and often missed in patients with minimal symptoms. The most common clinical presentation is fullness, presenting as a mass, usually both below and above the medial canthal tendon (Figs. 38.2, 38.3, and 38.4). It may be associated either with epiphora (Figs. 38.3 and 38.4) or not infrequently a chronic dacryocystitis [1–5]. Almost always unilateral, the presence of bloody tears, fullness of the medial canthal area, and partial patency of the lacrimal drainage system on irrigation are highly suggestive of an underlying tumor. Telangiectasia or ulceration of the overlying skin, globe displacement (superolaterally), and regional lymphadenopathy are late presentations although not uncommon [1–5]. Early diagnosis can only be made when there is a high degree of suspicion and with a low threshold to perform a biopsy especially with recurrent lesions. It is therefore imperative that there should be a guarded suspicion in all cases of adult nasolacrimal duct obstructions, especially when any of the clinical features described earlier are present. An astute ophthalmologist will be able to diagnose these based on high clinical suspicion and appropriate imaging, followed by either a needle or incisional biopsy. It is also for this reason that ideally, in all patients with nasolacrimal duct obstructions scheduled for either an external, endonasal dacryocystorhinostomy or endoluminal duct recanalization, routine preoperative workup should include a nasal endoscopy inspecting both the inferior and middle meatus (Fig. 38.5), the author's and most dacryologists' standard practice for years. Most cases, however, are still being diagnosed only upon open examination of the lacrimal sac during a dacryocystorhinostomy [20]. Therefore, when a lacrimal sac tumor is suspected in a patient with dacryocystitis, apart from preoperative imaging, it is advisable to inspect the lacrimal sac cavity and await histopathological confirmation prior to performing an osteotomy of the lacrimal sac fossa. Some experts also believe in routinely sending lacrimal sac wall specimens for routine histopathological examination although its value is commonly debated [11, 12].

Majority of the lacrimal drainage system tumors arise in the lacrimal sac, and these can be classified based on histopathology. Table 38.1 provides an overview and classification of lacrimal sac tumors. In general, 30–40% of tumors of

G. Sundar, F.R.C.S.Ed.
Orbit and Oculofacial Surgery, National University of Singapore, Singapore, Singapore
e-mail: gsundar1@yahoo.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_38

Table 38.1 Tumors of the lacrimal sac

Pseudotumors	Lacrimal sac mucocele, dacryocele
	Dacryoliths
	Granulomas 1. Non-specific inflammatory disorder 2. Granulomatous disorders like sarcoidosis, Wegener's granulomatosis, and tuberculosis
	Infective lesions, e.g., rhinosporidiosis Infiltrative lesions, e.g., amyloidosis
True tumors	**Epithelial tumors** *Lacrimal sac lining elements* 1. Papillomas: (a) Inflammatory papilloma (b) True papilloma: • Benign: – Squamous papilloma – Inverted (transitional cell/ Schneiderian) papilloma – Adenomatous papilloma • Malignant: – Transitional cell carcinoma (arising from inverted papilloma, Schneiderian papilloma) – Squamous cell carcinoma – Epidermoid carcinoma – Mucoepidermoid carcinoma *Lacrimal sac glandular elements* 1. Benign tumors: (a) Eosinophilic cystadenoma (oncocytoma) (b) Pleomorphic adenoma (benign mixed tumors) (c) Adenoacanthoma 2. Malignant tumors: (a) Oncocytic adenocarcinoma (b) Adenoid cystic carcinoma (c) Adenocarcinoma
	Lymphoproliferative tumors: 1. Non-Hodgkin's B-cell lymphoma 2. Lymphosarcoma 3. Hodgkin's lymphoma
	Mesenchymal tumors: 1. Capillary hemangioma 2. Cavernous hemangioma 3. Hemangiopericytoma 4. Neurilemmoma 5. Plexiform neurofibroma 6. Fibroma 7. Kaposi's sarcoma 8. Osteoma
	Melanotic tumors: malignant melanoma
	Secondary tumors: 1. *Nasal mucosa/maxillary sinus*: inverted papilloma, squamous cell carcinoma, nasopharyngeal carcinoma, mucoepidermoid carcinoma 2. *Orbital tumors*: orbital lymphangioma, squamous cell carcinoma of the conjunctiva, melanoma of the eyelid/conjunctiva, 3. *Skin*: basal cell carcinoma, squamous cell carcinoma, sebaceous gland adenocarcinoma 4. *Metastasis*: head and neck tumors or distant metastasis

the lacrimal sac are benign, and 60–70% are malignant [1–5]. Of the tumors 70% are of epithelial origin. Most benign lesions are squamous papillomas [6, 10]. A true papilloma demonstrates epithelial papillomatosis and acanthosis, while an inflammatory papilloma demonstrates granulomas. While most neoplasms are sporadic and of random origin, the human papillomavirus (HPV) has been implicated in the pathogenesis of benign neoplasms (HPV 11) and malignant neoplasms (HPV 18). Rarely, a squamous papilloma may undergo oncocytic metaplasia and develop into an oncocytoma [6, 7].

A not so uncommon type is the inverted papilloma, a variant of Schneiderian papilloma. Although histologically benign, it has a high recurrence rate especially with incomplete excision either primarily or secondarily and with malignant potential to a squamous cell carcinoma (10–15%) and thus should be treated as an aggressive neoplasm. Comprising 0.5–4% of primary nasal tumors, affecting men more than women, and commonly unilateral, these may either arise de novo or more commonly from the adjacent nasal cavity of maxillary sinus. While aggressive surgical treatment is indicated, radiation is contraindicated as it may increase the malignant transformation from a "benign" papilloma to a "malignant" carcinoma [1–3].

Malignant epithelial tumors commonly include squamous cell carcinoma and transitional cell carcinomas [1–3]. Squamous cell carcinomas have a wide range of differentiation from well-differentiated to poorly differentiated tumors with corresponding prognoses. Transitional cell carcinomas behave similar to those diagnosed in the urinary bladder. Since these have a tendency for intraepithelial spread down the nasolacrimal duct and nasal cavity, it is obligatory to carefully evaluate the nasal cavity and plan management accordingly [1–3]. Among carcinomas, mucoepidermoid carcinomas carry a very poor prognosis with almost 0% 5-year survival rate [8]. Lymphomas are the second-most common primary malignant tumors [2, 9, 10]. They are mostly of the B-cell type and, although quite rare, are more common than idiopathic inflammatory pseudotumors. Its occurrence in females has been reported to have a less favorable prognosis. Primary non-Hodgkin's lymphoma of the lacrimal sac has also been reported in children. Most, however, are diagnosed incidentally during a dacryocystorhinostomy from an altered mucosal appearance or a mass lesion [2, 9, 10].

Primary lacrimal sac melanoma is an extremely rare clinical entity with fewer than 25 cases reported [1–4]. The incidence of melanomas among lacrimal sac tumors varies between 4% and 13% in various series [2, 4]. The development of lacrimal sac melanoma has been related to multiple risk factors including older age, presence of dysplastic moles or nevi, delayed presentation, past history of surgery or interventions like incision biopsy, family history of mel-

anoma, and other sites with cutaneous melanoma [2, 4]. Unfortunately, due to limited experience with lacrimal sac melanomas, there are no standard treatment guidelines. Wide surgical excision with tumor-free margins is the preferred treatment [17, 18]. Radiotherapy, chemotherapy, or immunomodulatory agents like alpha-interferon have all been described as an adjuvant modality of management, but with questionable efficacy [1–4]. Targeted immunotherapy may play a role in the future in these rare and devastating malignancies and hold promise in experimental studies.

Secondary neoplasms of the lacrimal system are not uncommon and usually result from a direct contiguity from the ocular surface and eyelid malignancies, underlying nasal cavity and paranasal sinuses, or rarely the overlying skin. Involvement of the lacrimal drainage apparatus by conjunctival melanoma has also been reported with proposed means of spread including intraepithelial melanosis, "field" change, exfoliation of atypical melanocytes in tears, and less likely via hematologic or lymphatic spread [11, 12]. Rarely tumors from adjacent structures including fronto-ethmoidal osteomas and esthesioneuroblastomas from the skull base may also affect the lacrimal system.

Investigations

When there is a clinical suspicion of a space-occupying lesion in the lacrimal sac fossa, preoperative imaging is warranted [1–6]. Initial investigation may include either a contrast-enhanced computed tomography or a magnetic resonance imaging (MRI) or both. A dacryocystography can also be performed to identify space-occupying lesion of the lacrimal sac/nasolacrimal duct looking for a filling defect. However, it may not be able to differentiate between a dacryolith and primary tumor. Most lacrimal sac tumors involve the nasolacrimal duct as well.

Computed Tomography

CT scan of the lacrimal drainage system including the orbits and paranasal sinuses is often the initial imaging modality for all suspected cases of lacrimal drainage tumors [1–6]. This should be performed with and without contrast, with fine cuts, and with both soft tissue and bone windows. A clear outline of the bony nasolacrimal sac fossa and nasolacrimal duct with soft tissue enhancement is obtained and usually identifies the tumor with good precision (Figs. 38.6, 38.7, 38.8, and 38.9). While early neoplasms are confined with smooth expansion, medial canthal involvement with bone erosion is common in late stages [7] (Figs. 38.6 and 38.8).

Magnetic Resonance Imaging (MRI)

An MRI of the lacrimal sac fossa, orbits, and paranasal sinuses provides a clear delineation of the soft tissue involvement of the nasolacrimal duct and, more importantly, is able to differentiate soft tissue mass lesions from normal adjacent sinus mucosa and sinusitis (Figs. 38.10, 38.11, 38.12, and 38.13). Determination of intraconal spread of tumor is important as it has a prognostication role in deciding globe preservation versus globe sacrifice. Early infiltration of the surrounding structures is also seen well with MRI as compared to CT scans. Thus, a combination of CT scan and MRI is often complementary.

Positron Emission Tomography

PET-CT is indicated for initial staging (Fig. 38.14) and when systematic metastasis is suspected. It may also be useful to follow up patients long term. Any suspicious lesion should be biopsied and additional treatments instituted based on the findings.

Making a Diagnosis

A preoperative diagnoses may be made based on a high degree of suspicion alone based on symptoms and signs described earlier, confirmed by imaging studies [1–11]. When a mass lesion is confirmed, either a closed or open biopsy may be performed. Not infrequently a diagnosis is made on the presence of abnormal lacrimal mucosal features during a dacryocystorhinostomy, where a biopsy is warranted. Caution should be exerted on inadvertent and extensive tissue manipulation while performing either an endonasal or external DCR before opening the lacrimal sac as local recurrences can be both medically and medicolegally significant.

Closed Biopsy

This may be performed under topical anesthesia in an outpatient setting. A blunt canula may be passed through the upper or lower punctum, past the common canaliculus into the lacrimal sac with multiple passes (Fig. 38.15) [20]. Either a cytology or cell block may be prepared for an immediate diagnosis.

Open Biopsy

This may be performed either as an intentional biopsy or when encountered with an inadvertent or suspicious finding during lacrimal drainage surgery. When electively per-

formed, it is performed under local anesthesia through a small medial canthal incision with care taken to prevent tumor seeding. As mentioned earlier, when a tumor is suspected in a patient with dacryocystitis, it is advisable to expose and inspect the lacrimal sac mucosa with histopathological examination prior to performing an osteotomy. Routine biopsy of the lacrimal sac, although not commonly performed, has been reported to detect otherwise undetectable lacrimal sac tumors. The author is aware of several lacrimal sac tumors being diagnosed after exposure of the lacrimal sac during an endoscopic DCR, warranting additional and extensive surgery. Elective transnasal biopsy is indicated when there is a visible infiltrative lesion of the nasal/sinus mucosa along the lateral wall, inferior meatus, or maxillary sinus ostium encroaching on the lacrimal drainage system.

Management

Management of lacrimal sac neoplasms is dependent upon the histopathological diagnosis complemented by immunohistochemistry and the clinical stage of the disease. Most benign lesions may be managed by either limited excision or dacryocystectomy with care being taken to ensure complete resection of the tumor [1–4]. However, in cases of papillomas, specifically inverted papilloma, as the recurrence rate is quite high with potential malignant transformation, a more aggressive surgical treatment may be warranted [13]. In such cases postoperative imaging may serve as a good control to monitor adequacy of primary excision.

Primary malignant epithelial or stromal neoplasm localized to the lacrimal sac and nasolacrimal duct should be managed appropriately. In most cases, a globe-sparing tumor resection followed either by radiotherapy alone or chemoradiotherapy results in good outcomes [20, 21]. A complete excision of the entire nasolacrimal duct from the lacrimal sac fossa down the bony nasolacrimal duct with a medial maxillectomy is warranted. This may be performed either through an endoscopic or lateral rhinotomy approach, in concurrence with rhinologists or head and neck surgical oncologists, under frozen section control without breach of the underlying lateral nasal wall (Figs. 38.16, 38.17, 38.18, and 38.19). Recent advances in imaging techniques, greater precision and safety with image-guided navigational surgery, detailed preoperative treatment planning, and intraoperative guidance to ensure safe and complete resection have all contributed to a greater surgical success rates. When limited orbitectomy is performed where required, a simultaneous reconstruction of the bony defect with a contoured titanium mesh to provide a fixation anchor for the medial canthal tendon, globe support and serve as a supporting platform for the lower eyelid and cheek to minimize midface collapse is often performed [22, 23].

Any microscopic or minimal residual tumor may be controlled with external beam radiotherapy (60–70 Gy) tailored to cover adjacent areas. More extensive lesions involving the orbit, paranasal sinuses, midline, or skull base without dural breach may require an orbital exenteration with craniofacial resection with regional lymph node dissection (Fig. 38.20) followed by flap reconstruction and postoperative radiotherapy with or without concurrent chemotherapy [15, 22]. Even when aggressively treated, the recurrence rate for invasive squamous cell carcinoma and transitional cell carcinoma is approximately 50% with half of those being fatal [1, 3, 5, 23].

Lymphoproliferative infiltrative disorders warrant a systemic workup and, if documented to be a localized disease, may be treated with irradiation. Systemic disease may warrant systemic chemotherapy and additional treatment as indicated [9, 10].

Metastatic disease to the lacrimal system is quite rare and may be treated appropriate to the patient status and the nature of the primary malignancy, but most amenable to external beam radiotherapy [12, 13].

Lacrimal Drainage Rehabilitation After Tumor Removal

When a malignant tumor has been diagnosed and managed appropriately, most patients do not complain of epiphora as the ocular surface may have been rendered "dry" from the external beam radiation. In patients who are significantly symptomatic, a lacrimal drainage bypass procedure may however be considered, usually a conjunctivorhinostomy (CDCR) with Lester Jones tube. This is usually performed 4–5 years following the primary procedure provided there is no locoregional tumor presence or recurrence. Long-term results of these surgical procedures are not very well known, given the rarity of the indication.

Conclusion

In summary, lacrimal drainage system tumors may be either benign or malignant. Proximal and benign tumors are easily managed by simple and complete excision. Lower drainage system malignant tumors are more challenging but, when diagnosed early, can be completely resected with globe and vision preservation. However, when extensive, more radical surgical procedures with multimodality treatment often ensure satisfactory outcomes in selected patients.

Acknowledgments The author would like to thank Dr. Stephanie Young for proofreading and for her suggestions for changes to the original manuscript.

References

1. Heindl LM, Junemann AGM, Kruse FE, et al. Tumours of the lacrimal drainage system. Orbit. 2010;29:298–306.
2. Pe'er JJ, Stefanyszyn M, Hidayat AA. Nonepithelial tumours of the lacrimal sac. Am J Ophthalmol. 1994;118:650–8.
3. Stephanyszyn MA, Hidayat AA, Pe'er JJ, et al. Lacrimal sac tumours. Ophthal Plast Reconstr Surg. 1994;10:169–84.
4. Pujari A, Ali MJ, Mulay K, et al. The black lacrimal sac: a clinicopathological correlation of malignant melanoma with anterior lacrimal crest infiltration. Int Ophthalmol. 2014;34:111–5.
5. Ryan SJ, Font RL. Primary epithelial neoplasms of the lacrimal sac. Am J Ophthalmol. 1973;76:73–8.
6. Karcioglu ZA, Caldwell DR, Reed HT. Papillomas of the lacrimal drainage system. A clinicopathologic study. Ophthalmic Surg. 1984;15:670–6.
7. Pe'er J, Hidayat AA, IIsar M, et al. Glandular tumors of the lacrimal sac. Their histopathologic patterns and possible origins. Ophthalmology. 1996;103:1601–5.
8. Janakiram TN, Sagar S, Sharma SB, et al. Primary mucoepidermoid carcinoma of the lacrimal sac – a case report and literature review. Klin Oncol. 2016;29:291–4.
9. Kumar VA, Esmaeli B, Ahmed S, et al. Imaging features of malignant lacrimal sac and nasolacrimal duct tumours. Am J Neuroradiol. 2016;37:2134–7.
10. Hornblass A, Jakobiec FA, Bosniak S, et al. The diagnosis and management of epithelial neoplasms of the lacrimal sac. Ophthalmology. 1980;87:476–90.
11. Tanweer F, Mahkamova K, Harkness P. Nasolacrimal duct tumours in the era of endoscopic dacryocystorhinostomy: literature review. J Laryngol Otol. 2013;127:670–5.
12. Tucker N, Chow D, Stockl F, et al. Clinically suspected primary acquired nasolacrimal duct obstruction: clinicopathologic review of 150 patients. Ophthalmology. 1997;104:1882–6.
13. Nash M, Skippen B, Gal A, et al. The role of routine biopsy of the lacrimal sac during dacryocystorhinostomy surgery. Orbit. 2015;34:320–3.
14. Ni C, Wagoner MD, Wang WJ, et al. Mucoepidermoid carcinomas of the lacrimal sac. Arch Ophthalmol. 1983;101:1572–4.
15. Spalton DJ, O'Donnell PJ, Graham EM. Lethal midline lymphoma causing acute dacryocystitis. Br J Ophthalmol. 1981;65:503–6.
16. Benger RS, Frueh BR. Lacrimal drainage obstruction from lacrimal sac infiltration by lymphocytic neoplasia. Am J Ophthalmol. 1986;101:242–5.
17. Satchi K, McKelvie P, McNab AA. Malignant melanoma of the lacrimal drainage apparatus complicating conjunctival melanoma. Ophthal Plast Reconstr Surg. 2015;31:207–10.
18. Economides NG, Page RC. Metastatic melanoma of the lacrimal sac. Ann Plast Surg. 1985;15:244–6.
19. Wormald PJ, Ooi E, van Hasselt A, et al. Endoscopic removal of sinonasal inverted papilloma including endoscopic medial maxillectomy. Laryngoscope. 2003;113:867–73.
20. Low JR, Bian Ng S, Sundar G. Undifferentiated carcinoma of the lacrimal sac: case report and review of literature. Orbit. 2011;30:293–6.
21. El-Sawy T, Frank SJ, Hanna E, et al. Multidisciplinary management of lacrimal sac/nasolacrimal duct carcinomas. Ophtal Plast Reconstr Surg. 2013;29:454–7.
22. Alabiad CR, Weed DT, Walker TJ, et al. En bloc resection of lacrimal sac tumours and simultaneous orbital reconstruction: surgical and functional outcomes. Ophthal Plast Reconstr Surg. 2014;30:459–67.
23. Islam S, Thomas A, Eisenberg RL, et al. Surgical management of transitional cell carcinoma of the lacrimal sac: is it time for a new treatment algorithm? J Plast Reconstr Aesthet Surg. 2012;65:e33–6.

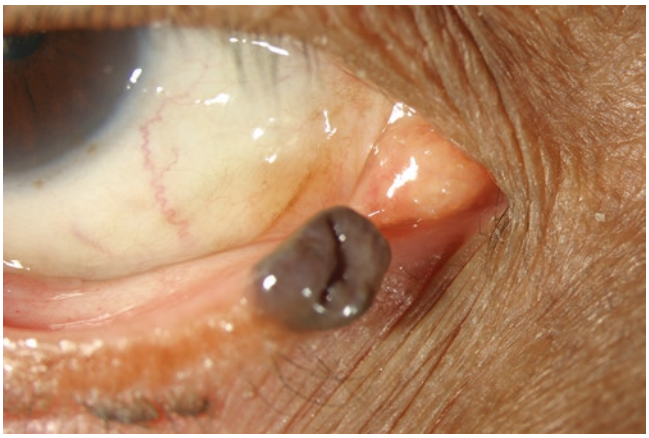


Fig. 38.1 Giant nevus of the right lower punctum

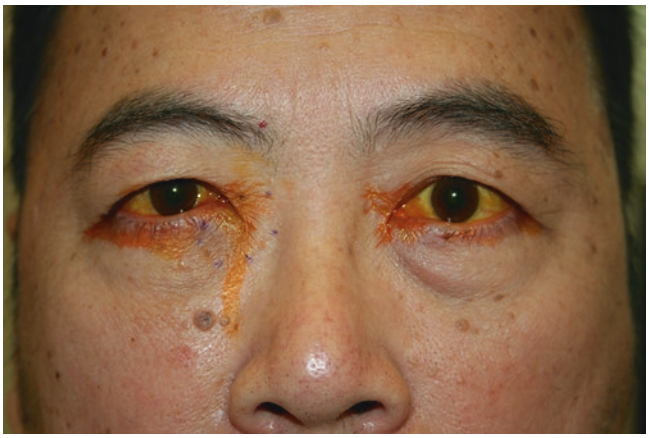


Fig. 38.3 Clinical photograph of a patient with a mass lesion in the medial canthal region. Also note the retained fluorescein dye disappearance test (FDDT)

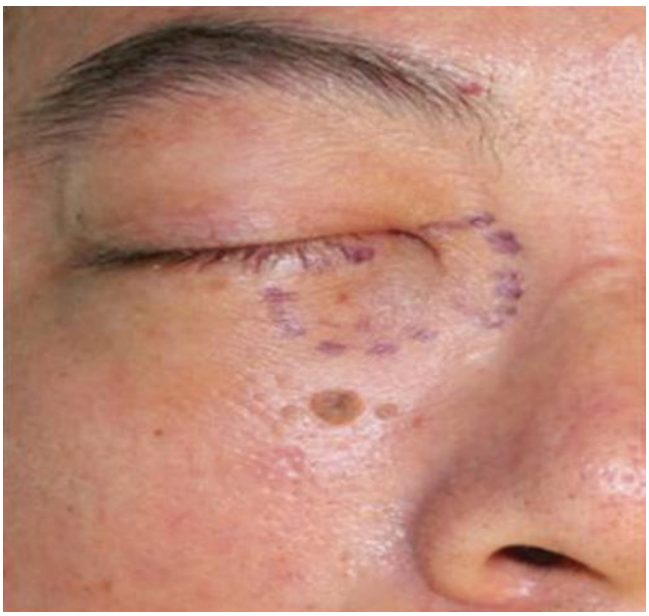


Fig. 38.2 Clinical photograph of a patient presenting with a palpable mass above and below the medial canthal tendon with epiphora

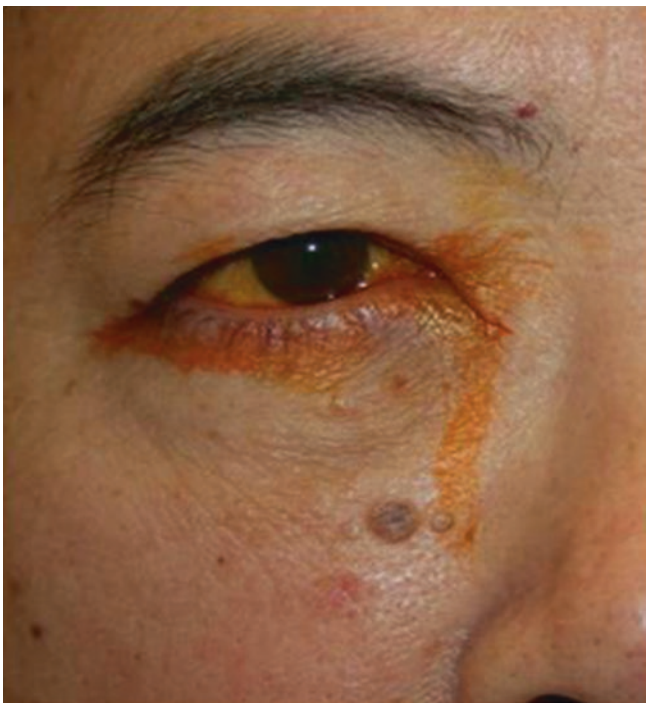


Fig. 38.4 A close-up photo of the patient in Fig. 38.3. One can better appreciate the subtle medial canthal fullness

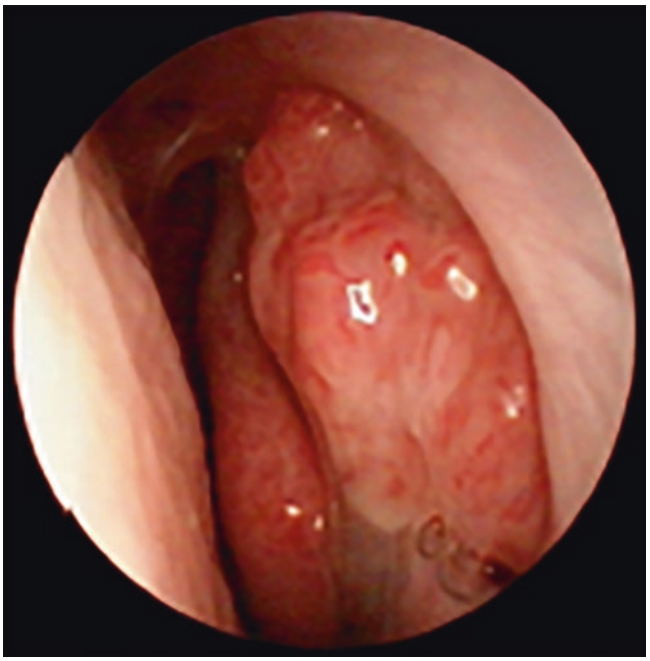


Fig. 38.5 Endoscopic view of the left nasal cavity showing a lacrimal sac fossa tumor

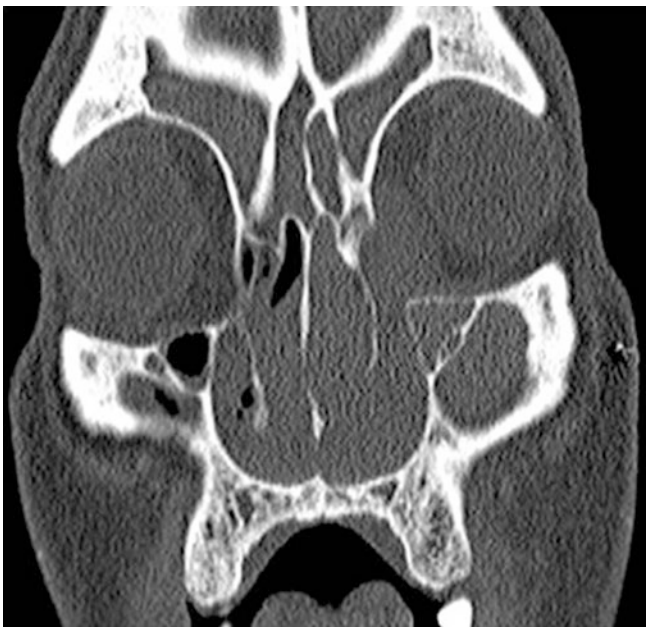


Fig. 38.7 Coronal CT (bone window) of the same patient clearly showing the bony destruction by the lacrimal sac tumor

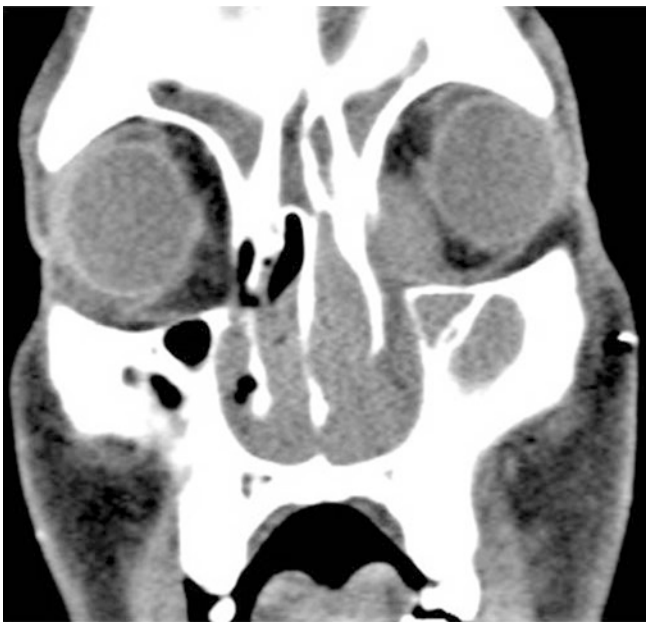


Fig. 38.6 Coronal CT showing lacrimal sac tumor (T cell lymphoma) with orbital and nasal/paranasal sinus extension crossing midline

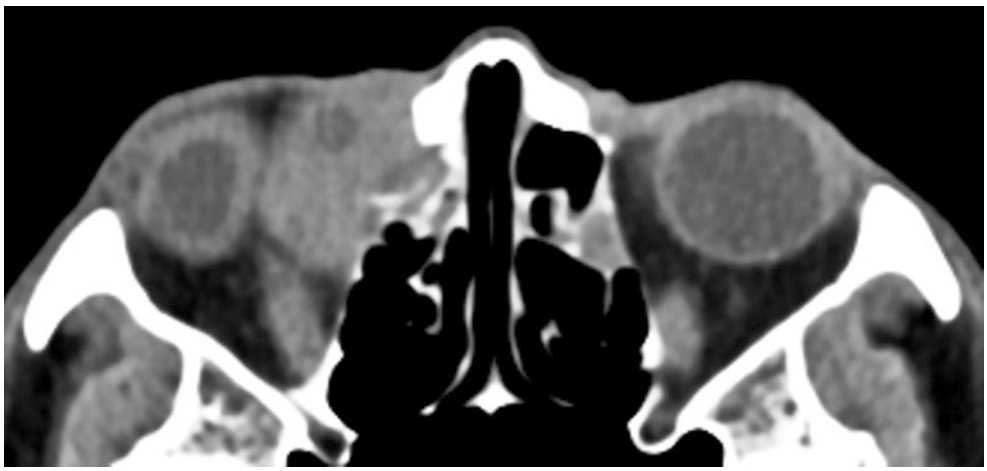


Fig. 38.8 Axial CT scan showing a right lacrimal sac malignant lesion in early stages

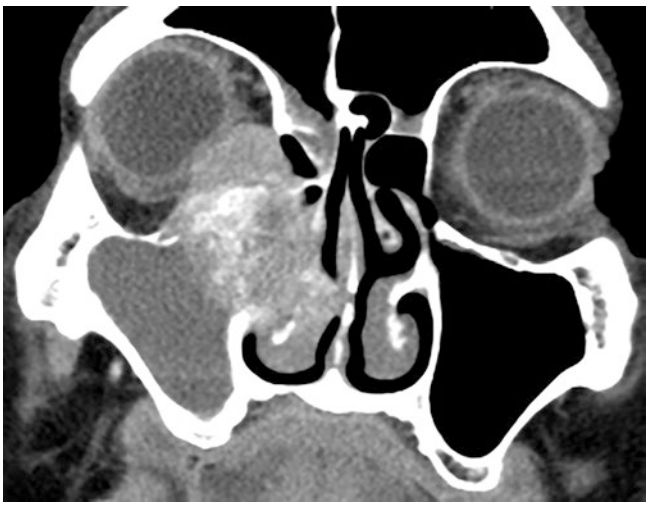


Fig. 38.9 Coronal CT scan showing a right lacrimal sac malignancy with bony destruction in the vicinity and extension into orbits and nasal cavity

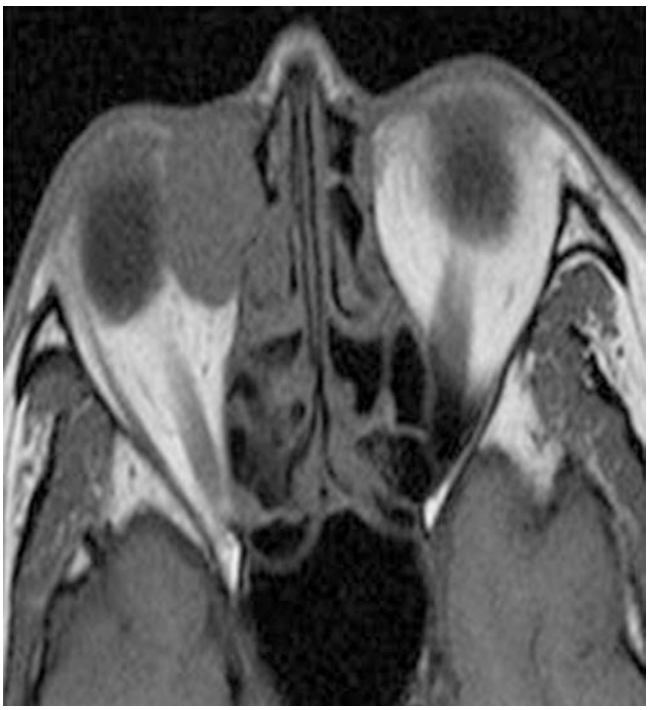


Fig. 38.10 MRI, T1-weighted, axial cut showing a lacrimal sac mass lesion abutting and displacing the globe. Note the lesion is hypointense on T1

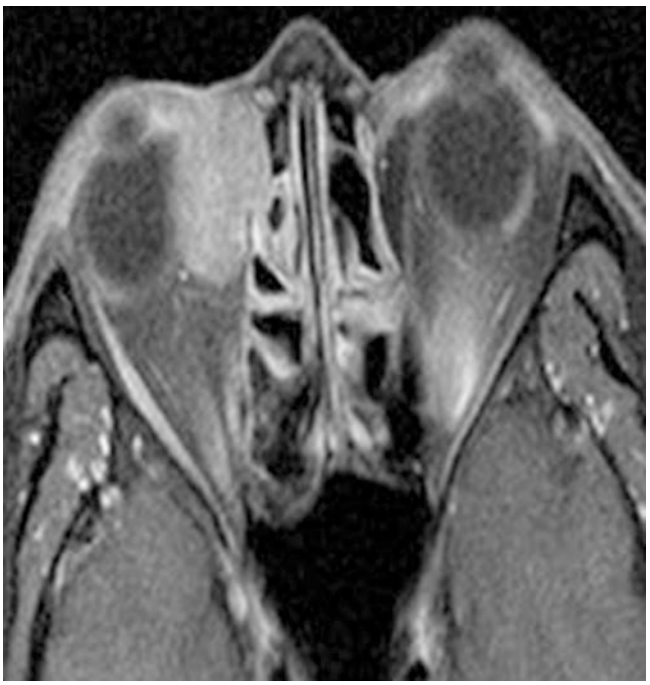


Fig. 38.11 MRI, T1-weighted, axial cut of the same patient in Fig. 38.10 shows enhancement with contrast. The mass was later proved histopathologically to be an undifferentiated carcinoma of the lacrimal sac

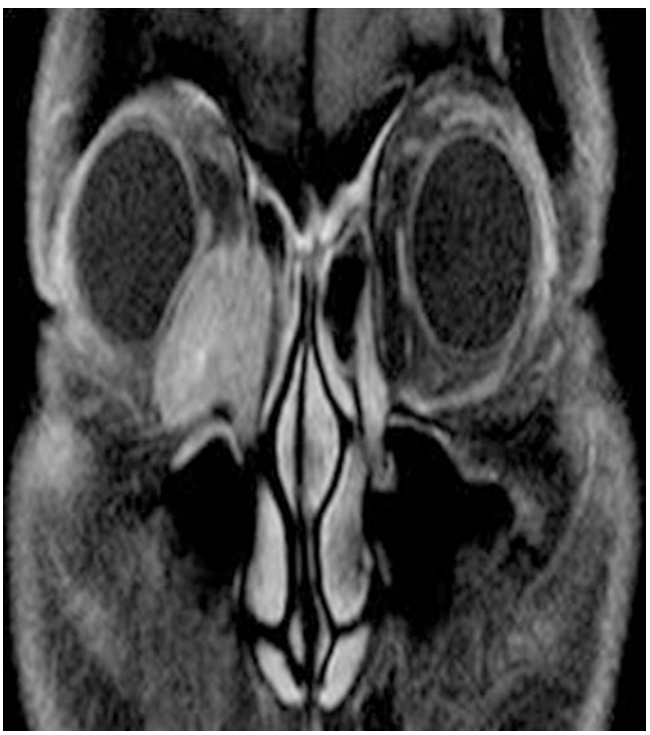


Fig. 38.12 MRI, T1-weighted, coronal cut showing a lacrimal sac mass indenting the globe and displacing it superolaterally. Note the lesion is hypointense on T1

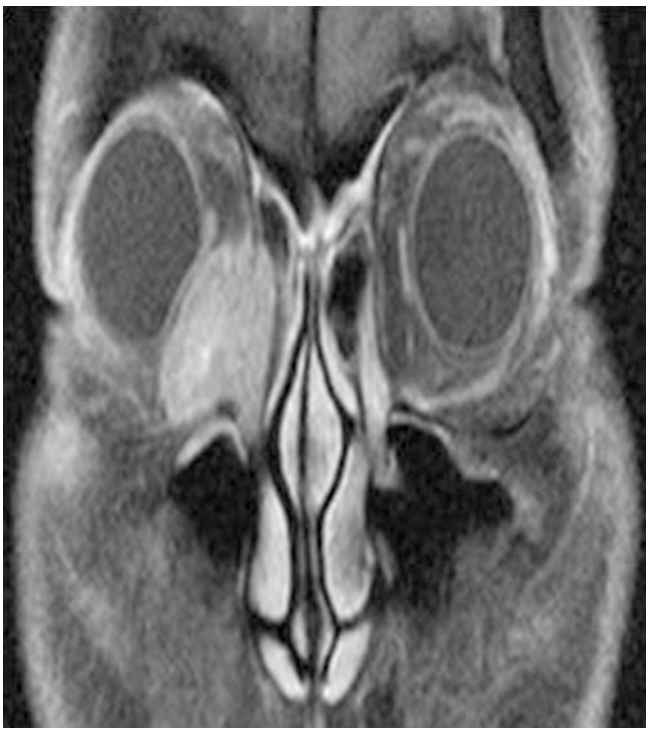


Fig. 38.13 MRI, T1-weighted, coronal cut of the same patient as in Fig. 38.12 showing uniform enhancement with contrast

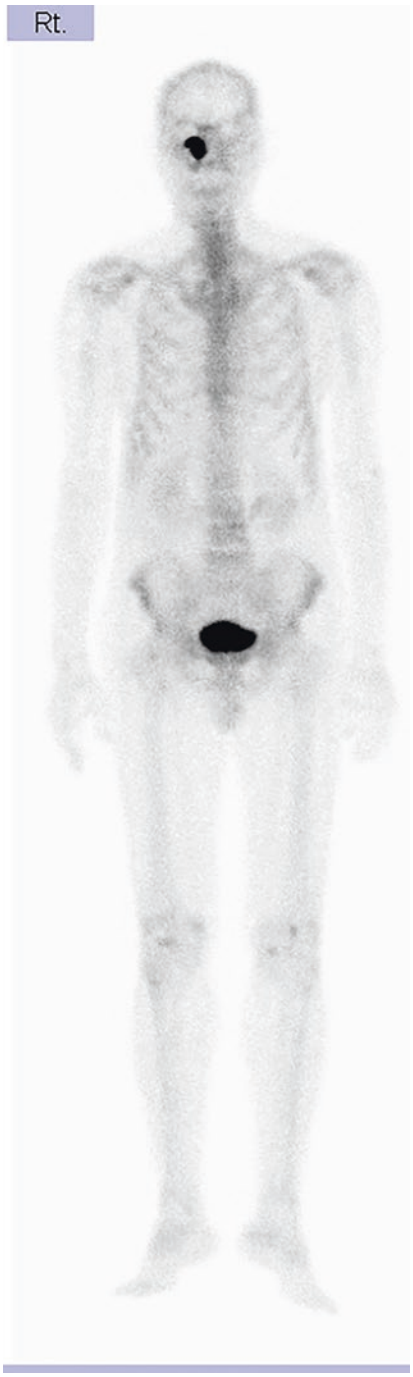


Fig. 38.14 PET-CT whole body for staging of the disease

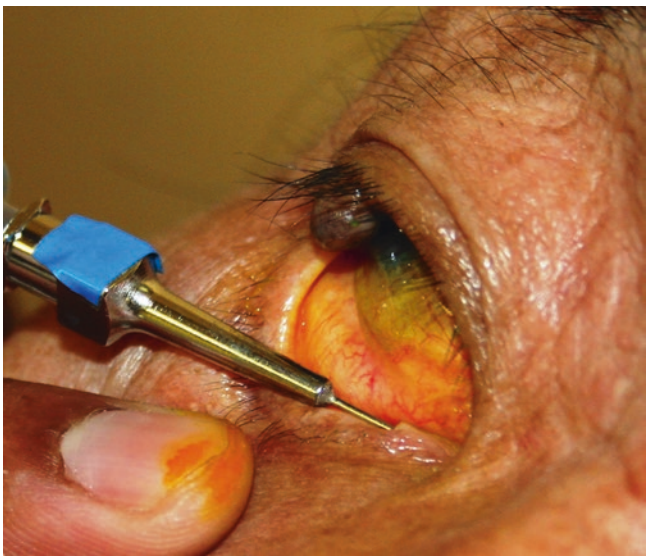


Fig. 38.15 Transcanalicular core needle biopsy

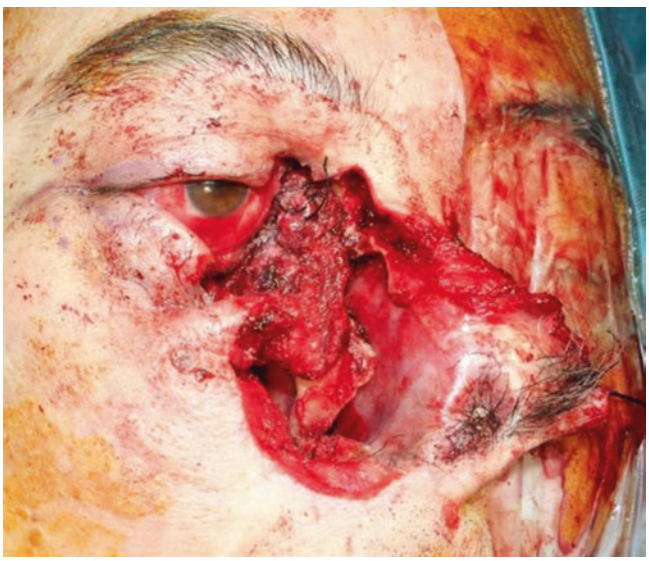


Fig. 38.16 Medial maxillectomy through a lateral rhinotomy approach showing desirable tumor exposure with good margins

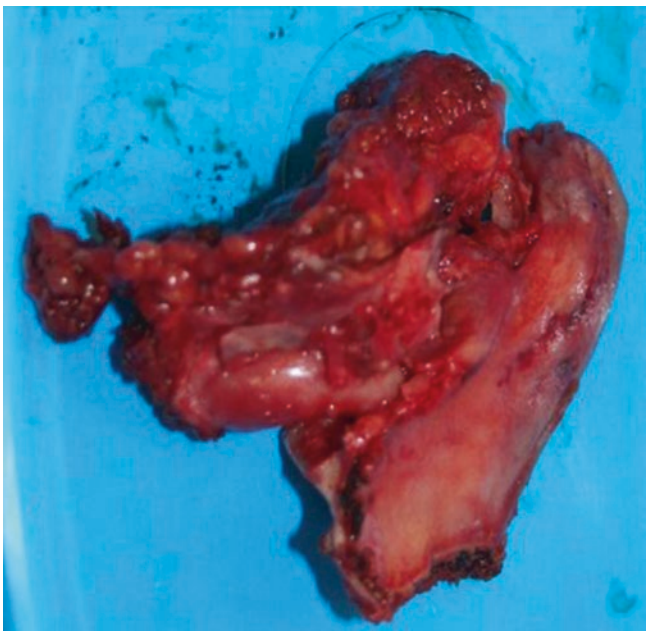


Fig. 38.17 The excised tumor specimen of the same patient as in Fig 38.16

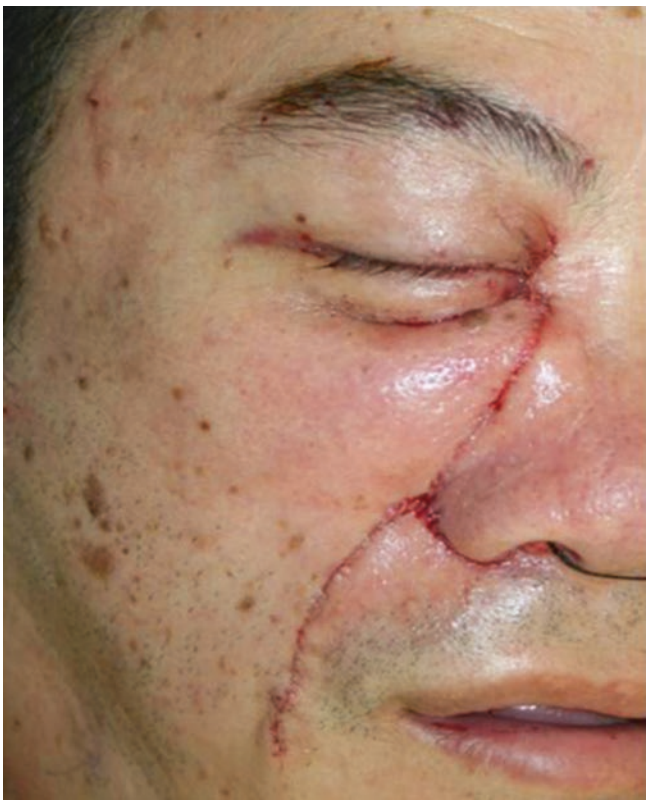


Fig. 38.18 Immediate post-reconstruction image of the same patient as in Fig 38.16

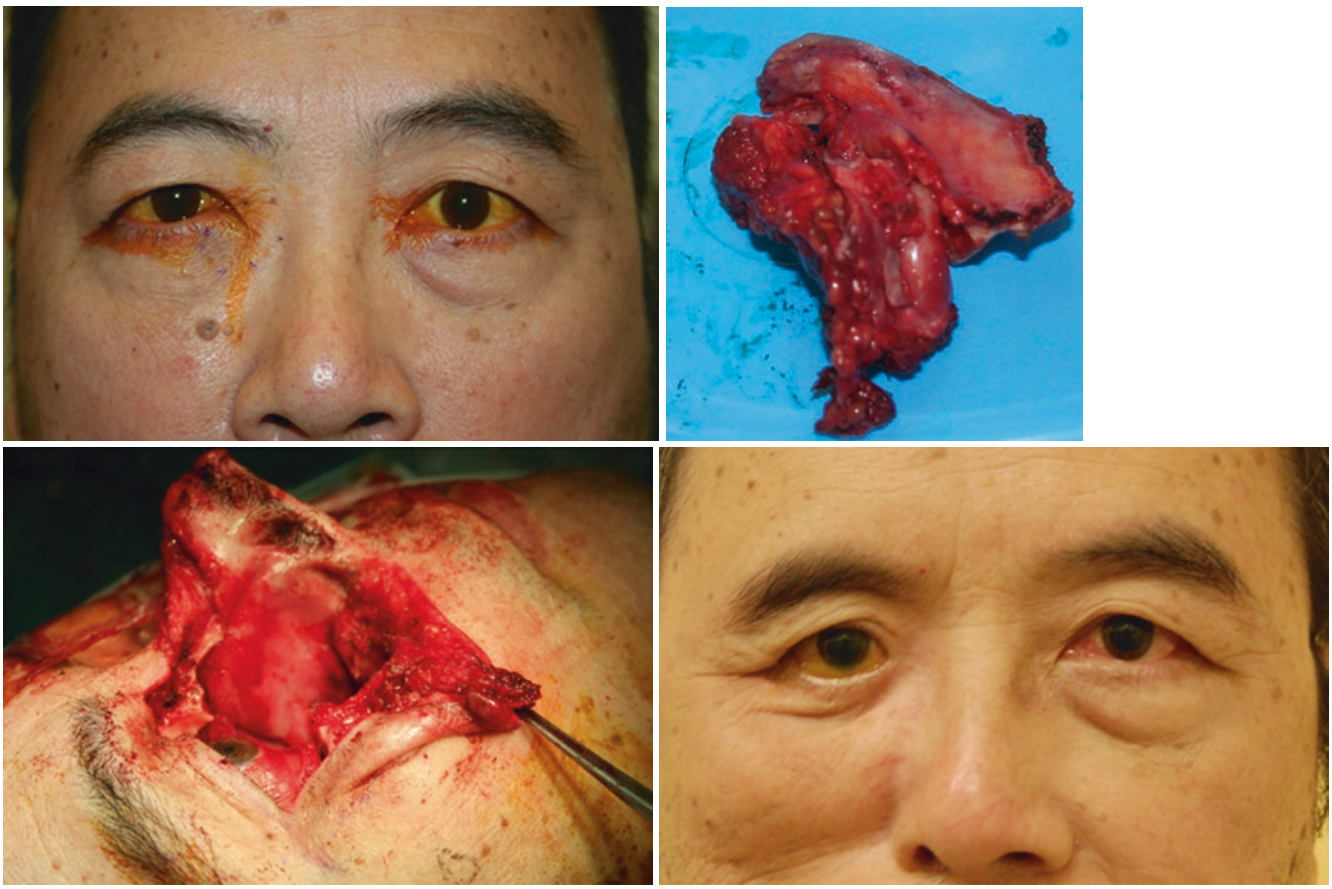


Fig. 38.19 A patient with a poorly differentiated carcinoma of the right lacrimal sac, preoperative, intraoperative and following reconstruction

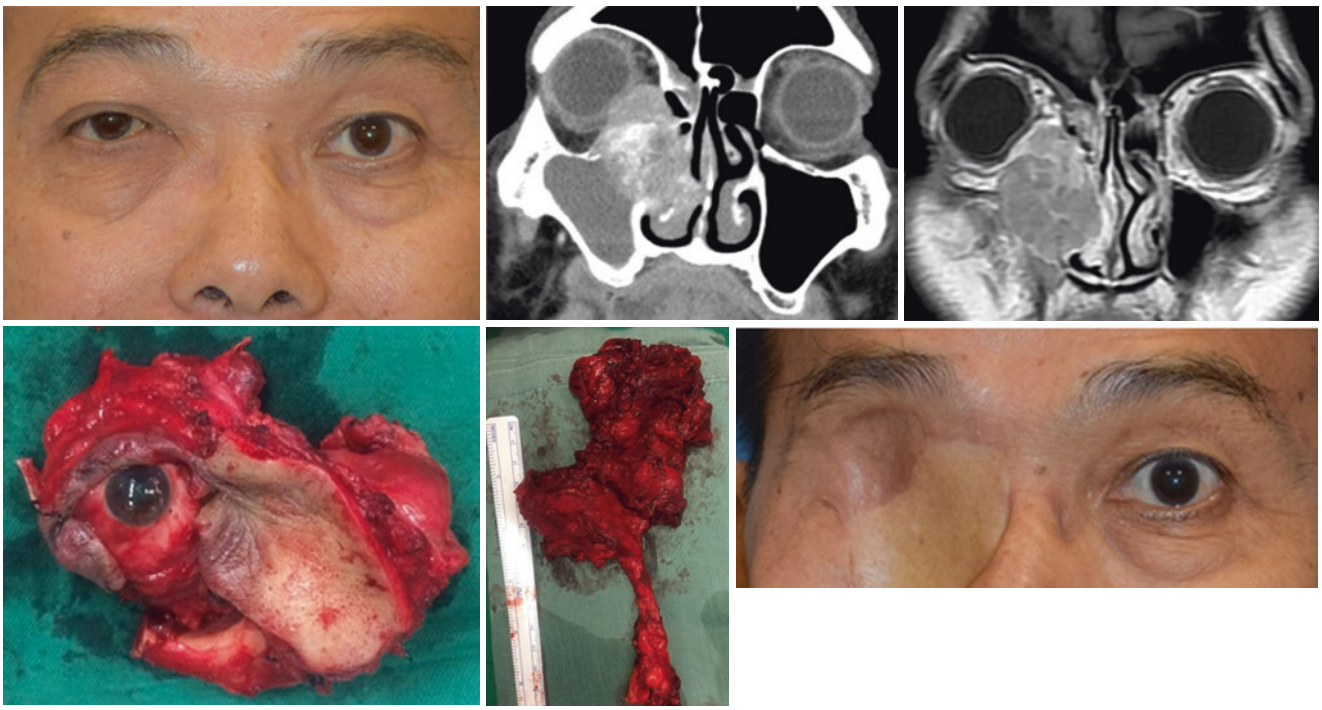


Fig. 38.20 Lacrimal sac carcinoma which underwent exenteration and regional lymph node dissection. Note the appearance following a reconstruction

Dacryocystectomy: Indications and Techniques

39

Mohammad Javed Ali

Introduction

Dacryocystectomy or DCT refers to a complete surgical extirpation of the lacrimal sac. It was first described by Thomas Woolhouse in 1724 and was the standard of care in its crude form, before the advent of dacryocystorhinostomy (DCR) for management of dacryocystitis and lacrimal fistulae [1]. Rudolph Berlin later popularized it in the nineteenth century [1]. Dacryocystectomy in its journey since then has unfortunately seen many ups and downs and suffered major humiliation in the 1920s wherein it was described by few authors as "an act of surgical despair; 'a useless and barbaric mutilation" and "a malpractice" [1]. We have come far away from those days and DCT is now considered an important part of the lacrimal surgeon's armamentarium. The usual approach in most of the cases is through a transcutaneous incision except in certain exceptional circumstances where endoscopic approach may be needed [2].

Goals

There are two clear goals of dacryocystectomy procedure. First is to have a clear plane of sac excision and avoid injury to periorbita and surrounding bones. Second is to have a complete excision of the sac along with the nasolacrimal duct without leaving any remnants behind. Since both these purposes are well served by an external route, it is the preferred approach.

Indications

1. Dacryocystectomy is one of the recognized surgical modalities for management of malignant lacrimal sac tumors [3–5]. This may have implications on life salvage, increased survival, or improvement of quality of life in such patients. Indications apart from this can be considered as relative indications and can be a subject of debate.
2. Recurrent dacryocystitis in patients with severe dry eyes [6, 7].
3. Dacryocystitis in patients with coexisting bleeding diathesis [6, 7].
4. Dacryocystitis in patients with predisposing conditions that cause nasal scarring like cicatricial pemphigoid, systemic lupus erythematosus, and Crohn's disease [6–8].
5. Rare cases of extensive Wegener's granulomatosis which requires nasal bones for future reconstructions [8].
6. Frail elderly patients with chronic dacryocystitis with cardiac or neurological comorbidities [6, 7, 9, 10].
7. Elderly patients with dacryocystitis with ocular comorbid conditions that require urgent attention like microbial keratitis, advance cataract, or lens-induced glaucoma, where epiphora is not a serious complaint [11]. The primary goal here is facilitation of visual rehabilitation.
8. Recurrent dacryocystitis in an elderly patient on beta-blockers where epiphora is not a serious complaint [10]. Serious systemic toxicity of beta-blockers is aggravated after DCR since there is direct absorption of drug from the nasal mucosa into systemic circulation, bypassing the hepatic metabolism.
9. Multiple times failed DCR in patients with dry eyes or recurrent dacryocystitis [6, 12].
10. Recurrent inflammation from the remnant of sac in a previously incomplete dacryocystectomy, specially if associated with comorbidities.
11. Recurrent chronic dacryocystitis with fibrotic sacs following severe trauma [13].

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_39

12. Severe atrophic rhinitis [13].
13. Lacrimal sac mucopyoceles with nasal malformations [13], congenital partial arrhinia, or nasal hypoplasia.

Advantages

Where indicated dacryocystectomy has advantages in terms of aiding complete extirpation of tumors, technically easier, less learning curve, quickly performed under local anesthesia, less invasive and does not violate nasal mucosa, minimal bleeding, no hospitalization, early recovery, and overall lesser morbidity [3–11].

Preoperative Requisites

1. Confirmation of the diagnosis of dacryocystitis with nasolacrimal duct obstruction
2. Imaging modalities like CT scan and MRI in cases where lacrimal sac tumors are suspected
3. Schirmer's test and others for establishing severe dry eyes if any
4. Good counseling about the objectives of surgery and persistence of epiphora postoperatively
5. Stable medical status
6. Bleeding and clotting profiles, if the patient is on anticoagulants
7. Fitness for anesthesia (LA/MAC vs GA)

Surgical Technique

Anesthesia

The surgery can be done under general anesthesia or local anesthesia. The latter is the most commonly employed modality. Local anesthesia is given by either infiltration or topical application. For infiltration, 2% lignocaine with 0.5% Bupivacaine with adrenaline (1: 200,000) is used, unless there is a medical contraindication for use of adrenaline. Infratrochlear nerve that supplies the lacrimal apparatus is blocked first. The nondominant hand marks the supraorbital notch, the needle is inserted into the lateral edge of the medial third of the eyebrow and advanced to just medial to medial canthus, and 1–2 cc of the drug is injected (Fig. 39.1). The tissue along the anterior lacrimal crest is infiltrated subcutaneously and the needle enters deeper at about 3 mm medial to medial canthus, and without withdrawing the needle, the drug is injected into deeper tissues up to periosteum both superiorly and inferiorly to block the nasociliary and anterior ethmoidal nerves (Fig. 39.2). Occasionally an infraorbital nerve block may be required in cases of wide excision (malignancies). A drop of topical proparacaine is placed in conjunctival cul de sac for intraoperative comfort.

Incision

Though various incisions have been described, the author prefers the commonly used curvilinear incision of about 10–12 mm in length, 3–4 mm from the medial canthus along the anterior lacrimal crest and along the relaxed skin tension lines (Fig. 39.3). However extension of this skin incision above the medial canthus can lead to scars and epicanthic folds. An alternate can be the use of a straight incision at the lateral surface of the nose, 8–10 mm from the medial canthus. In cases of malignant lacrimal sac tumors, the incisions may be much longer and at variable locations based on the size and adjacent spread of the lesion, for example, the Weber-Ferguson incision, if lateral rhinotomy is additionally planned. The ophthalmologist should follow a multidisciplinary approach as appropriate when managing lacrimal sac malignancies.

Sac Exposure

Blunt dissection is carried on to separate the subcutaneous tissues and orbicularis muscle and reach the periosteum (Fig. 39.4). A freer's elevator is used to separate the periosteum from the bone and reflect it laterally (Fig. 39.5). As the periosteum is being reflected laterally, the anterior limb of medial canthal tendon is noted attached to it just anterior to the anterior wall of the lacrimal sac (Fig. 39.6). Lacrimal fascia, which is contiguous with the periosteum, is adherent near the medial canthal tendon and hence reflection of the tendon aids in lacrimal sac dissection (Fig. 39.6). The tendon is cut at the suture of Notha and the medial wall of the sac is bluntly separated from the bones of the lacrimal fossa.

Sac Dissection

The lateral wall is separated with the help of Westcott scissors by separating it from the orbicularis oculi. The closed blades of the scissor are then directed downward between the lateral wall of the sac on one side and orbicularis and periorbita on the other. The common canaliculus needs to be severed from the sac during this step. To avoid perforation of sac as well as to detect inadvertent perforation intraoperatively, one can use fluorescein stained viscoelastics or methylene blue [6, 8]. The sac needs to be filled with either of these materials before the beginning of dissection. The superior wall and the posterior wall can be separated from the fascia with a Westcott scissor right up to the nasolacrimal duct (Fig. 39.7).

Sac Amputation

Once the sac is dissected all around and separated from its soft tissue attachments, the sac is amputated at its junction with the nasolacrimal duct (Fig. 39.8). In cases of lacrimal sac tumors, the amputation is carried at a point as far as possible toward the distal nasolacrimal duct. Occasionally, bony nasolacrimal duct along with a lateral rhinotomy or medial orbital wall excision is combined with dacryocystectomy, depending on the extent of malignancy.

Cautery

After the sac removal, the common internal canaliculus, nasolacrimal duct stump and any remnant sac lining, if any should be cauterized to prevent recurrences (Fig. 39.9). The canaliculi are cauterized separately using Ellman Surgitron needle (Ellman Int Inc., New York, USA) in a coagulation mode or with the help of a probe within the canaliculus. The punctum and the canaliculi show an immediate whitish discoloration following a successful cautery.

Wound Closure

Once hemostasis is achieved, the orbicularis is sutured back with 6-0 vicryl followed by skin closure with 6-0 prolene or vicryl or silk based on surgeon's preference.

Extended Dacryocystectomy

Extended dacryocystectomy refers to complete extirpation of lacrimal sac along with any of the surrounding structures like nasolacrimal duct, overlying lacrimal fossa bone, frontal process of maxilla, ethmoids, lateral nasal wall, anterior part of medial orbital wall, and surrounding soft tissues (Figs. 39.10, 39.11, 39.12, 39.13, and 39.14). Extended dacryocystectomy is indicated in lacrimal sac tumors and the extent of tumor infiltration into surrounding structures determines the extent of the surgery [3–5].

Endoscopic Dacryocystectomy

Shams et al. [2] described a bilateral endoscopic dacryocystectomy as an alternative in an elderly patient suffering from chronic dacryocystitis without symptomatic epiphora, where an external incision was undesirable in view of past history of wound infections secondary to picking. This indication can be extended in any case where the mental state of the patient may be a restrictive factor in maintenance of a healthy external wound. The technique is initially just like a routine endoscopic DCR, where after raising the mucosal flaps, the osteotomy is performed to expose the lacrimal sac completely. The sac can then be removed completely in one go or piecemeal by incising the sac and removing anterior and posterior walls separately. The common canalicular opening and the remnant nasolacrimal ducts can be cauterized just like in an external dacryocystectomy. Although endoscopic approach entails bone removal, we believe that a few exceptional circumstances may warrant its need.

Tips for Hemostasis

Although profuse bleeding is rarely expected in a dacryocystectomy, the profile of the patient (bleeding diathesis, anticoagulant therapy) and etiology (tumors) can sometimes influence the need for a preoperative assessment and intraoperative management of hemorrhage. The following can be useful tips in such patients.

1. Good preoperative assessment to rule out bleeding diathesis or anticoagulant use.
2. Preoperative blood pressure assessment.
3. Raising the head end of the table when needed.
4. Avoid known blood vessels.
5. Good illumination and a well powered suction.
6. Judicious use of cautery.
7. Keep materials like gel foam or bone wax in the armamentarium.

Postoperative Measures and Follow-Up

Once wound is closed, reassure the patient that the surgery went fine. The wound can be patched. The patient is started on topical antibiotics and oral analgesics.

On the first day after surgery, the patch, if any, is gently removed, and wounds are dressed with povidone iodine 5% or other similar drugs based on surgeon's preference along with topical antibiotics and oral analgesics. Extended dacryocystectomy may warrant prophylactic oral antibiotics. Patients who underwent endoscopic dacryocystectomy may need additional nasal decongestants based on surgeon's preference. One week postoperatively, the sutures are removed, and medications discontinued. Further follow-ups are tailored according to the indication for which a dacryocystectomy was performed.

Histopathology

All samples of lacrimal sac should be examined grossly (Fig. 39.15) to look for any unusual features like any mass, unusual discoloration, diverticulas, and partly missing walls

before sending for a histopathological analysis. In case of lacrimal sac tumors, the margins of the extended dacryocystectomy are studied separately to comment on tumor infiltration and this has significant bearing on further treatment. Lacrimal sacs removed for non-tumor indications are also important since a lot of information on chronic inflammatory changes and specific granulomatous disorders that may have been undetected preoperatively can be studied and the information utilized for further management [4, 6]. Recently there has also been a lot of interest to look into lacrimal drainage-associated lymphoid tissues and its derangements in chronic dacryocystitis [14].

Complications

Complications following a dacryocystectomy are rare. Inadvertent injury to the angular vein may cause profuse bleeding. This can easily be avoided if incisions are not on the site or very close to the vicinity of angular vein. Other complications include wound dehiscence, wound infection, increased tear meniscus and epiphora, recurrent dacyrocystitis secondary to remnant sac, and a prominent facial scar.

Although very rare, two cases of retrobulbar hematomas causing visual loss and one case of orbital cellulitis following a dacryocystectomy have been reported [1, 11]. The possible cause could be violation of periorbita and orbital septum during the surgery, which may result in orbital hemorrhage and hematoma and consequent optic nerve compression and visual loss. In the eventuality of a vision-threatening hematoma, standard protocols for managing a retrobulbar hemorrhage should be followed.

Lacrimal Rehabilitation

Numerous options have been described in the literature for managing epiphora following a dacryocystectomy. The most commonly practiced option is a conjunctivo-dacryocystorhinostomy (CDCR) using either the Jones tubes or Gladstone-Putterman tubes (Fig. 39.16) [15]. A canaliculo-dacryocystorhinostomy has been described in cases where the entire canaliculi are normal with absence of sac following a dacryocystectomy.[16.] Occasional cases where a remnant sac is suspected, a regular dacryocystorhinostomy has been described [16]. Botulinum toxin injection into the lacrimal gland to manage epiphora following a dacryocystectomy is still not a well-established or widely practiced procedure.

Conclusion

In conclusion, although dacryocystectomy is a sparingly used lacrimal surgery, it has its own specific and relative indications. Extended dacryocystectomy is a very useful and life-saving surgery in lacrimal sac tumors. It also appears to make sense to perform a dacyrocystectomy on recurrent dacryocystitis in patients with dry eye or certain systemic comorbidities. The surgery is technically easier with a quick learning curve and should be taught to ophthalmology residents and oculoplastics fellows.

References

1. Duke-Elder S, MacFaul PA. The ocular adnexa. In: Duke-Elder S, editor. System of ophthalmology, volume 13, part II. London: Henry Kimpton; 1974. p. 715–8.
2. Shams PN, Selva D. An endoscopic endonasal approach to dacryocystectomy. Orbit. 2013;32:134–6.
3. Heindl LM, Junemann AGM, Kruse FE, Holbach LM. Tumors of the lacrimal drainage system. Orbit. 2010;29:298–306.
4. Pujari A, Ali MJ, Mulay K, Naik MN, et al. The black lacrimal sac: a clinicopathological correlation of a malignant melanoma with anterior lacrimal crest infiltration. Int Ophthalmol. 2014;34:111–5.
5. Low JR, Ng SB, Sundar G. Undifferentiated carcinoma of the lacrimal sac: case report and review of literature. Orbit. 2011;30:293–6.
6. Mauriello JA, Vadehra VK. Dacryocystectomy: surgical indications and results in 25 patients. Ophthal Plast Reconstr Surg. 1997;13:216–20.
7. VasilakisM,BrouzasD,CharakidasA,etal.Dacyrocystosclerotherapy. Ophthal Plast Reconstr Surg. 2001;17:111–4.
8. Baddeley PA, Lewis GD, Lane CM. A novel technique to facilitate dacryocystectomy using viscoelastic substances. Orbit. 2011;30:158–9.
9. Cook HL, Olver JM. Dacryocystectomy as a treatment of chronic dacryocystitis in a frail, elderly patient. Eye. 2004;18:334–6.
10. Detorakis ET, Tsilimbaris MK. Dacryocystectomy for the treatment of nasolacrimal duct obstruction in elderly patients treated with beta-blockers. Ophthal Plast Reconstr Surg. 2009;25:417.
11. Pai VH, Rao KA, Bhandary SV. Visual loss following dacryocystectomy. Ophthalmic Surg Lasers Imaging. 2006;37:494–6.
12. Boynton JR, Anawis MA. Role of dacryocystectomy in the management of failed dacyrocystorhinostomy associated with chronic dacryocystitis. Ophthalmic Surg Lasers. 1996;27:133–6.
13. Matayoshi S, Baak AV, Cozac A, et al. Dacryocystectomy: indications and results. Orbit. 2004;23:169–73.
14. Ali MJ, Mulay K, Pujari A, Naik MN. Derangements of lacrimal drainage associated lymphoid tissue (LDALT) in human chronic dacryocystitis. Ocul Immunol Inflamm. 2013;21:417–23.
15. Ali MJ, Honavar SG, Naik MN. Endoscopically guided minimally invasive bypass tube intubation without DCR: evaluation of drainage and objective outcomes assessment. Minim Invasive Ther Allied Technol. 2013;22:104–9.
16. Saxena RC. Anastomotic surgery after the operation of dacryocystectomy. Indian J Ophthalmol. 1975;23:16–9.

Fig. 39.1 Local infiltration anesthesia

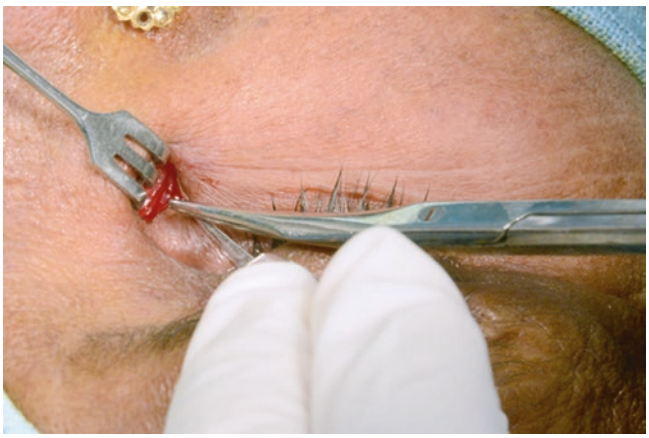


Fig. 39.4 Dissection to reach the periosteum

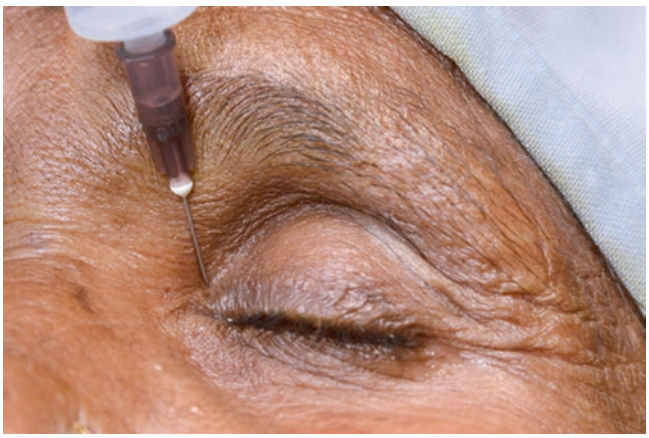


Fig. 39.2 Anterior ethmoidal nerve block

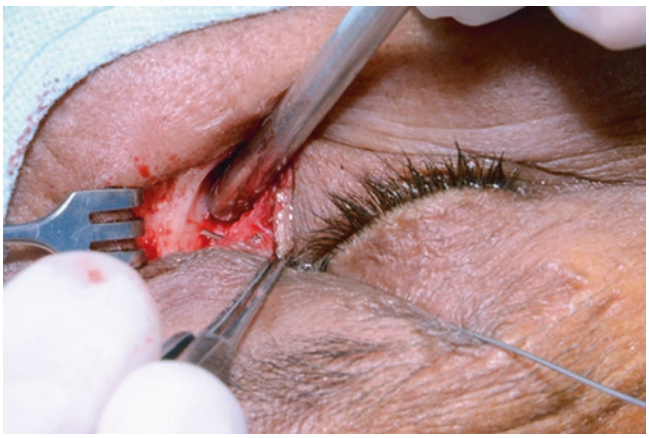


Fig. 39.5 Lateral reflection of sac from lacrimal fossa

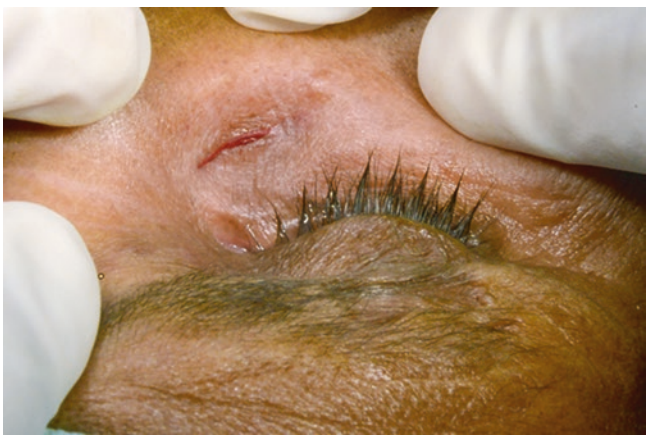


Fig. 39.3 Curvilinear incision

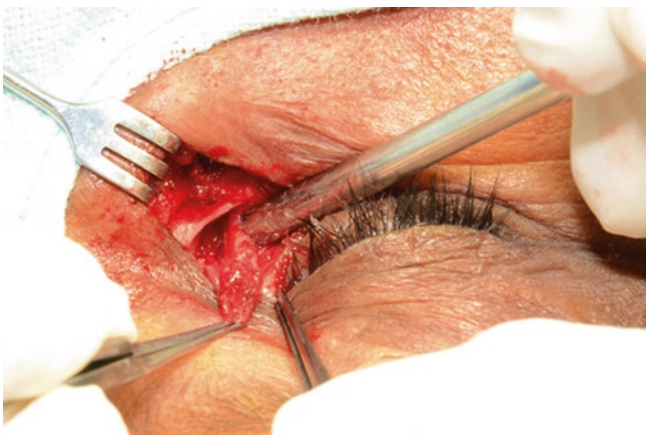


Fig. 39.6 Exposing the medial canthal attachments

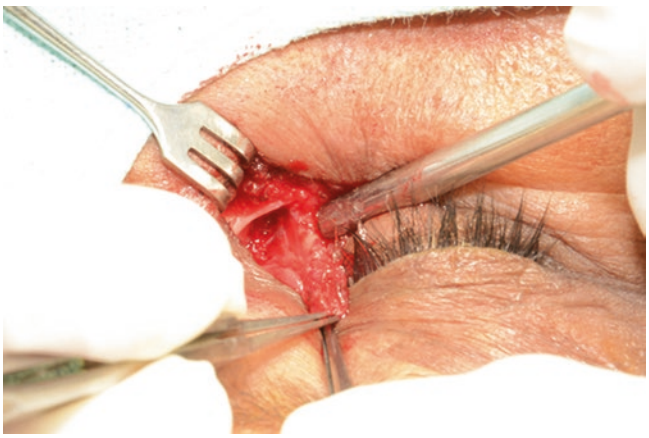


Fig. 39.7 Complete dissection of sac up to nasolacrimal duct

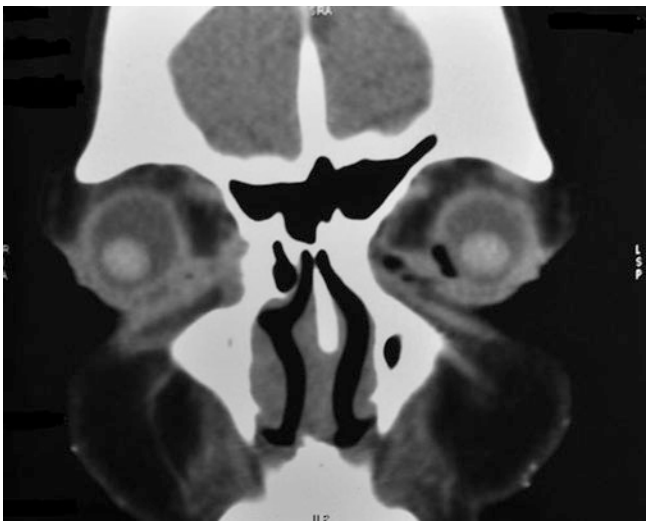


Fig. 39.10 Coronal CT of a lacrimal sac malignancy with lacrimal crest involvement

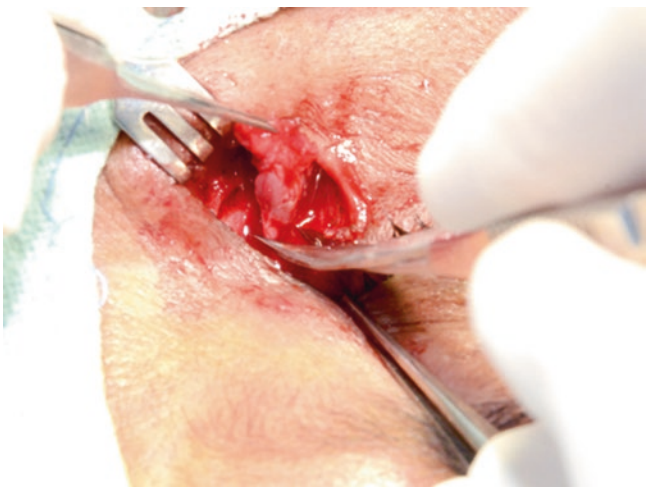


Fig. 39.8 Lacrimal sac amputation

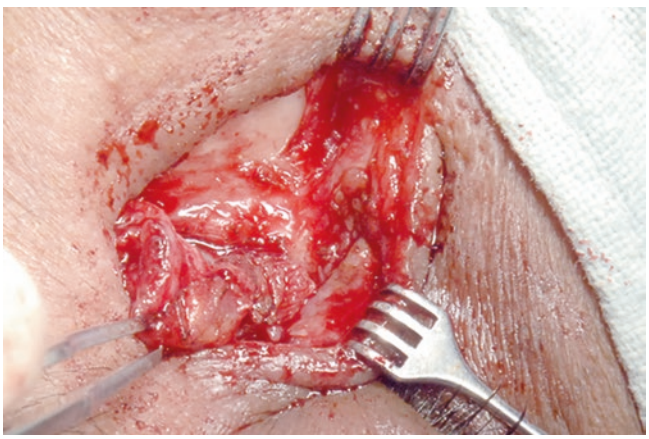


Fig. 39.11 Extended dacryocystectomy showing wide soft tissue margins

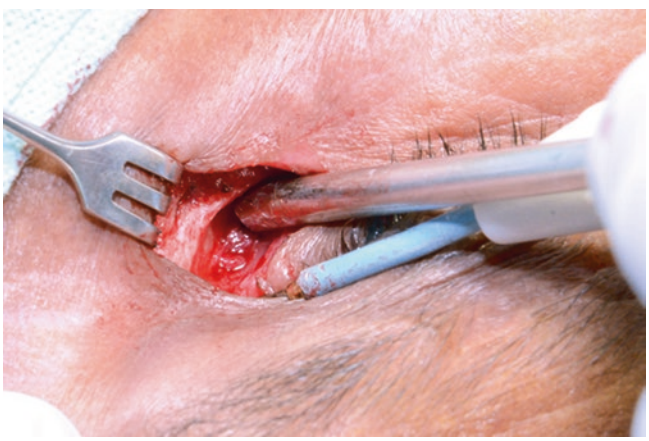


Fig. 39.9 Cautery to secure hemostasis

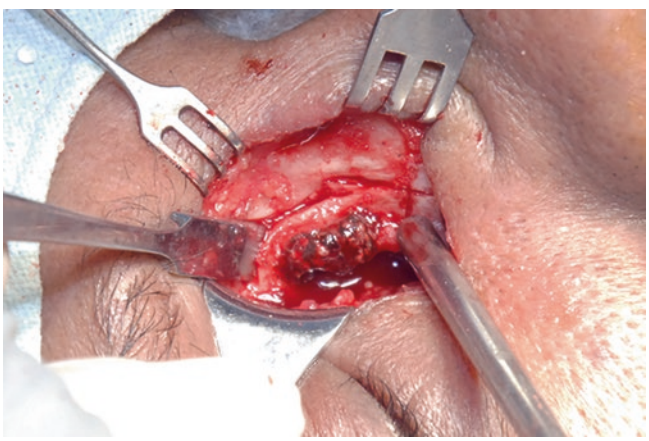


Fig. 39.12 Margins for the bony osteotomy around the tumor infiltration

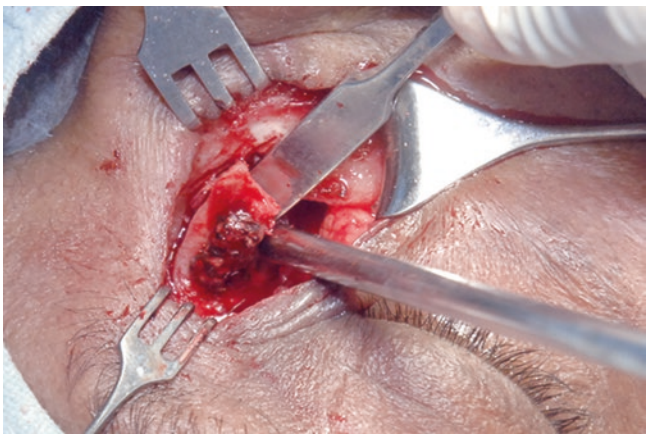


Fig. 39.13 Osteotomy completed

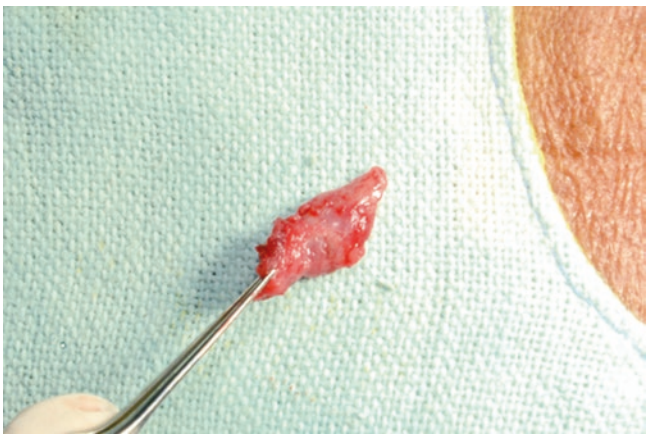


Fig. 39.15 Lacrimal sac for histopathological examination

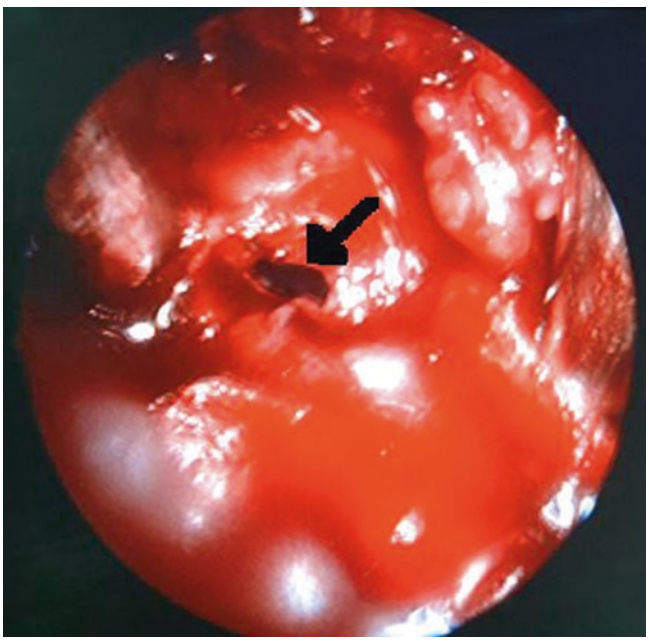


Fig. 39.14 Endoscopic view of the removed nasolacrimal duct till the opening in inferior meatus (*black arrow*)

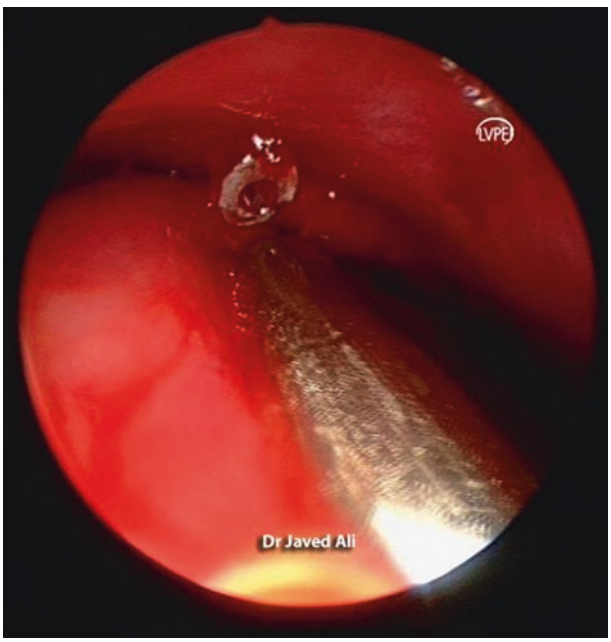


Fig. 39.16 Endoscopic CDCR

Botulinum Toxin in Refractory Epiphora

40

Pelin Kaynak and Mohammad Javed Ali

Introduction

The lacrimal gland is innervated by the cholinergic fibers of the seventh cranial nerve. Injection of botulinum toxin A (BTA) in the lacrimal gland is hypothesized to decrease the tear production by blocking presynaptic release of acetylcholine into neuromuscular end plates of cholinergic nerve fibers [1]. Therefore, injection of BTA into the lacrimal gland can be an alternative treatment for epiphora due to severe gustatory hyperlacrimation, unsalvageable proximal lacrimal drainage system obstructions, and refractory functional epiphora. Studies about the use of BTA injection in the lacrimal gland for the treatment of gustatory hyperlacrimation [2–13], and functional epiphora [14] have been published in the literature. Results of BTA injections in patients with epiphora owing to obstruction of proximal lacrimal apparatus have been also reported [13, 15, 16]. Encouraging results have been presented when the efficacy of BTA injection into the lacrimal gland was compared with conjunctivodacryocystorhinostomy (CDCR) in treatment of epiphora for complete proximal lacrimal drainage obstructions [17]. This chapter will discuss BTA properties, mechanism of action, and injection techniques into the lacrimal gland and complications.

Botulinum Neurotoxin

Botulinum toxin is the poisonous exotoxin of *Clostridium*. The bacterium *Clostridium botulinum* produces eight antigenically distinct exotoxins. Serologic types include A, B, C, D, E, F, and G. Type E is also produced by *C. butyricum*. Type F is produced by *Clostridium baratii* [18]. Type A, B, and E botulinum toxins are colorless, odorless, and tasteless. Only these three types of toxins affect humans and can cause systemic botulism. Type A is the most potent toxin, followed by types B and F. Each botulinum toxin is synthesized as a single-chain protein, which is inactive until it is cleaved by bacterial proteases into its active form. The active botulinum toxins are composed of two chains: one heavy chain joined to a light chain by a relatively weak disulfide bond, which contributes to the instability of the molecule. The toxin is inactivated by heat and multiple environmental factors [18, 19].

Mechanism of Action

Botulinum toxin blocks the release of acetylcholine from its vesicles at the presynaptic nerve terminal. It also inhibits release of acetylcholine at the autonomic ganglia, postganglionic parasympathetic, and sympathetic nerve endings. The different serotypes bind to different sites on the motor neuron terminal. The heavy chain functions both as a channel and a companion to bring the light chain across the endosomal membrane and then into the cytosol in the presynaptic region. The light chain then acts inside the cell on synaptosomal-associated protein receptor proteins (SNARE) to block the release of the vesicle-bound neurotransmitter acetylcholine from nicotinic and muscarinic nerve endings. Muscle weakness does not become evident immediately but takes 2–4 days, due to the continued release of acetylcholine from vesicles that have not been blocked by the toxin. Recovery of muscle activity typically begins 3–4 months after injection and is thought to occur due to the regeneration of new end plate units [19].

Commercial Preparations

Doses of all commercially available forms of botulinum toxin are expressed in terms of units (mouse units). The standard measurement of the potency of the toxin is one interna-

P. Kaynak, M.D. (✉)
Ophthalmic Plastics Surgery, Beyoglu Eye Research and Training Hospital, Istanbul, Turkey
e-mail: pkaynak@gmail.com

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_40

tional unit (IU), which is the amount of toxin that kills 50% of a group of 18–20 female Swiss-Webster mice (LD50) when injected intraperitoneally. The LD50 in humans is estimated to be approximately 2730 IU [18, 20, 21].

Ona-botulinum toxin A, commercially available as BOTOX® and BOTOX® Cosmetic (Allergan plc (NYSE: AGN, Dublin, Ireland), is a dry, protein crystalline complex of botulinum toxin A which contains 50 or 100 units per bottle. Abo-botulinum toxin A, commonly marketed as Dysport® (Ipsen, Slough, UK), and Inco-botulinum toxin A as Xeomin® (Merz Pharma GmbH & Co. KGaA, Germany).

The onset of effect takes 24–48 h and maximum effect is achieved at 7–10 days. The effect usually lasts 4–6 months. Repeated injections may delay the onset, but sometimes a more protracted effect may occur.

Botulinum toxin B has a faster onset of action, better diffusion into tissues, and prolong action as compared to BTA; however, they have not been used for lacrimal gland injections, mainly due to the evidence of inflammatory response in animal models and also because its potency is less that BTA [19, 20].

Reconstitution and Storage

Botulinum toxin A is recommended to be reconstituted with sterile non-preserved 0.9% NaCl solution before injection and must be kept at 4 °C until injection. It has to be injected within 4 h after reconstitution for maximum activity. The weak disulfide bonds between the two chains of the toxin render it fragile under mechanical stress such as frothing when diluting and agitating the liquid inside the vial. BTA is used for lacrimal glandular injections.

Table 40.1 shows the approximate botulinum toxin A concentration with various volumes of diluent used for two most commonly used commercial forms: Botox® and Dysport® [18–23].

The concentration of the botulinum toxin depends on the amount of diluent in the vial which can be determined by the physician. The usual concentrations used for lacrimal gland are 1.25–2.5 units/0.1 ml.

Table 40.1 Botulinum toxin A concentration with various volumes of diluent

0.9% NaCl added (ml)	Botox® dose (U/0.1 ml)	Dysport® dose (U/0.1 ml)
1	10	50
2	5	25
4	2.5	12.5
8	1.25	6.25
10	1	5

Warning and Contraindications

It is important to note that the use of BTA for refractory epiphora is not yet FDA approved. Hence, it would be wise to point out that this is an off-label use of botulinum neurotoxin, and adequate prior informed consent is necessary. Pregnancy and lactation, neuromuscular junction disorders (*Myasthenia gravis*), peripheral motor neuropathies, active infections, and hypersensitivity to any of the contents are well-known contraindications for use of botulinum toxin.

Rationale for Its Use in Epiphora

Botulinum neurotoxin has been used to control hypersecretion from glands supplied by cholinergic neurons in the head and neck area [23]. Since the lacrimal gland is innervated by the cholinergic fibers of the facial nerve, injection of botulinum toxin A (BTA) in the lacrimal gland decreases tear production by blocking presynaptic release of acetylcholine into neuromuscular end plates of cholinergic nerve fibers [1]. Therefore, injection of BTA in the lacrimal gland has been investigated as an alternative symptomatic treatment to stop epiphora temporarily, in gustatory hyperlacrimation and in anatomic and functional lacrimal drainage blockage.

In 1998, Borojerdi and colleagues injected botulinum neurotoxin into the lacrimal gland to treat hyperlacrimation in two patients and into the orbital portion of the orbicularis oculi muscle in ten patients with abnormal facial movements post facial palsy. Two patients who received injections into the lacrimal gland had complete recovery of the epiphora, whereas half of those who received orbicularis oculi muscle injections had shown reduced lacrimation [2]. Eleven peer-reviewed articles followed since 1999, where botulinum neurotoxin injections into the lacrimal gland either had a temporary yet complete relief or decreased epiphora [3–13].

Whittaker et al. [14] showed decrease in epiphora in 14 patients with functional lacrimal outflow obstructions with anatomical patency of the drainage apparatus. BTA injections in patients with epiphora owing to anatomical obstructions of lacrimal apparatus have also been reported [13, 15–17].

Injection Technique and Dose

Purified BTA injection in the lacrimal gland can be easily performed under topical anesthesia with proparacaine 0.5%. It is preferable to get high concentration in small volume to minimize the spread of neurotoxin to the vicinity of the injection site.

The upper eyelid is retracted with a finger, and the patient can be asked to look extreme inferomedially to expose the palpebral lobe of the lacrimal gland. Alternatively, the eyelid

can also be everted with a Desmarres retractor. Although both transcutaneous and transconjunctival approaches can be used, the authors prefer the latter. The reasons being direct visualization of the gland and also the chance of spread into surrounding tissues is less. BTA is injected into the lacrimal gland, as seen in Figs. 40.1, 40.2, and 40.3. Tuberculin syringes with 27–30-gauge needles are preferred which allow more painless and accurate injections into the gland with relatively low risk of bleeding. The dose of the drug injected can vary from 1.25 U/o.1 ml–5 U/0.1 ml. The authors of this chapter prefer to start from 2.5 units and escalate if needed based on the response. Kaynak et al. have shown that a dose of 4 U/o.1 ml was effective in 70% of the patients at 15th post-injection day, with no epiphora or a grade 1–2 Munk score [17]. The patients who do not respond at the second week can be injected a second dose of botulinum neurotoxin before labeling them as non-responsive.

Post-injection Assessment

Assessment is preferably performed at 1 week and 1, 3, and 6 months post-injection. Apart from subjective measures like the Munk scoring, Schirmer tests must be done prior to BTA injections since the tear production was reported to significantly decrease in majority of the studies and can potentially lead to dry eyes. Other measures like tear meniscus assessment can provide finer objective outcomes with BTA.

Outcomes and Complications

Since 1998, a total of 51 patients with gustatory hyperlacrimation (or crocodile tear syndrome) have been treated with BTA injections into the lacrimal gland [2–13]. All of these studies reported complete or near-complete resolution of aberrant tearing within 1–2 weeks of treatment. Only infrequent and reversible complications such as ptosis, lagophthalmos, diplopia, conjunctivitis, and dry eye were observed.

A study by Nava-Castaneda et al. [10] reveals that a 2.5-U BTA injection into the palpebral lobe of the lacrimal gland diminishes epiphora due to gustatory hyperlacrimation from the first week and may last up to week 24. Baranano and Miller [8] reported a patient with gustatory lacrimation who has been successfully managed for 3 years with injections of BTA every 8–11 months, suggesting that multiple injections continue to impact epiphora.

BTA has also been used to minimize symptomatic tearing in patients with lacrimal obstruction [13, 15, 16] and functional tearing [14]. Wojno [13] has published that 63% of patients with lacrimal outflow obstructions, mostly or completely improved with 2.5 units of BTA. This outcome has improved to 71% with an additional 2.5 units of BTA to those with less than maximal improvement. Underlying pathologies in these patients has not been elaborated. Ziahosseini et al. [15] have injected BTA into the lacrimal glands of 22 eyes of 17 patients of troublesome epiphora with a mean age of 70.3 years. Etiologies included canalicular obstructions, nasolacrimal duct (NLD) obstructions and epiphora after punctal cautery. In their symptoms 60% had improvement and a significant improvement in Munk scores effective for 10 weeks. Because advanced age, frailty, and coexisting morbidities often make attending clinics difficult for elderly patients, BTA was suggested as a useful alternative to surgery in this group of patients. The patients who were initially given doses more than 2.5 units with no complications had subsequently achieved similar improvement with 2.5 unit injections, suggesting that higher doses may not produce superior outcomes. They did not observe any side effects with higher doses, except that the symptoms in one patient with associated recurrent cicatricial ectropion deteriorated after 2.5 units. This patient improved after ectropion repair. The message is that eyelid malpositions, if any, should be addressed first before BTA use.

Proximal obstruction of the lacrimal drainage system in children is also difficult to treat with surgical options. CDCR with Jones tube is rarely performed in children with a higher complication rate. Excellent patient co-operation and compliance is required. Eustis and Babiuch presented that they have successfully treated epiphora in three children (8, 9, and 16 years old) for 6–13 months [16].

Kaynak et al. published that BTA to lacrimal gland may be an alternative to CDCR in proximal obstruction related epiphora with similar outcome and less complications up to 6–12 months resolution of symptoms, and repeated injections are effective in resolving the symptoms [17].

Whittaker et al. [14] investigated the usefulness of BTA in patients with functional epiphora and achieved reduction in epiphora after transconjunctival injections of 2.5–5 units of BTA in the palpebral lobe of the lacrimal gland in 86% of patients, with the effect persisting in 66% of patients for 3 months. Two patients in this group encountered transient ptosis and diplopia.

Montoya et al. [5] suggested that a transconjunctival injection was preferred due to the ability to directly visualize the lacrimal gland during injection. Falzon et al. [12] published their meta-analysis where they have found the transconjunctival approach to be associated with fewer complications [12].

BTA has been used safely with no long-term side effects. Neither apparent benefits of higher doses nor actual dose or concentration comparisons have been published. Demetriades et al. [1] reported that no evidence of histological changes, particularly no inflammatory response, have been observed in the lacrimal glands of rabbits following injections of 1.25 and 2.5 units of BTA [1]. Kim et al. [24] have also reported similar findings and found it safe. The absence of histological changes in orbicularis oculi muscle

following BTA injections for blepharospasms is also documented [25]. However, lacrimal gland injections of botulinum neurotoxin B (BTB) in animal models have caused ocular surface changes such as corneal fluorescein staining and significantly decreased tear production with ocular surface inflammation [26].

Up to 10% of patients eventually develop antibodies to the toxin; this occurs more frequently in those who receive larger doses at more frequent intervals. This resistance is believed to result from the production of antibodies to the toxin over time. However, this does not appear to be the case in glandular disorders [27].

Conclusion

Botulinum toxin A injection into the lacrimal gland is an evolving treatment modality for controlling epiphora due to gustatory hyperlacrimation, refractory epiphora secondary to unsalvageable lacrimal drainage, and troublesome functional epiphora. Further studies are required to determine the optimum dose, concentration, and route of delivery [28].

References

1. Demetriades AM, Leyngold IM, D'Anna S, et al. Intraglandular injection of Botulinum toxin a reduces tear production in rabbits. Ophthal Plast Reconstr Surg. 2013;29:21–4.
2. Boroojerdi B, Ferbert A, Schwarz M, et al. Botulinum toxin treatment of synkinesia and hyperlacrimation after facial palsy. J Neurol Neurosurg Psychiatry. 1998;65:111–4.
3. Riemann R, Pfennigsdorf S, Riemann E, et al. Successful treatment of crocodile tears by injection of botulinum toxin into the lacrimal gland: a case report. Ophthalmology. 1999;106:2322–4.
4. Hofmann JR. Treatment of Frey's syndrome (gustatory sweating) and 'crocodile tears' (gustatory epiphora) with purified botulinum toxin. Ophthal Plast Reconstr Surg. 2000;16:289–91.
5. Montoya FJ, Riddell CE, Caesar R, et al. Treatment of gustatory hyperlacrimation (crocodile tears) with injection of botulinum toxin into the lacrimal gland. Eye. 2002;16:705–9.
6. Yavuzer R, Başterzi Y, Akata F. Botulinum toxin a for the treatment of crocodile tears. Plast Reconstr Surg. 2002;110:369–70.
7. Keegan DJ, Geerling G, Lee JP, et al. Botulinum toxin treatment for hyperlacrimation secondary to aberrant regenerated seventh nerve palsy or salivary gland transplantation. Br J Ophthalmol. 2002;86:43–6.
8. Baranano DE, Miller NR. Long term efficacy and safety of botulinum toxin a injection for crocodile tears syndrome. Br J Ophthalmol. 2004;88:588–9.
9. Kyrmizakis DE, Pangalos A, Papadakis CE, et al. The use of botulinum toxin type a in the treatment of Frey and crocodile tears syndromes. J Oral Maxillofac Surg. 2004;62:840–4.
10. Nava-Castañeda A, Tovilla-Canales JL, Boullosa V, et al. Duration of botulinum toxin effect in the treatment of crocodile tears. Ophthal Plast Reconstr Surg. 2006;22:453–6.
11. Ito H, Ito H, Nakano S, Kusaka H. Low-dose subcutaneous injection of botulinum toxin type a for facial synkinesis and hyperlacrimation. Acta Neurol Scand. 2007;115:271–4.
12. Falzon K, Galea M, Cunniffe G, Logan P. Transconjunctival botulinum toxin offers an effective, safe and repeatable method to treat gustatory lacrimation. Br J Ophthalmol. 2010;94:379–80.
13. Wojno TH. Results of lacrimal gland botulinum toxin injection for epiphora in lacrimal obstruction and gustatory tearing. Ophthal Plast Reconstr Surg. 2011;27:119–21.
14. Whittaker KW, Matthews BN, Fitt AW, et al. The use of botulinum toxin a in the treatment of functional epiphora. Orbit. 2003;22:193–8.
15. Ziahosseini K, Al-Abbadi Z, Malhotra R. Botulinum toxin injection for the treatment of epiphora in lacrimal outflow obstruction. Eye (Lond). 2015;29:656–61.
16. Eustis HS, Baiuch A. Use of botulinum toxin injections to the lacrimal gland for epiphora in children with proximal obstruction of lacrimal drainage system. J Pediatr Ophthalmol Strabismus. 2012;16:e15–6.
17. Kaynak P, Karabulut GO, Ozturker C, et al. Comparison of botulinum toxin-a injection in lacrimal gland and conjunctivodacryocystorhinostomy for treatment of epiphora due to proximal lacrimal system obstruction. Eye (Lond). 2016;20:1–7.
18. Allergan BOTOX® COSMETIC (botulinum toxin type A) purified neurotoxin complex. Manufacturer's manual. Downloaded from www.botoxmedical.com, 2016.
19. Lipham WJ. What is botulinum toxin and how does it work? In: Lipham WJ, editor. Cosmetic and clinical applications of Botox and dermal fillers. Thorofare, NJ: Slack Incorporated; 2004. p. 6–9.
20. Lipham WJ. Getting started, commercially available products, basic equipment and supplies, reconstitution and dilution recommendations and clinical implementations. In: Lipham WJ, editor. Cosmetic and clinical applications of Botox and dermal fillers. Thorofare, NJ: Slack Incorporated; 2004. p. 23–37.
21. Quinn N, Hallett M. Dose standardization of botulinum toxin. Lancet. 1989;1:964.
22. Odergren T, Hjaltason H, Kaakkola S, et al. A double blind, randomized, parallel group study to investigate the dose equivalence of Dysport and Botox in the treatment of cervical dystonia. J Neurol Neurosurg Psychiatry. 1998;64:6–12.
23. Ellies M, Laskawi R, Rohrbach-Volland S, et al. Blocking secretion of exocrine glands in the head-neck area by administration of botulinum toxin a therapy of a rare disease picture. HNO. 2001;49:807.
24. Kim JW, Baek S. Functional and histologic changes in the lacrimal gland after botulinum toxin injection. J Craniofac Surg. 2013;24:1960–9.
25. Harris CP, Alderson K, Nebeker J, et al. Histologic features of human orbicularis oculi treated with botulinum a toxin. Arch Ophthalmol. 1991;109:393–5.
26. Zhu L, Zhang C, Chuck RS. Topical steroid and non-steroidal anti-inflammatory drugs inhibit inflammatory cytokine expression on the ocular surface in the botulium toxin B-induced murine dry eye model. Mol Vis. 2012;18:1803–12.
27. Laing TA, Laing ME, O'Sullivan ST. Botulinum toxin for treatment of glandular hypersecretory disorders. J Plast Reconstru Aesth Surg. 2008;61:1024–8.
28. Singh S, Ali MJ, Paulsen F. A review on use of botulinum toxin for intractable lacrimal drainage disorders. Int Ophthalmol. 2017 (Epub).

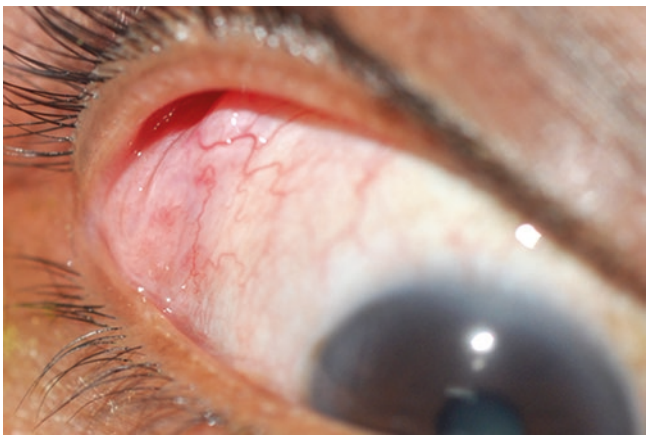


Fig. 40.1 Exposing the palpebral lobe of the lacrimal gland

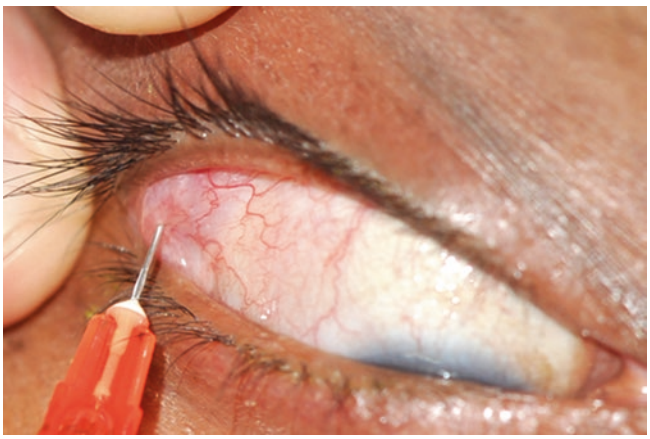


Fig. 40.3 Needle well set within the lacrimal gland tissue. Note that level of the needle and its distance from the ocular surface

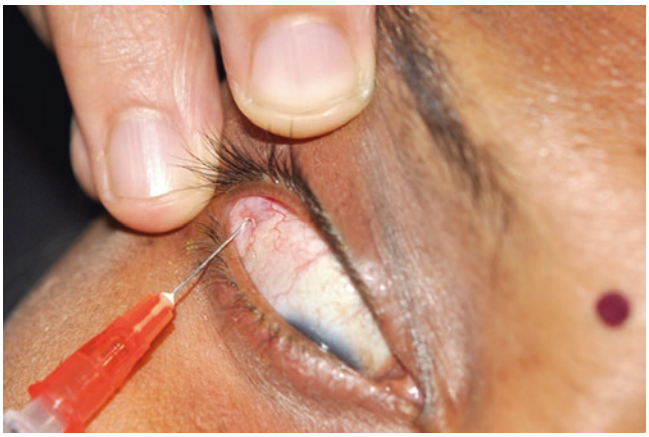


Fig. 40.2 BTA injection under direct visualization

Lacrimal Surgeries and Bacteremia

41

Mohammad Javed Ali and Khaled Abu-Haleeqa

Introduction

The blood is a sterile environment. Bacteremia can be defined as the presence of viable bacteria in the bloodstream [1]. This entity is different from sepsis, which is the host response to viable bacteria in the blood [2]. Bacteremia can be primary or secondary. Primary bacteremia occurs when the organism gains direct access to the blood, for example, via an injection or an infected catheter [3, 4]. Secondary bacteremia occurs when the organism gains access via a different site of the body, for example, bone infections or a liver abscess [5]. Bacteremia can also be transient, intermittent, or persistent. Transient bacteremia is common and usually harmless and can occur following brushing, flossing, or transient introduction of instruments like endoscopes in a mucosal cavity [6]. Intermittent bacteremia occurs secondary to intermittent seeding from a site of infection like an abscess [7]. Persistent bacteremia can be fatal and occurs when there is a continuous seeding from a source like an infected cardiac valve or central line [8]. Bacteremia has been documented with surgical (dental and gastrointestinal surgeries) or nonsurgical (endoscopy and endotracheal intubation) interventions [9–11]. This chapter would examine the bacteremia in common lacrimal surgeries and its implications in surgical preparations and management.

Nasolacrimal Duct Probing and Bacteremia

Probing is one of the established modalities of management for congenital nasolacrimal duct obstructions [12–14]. Bacteremia is a possibility in view of intervention into mucosal tissues, and implications can be serious because most patients are in the range of 1–3 years. There have been few reports with regard to bacteremia during probing [15–20]. Bacteremia has been documented following probing in multiple studies, and the organisms isolated include *Staphylococcus aureus*, *Streptococcus viridians*, *Streptococcus pneumonia*, broad categories of alpha and gamma *Streptococci*, *and Haemophilus influenzae* [15, 16, 19, 20]. The incidence of bacteremia ranged from 4% to 22.5% [15, 16, 19]. Since most of these organisms are known to be etiological factors in infective endocarditis, prophylactic antibiotics were advocated in acute dacryocystitis and cases at high risk like those with cardiac anomalies [15, 16, 19, 20]. In addition, it was noted that those infants with acute dacryocystitis who had a prophylactic antibiotic cover were less likely to need a repeat probing ($P < 0.004$) [16]. Ganguly et al. [15] studied 31 eyes of 25 consecutive patients for probing-induced bacteremia. Blood samples of infants were taken 5 min before and after probing, and a highly sensitive method of blood culture called BacT ALERT was used (bioMerieux, Durham, NC, USA) (Figs. 41.1 and 41.2). This system utilizes a calorimetric sensor that detects carbon dioxide, a metabolic by-product of the bacteria. The signal intensity is picked up by automated machines (Fig. 41.3) and if some sample is flagged as positive, the organisms were identified using a VITEK 2 system (bioMerieux, Durham, NC, USA) (Fig. 41.4). Probing-induced bacteremia was defined as a negative pre-probing culture and a positive post-probing culture. All cases were routine except one child with unilateral dacryocele with acute dacryocystitis. None of the patients other than the case of acute dacryocystitis showed any bacteremia. This led the authors to conclude that routine probing in systemically healthy children does not mandate any prophylaxis; however, the same cannot be true if intervention is planned in an acute infective state.

Contrary opinions have also been voiced in the literature. Venugopalan et al. [18] showed very low incidence of bacteremia in a wide variety of extraocular surgeries and advocated against the use of routine antibiotic prophylaxis and

M. Javed Ali, F.R.C.S. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

K. Abu-Haleeqa, M.D.
Department of Ophthalmology, Mafraq Hospital, Abu Dhabi, UAE

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_41

stressed on a good pre- and intraoperative asepsis. Pollard et al. [21] reported 20 infants with acute dacryocystitis who underwent probing without any antibiotic cover and found it to be safe and effective. However, they did not specifically investigate for bacteremia.

Taking all the accounts into consideration, it can be proposed that routine antibiotic prophylaxis is not required for probing in systemically healthy children with CNLDO. However, it is better to give an antibiotic cover, if probing is considered in children with acute dacryocystitis or if the child had high-risk factors like a congenital cardiac abnormality.

Dacryocystorhinostomy and Bacteremia

Dacryocystorhinostomy (DCR) is a commonly performed surgery for managing complete nasolacrimal duct obstructions [22, 23]. There has been a controversy with regard to the use of routine postoperative antibiotics after a DCR and their role in preventing wound infections [24–28]. A DCR surgery is regarded as a clean contaminated type of operative procedure [29]. Those who advocate for the prophylaxis have shown a five- to tenfold decrease in the rate of soft tissue infection and cellulitis with the use of antibiotics [25, 26]. Comparative efficacy has been demonstrated between intraoperative and postoperative use. However, contrary opinions have been raised in very large series (n = 697) where the routine use of postoperative antibiotic prophylaxis was not found to lower the infection rates [27]. Dulku et al. [28] found it hard to justify the use of antibiotics postsurgery since the number needed to treat to prevent one infection after DCR would be 104, and this appears quite high.

In a series on extraocular surgery, Venugopalan et al. [18] demonstrated *Haemophilus influenzae* bacteremia in a single case of DCR. Ali et al. [24] specifically investigated the issue of bacteremia during a DCR surgery. They prospectively studied 50 patients in whom blood samples were drawn intraoperatively during two different time points (nasal and lacrimal sac mucosa fashioning). The blood was immediately inoculated in Columbia broth, and an additional dual medium (HiMedia Laboratories, Mumbai, India) (Figs. 41.5, 41.6, 41.7, and 41.8), and subcultures were subsequently performed. All the samples and the subcultures were uniformly negative for bacteremia. Clean cases without sac discharge on marsupialization were not given postoperative antibiotics, and none had developed postoperative infections.

Epidemiological studies have shown that nearly half of antibiotic prescriptions are prophylactic in nature [30]. There is also an association of antibiotic resistance and unnecessary usage. As of now, there is no evidence that justifies routine use of postoperative antibiotics in routine DCR cases with good aseptic precautions. The authors do not use postoperative prophylaxis and instead routinely use a single dose of intravenous antibiotic just prior to incision. However, when performing a DCR in the setting of an acute dacryocystitis, it would be a good idea to administer antibiotics intraoperatively as well as postoperatively.

References

1. Seifert H. The clinical importance of microbiological findings in the diagnosis and management of blood stream infections. Clin Infect Dis. 2009;48:S238–45.
2. Fan SL, Miller NS, Lee J, et al. Diagnosing sepsis: the role of laboratory medicine. Clin Chim Acta. 2016;460:203–10.
3. Manian FA. ISDA guidelines for the diagnosis and management of intravascular catheter-related bloodstream infection. Clin Infect Dis. 2009;49:1770–1.
4. Suzuki M, Satoh N, Nakamura M, et al. Bacteremia in hemodialysis patients. World J Nephrol. 2016;5:489–96.
5. Pääkkönen M, Kallio PE, Kallio MJ, et al. Does bacteremia associated with bone and joint infections necessitate prolonged parenteral antibiotic therapy? J Pediatric Infect Dis Soc. 2016;4:174–7.
6. Forner L, Larsen T, Kilian M, et al. Incidence of bacteremia after chewing, tooth brushing and scaling in individuals with periodontal inflammation. J Clin Periodontol. 2006;33:401–7.
7. Akuzawa N, Hatori T, Kitahara Y, et al. Multiple liver abscesses and bacteremia caused by Streptococcus constellatus: a case report. Clin Case Rep. 2016;5:69–74.
8. Moskalewicz RL, Isenalumhe LL, Luu C, et al. Bacteremia in non-neutropenic pediatric oncology patients with central venous catheters in the ED. Am J Emerg Med. 2017;35:20–4.
9. Wilson W, Taubert KA, Gewitz M, et al. Prevention of infective endocarditis: guidelines from the American Heart Association: a guideline from the American Heart Association Rheumatic Fever, endocarditis and Kawasaki Disease Committee, Council for Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group. J Am Dent Assoc. 2008;139(Suppl):3S–24S.
10. Varma JR. Antibiotic prophylaxis for lower gastrointestinal endoscopy. Prim Care. 1995;22:445–50.
11. Lockhart PB, Brennan MT, Kent ML, et al. Impact of amoxicillin prophylaxis on the incidence, nature and duration of bacteremia in children after intubation and dental procedures. Circulation. 2004;109:2878–84.
12. Wallace EJ, Cox A, White P, et al. Endoscopic-assisted probing for congenital nasolacrimal duct obstruction. Eye. 2006;20:998–1003.
13. Ali MJ, Kamal S, Gupta A, et al. Simple versus complex congenital nasolacrimal duct obstructions: etiology, management and outcomes. Int Forum Allergy Rhinol. 2015;5:174–7.
14. Kashkouli MN, Kassaee A, Tabatabaee Z, et al. Initial probing in children under 5 years: cure rate and factors affecting the success rate. J AAPOS. 2002;6:360–3.
15. Ganguly A, Ali MJ, Padmaja K, et al. Bacteremia following nasolacrimal duct probing: is there a role of preoperative antibiotic prophylaxis? Ophthal Plast Reconstr Surg. 2016;32:90–2.
16. Baskin DE, Reddy AK, Chu YI, et al. The timing of antibiotic administration in the management of infant dacryocystitis. J AAPOS. 2008;12:456–9.
17. Grech V, Sammut P, Parascandolo R, et al. Bacterial endocarditis following lacrimal duct probing. J Pediatr Ophthalmol Strabismus. 2001;38:49–50.

18. Venugopalan P, Ganesh A, Rafay AA, et al. Low frequency of bacteremia during eye surgery obviates the need for endocarditis prophylaxis. Eye. 2001;15:753–5.
19. Eippert GA, Burnstine RA, Bates JH. Lacrimal duct probing induced bacteremia: should children with congenital heart defects receive antibiotic prophylaxis? J Pediatr Ophthalmol Strabismus. 1998;35:38–40.
20. Schaeffer AR, Gordon RA, Sood SK. Bacteremia following nasolacrimal duct probing. Invest Ophthalmol Vis Sci (Abs). 1990;31:610.
21. Pollard ZF. Treatment of acute dacryocystitis in neonates. J Pediatr Ophthalmol Strabismus. 1991;28:341–3.
22. Feng Y, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
23. Ali MJ, Psaltis AJ, Murphy J, et al. Primary powered endoscopic dacryocystorhinostomy: a decade of experience. Ophthal Plast Reconstr Surg. 2015;31:219–21.
24. Ali MJ, Ayyar A, Motukupally SR. Bacteremia during dacryocystorhinostomy: results of intra-operative blood cultures. J Ophthalmic Inflamm Infect. 2014;4:27–30.
25. Vardy SJ, Rose GE. Prevention of cellulitis after open lacrimal surgery: a prospective study of three methods. Ophthalmology. 2000;107:315–7.
26. Walland MJ, Rose GE. Soft tissue infections after open lacrimal surgery. Opthalmology. 1994;101:608–11.
27. Pinar-Sueiro S, Fernandez-Hermida R, Gibelalde A, et al. Study of effectiveness of antibiotic prophylaxis in external dacryocystorhinostomy: a review of 697 cases. Ophthal Plast Reconstr Surg. 2010;26:467–72.
28. Dulku S, Akinmade A, Durrani OM. Post-operative infection rate after dacryocystorhinostomy without the use of systemic antibiotic prophylaxis. Orbit. 2012;31:44–7.
29. Hsu P, Bullocks J, Matthews M. Infection prophylaxis update. Semin Plast Surg. 2006;20:241–8.
30. Cruse PJ, Foord R. The epidemiology of wound infection. A 10 year prospective study of 62,939 wounds. Surg Clin North Am. 1980;60:27–40.

Fig. 41.1 Diagnosis of bacteremia—a BacT^{R} culture bottle. Note the gas permeable sensor at the base

Fig. 41.2 Diagnosis of bacteremia—an inoculated BacT^{R} bottle

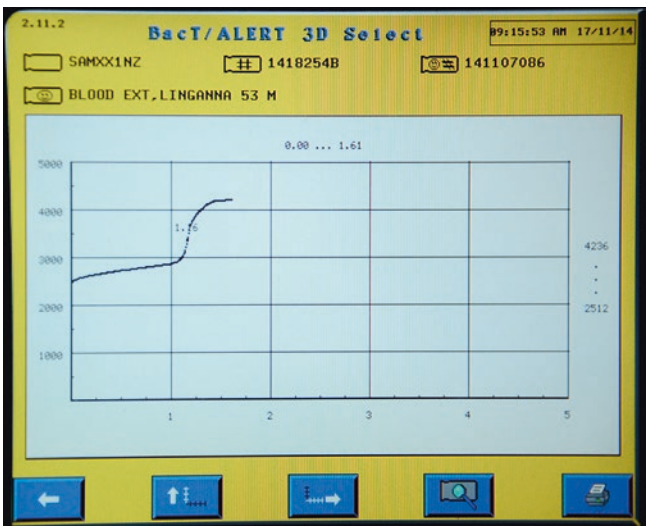


Fig. 41.3 Console of the BacT^{R} microbial detection system, flagging a positive result

Fig. 41.4 The VITEK2^{R} system

Fig. 41.5 Diagnosis of bacteremia—Columbia broth culture bottle

Fig. 41.6 Diagnosis of bacteremia—dual media culture bottle

Fig. 41.7 Diagnosis of bacteremia—an inoculated dual media culture bottle

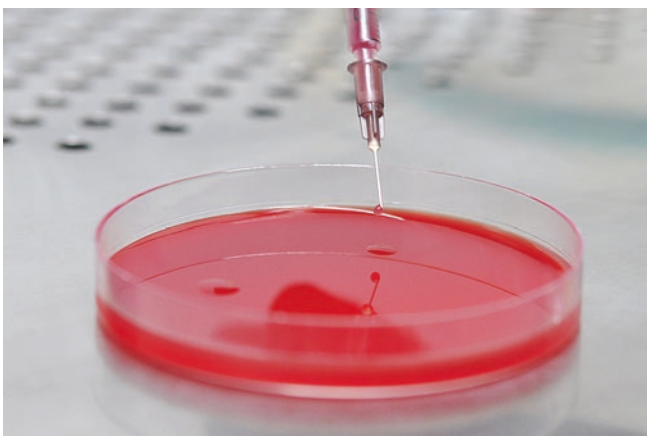


Fig. 41.8 Diagnosis of bacteremia—subcultures from the inoculated specimens

Electron Microscopy of the Lacrimal System

42

Mohammad Javed Ali

Introduction

Ultrastructural studies helps in understanding the tissue functions and aberrations at a cellular and subcellular level. It is carried out using electron microscopy. Two broad categories of electron microscopes are scanning and transmission. Scanning electron microscopy (Fig. 42.1) displays images of a sample by scanning it with a beam of electrons. The electron beams are scanned in a raster pattern, and they interact with the atoms in the sample giving details of the surface topography and compositions. Transmission electron microscopy (Fig. 42.2) works by transmitting electrons through an ultrathin specimen and detecting images which happen as a result of interaction of the transmitted electrons with the specimen. It has a far higher resolution than scanning methods and can study intracellular details. Very few studies have looked at the ultrastructural features for lacrimal drainage system [1–8]. The earliest to study was Radnot in 1972 [1] followed by Adenis in 1980 [3, 4] and subsequent remarkable work by Paulsen [6–8]. The current chapter would provide an overview of recent works in the lacrimal drainage system and the vast potential to do more in this area.

Electron Microscopy of the Normal Lacrimal Passages

Electron microscopy is a very useful modality to study the anatomical ultrastructure of the lacrimal drainage system. Scanning electron microscopy (SEM) of healthy lacrimal systems has shown demonstrable anatomical junctions between the distal portion of the punctum and the proximal most portion of the vertical canaliculus (Fig. 42.3) [9]. Such anatomical junction were also noted between the lacrimal sac and nasolacrimal ducts (Fig. 42.4). The mucosa of the canaliculus was occasionally thrown into folds with the surface showing rugae as compared to the normal smooth architecture (Fig. 42.5). These are likely to represent the valvular structures of the lacrimal system [9]. In the vicinity of the canaliculi, the orbicularis fibers were found to be very well organized in bundles (Fig. 42.6). The fundus of the lacrimal sac showed very peculiar glands not found elsewhere (Fig. 42.7) and whose function is not yet known. The walls of the lacrimal sac and nasolacrimal ducts showed dense vascular plexus which included wide luminal arteries, throttle veins, and large capacitance vessels (Fig. 42.8). The mucosa of the lacrimal sacs showed well-defined elevations of submucosal lymphoid follicles (Fig. 42.9). These topographic studies have a potential to enhance our anatomico-physiological understanding which may then be translated for better clinical understanding and patient managements.

Ultrastructural Changes in Punctal Stenosis

Inflammation and fibrosis have long been implicated as a common pathogenic mechanism in punctal stenosis. Direct histopathological studies of the punctal tissues in stenosis have shown marked subepithelial fibrosis with predominant lymphocytic infiltration by CD45 and CD3 cells [10]. Electron microscopy has shown blunted microvilli, inter- and intracellular edema, irregular deposition of collagen, and activated fibroblasts with typical lymphocytes in their vicinity (Figs. 42.10 and 42.11) [10]. The ultrastructural effects to noxious stimuli are likely to be variable and would corroborate with the degree of inflammation. The close proximities of lymphocytes and fibroblasts could possibly signal some intercellular communications and influences. These studies open up more avenues for better understanding of the etiopathogenesis of punctal stenosis.

M. Javed Ali, F.R.C.S.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 500034, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_42

Electron Microscopy in Failed Dacryocystorhinostomy

Complete cicatricial closure of the ostium is one of the common causes of a failed DCR [11, 12]. The precise nasal mucosal wound healing is unclear, and human models of wound healing have shown four distinct phases: first phase (7–12 days) of wound enveloping by blood crusts, second phase (2–4 weeks) of granulation tissue formation, third phase (4–8 weeks) of tissue edema, and fourth phase (12–14 weeks) of macroscopic normalization [13]. Tissues from complete cicatricial closures, analyzed by electron microscopy, showed irregular laying of collagen in bundles with numerous intervening fibroblasts and mononuclear lymphocytic infiltrates (immunophenotyping showed them to be CD3+, CD5+, and CD20+ essentially reflecting mixed T and B lymphocytes) [14]. Amorphous bony osteoid was noted in the fibrillary background with numerous metabolically active osteoblasts (Figs. 42.12 and 42.13). These osteoblasts showed hyperproliferative mitochondria, large Golgi apparatus, and dense endoplasmic reticulum [14]. There is hence ample evidence of new bone formation within the scarred DCR tissues, and these may open up newer avenues in understanding the wound healing patterns and possible adjunctive pharmacotherapies.

Ultrastructural Effects of Mitomycin C in Dacryocystorhinostomy

Mitomycin C (MMC) has been used in dacryocystorhinostomy to modulate aggressive wound healings and prevent cicatricial closure of the DCR ostium [15, 16]. Various basic science studies have provided evidence of its effects on the nasal mucosal fibroblasts [17, 18]. Clinical application is either in the form of an intraoperative topical application and/or injectable in the circumostial (COS) areas, a technique described as COS-MMC [19–21]. Ultrastructural effects of topical MMC (0.02%, 3 min) and COS-MMC (0.2 mg/ml) on nasal mucosa were evaluated and compared with the untreated naïve nasal mucosa (as controls) (Fig. 42.14 and 42.15) [22]. Detailed transmission electron microscopic effects of standardized MMC on nasal mucosa using various modalities of drug applications were documented. The MMC affected all the components of the mucosa including epithelium, glands, vascular, and fibrocollagenous tissues. The nasal mucosal fibroblasts show a dramatic structural response to MMC, including development of intracellular edema, pleomorphic and vesicular mitochondria, dilated smooth and rough endoplasmic reticulum, and chromatin condensation. Moreover, both, topical and COS-MMC, showed profound changes in nasal mucosal fibroblasts, but the effects seem to be more marked in the COS-MMC group without any tissue necrosis. These evidences show that MMC is likely to be effective against aggressive wound healing if used in appropriate doses with standardized techniques.

Lacrimal Stents and Biofilms

Monocanalicular and bicanalicular stents are commonly used in lacrimal surgeries for a variety of indications [23, 24]. They are believed to maintain the lacrimal passages during the canalicular (as in lacerations) or ostial (as in DCR) healing. In addition, they have been shown to be effective in functional epiphoras since they dilate the passages and reduce the resistance to flow [25]. When used, the duration of intubation has always been a matter of debate. In addition, they have been shown to act as a nidus for harboring numerous microorganisms [26, 27].

Biofilm is a complex microbial community encased itself in a self-produced exopolysaccharide matrix that is irreversibly attached to a surface [28]. Biofilms provide multiple advantages to the microbes living in it including reduction of metabolic needs and resistance to antimicrobial agents. Bacterial biofilms on lacrimal stents are identified on scanning electron microscopy by the presence of microcolony clusters or towers consisting of bacterial bodies 0.05–5 μ, surrounded within an exopolysaccharide matrix, complex water channels, and 3D structures [29].

Lacrimal stents have shown to harbor biofilms in multiple studies (Figs. 42.16 and 42.17) [28, 30–34]. The mean biomass has been estimated to be 0.9385 $\mu m^3/\mu m^2$ at 4 weeks from intubation [28]. The biofilms and physical deposits have been shown to be more concentrated at the ocular segment loop in bicanalicular stents and ampullary portion of the stent head in mini-monoka stents [31, 32]. Mixed bacterial and fungal biofilms have been noted in the intraluminal areas of stents [33]. As the duration of retention increases beyond 4 weeks, the biofilms and deposits become denser, multilayered, and extensive [34]. All these studies have provided directions with regards to minimizing the duration of stents (4 weeks) and probably the need to develop lumen-less stents.

References

1. Radnot M. Ultrastructure of the lacrimal sac. Ann Ophthalmol. 1972;4:1050–7.
2. Radnot M. The cilia of the lacrimal sac epithelium – SEM studies. Klin Monatsbl Augenheilkd. 1977;170:428–30.
3. Adenis JP, Loubet A, Leboutet MJ, et al. Ultrastructural aspect of different levels of the lacrimal system. J Fr Ophthalmol. 1980;3:343–8.
4. Adenis JP, Loubet A, Leboutet MJ, et al. Ultrastructural morphology at the different levels of the lacrimal passage mucosa. Arch Anat Cytol Pathol. 1980;28:371–5.

5. Radnot M. The fine structure of the oncocytes of the lacrimal sac. Klin Monatsbl Augenheilkd. 1981;179:249–50.
6. Thale A, Paulsen F, Rochels R, et al. Functional anatomy of the human efferent tear ducts: a new theory of tear outflow mechanism. Graefes Arch Clin Exp Ophthalmol. 1998;236:674–8.
7. Paulsen FP, Thale A, Hallmann UJ, et al. The cavernous body of human efferent tear ducts: function in tear outflow mechanism. Invest Ophthalmol Vis Sci. 2000;41:965–70.
8. Paulsen F. The human nasolacrimal ducts. Adv Anat Embryol Cell Biol. 2003;170:1–106.
9. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of the external and internal surfaces of normal adult lacrimal drainage system. Ophthal Plast Reconstr Surg. 2015;31:414–7.
10. Ali MJ, Mishra DK, Baig F, et al. Punctal stenosis: histopathology, immunology and electron microscopic features – a step towards unraveling the mysterious etiopathogenesis. Ophthal Plast Reconstr Surg. 2015;31:98–102.
11. Dave TV, Mohammed FA, Ali MJ, et al. Etiologic analysis of 100 failed anatomical dacryocystorhinostomies. Clin Ophthalmol. 2016;10:1419–22.
12. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomies. Int Forum Allergy Rhinol. 2014;4:1016–9.
13. Watelet JB, Bachert C, Gevaert P, et al. Wound healing of the nasal and paranasal mucosa: a review. Am J Rhinol. 2002;16:77–84.
14. Ali MJ, Mishra DK, Baig F, et al. Histopathology, immunohistochemistry, and electron microscopic features of a dacryocystorhinostomy ostium cicatrix. Ophthal Plast Reconstr Surg. 2016;32:333–6.
15. Xue K, Mellington FE, Norris JH. Meta-analysis of the adjunctive use of mitomycin C in primary and revision, external and endonasal dacryocystorhinostomy. Orbit. 2014;33:239–44.
16. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
17. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration – a fundamental study on human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
18. Kumar V, Ali MJ, Ramachandran C. Effect of mitomycin-C on contraction and migration of human nasal mucosa fibroblasts: implications in dacryocystorhinostomy. Br J Ophthalmol. 2015;99:1295–300.
19. Nair AG, Ali MJ. Mitomycin-C in dacryocystorhinostomy: from experimentation to implementation and the road ahead: a review. Indian J Ophthalmol. 2015;63:335–9.
20. Kamal S, Ali MJ, Naik MN. Circumostial mitomycin C (COS-MMC) in external and endoscopic dacryocystorhinostomy: efficacy, safety profiles and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
21. Singh M, Ali MJ, Naik MN. Long-term outcomes of circumostial injection of mitomycin C (COS-MMC) in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:423–4.
22. Ali MJ, Baig F, Lakshman M, et al. Electron microscopic features of nasal mucosa treated with topical and circumostial injection of mitomycin C: implications in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:103–7.
23. Unlu H, Aslan A, Toprak B, et al. Comparison of surgical outcomes in primary endoscopic dacryocystorhinostomy with and without silicone intubation. Ann Otol Rhinol Laryngol. 2002;111:704–9.
24. Feng YF, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
25. Moscato EE, Dolmetsch AM, Silkiss RZ, Seiff SR. Silicone intubation for the treatment of epiphora in adults with presumed functional nasolacrimal duct obstruction. Ophthal Plast Reconstr Surg. 2012;28:35–9.
26. Kim SE, Lee J, Lee SY. Clinical significance of the microbial growth on the surfaces of silicone tubes removed from dacryocystorhinostomy patients. Am J Ophthalmol. 2012;153:253–7.
27. Ali MJ, Manderwad G, Naik MN. The microbiological spectrum and antibiotic sensitivity profile of extubated silicone stents following dacryocystorhinostomy. Orbit. 2013;32:298–303.
28. Murphy J, Ali MJ, Psaltis AJ. Biofilm quantification on nasolacrimal silastic stents after dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:396–400.
29. Ramadan HH, Sanclemann JA, Thomas JG. Chronic rhinosinusitis and biofilms. Otolaryngol Head Neck Surg. 2005;132:414–7.
30. Samimi B, Bielory BP, Miller D, et al. Microbiological trends and biofilm growth on explanted periorbital biomaterials: a 30 year review. Ophthal Plast Reconstr Surg. 2013;29:376–81.
31. Ali MJ, Baig F, Lakshman M, et al. Biofilms and physical deposits on nasolacrimal silastic stents following dacryocystorhinostomy: is there a difference between ocular and nasal segments? Ophthal Plast Reconstr Surg. 2015;31:452–5.
32. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of extubated monoka stents. Ophthal Plast Reconstr Surg. 2017;33(2):90–2.
33. Ali MJ, Baig F, Naik MN. Electron microscopic features of intraluminal portion of nasolacrimal silastic stents following dacryocystorhinostomy. Is there a need for stents without a lumen? Ophthal Plast Reconstr Surg. 2016;32:252–6.
34. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of nasolacrimal silastic stents retained for prolong durations following dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2016;32:20–3.

Fig. 42.1 Scanning electron microscope

Fig. 42.2 Transmission electron microscope

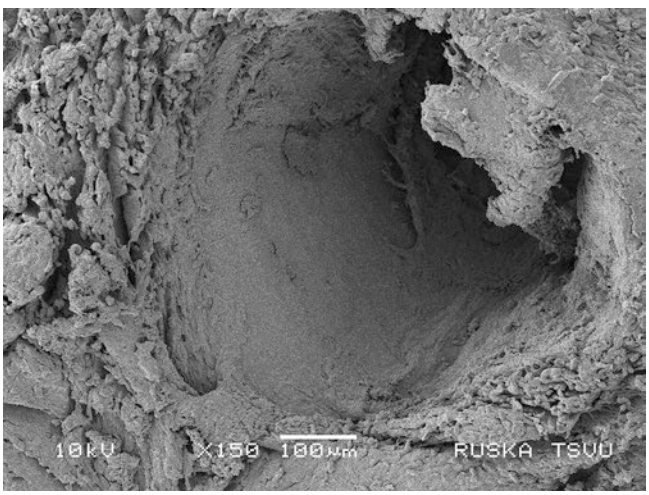


Fig. 42.3 Scanning electron microscopic (SEM) image of the punctum. Note the end on view into the lumen and the raised junctional area between the inner punctum and the beginning of the vertical canaliculus (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

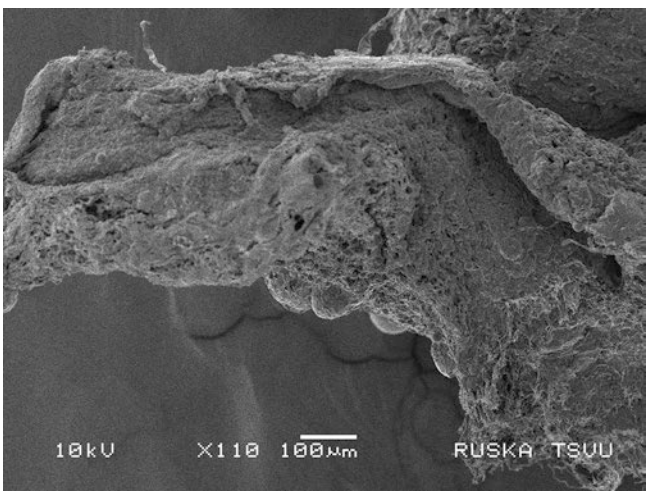


Fig. 42.4 SEM image of the junction of lacrimal sac and nasolacrimal duct. Note the little narrowing and kink at the junctional area (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

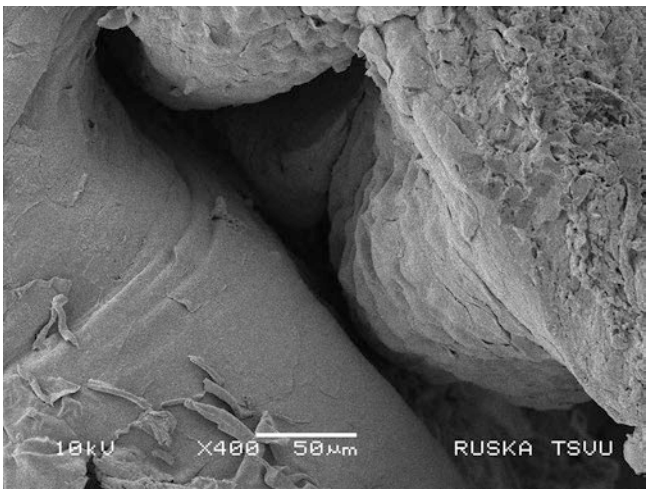


Fig. 42.5 SEM image showing an end-on view into the canalicular lumen. Note one wall of the canaliculus appearing smooth while the other is folded upon itself with surface showing the rugae (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

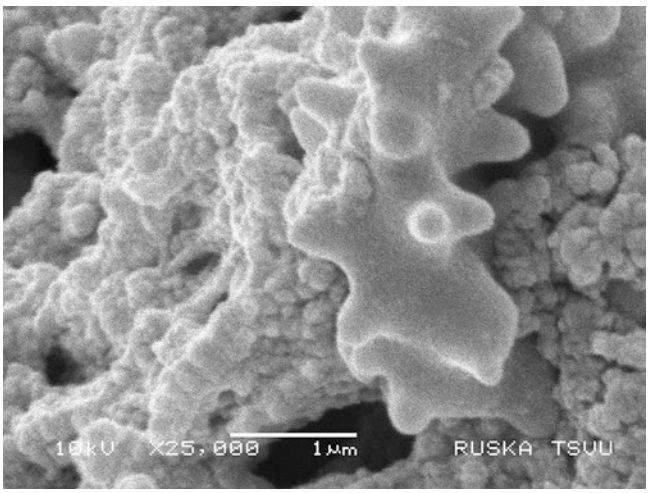


Fig. 42.7 SEM image of the epithelial surface of the fundus showing well-defined glands and opening of the ducts (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

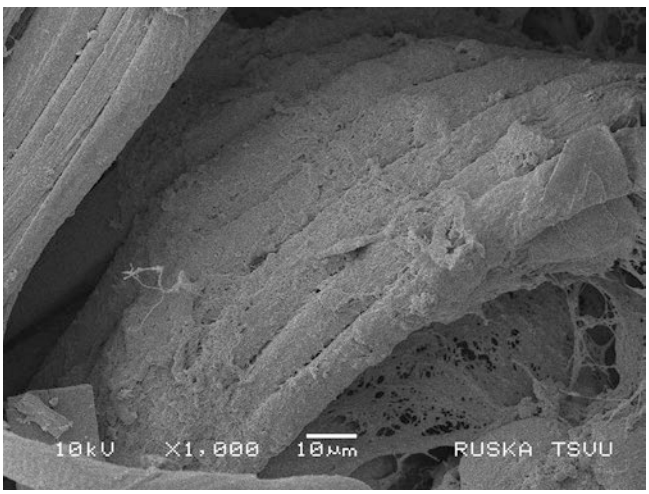


Fig. 42.6 SEM image from the vicinity of the canaliculus showing well-defined arrangement of the muscle fibers (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

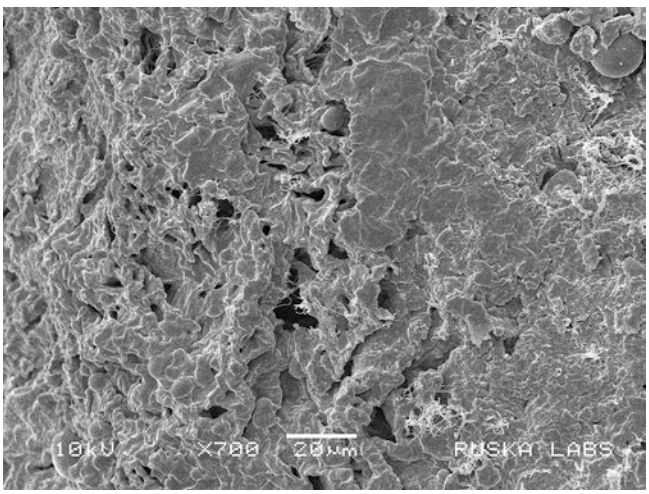


Fig. 42.8 SEM image of the external lacrimal sac wall showing the dense vascular plexus (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

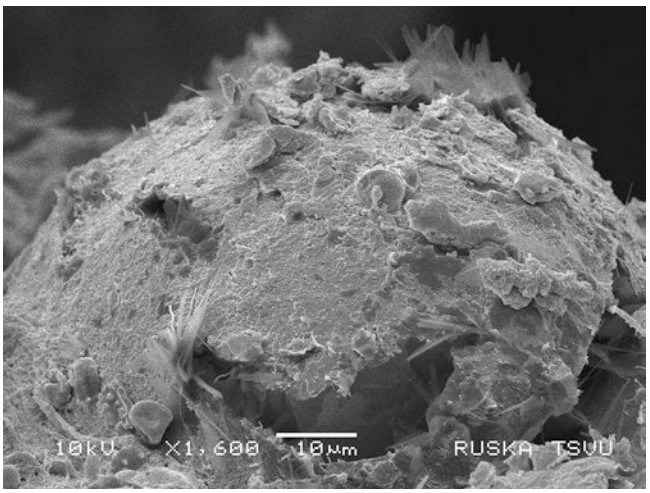


Fig. 42.9 SEM image of the luminal surface of lacrimal sac showing a well-defined lymphoid follicular area (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:414–417)

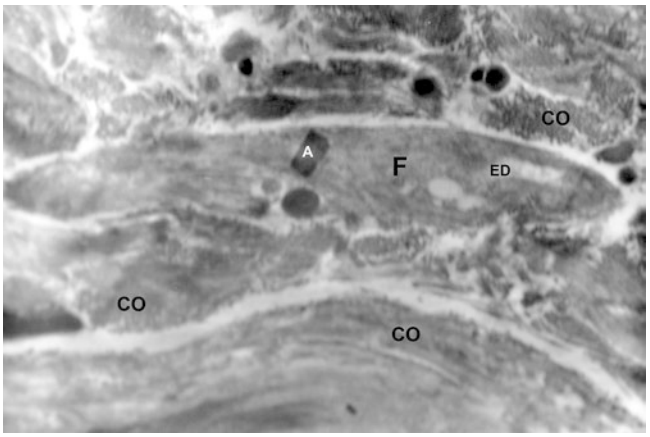


Fig. 42.10 Transmission electron microscopy (TEM) image showing compressed fibroblast (F) with dense and irregular collagen (CO) bundles (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:98–102)

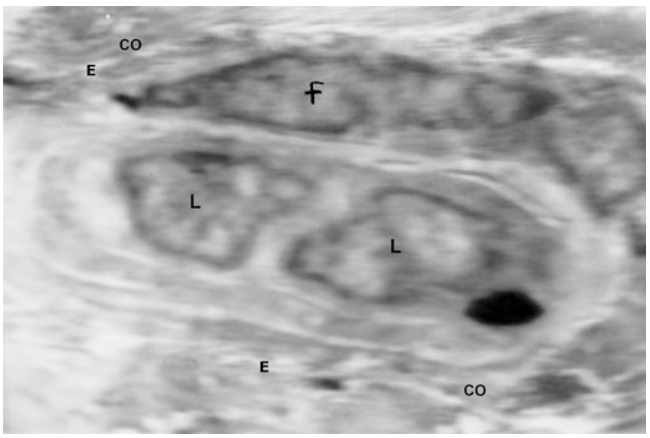


Fig. 42.11 TEM image showing mononuclear lymphocytic infiltration (L) in the vicinity of fibroblasts (F) (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:98–102)

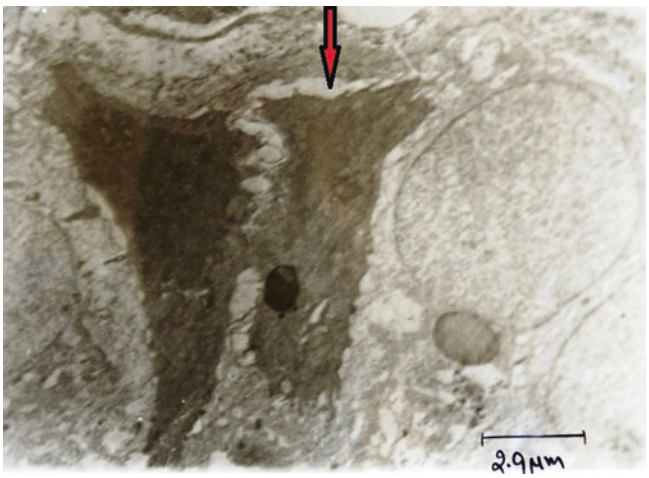


Fig. 42.12 Transmission electron microscopy (TEM) image showing laying of osteoid (*arrow*) in a fibrillary background. (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2016;32:333–336)

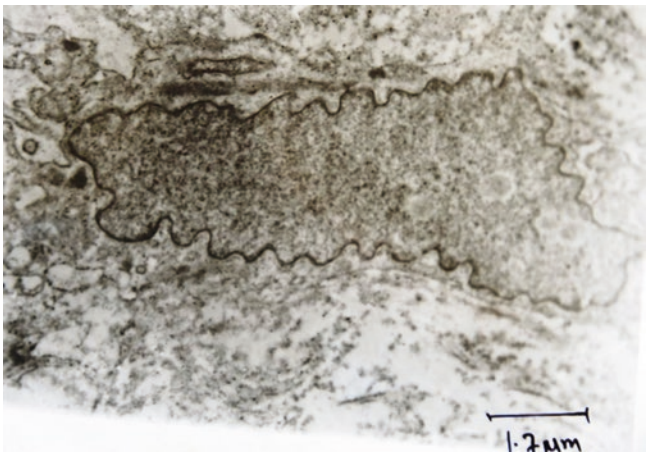


Fig. 42.13 TEM image showing an active osteoblast with abundant rough endoplasmic reticulum (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2016;33:333–336)

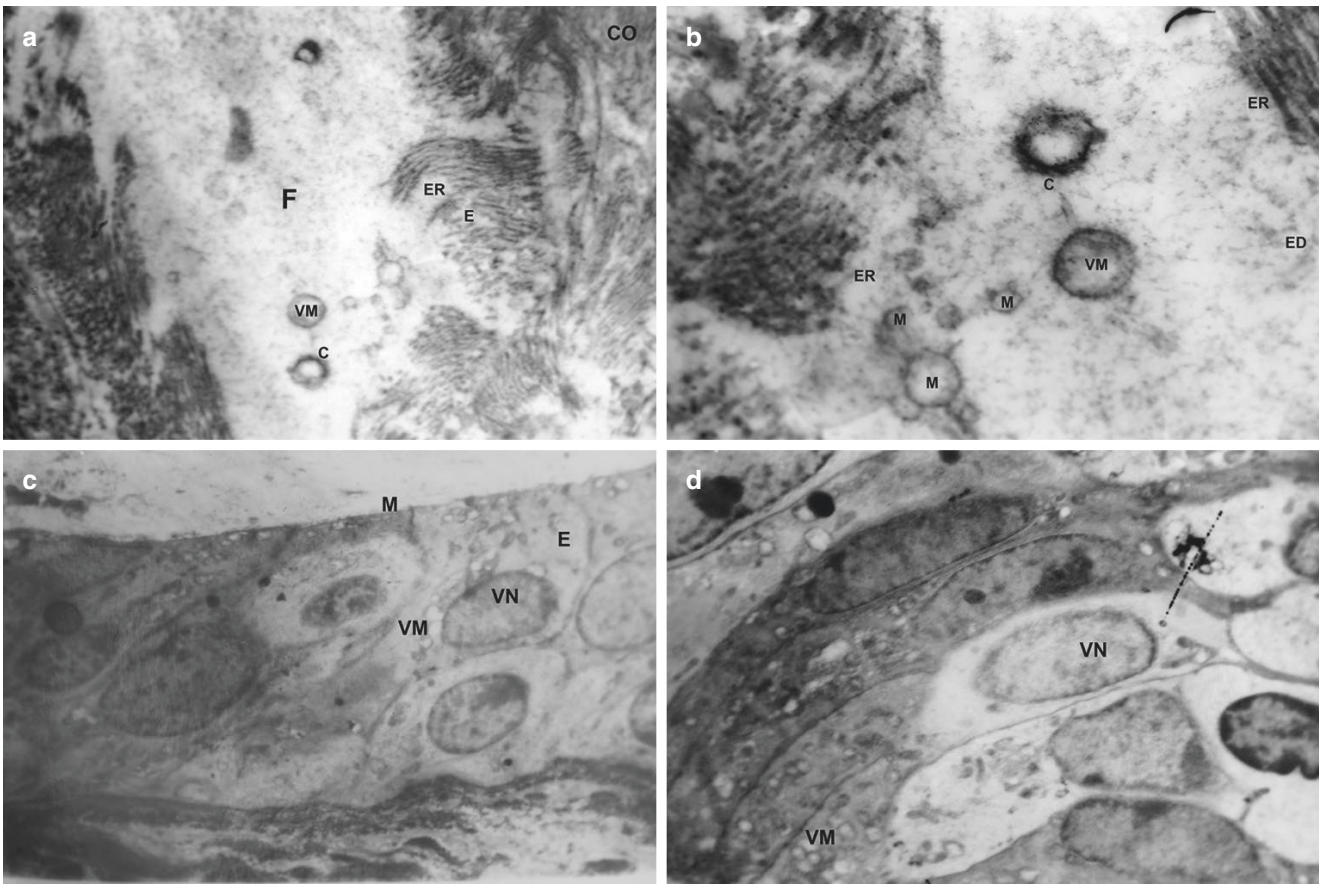


Fig. 42.14 Ultrastructural features following MMC application. TEMG high magnification of fibroblast (F) shows retained cellular outline on one side with dilated endoplasmic reticulum (ER), vesicular mitochondria (VM) with peripheral chromatin condensation (C) (OM × 13,510) (Panel **a**). TEMG high magnification showing subcellular features of fibroblast including dilated endoplasmic reticulum (ER), pleomorphic mitochondria (M), vesicular mitochondria (VM) with peripheral chromatin condensation (C), and scattered electron dense (ED) granular material. (OM × 28,950) (Panel **b**). TEMG of COS-MMC-treated mucosa showing attenuated epithelium (E) with vesicular nuclei (VN) and vesicular mitochondria (VM) and sparse microvilli (M) (OM × 3860) (Panel **c**). TEMG of COS-MMC-treated epithelium in a higher magnification showing vesicular nuclei (VN) and vesicular mitochondria (VM) (OM × 4825) (Panel **d**) (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2015;31:103–107)

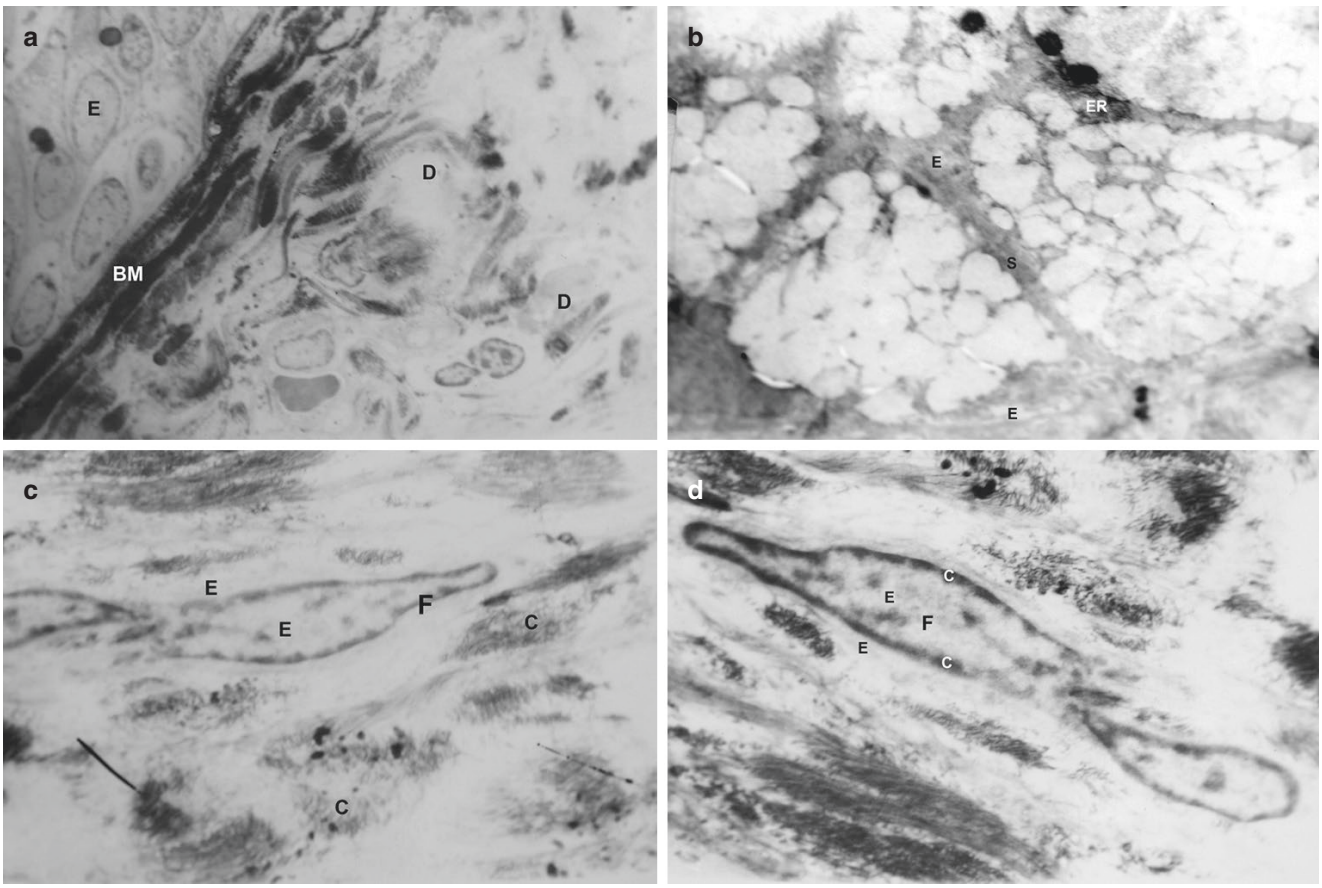


Fig. 42.15 Ultrastructural features following COS-MMC treatment. TEMG showing grossly attenuated epithelium (E) with discontinuous basement membrane (BM) and disorganized sub epithelial tissues (D) (OM × 2316) (Panel **a**). Glandular tissue showing thickened septa (S) with empty secretory vesicles and gross edema (E) and disturbed endoplasmic reticulum (ER) (OM × 4825) (Panel **b**). TEMG shows sparse and disorganized collagen fibers (C) due to widespread edema (E). Fibroblast (F) shows gross intracellular edema (E) (OM × 7720) (Panel **c**). TEMG showing fibroblasts (F) at a higher magnification to see the diffuse peri and intracellular edema (E) with peripheral chromatin condensation. Note that one of the fibroblasts has lost part of its cellular outline (OM × 9650) (Panel **d**) (Courtesy Ali et al., Ophthal Plast Reconstr Surg 2015;31:103–107)

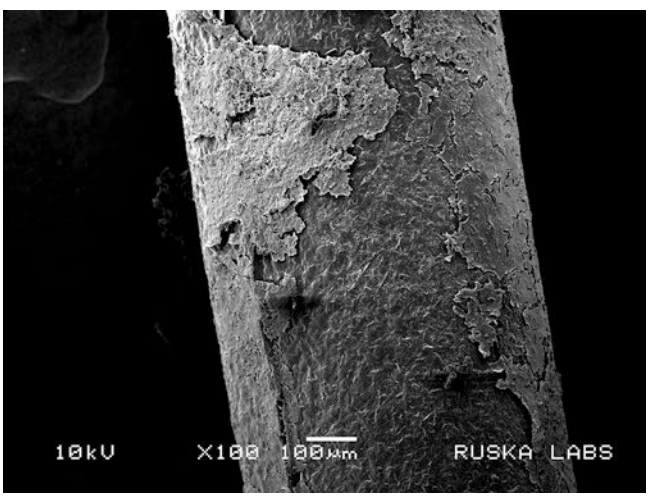


Fig. 42.16 SEM image of a lacrimal stent showing thick integration of physical deposits and biofilms (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2017;33:90–92)

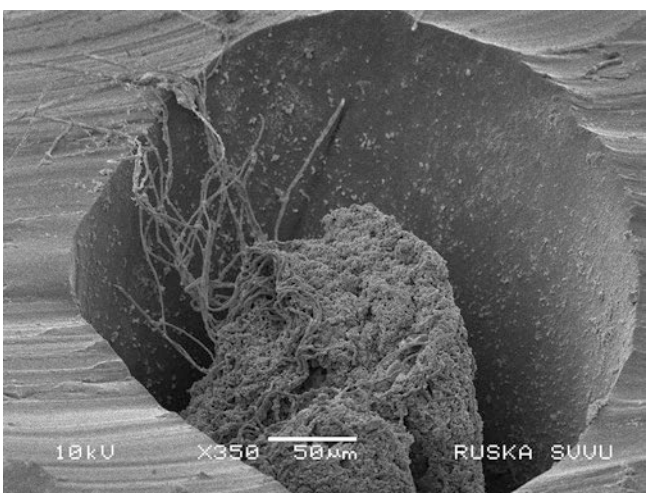


Fig. 42.17 SEM image of an intraluminal portion of lacrimal stent showing the presence of a mixed biofilm mass (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2016;32:252–256)

Debates in Dacryology: The Ostium Dilemma

43

Andrea Zarkovic, Dan Brettell, Edwin C. Figueira, Simon N. Madge, Marcus M. Marcet, and Dinesh Selva

Introduction

An ostium is an opening into a body cavity or a vessel. In the current context, it is the surgical opening that is created into the nasal cavity in a dacryocystorhinostomy (DCR). The ideal size, extent, location, and postoperative behaviors of a DCR ostium have been a subject of numerous debates and are controversial. This chapter will examine these aspects in the light of current literature.

Intraoperative and Postoperative Ostium: Does Size Matter?

One of the commonest causes of dacryocystorhinostomy (DCR) failure is the closure of the ostium due to healing of the mucosal edges, formation of synechiae, or presence of granulation tissue [1]. Another postulated cause of failure is the sump syndrome where a remnant of the inferior lacrimal sac acts as a non-draining reservoir [2]. These complications can be minimized by creating an adequately sized and appropriately placed ostium.

The ideal dimensions for the bony ostium in DCR remain unclear. Many authors believe the ostium should be long enough to allow opening of the entire lacrimal sac from the fundus to the junction with the nasolacrimal duct. It should be wide enough to allow creation of lacrimal sac flaps that lie apposed to the nasal mucosal flaps to promote primary intention healing. Similarly, complete marsupialization of the sac into the lateral nasal cavity is thought to achieve the lowest rate of ostial closure [3–5]. Others accept a smaller opening of the sac with a correspondingly smaller bony ostium.

Argin et al. [6] attempted to define the exact dimensions for a bony ostium in the belief that creation of a large ostium will prevent closure. Ben Simon et al. [7] found a positive correlation between intraoperative osteotomy size and postoperative ostium measurements. In contrast, other studies reported that the initial ostium size does not necessarily correlate with the final size [8–10]. Many authors also found that the intraoperative and final ostium size were not predictive of success [7, 8]. However, Ezra et al. [9] observed a correlation between ostial size at 2 weeks and a successful outcome.

In a prospective study of 161 endoscopic DCRs where the entire sac was marsupialized, Chan and Selva [8] found the majority of ostial shrinkage occurred within the first 4 weeks. The average ostial measurement 12 months postoperatively was 64.7% of the initial bony osteotomy. In another prospective study of 49 endoscopic DCR procedures, Mann and Wormald [11] showed very similar results with the ostium measuring 77% of the intraoperative size after 4 weeks and very little change after that. Similar results have been observed for external DCR [7, 9, 10].

Ostium and Anatomical Variations

Some patients have features that make the endoscopic DCR surgery easier, such as a large lacrimal sac, thin lacrimal bone, small middle turbinate, posterior uncinate process, or an internal common opening that is situated more inferiorly in the lacrimal sac. Others have more challenging anatomy, for example, small lacrimal sac, thick frontal process of the maxilla, ethmoidal air cells significantly overlying the

A. Zarkovic, FRANZCO • D. Brettell, M.D.
S.N. Madge, F.R.C.Ophth.
Department of Ophthalmology, Wye Valley Trust, NHS Hereford, Hereford, UK

E.C. Figueira, FRANZCO
Ophthalmic Plastics Surgery, Royal Adelaide Hospital, Adelaide, Australia

M.M. Marcet, M.D.
Department of Ophthalmology, University of Hong Kong, Cyberport, Hong Kong

D. Selva, FRANZCO (✉)
Ophthalmology and Visual Sciences, University of Adelaide, Adelaide, Australia
e-mail: saioph@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_43

lacrimal sac, or a high internal common opening, which may predispose them to a higher failure rate [12]. Konuk et al. [13] identified large middle turbinates and severe septal deviation as causative factors in 14% of failed cases.

Planning the best location and size of the bony osteotomy in endonasal DCR is dependent on awareness of the variations in anatomical landmarks of the lateral nasal wall. The most commonly used landmarks are the maxillary line and the axilla of the middle turbinate [14]. Based on cadaveric dissections, Orhan found that the maxillary line overlapped the lacrimal sac in 18/20 cadaveric specimens and that the lacrimal sac was located posterior to the maxillary line in the other two specimens [15]. However, Ali et al. [16] in their cadaveric study found that the spatial relationship of the maxillary line and head of middle turbinate is not constant and hence should not be solely relied upon during surgery. There is also considerable variability in the location of another important landmark, the lacrimo-maxillary suture (LMS). Shams et al. found that the LMS was centrally located in the fossa in 25% of Caucasian orbits, while in 32% of orbits, it was located closer to the posterior lacrimal crest indicating predominance of the thicker maxillary bone [17]. In contrast, a study of Indian orbits noted a centrally located LMS in 79% of specimens and a maxillary dominant fossa in only 8.3% [18]. A study based on CT findings in Asian orbits found that the lacrimal fossa was formed predominantly by the frontal process of maxilla in 79% of patients [19].

Factors Affecting Wound Healing and Soft Tissue Ostial Size

Factors other than the size of the bony osteotomy may also affect the ultimate size of the ostium. Studies have shown that in cases of failed surgery due to osteotomy closure, healing occurs predominantly by fibrosis with very little new bone formation [20]. Especially in adults, bone growth would not be expected across a mucosal anastomosis or in the absence of periosteum, which is removed during surgery.

Once an ostium is created, the mucosal and bony edges will trigger an inflammatory response. The extent of the inflammation depends on the size of the defects between the raw edges and the individual's innate healing response. While it seems intuitive that approximation of mucosal edges would lead to less granulation and scarring, several authors have described comparable success rates regardless of the number of created flaps [21–23]. Khalifa et al. [21] conducted a prospective randomized controlled trial comparing endoscopic DCR with double posteriorly based nasal and lacrimal flaps to a technique in which the nasal and lacrimal mucosa are removed without creation of flaps. Although there was a better healing profile with fewer debridement sessions in the double flap group, this did not lead to a statistically significant increase in success rate (92% versus 87%). However, several authors reported anatomical patency rates of more than 95% in endoscopic DCR with the double flap technique, which allows complete marsupialization of the lacrimal sac into the lateral nasal wall [8, 24]. For external DCR, comparable success rates were achieved between groups where both anterior and posterior flaps were sutured and groups where only the anterior flaps were sutured and the posterior flaps where left either unsutured [25] or were excised [26]. Baldeschi et al. compared different patterns of mucosal dissection resulting in different number and extent of unsutured mucosal margins in external DCR. They found the length of the margins did not adversely affect the success rate [27].

Anatomical variations in the lacrimal fossa and location of ethmoidal air cells mean that the apposition of mucosal edges may be achieved with different flap designs in different individuals. One may postulate that mucosal apposition rather than a standardized flap design may influence healing and hence the success rate. Despite the lack of evidence regarding the need for mucosal apposition, it is the authors' preference to achieve apposition where possible to minimize secondary intention healing and the associated fibrosis.

Modulation of Wound Healing and Influence on Ostium Size

Numerous studies have evaluated the antifibrotic properties of adjunctive mitomycin C (MMC) in an attempt to modulate the healing process during the initial stage of soft tissue granulation and thereby reduce the rate of anatomical failure.

Studies comparing the postoperative osteotomy size have found significantly larger ostia in patients treated with intraoperative MMC compared to control group both for external [28] and endoscopic DCR [29, 30]. A recent meta-analysis suggested that intraoperative MMC application may reduce the closure rate of osteotomies and enhance the success rate in external DCR [31] and both primary and revision endo-DCR [32]. However, several studies have failed to show any beneficial effect [33–36]. No adverse effects from MMC were found in any of the DCR studies.

MMC dosage has ranged between 0.2 and 0.5 mg/ml and the exposure time from 2–30 min [32, 37]. Ali et al. [38] in their in vitro study attempted to address this issue and found that a concentration of 0.02% for 3 min was the optimal dose. The MMC is generally applied topically but circumostial injection can also be used [39]. In their randomized controlled study, You and Feng [36] found no significant difference in patency rate and ostium size between the groups receiving topical MMC in concentrations of 0.2 mg/ml or 0.5 mg/ml, and both groups had better outcomes compared

to the control group. In contrast, intraoperative or postoperative use of 5-Fluorouracil does not appear to influence the ostial size or the success rates [40, 41]. Wu et al. [42] reported significant improvement of ostial patency for endoscopic DCR with use of Merogel, a hyaluronic acid derivative thought to promote epithelial healing and reduce scarring but there have been no other studies with this agent.

Surgeons have also utilized steroids both topically and in the form of injections into the tissue adjacent to the ostium, but again there remains no evidence base on the effect this might have on patency rates. Although there is no strong evidence of the use of wound modulators, however, such agents can be considered in the context of a possible higher risk of ostial closure such as in revision DCR [43].

Updates (2015–2016)

The creation of an ostium of sufficient size and the correct location remains the best way to ensure surgical success in dacryocystorhinostomy (DCR). Minimizing local tissue trauma and the careful postoperative examination of the ostium site can also help reduce soft tissue granulomas, scarring, and synechiae.

Ostium Size

In their prospective trial of 92 patients, Balikoglu-Yilmaz et al. [44] examined the rates of success between endoscopic, external, and transcanalicular diode DCR. External DCR gave the highest rates of anatomical and functional success, as well as the largest ostium (33.7 ± 17.4 mm) and lowest rate of granuloma formation. Longari et al. [45] performed a retrospective review on 84 patients who underwent endoscopic DCR and found that the use of silicone intubation led to a smaller ostium and higher rate of postoperative soft tissue changes. Once the ostium has been created, Ali et al. [46] demonstrated through repeated endoscopic review at 4 weeks, 6 months, 1 year, and 2 years that the change in size is minimal beyond 4 weeks after surgery (At 4 weeks, 11.25 × 7.07 mm to 10.15 × 6.45 mm at 2 years). In examining the cause of initial failure discovered at redo external DCRs, Sullivan et al. [47] demonstrated that insufficient ostium size is more likely if the primary operation was done by a fellow rather than a consultant. In those cases performed by a consultant, the most likely cause of failure was a soft tissue obstruction. Dave et al. [48] analyzed 100 cases of external and endoscopic failed DCRs and found that the commonest causes were inadequate osteotomy (69.8% in failed external DCRs versus 85.1% in failed endoscopic DCRs) and cicatricial closure of ostium (50.6% in failed external DCRs versus 55.5% in failed endoscopic DCRs).

Wound Healing and Soft Tissue Ostial Size

Soft tissue granulomas, scarring, and synechiae can all lead to DCR failure despite the creation of a large and well-located bony ostium. Ali et al. [49] in their study of outcomes of endoscopic dacryocystorhinostomy between consultants and fellows have shown that from the healing perspective, the ostium granulomas and turbinoseptal synechiae were more common among the less experienced surgeons. This could potentially reflect on finer operative techniques and better achievement of mucosa to mucosa flaps approximation. Previous groups have studied the effects of mucosal flap creation and positioning, with a recent study by Roh et al. [50] examining the effects of the choice of instrument to create a mucosal incision in endonasal DCR. They found that the use of a sickle knife leads to significantly shorter healing times than the use of electrocautery, but that the creation of a mucosal flap did not affect the success rate. A contemporaneous prospective trial by Tachino et al. [51] investigated the success of an endoscopic technique that involved suturing anastomotic edges; finding this technique had a higher success rate and larger ostium size than the group where no suturing was performed.

Modulation of Wound Healing

In an effort to understand the wound healing and subsequent biological modulation, Ali et al. [52] studied the histopathology, immunohistochemistry, and electron microscopy of cicatricial tissues from the closed DCR ostium. Apart from the expected scar tissue, they found evidence of new bone formation and mixed T and B lymphocytic infiltrate. Electron microscopic features of scarred ostial tissues include numerous fibroblasts with disorganized collagen and metabolically active osteoblasts with hyperproliferative mitochondria and dense endoplasmic reticulum. On the clinical front, in examining the appearance and behavior of ostial granulomas, Ali et al. [53] noted that with early detection treatment can be as simple as using topical steroids, with over 90% of early granulomas resolving.

Conclusion

These recent advances have helped to support our initial conclusions: that while no consensus exists on the "gold standard" bony ostium size or soft tissue positioning, the best chance for surgical success is in full exposure and marsupialization of the entire lacrimal sac with flap apposition to promote primary intention healing. At present, no strong evidence exists that the use of wound modulators improves success rates.

References

1. Allen KM, Berlin AJ. Intranasal endoscopic analysis of dacryocystorhinostomy failure. Ophthal Plast Reconstr Surg. 1988;4:143–5.
2. Welham RA, Henderson PH. Results of dacryocystorhinostomy: analysis of causes for failure. Trans Ophthalmol Soc UK. 1973;93:601–9.
3. Wormald P, Kew J, van Hasselt CA. The intranasal anatomy of the naso-lacrimal sac in endoscopic dacryocystorhinostomy. Otolaryngol Head Neck Surg. 2000;123:307–10.
4. Wormald P. Powered endoscopic dacryocystorhinostomy. Laryngoscope. 2002;112:69–72.
5. Rose GE. The lacrimal paradox: toward a greater understanding of success in lacrimal surgery. Ophthal Plast Reconstr Surg. 2004;20:262–5.
6. Argin A, Görür K, Ozcan C, et al. The role of larger osteotomy in long term success in external dacryocystorhinostomy. J Plast Reconstr Aesthet Surg. 2008;61:615–9.
7. Ben Simon GJ, Brown C, McNab AA. Larger osteotomies result in larger ostia in external dacryocystorhinostomies. Arch Facial Plast Surg. 2012;14:127–31.
8. Chan W, Selva D. Ostium shrinkage after endoscopic dacryocystorhinostomy. Ophthalmology. 2013;120:1693–6.
9. Ezra E, Restori M, Mannor GE, et al. Ultrasonic assessment of rhinostomy size following external dacryocystorhinostomy. Br J Ophthalmol. 1998;82:786–9.
10. Bumsted RM, Linberg JV, Anderson RL, et al. External dacryocystorhinostomy: a prospective study comparing the size of the operative and healed ostium. Arch Otolaryngol. 1982;108:407–10.
11. Mann B, Wormald PJ. Endoscopic assessment of the dacryocystorhinostomy ostium after endoscopic surgery. Laryngoscope. 2006;116:1172–4.
12. Goldberg R. Endonasal dacryocystorhinostomy: is it really less successful? Arch Ophthalmol. 2004;122:108–10.
13. Konuk O, Kurtulmusoglu M, Knatova Z, et al. Unsuccessful lacrimal surgery: causative factors and results of surgical management in a tertiary referral center. Ophthalmologica. 2010;224:361–6.
14. Chastain J, Cooper MH, Sindwani R. The maxillary line: anatomic characterization and clinical utility of an important surgical landmark. Laryngoscope. 2005;115:990–2.
15. Orhan M, Saylam CY, Midilli R. Intranasal localization of the lacrimal sac. Arch Otolaryngol Head Neck Surg. 2009;135:764–70.
16. Ali MJ, Nayak JV, Vaezeafshar R, et al. Anatomic relationship of nasolacrimal duct and major lateral wall landmarks: cadaveric study with surgical implications. Int Forum Allergy Rhinol. 2014;4:684–8.
17. Shams P, Abed SF, Shen S, et al. A cadaveric study of the morphometric relationships and bony composition of the caucasian nasolacrimal fossa. Orbit. 2012;31:159–61.
18. Bisaria K, Saxena RC, Bisaria SD, et al. The lacrimal fossa in Indians. J Anat. 1989;166:265–8.
19. Woo K, Maeng HS, Kim YD. Characteristics of intranasal structures for endonasal dacryocystorhinostomy in asians. Am J Ophthalmol. 2011;152:491–8.
20. McLean C, Cree IA, Rose GE. Rhinostomies: an open and shut case? Br J Ophthalmol. 1999;83:1300–1.
21. Khalifa MA, Ragab SM, Saafan ME, et al. Endoscopic Dacryocystorhinostomy with double posteriorly based nasal and lacrimal flaps: a prospective randomized controlled trial. Otolaryngol Head Neck Surg. 2012;147:782–7.
22. Kansu L, Aydin E, Avci S, et al. Comparison of surgical outcomes of endonasal dacryocystorhinostomy with or without mucosal flaps. Auris Nasus Larynx. 2009;36:555–9.
23. Massegur H, Trias E, Adema JM. Endoscopic dacryocystorhinostomy: modified technique. Otolaryngol Head Neck Surg. 2004;130:39–46.
24. Tsirbas A, Wormald PJ. Mechanical endonasal dacryocystorhinostomy with mucosal flaps. Br J Ophthalmol. 2003;87:43–7.
25. Turkcu FM, Oner V, Tas M, et al. Anastomosis of both posterior and anterior flaps or only anterior flaps in external dacryocystorhinostomy. Orbit. 2012;31:383–5.
26. Serin D, Alagoz G, Karslioglu S, et al. External Dacryocystorhinostomy: double-flap anastomosis or excision of the posterior flaps? Ophthal Plast Reconstr Surg. 2007;23:28–31.
27. Baldeschi L, MacAndie K, Hintschich C. The length of unsutured mucosal margins in external dacryocystorhinostomy. Am J Ophthalmol. 2004;138:840–4.
28. Kao SC, Liao CL, Tseng JH, et al. Dacryocystorhinostomy with intraoperative mitomycin C. Ophthalmology. 1997;10:486–91.
29. Mudhol R, Zingade ND, Mudhol RS, et al. Prospective randomized comparison of mitomycin C application in endoscopic and external dacryocystorhinostomy. Indian J Otolaryngol Head Neck Surg. 2013;65:255–9.
30. Tirakunwichcha S, Aeumjaturapat S, Sinprajakphon S, et al. Efficacy of mitomycin C in endonasal endoscopic dacryocystorhinostomy. Laryngoscope. 2011;121:433–6.
31. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
32. Cheng SM, Feng YF, Xu L, et al. Efficacy of mitomycin C in endoscopic dacryocystorhinostomy: a systematic review and meta-analysis. PLoS One. 2013;8:e62737.
33. Zilelioglu G, Ugurbas SH, Anadolu Y, et al. Adjunctive use of mitomycin C on endoscopic lacrimal surgery. Br J Ophthalmol. 1998;82:63–6.
34. Prasanaraj T, Kumar P, Narasimhan I, et al. Significance of adjunctive mitomycin C in endoscopic dacryocystorhinostomy. Am J Otolaryngol Head Neck Med Surg. 2012;33:47–50.
35. Ragab SM, Elsherif HS, Shehata EM, et al. Mitomycin C–enhanced revision endoscopic dacryocystorhinostomy: a prospective randomized controlled trial. Otolaryngol Head Neck Surg. 2012;147:937–42.
36. You Y, Fang CT. Intraoperative mitomycin C in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2001;17:115–9.
37. Ari S, Gun R, Surmeli S, et al. Use of adjunctive mitomycin C in external dacryocystorhinostomy surgery compared with surgery alone in patients with nasolacrimal duct obstruction: a prospective, double masked, randomized controlled trial. Curr Ther Res. 2009;70:267–73.
38. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration – a fundamental study on human nasal mucosa fibroblast. Ophthal Plast Reconstr Surg. 2013;29:469–74.
39. Kamal S, Ali MJ, Naik MN. Circumostial injection of mitomycin C in external and endoscopic dacryocystorhinostomy: efficacy, safety profiles and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
40. Bakri K, Jones N, Downes R, et al. Intraoperative fluorouracil in endonasal laser dacryocystorhinostomy. Arch Otolaryngol Head Neck Surg. 2003;129:233–5.
41. Costa MN, Marcondes AM, Sakano E, et al. Endoscopic study of the intranasal ostium in external dacryocystorhinostomy. Postoperative influence of saline solution and 5-fluorouracil. Clinics. 2007;62:41–6.
42. Wu W, Cannon PS, Yan W, et al. Effects of merogel coverage on wound healing and ostial patency in endonasal endoscopic dacryocystorhinostomy for primary chronic dacryocystitis. Eye. 2011;25:746–53.
43. Marcet MM, Kuk AKT, Phelps PO. Evidence-based review of surgical practices in endoscopic endonasal dacryocystorhinostomy for primary acquired nasolacrimal duct obstruction and other new indications. Curr Opin Ophthalmol. 2014;25:443–8.

44. Balikoglu-Yilmaz M, Yilmaz T, Taskin U, et al. Prospective comparison of 3 dacryocystorhinostomy surgeries: external versus endoscopic versus transcanalicular multidiode laser. Ophthal Plast Reconstr Surg. 2015;31:13–8.
45. Longari F, Dehgani-Mobaraki P, Ricci AL, et al. Endoscopic dacryocystorhinostomy with and without silicone intubation: 4 years retrospective study. Eur Arch Otorhinolaryngol. 2016;273:2079–84.
46. Ali MJ, Psaltis AJ, Ali MH, et al. Endoscopic assessment of the dacryocystorhinostomy ostium after powered endoscopic surgery: behaviour beyond 4 weeks. Clin Experiment Ophthalmol. 2015;43:152–5.
47. Sullivan L, Fearnley T, Al-Maskari A, et al. External dacryocystorhinostomy in consultants and fellows – a comparison of the causes of failure. Hippokratia. 2015;19:216–8.
48. Dave T, Mohammed FA, Ali MJ, et al. Etiologic analysis of 100 anatomically failed dacryocystorhinostomies. Clin Ophthalmol. 2016;10:1419–22.
49. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes in primary powered endoscopic dacryocystorhinostomies: comparison between experienced versus less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.
50. Roh HC, Baek S, Lee H, et al. Comparison of impact of four surgical methods on surgical outcomes in endoscopic dacryocystorhinostomy. J Craniomaxillofac Surg. 2016;44:749–52.
51. Tachino H, Fujisaka M, Fuchizawa C, et al. Endonasal flap suture-dacryocystorhinostomy (eFS-DCR): a new surgical technique for nasolacrimal duct obstruction (NLDO). Acta Otolaryngol. 2015;135:162–8.
52. Ali MJ, Mishra DK, Baig F, et al. Histopathology, immunohistochemistry and electron microscopic features of a dacryocystorhinostomy ostium cicatrix. Ophthal Plast Reconstr Surg. 2016;32:333–6.
53. Ali MJ, Wormald PJ, Psaltis AJ. The dacryocystorhinostomy ostium granulomas: classification, indications for treatment, management modalities and outcomes. Orbit. 2015;34:146–51.

Debates in Dacryology: The Mitomycin C Dilemma

44

Yi-Fan Feng

Introduction

The most common reason for the failure of dacryocystorhinostomy (DCR) surgery is the formation of scar or granulation tissue over the osteotomy site. From the literature, it is clear that fibrous tissue growth, scarring, and granulation tissue formation during the healing process will decrease or compromise the created surface area of the osteotomy site, leading to surgical failure [1, 2]. Also, the healing process has the potential to promote adhesion of the middle turbinate and septum to the osteotomy site or induce an obstruction of the common canaliculus [3]. Thus, if we can inhibit fibrous tissue growth and scarring by applying antiproliferative agents over the anastomosed flaps and osteotomy site, the failure rate may be minimized [4].

Mitomycin C (MMC) is an antibiotic isolated from *Streptomyces caespitosus*. It has a molecular weight of 334 Da and is soluble in water and organic solvents [5]. MMC contains quinone, carbamate, and aziridine groups, all of which may contribute to its activity. The drug is a bioreductive alkylating agent that undergoes metabolic reductive activation and has various oxygen tension-dependent cytotoxic effects on the cells, including the cross-linking of DNA [6]. Although DNA alkylation can occur at any stage in the cell cycle, the biological consequences are most severe during DNA synthesis. In addition, inhibition of RNA and protein synthesis is a non-specific mechanism of cell toxicity. Furthermore, under aerobic conditions, as occurs predominantly in ophthalmic use, intermediates react with molecular oxygen to generate free radicals, causing cytotoxicity via lipid peroxidation, and subsequently DNA and protein damage [5].

MMC is primarily used systemically for the treatment of malignancies and has gained popularity as a topical adjunctive therapy in ocular and adnexal surgery over the past two decades. Now, MMC is used as an anti-scarring agent in a wide range of ocular surgeries and laser-assisted procedures, including glaucoma filtering surgery [7, 8], pterygium surgery [9, 10], corneal refractive surgery [11], and lacrimal surgery [12, 13]. In this chapter, we will focus on the application of MMC in dacryocystorhinostomy.

Experimental Evidence

Normal wound healing is a complex cascade of events involving multiple cell types and their products, including growth factors and chemokines. The fibroblast is the key player in the scarring response; among its crucial functions are proliferation, extracellular matrix (ECM) production, and contraction and migration. Many of these functions are under the control of growth factors and the specific receptors through which they elicit their effects. For example, exposure to MMC resulted in an increased production of transforming growth factor β (TGF-β) and basic fibroblast growth factor (bFGF); decreased number of receptors for TGF- β, bFGF, and epidermal growth factor (EGF); decreased type I collagen and fibronectin production; and decreased cellular migration, thereby influencing wound healing [14].

A series of basic studies have been performed to investigate the effect of MMC exposure to Tenon's capsule fibroblasts and confirmed suppression of Tenon's capsule fibroblasts by MMC [15–17]. However, studies on human Tenon's fibroblast cannot entirely be extrapolated since the application of MMC in DCR is to the nasal mucosa. The vascularity of these two structures is poles apart and hence not comparable. To date, only two published studies were performed to observe the effect of MMC on cultured human nasal mucosa fibroblasts [18, 19]. Hu et al. [18] reported higher doses and longer exposures resulted in higher rates of growth suppression with a maximal effect of 31.3% suppression following 5-min exposure with 0.4 mg/ml of MMC. Of note, normal regrowth occurred within 2–3 days and

Y.-F. Feng, M.D., Ph.D.
Department of Ophthalmology, Zhongshan Hospital and Fudan University, Shanghai, China
e-mail: wzafengyifan@163.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_44

complete confluence was observed after 5–7 days. More recently, the results in another fundamental study by Ali et al. [19] indicated that 0.4 mg/ml MMC beyond 5 min and 0.5 mg/ml concentration at all time points were lethal and caused extensive cell death. Figures 44.1 and 44.2 provide experimental evidence on the effects of MMC on human nasal mucosal fibroblasts. They suggested that the probable optimal MMC treatment for preventing cell proliferation of human nasal mucosal fibroblasts in vitro by inducing cell cycle arrest, without causing extensive cell death is 0.2 mg/ml when used for 3 min [19].

A few studies have investigated the effects of MMC on sino-nasal tissue in a rabbit model of maxillary sinus antrostomies and attempted to provide further evidences for the MMC applications. Ingrams et al. [20] investigated the effects of 5-min applications of varying doses of MMC to surgically created maxillary antrostomies in a rabbit model. Their results demonstrated improved rates of ostial patency with increasing doses when compared with the control side. Additionally, return to normally ciliary function was demonstrated in all MMC-treated sides including those that received doses considered cytocidal (1.0 mg/ml) to fibroblasts. Their results were supported by a similar study by Rahal et al. [21] that demonstrated a significantly higher rate of ostial patency in the MMC-treated side with normal reepithelialization at the time of animal sacrifice. Kavuzlu et al. [22] investigated the effect of the topical use of MMC intraoperatively in single dose versus two doses (intra- and postoperatively) on the narrowing of antrostomy in maxillary rabbit sinus antrostomies created experimentally. Animals were sacrificed at 8 weeks, and examination revealed that the antrostomy areas were significantly larger in the two-dose group than the single-dose group. Unfortunately, there was no study directly to investigate the effects of MMC in the animal model of DCR surgery.

The collective evidence as detailed above supports the dose-dependent, suppressive effects of MMC on fibroblast activity. Given the critical role of fibroblasts in scar formation, these studies highlight the potential for MMC to modulate postoperative wound healing in DCR surgery.

Clinical Evidence

The cumulative basic science foundations and clinical experience in other disciplines have prompted clinical trials investigating the efficacy of MMC to decrease scar formation following DCR in humans, and numerous clinical studies have been published in this regard [13, 23–48]. In DCR surgery, the most familiar way is to soak MMC over the osteotomy site and the anastomosed flaps. This modification should theoretically reduce the fibrous adhesion between the osteotomy site and the nasal septum as well as inhibit scarring around the opening of the common canaliculus, which prevents further shrinkage of the final surface area of the osteotomy and obstruction of the common canaliculus opening.

Multiple issues require attention prior to determining the role of MMC in DCR, including safety and efficacy. To date, there have been no complications directly associated with the use of MMC following DCR surgeries. Both systemic and local complications, however, have been described in other fields. This is because of its prolonged cytological toxicity. Myelosuppression following the use of MMC results from systemic absorption and would be unlikely when used in topical form. Local complications have been described in ophthalmologic applications including ulceration and epithelial toxicity. Some complications such as corneal ulcer, corneal perforations, scleral thinning, secondary cataract, endophthalmitis, hypotony, and maculopathy have been reported from the use of MMC in pterygium and glaucoma surgery [23, 24]. Differentiation of normal postoperative healing from local complications due to MMC can only be determined with endoscopic surveillance of the ostium.

More and more prospective, randomized studies have attempted to determine the efficacy of MMC following DCR in humans (Table 44.1). In the first randomized controlled study, Kao et al. [25] reported the use of MMC in a series of 14 patients who underwent DCR with and without MMC. At 6-month follow-up, osteotomy size was significantly larger in patients in whom MMC was used compared with controls. These findings were supported in subsequent studies which showed an increase in both ostium size and patency with the use of MMC during external DCR [26] and endoscopic DCR [27]. These studies revealed that MMC can minimize postoperative fibrosis and granulations, thereby maintaining a bigger postoperative ostium throughout the postoperative observation period [28]. With the popularity of evidence-based medicine, separate meta-analysis on the efficacy of MMC both in external and endoscopic DCR has been performed more recently and demonstrated it to be not only a safe adjuvant but was also useful in decreasing the osteotomy closure rates [13, 29–31]. Meta-analyses also found MMC to enhance the success rates of both primary and revision endoscopic DCR [13, 29–31].

Dilemmas and Challenges

As described above, the preliminary basic science evidence, in addition to the ophthalmology experience, provides theoretical support for the use of MMC in DCR. Although the antiproliferative effect of MMC was proven both in cell cultures and animal studies, it could not be demonstrated in clinical studies that the use of MMC following DCR influenced healing significantly. A discussion of the possible reasons behind these results is critical for improved protocol designs for future studies.

Table 44.1 Comparison of randomized controlled studies on dacryocystorhinostomy with intraoperative Mitomycin C (MMC)

First author/year	Surgical technique	Type of DCR	MMC concentration	MMC exposure time	No. eyes (MMC/control)	Follow-up (months)	Silicone tube use	Success rate (MMC vs. control)
Kao et al. (1997) [25]	EX-DCR	Primary	0.2 mg/ml	30 min	15 (7/8)	6	Yes	100% vs.87.5%
Yildirim et al. (2007) [38]	EX-DCR	Primary	0.2 mg/ml	30 min	40 (20/20)	12	Yes	95% vs. 85%
Liao et al. (2000) [4]	EX-DCR	Primary	0.2 mg/ml	30 min	88 (44/44)	10	Yes	95.5% vs. 88.6%
Roozitalab et al. (2004) [39]	EX-DCR	Primary	0.2 mg/ml	30 min	130 (65/65)	6	No	90.5% vs. 92.4%
Yalaz et al. (1999) [40]	EX-DCR	Primary	0.5 / 1.0 mg/ml	5 min	40 (20/20)	12–18	No	95% vs. 90%
Eshraghy et al. (2011) [41]	EX-DCR	Primary	0.2 mg/ml	5 min	88 (42/46)	6–15	Yes	73.8% vs. 69.6%
Gonzalvo et al. (2000) [26]	EX-DCR	Primary	0.2 mg/ml	2 min	17 (9/8)	6–18	No	100% vs. 75%
Qadir et al. (2014) [42]	EX-DCR	Primary	0.2 mg/ml	5 min	50 (25/25)	6	No	96% vs. 80%
Ghosh et al. (2006) [43]	EN-DCR	Primary	0.2 mg/ml	2 min	30 (15/15)	12	No	80% vs. 86.7%
Prasannaraj et al. (2012) [44]	EN-DCR	Primary	0.2 mg/ml	10 min	38 (17/21)	6	No	82.3% vs. 85.7%
Tirakunwichcha et al. (2011) [27]	EN-DCR	Primary	0.5 mg/ml	3 min	50 (26/24)	12	Yes	84.6% vs. 79.2%
Farahani et al. (2008) [45]	EN-DCR	Primary	0.2 mg/ml	3 / 15 min	92 (46/46)	12.17/12.80	Yes	91.3% vs. 87%
Penttilä et al. (2011) [46]	EN-DCR	Revison	0.4 mg/ml	5 min	30 (15/15)	6	No	93% vs. 60%
Özkiriş et al. (2012) [47]	EN-DCR	Revison	0.5 mg/ml	5 min	36 (18/18)	11.5/12.7	Yes	88.9% vs. 55.5%
Ragab et al. (2012) [48]	EN-DCR	Revison	0.5 mg/ml	10 min	76 (38/38)	12	Yes	82.9% vs. 80.6%

Firstly, while MMC has been used extensively in DCR surgery, the appropriate concentrations and treatment durations have not been standardized. In addition, wound healing in the postoperative ostium is a complex series of events mediated by several cell types molecular pathways and occurs over a period of 6–8 weeks [32]. Modulation of this process by MMC would require a prolonged effect that may not be possible with a single intraoperative application. Therefore, it may be worth noting that new treatment schemes have been developed, such as the use of MMC intra- and postoperatively in two separate applications as shown by Henson et al. [33] Similarly, given the dose-dependent activity of MMC on fibroblasts demonstrated in basic science studies, clinical application would require an adequate dose for an adequate period of time. It is possible that higher doses of MMC and/or longer exposure times of MMC may be required following DCR surgery than in other applications because it may be diluted with the bleeding and irrigation that occurs postoperatively [32]. For exactly this reason, Ali et al. [34] have proposed a new technique of injecting MMC circumostially, and their 1-year data in DCR is encouraging.

Secondly, the question remained unanswered whether MMC application can reduce scarring and enhance the success rate in the presence of confounding effects of silicone intubation. To prevent obliteration of the intranasal lacrimal sac ostium, many surgeons prefer to insert either bi- or monocanalicular silicone tubes to stent the internal ostium. However, it has been postulated that silicone tubing itself may cause tissue granulation, predisposing the site to postoperative infection and adhesions, and canalicular lacerations, resulting in surgical failure [35]. Thus, some surgeons suggested the use of MMC to suppress fibrous proliferation and scar formation during DCR surgery along with silicone intubation. Further studies are needed to discuss whether adjunctive MMC application during silicone intubation has additional benefit over silicone intubation alone.

Lastly, despite apparently higher rates of success with no significant complications using MMC in adult lacrimal surgery, similar studies are scarce in pediatric DCR surgery. In a prospective, large case series study, Dolmetsch et al. [36] showed non-laser endonasal DCR with MMC was a safe and successful procedure for the treatment of congenital nasolacrimal duct obstruction in children. Young patients (especially children) may present with a failure of lacrimal drainage procedures on account of an overwhelming healing response [37]. Given that the management and indications for MMC in DCR surgery are different in young patients and adults, more data is needed to draw definitive conclusions. Table 44.1 lists all the randomized trials of DCR with and without MMC and their outcomes [4, 25, 27, 38–48].

Updates (2015–2016)

Collagen Contractility, Scratch Wound Assays, and MMC

Kumar et al. [49] performed an in vitro study on human nasal mucosal fibroblast cultures. Myofibroblasts were induced using the human transforming growth factor-β1 (TGF-β1). Various concentrations of MMC were used to study the abilities of activated myofibroblasts for collagen contractility. Scratch wounds were created to assess the healing responses to multiple MMC concentrations. They found that MMC inhibited the TGF-β1-induced collagen contractility in a dose-dependent manner. MMC-treated fibroblast showed decreased migration and delayed wound healing. They found that at the minimum effective dose of 0.2 mg/ml for 3 min, TGF-β1-induced transformation to myofibroblast was inhibited and so was collagen contractility and the ability to cover and heal a wound. These findings corroborated with earlier findings on the minimum effective dosage using different experimental techniques [19].

Circumostial Injection of MMC (COS-MMC)

Intraoperative MMC application still is one of the most popular methods, in spite of various concentrations (ranging 0.02–0.5 mg/ml) and durations (ranging 2–30 min) that have been reported. The standard technique is to use a cotton-tip applicator soaked in MMC applied under the nasal and lacrimal flaps for the desired duration followed by copious irrigation with normal saline [13, 30, 50, 51]. Kamal et al. [34] recently described a modified technique of injecting MMC called circumostial MMC (COS-MMC), where after fashioning the mucosal flaps, intramucosal injection of 0.02% MMC was injected at four points (0.1 ml at each point) along the edges of the freshly created ostium. By using this technique, they reported that the anatomical and functional success rates were achieved in 97.3% and 96.4% of the patients, respectively, during a short follow-up period [34] and were maintained at 93.6% during a long-term follow-up period [52]. However, the limitations of this study were the lack of control group and possible confounding effect of silicone tube.

In a subsequent study in vitro, Ali et al. [53] evaluated the ultrastructural effects of topical MMC (0.02%, 3 min) and COS-MMC on nasal mucosa and compared them with the untreated naïve nasal mucosa (as controls) (Figs. 44.3, 44.4 and 44.5). This study for the first time documented detailed transmission electron microscopic effects of standardized MMC on nasal mucosa using various modalities of drug applications. The authors reported that the nasal mucosal fibroblasts show a dramatic structural response to MMC,

including intracellular edema, pleomorphic and vesicular mitochondria, dilated smooth and rough endoplasmic reticulum, and chromatin condensation. Moreover, both, topical and COS-MMC showed profound changes in nasal mucosal fibroblasts, but the effects seem to be more marked in the COS-MMC group.

Despite limited data, the current high clinical success rates along with basic science findings mentioned above indicate that COS-MMC may be a safe and effective adjunctive in DCR, particularly in high-risk cases like revision and post-traumatic DCR's. Further studies in regard to COS-MMC with a larger sample size and longer follow-ups are required to be able to provide clinical guidelines.

Post-operative MMC Application

During wound healing, fibroblast formation occurs around the wound 7 days after the injury [54]. However, the concentration of MMC in the area of topical application declined rapidly within 24 h, and a fraction of the fibroblasts showed regrowth within 2–3 days [18]. Given the critical role of fibroblasts in scar formation, a continuous application of MMC until fibrosis formation may be more effective than single intraoperative MMC application.

Rathore et al. [55] in their series of endonasal DCRs packed the nasal cavity with 0.05% MMC nasal pack for 48 h. They observed that postoperative retention of nasal packs for 48 h after endonasal DCR did not cause any major side effect. Postoperatively, the nasal cavity which had been packed with MMC had healthy nasal mucosa during the entire follow-up, as compared to the control group where the saline nasal pack was used, and where synechiae were seen in 65.2% of the patients [55].

In another prospective study conducted by Henson et al. [33], a 5-min application of MMC (0.4 mg/ml), without irrigation, was done intraoperatively as well as postoperatively at 1 week, 2 weeks, and 3 weeks. Encouragingly, the multiple postoperative applications of MMC in endocanalicular laser DCR were safe and effective, with the success rate of 92.8%.

In a recent study comparing the efficacy of postoperative topical MMC with intraoperative MMC application in endoscopic DCR, Do et al. [56] used three groups: control group 1, operated without MMC; experimental group 2, with intraoperative application of 0.02% MMC for 5 min; and experimental group 3, with 0.02% MMC eye drops for 5 days after surgery. Their results showed that the success rate between the Group 2 and Group 3 was similar, but both higher than that in Group 1. Moreover, none of the patients had adverse effects associated with postoperative MMC application. The authors attributed the high success rate of MMC eye drop application to the consistent inhibition of fibrous tissue growth in both ostium site and canaliculus.

Although the beneficial effect from the long-lasting application has been proposed, whether it is superior to the single intraoperative MMC application is still debated. Moreover, a recent study in vitro provided evidence that low concentration and short duration of MMC treatment is efficient in reducing increased contraction and migration of human nasal mucosal fibroblasts in response to injury [49]. Therefore, large randomized studies are required prior to establishing clinical guidelines for the use of MMC in DCR.

Conclusion

The successful use of MMC in ophthalmology and increasing use in otolaryngology have spurred interest in its use for lacrimal surgery. The newer delivery techniques, such as COS-MMC or postoperative application of MMC eye drops, could provide sustained drug delivery and that may affect the outcomes of the DCR surgery. Moreover, histopathological studies of nasal mucosa following different modes of MMC delivery are also useful for making a suitable choice. There are still many issues that remain to be addressed to satisfaction, including perhaps the most important one: efficacy vs. safety. In the future, large randomized studies are required prior to definitive conclusions regarding the use of MMC in DCR surgery.

References

1. Allen KM, Berlin AJ, Levine HL. Intranasal endoscopic analysis of dacryocystorhinostomy failure. Ophthal Plast Reconstr Surg. 1988;4:143–5.
2. Jokinen K, Karja J. Endonasal dacryocystorhinostomy. Arch Otolaryngol. 1974;100:41–4.
3. McLachlan DL, Shannon GM, Flanagan JC. Results of dacryocystorhinostomy: analysis of the reoperations. Ophthalmic Surg. 1980;11:427–30.
4. Liao SL, Kao SC, Tseng JH, et al. Results of intraoperative mitomycin C application in dacryocystorhinostomy. Br J Ophthalmol. 2000;84:903–6.
5. Verweij J, Pinedo HM. Mitomycin C: mechanism of action, usefulness and limitations. Anti-Cancer Drugs. 1990;1:5–13.
6. Reddy MV, Randerath K. 32P-analysis of DNA adducts in somatic and reproductive tissues of rats treated with the anticancer antibiotic, mitomycin C. Mutat Res. 1987;179:75–88.
7. Maestrini HA, Cronemberger S, Matoso HD, et al. Late needling of flat filtering blebs with adjunctive mitomycin C: efficacy and safety for the corneal endothelium. Ophthalmology. 2011;118:755–62.
8. Reibaldi A, Uva MG, Longo A. Nine-year follow-up of trabeculectomy with or without low-dosage mitomycin-c in primary open-angle glaucoma. Br J Ophthalmol. 2008;92:1666–70.
9. Young AL, Ho M, Jhanji V, et al. Ten-year results of a randomized controlled trial comparing 0.02% mitomycin C and limbal conjunctival autograft in pterygium surgery. Ophthalmology. 2013;120:2390–5.
10. Diaz L, Villegas VM, Emanuelli A, et al. Efficacy and safety of intraoperative mitomycin C as adjunct therapy for pterygium surgery. Cornea. 2008;27:1119–21.
11. Chen SH, Feng YF, Stojanovic A, et al. Meta-analysis of clinical outcomes comparing surface ablation for correction of myopia with and without 0.02% mitomycin C. J Refract Surg. 2011;27:530–41.

12. Xue K, Mellington FE, Norris JH. Meta-analysis of the adjunctive use of mitomycin C in primary and revision, external and endonasal dacryocystorhinostomy. Orbit. 2014;33:239–44.
13. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
14. Occleston NL, Daniels JT, Tarnuzzer RW, et al. Single exposures to antiproliferatives: long-term effects on ocular fibroblast wound-healing behaviour. Invest Ophthalmol Vis Sci. 1997;38:1998–2007.
15. Kim JW, Kim SK, Song IH, et al. Mitomycin C-induced apoptosis in cultured human Tenon's capsule fibroblasts. Korean J Ophthalmol. 1999;13:7–15.
16. Hu D, Chen PP, Oda D. The effect of mitomycin C after long-term storage on human Tenon's fibroblast proliferation. J Glaucoma. 1999;8:302–5.
17. Jampel HD. Effect of brief exposure to mitomycin C on viability and proliferation of cultured human Tenon's capsule fibroblasts. Ophthalmology. 1992;99:1471–6.
18. Hu D, Sires BS, Tong DC, et al. Effect of brief exposure to mitomycin C on cultured human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2000;16:119–25.
19. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration—a fundamental study on human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
20. Ingrams DR, Volk MS, Biesman BS, et al. Sinus surgery: does mitomycin C reduce stenosis? Laryngoscope. 1998;108:883–6.
21. Rahal A, Peloquin L, Ahmarani C. Mitomycin C in sinus surgery: preliminary results in a rabbit model. J Otolaryngol. 2001;30:1–5.
22. Kavuzlu A, Arslan N, Tastan E, et al. The effects of repetitious topical use of mitomycin C on antrostomy patency in maxillary antrostomy created rabbit model. Eur Arch Otorhinolaryngol. 2011;268:1597–603.
23. Zacharia PT, Deppermann SR, Schuman JS. Ocular hypotony after trabeculectomy with mitomycin C. Am J Ophthalmol. 1993;116:314–26.
24. Rubinfeld RS, Pfister RR, Stein RM, et al. Serious complications of topical mitomycin-C after pterygium surgery. Ophthalmology. 1992;99:1647–54.
25. Kao SC, Liao CL, Tseng JH, et al. Dacryocystorhinostomy with intraoperative mitomycin C. Ophthalmology. 1997;104:86–91.
26. Gonzalvo IF, Fuertes FI, Fernandez TF, et al. External dacryocystorhinostomy with mitomycin C. Clinical and anatomical evaluation with helical computed tomography. Arch Soc Esp Oftalmol. 2000;75:611–7.
27. Tirakunwichcha S, Aeumjaturapat S, Sinprajakphon S. Efficacy of mitomycin C in endonasal endoscopic dacryocystorhinostomy. Laryngoscope. 2011;121:433–6.
28. Deka A, Bhattacharjee K, Bhuyan SK, et al. Effect of mitomycin C on ostium in dacryocystorhinostomy. Clin Experiment Ophthalmol. 2006;34:557–61.
29. Xue K, Mellington FE, Norris JH. Meta-analysis of the adjunctive use of mitomycin C in primary and revision, external and endonasal dacryocystorhinostomy. Orbit. 2014 (Epub).
30. Cheng SM, Feng YF, Xu L, et al. Efficacy of mitomycin C in endoscopic dacryocystorhinostomy: a systematic review and meta-analysis. PLoS One. 2013;8:e62737.
31. Feng YF, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
32. Tabaee A, Brown SM, Anand VK. Mitomycin C and endoscopic sinus surgery: where are we? Curr Opin Otolaryngol Head Neck Surg. 2007;15:40–3.
33. Henson RD, Cruz HL, Henson RG, et al. Post-operative application of Mitomycin-C in endocanalicular laser dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2012;28:192–5.
34. Kamal S, Ali MJ, Naik MN. Circumostial mitomycin C (COS-MMC) in external and endoscopic dacryocystorhinostomy: efficacy, safety profiles and outcomes. Ophthal Plast Reconstr Surg. 2014;30:187–90.
35. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report by the American Academy of ophthalmology. Ophthalmology. 2001;108:2369–77.
36. Dolmetsch AM, Gallon MA, Holds JB. Non-laser endoscopic endonasal dacryocystorhinostomy with adjunctive mitomycin C in children. Ophthal Plast Reconstr Surg. 2008;24:390–3.
37. Sodhi PK, Verma L, Ratan SK. Young age – a risk factor for failure of dacryocystorhinostomy. Orbit. 2004;23:237–9.
38. Yildirim C, Yaylali V, Esme A, et al. Long-term results of adjunctive use of mitomycin C in external dacryocystorhinostomy. Int Ophthalmol. 2007;27:31–5.
39. Roozitalab MH, Amirahmadi M, Namazi MR. Results of the application of intraoperative mitomycin C in dacryocystorhinostomy. Eur J Ophthalmol. 2004;14:461–3.
40. Yalaz M, Firincciogullari E, Zeren H. Use of mitomycin C and 5-fluorouracil in external dacryocystorhinostomy. Orbit. 1999;18:239–45.
41. Eshraghy B, Raygan F, Tabatabaie SZ, et al. Effect of mitomycin C on success rate in dacryocystorhinostomy with silicone tube intubation and improper flaps. Eur J Ophthalmol. 2012;22:326–9.
42. Qadir M, Ahangar A, Dar MA, et al. Comparative study of dacryocystorhinostomy with and without intraoperative application of Mitomycin C. Saudi J Ophthalmol. 2014;28:44–8.
43. Ghosh S, Roychoudhury A, Roychaudhuri BK. Use of mitomycin C in endo-DCR. Indian J Otolaryngol Head Neck Surg. 2006;58:368–9.
44. Prasannaraj T, Kumar BY, Narasimhan I, et al. Significance of adjunctive mitomycin C in endoscopic dacryocystorhinostomy. Am J Otolaryngol. 2012;33:47–50.
45. Farahani F, Ramezani A. Effect of intraoperative mitomycin C application on recurrence of endoscopic dacryocystorhinostomy. Saudi Med J. 2008;29:1354–6.
46. Penttila E, Smirnov G, Seppa J, et al. Mitomycin C in revision endoscopic dacryocystorhinostomy: a prospective randomized study. Am J Rhinol Allergy. 2011;25:425–8.
47. Ozkiris M, Ozkiris A, Goktas S. Effect of mitomycin C on revision endoscopic dacryocystorhinostomy. J Craniofac Surg. 2012;23:e608–10.
48. Ragab SM, Elsherif HS, Shehata EM, et al. Mitomycin C-enhanced revision endoscopic dacryocystorhinostomy: a prospective randomized controlled trial. Otolaryngol Head Neck Surg. 2012;147:937–42.
49. Kumar V, Ali MJ, Ramachandran C. Effect of mitomycin-C on contraction and migration of human nasal mucosa fibroblasts: implications in dacryocystorhinostomy. Br J Ophthalmol. 2015;99:1295–300.
50. Nair AG, Ali MJ. Mitomycin-C in dacryocystorhinostomy: from experimentation to implementation and the road ahead: a review. Indian J Ophthalmol. 2015;63:335–9.
51. Qian Z, Zhang Y, Fan X. Clinical outcomes of dacryocystorhinostomy with or without intraoperative use of mitomycin C: a systematic review and meta-analysis. J Ocul Pharmacol Ther. 2014;30:615–24.
52. Singh M, Ali MJ, Naik MN. Long-term outcomes of circumostial injection of mitomycin C (COS-MMC) in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:423–4.
53. Ali MJ, Baig F, Lakshman M, et al. Electron microscopic features of nasal mucosa treated with topical and circumostial injection of mitomycin C: implications in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:103–7.
54. Brown MT. Wound healing. In: Cummings CW, Fredrickson JM, editors. Otolaryngology head and neck surgery. St. Louis, MO: Mosby; 1998. p. 187–8.
55. Rathore PK, Kumari Sodhi P, Pandey RM. Topical mitomycin C as a postoperative adjunct to endonasal dacryocystorhinostomy in patients with anatomical endonasal variants. Orbit. 2009;28:297–302.
56. Do JR, Lee H, Baek S, Lee TS, Chang M. Efficacy of postoperative mitomycin-C eye drops on the clinical outcome in endoscopic dacryocystorhinostomy. Graefes Arch Clin Exp Ophthalmol. 2016;254:785–90.

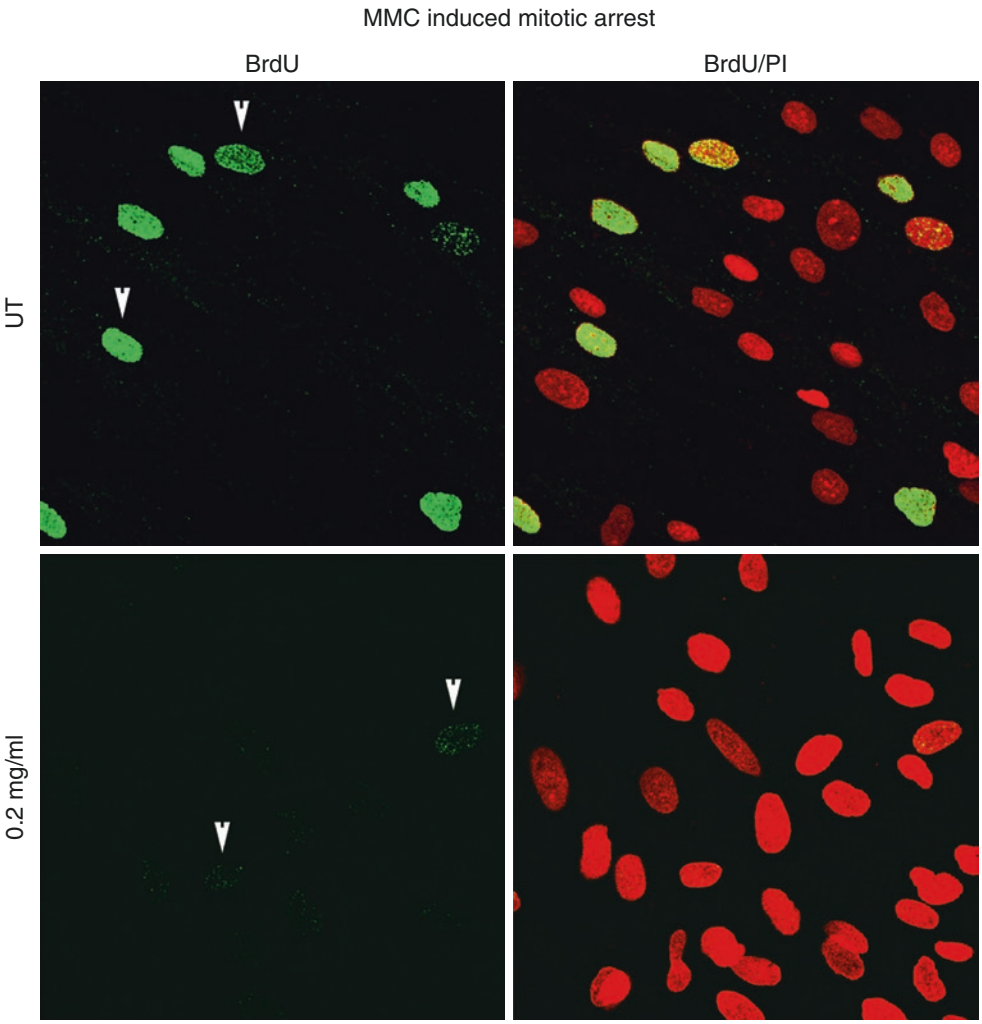


Fig. 44.1 Bromodeoxyuridine/propidium iodine staining (BrdU/PI staining). Untreated (UT) and treated (0.2 mg/ml, 3 min) human nasal mucosal fibroblasts. As compared to untreated, very few cells have taken up the stain indicating mitotic arrest or delayed cell cycle progression (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2013;29:469–474)

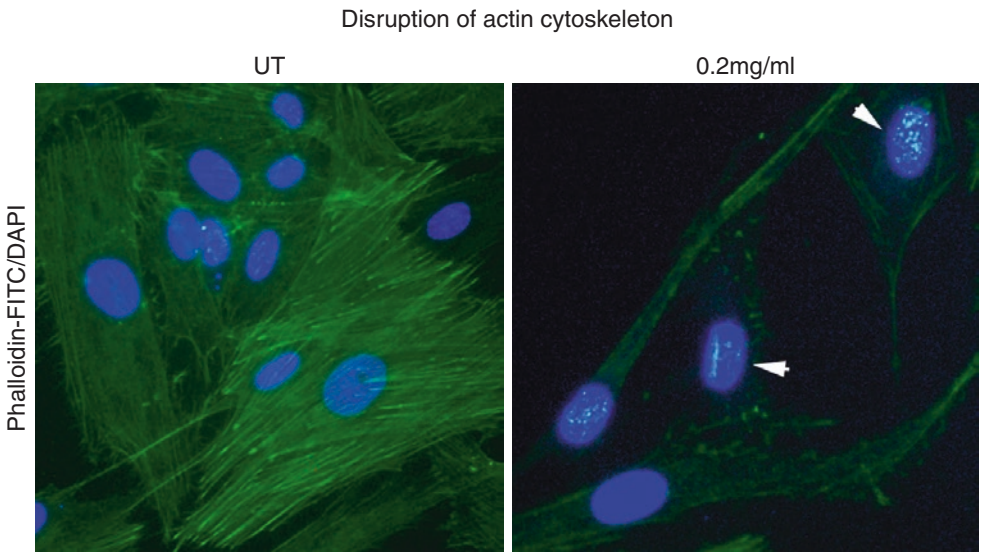


Fig. 44.2 Actin/phalloidin staining. Untreated (UT) and treated (0.2 mg/ml, 3 min) human nasal mucosal fibroblasts. As compared to untreated, the treated cells show complete disruption of actin cytoskeleton (*green fibers*) and chromatin condensation (*blue*) on DAPI staining indicating arrested and apoptotic cells (Courtesy: Ali et al., Ophthal Plast Reconstr Surg 2013;29:469–474)

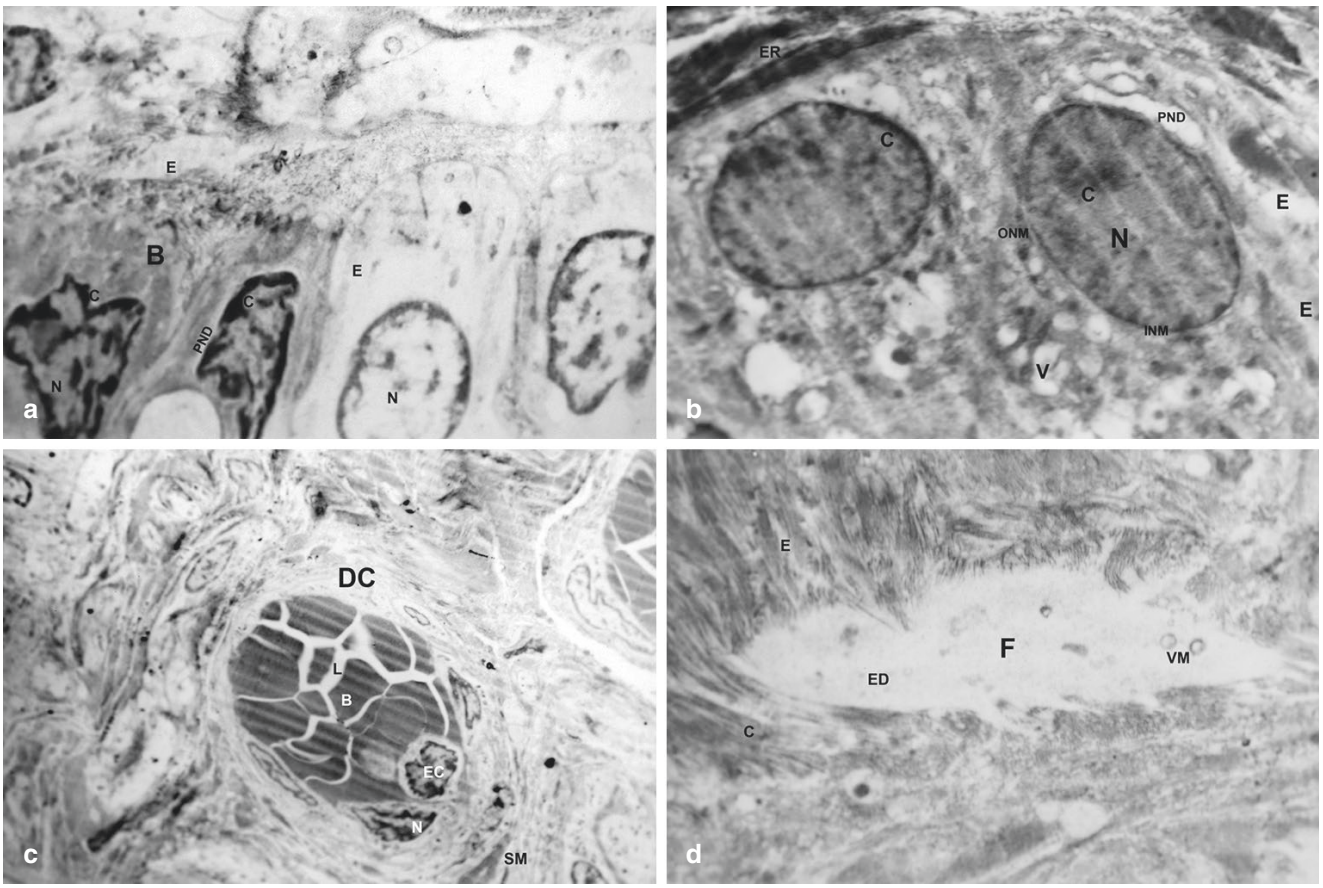


Fig. 44.3 Ultrastructural features following topical MMC treatment. TEMG showing epithelial changes up to the basal cells (B) with inter- and intracellular edema (E), degenerating nuclei (N), peripheral nuclear chromatin condensation (C), and perinuclear dilatation (PND) (OM × 6755) (panel **a**). TEMG of glandular cells showing vesicular cytoplasm (V), dilated endoplasmic reticulum (ER), nuclei (N) with widespread chromatin condensation (C), disruption of outer nuclear membrane (ONM), and perinuclear dilatations (PND) (OM × 7720) (panel **b**). TEMG showing a dilated microcapillary (D) with a lumen (L) filled with erythrocytes (B). The endothelial cell (EC) is edematous with disorganized nucleus (N). Smooth muscle (SM) fibers are seen in the vicinity (OM × 2316) (panel **c**). Edematous collagen fibers (C) with a swollen fibroblast (F) with scanty electron dense granules (ED) and vesicular mitochondria (VM) (OC × 7720) (panel **d**) (Courtesy Ali et al., Ophthal Plast Reconstr Surg. 2015;31:103–107)

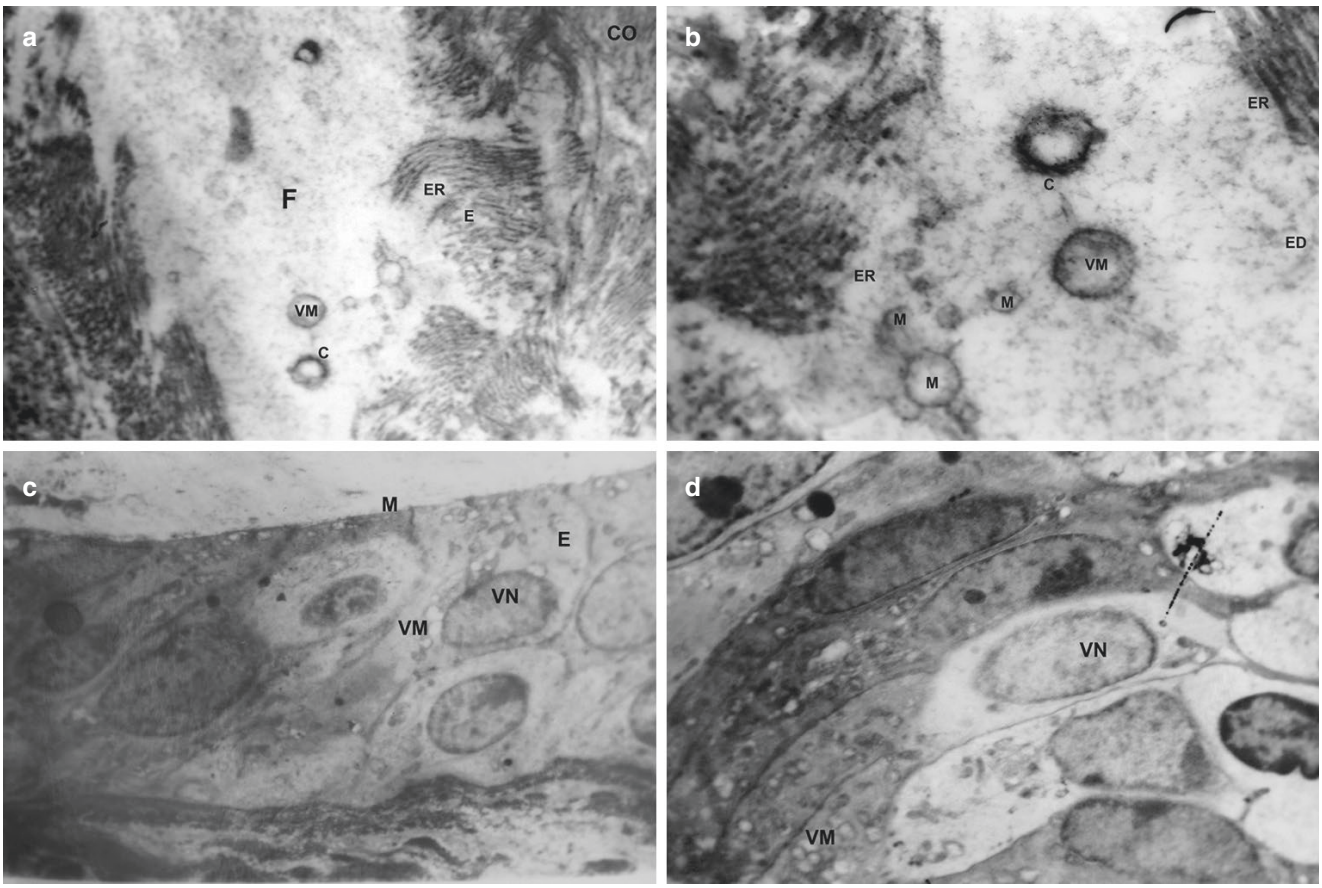


Fig. 44.4 Ultrastructural features following MMC application. TEMG high magnification of fibroblast (F) shows retained cellular outline on one side with dilated endoplasmic reticulum (ER) and vesicular mitochondria (VM) with peripheral chromatin condensation (C) (OM × 13,510) (panel **a**). TEMG high magnification showing subcellular features of fibroblast including dilated endoplasmic reticulum (ER), pleomorphic mitochondria (M), vesicular mitochondria (VM) with peripheral chromatin condensation (C), and scattered electron dense (ED) granular material. (OM × 28,950) (panel **b**). TEMG of COS-MMC-treated mucosa showing attenuated epithelium (E) with vesicular nuclei (VN) and vesicular mitochondria (VM) and sparse microvilli (M) (OM × 3860) (panel **c).** TEMG of COS-MMC-treated epithelium in a higher magnification showing vesicular nuclei (VN) and vesicular mitochondria (VM) (OM × 4825) (panel **d**) (Courtesy: Ali et al., Ophthal Plast Reconstr Surg. 2015;31:103–107)

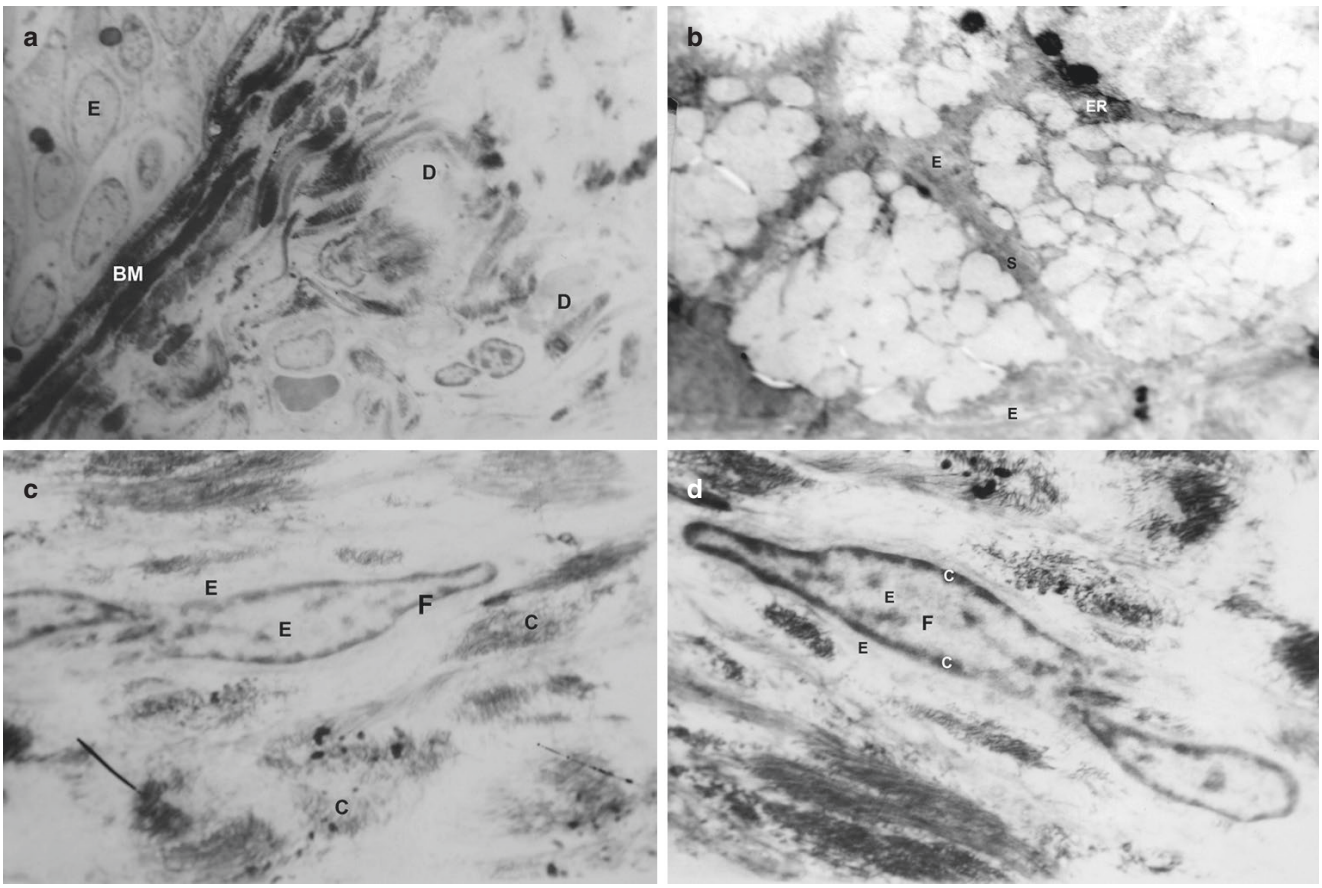


Fig. 44.5 Ultrastructural features following COS-MMC treatment. TEMG showing grossly attenuated epithelium (E) with discontinuous basement membrane (BM) and disorganized subepithelial tissues (D) (OM × 2316) (panel **a**). Glandular tissue showing thickened septa (S) with empty secretory vesicles and gross edema (E) and disturbed endoplasmic reticulum (ER) (OM × 4825) (panel **b**). TEMG shows sparse and disorganized collagen fibers (C) due to widespread edema (E). Fibroblast (F) shows gross intracellular edema (E) (OM × 7720) (panel **c**). TEMG showing fibroblasts (F) at a higher magnification to see the diffuse peri- and intracellular edema (E) with peripheral chromatin condensation. Note that one of the fibroblasts has lost part of its cellular outline. (OM × 9650) (panel **d**) (Courtesy Ali et al., Ophthal Plast Reconstr Surg. 2015;31:103–107)

Debates in Dacryology: The Intubation Dilemma!

45

Edwin C. Figueira, Dan Brettell, Andrea Zarkovic, Simon N. Madge, Marcus M. Marcet, and Dinesh Selva

Introduction

The use of stenting in dacryocystorhinostomy (DCR) for primary acquired nasolacrimal duct obstruction (PANDO) in the absence of canalicular disease is controversial. There is no definitive evidence to support the routine use of intubation in DCR for PANDO [1–3]. Advocates for stenting report an increased patency rate, due to presumed maintenance of canalicular and ostial patency [4, 5]. However, recent meta-analyses have not found a significant benefit from routine intubation. In addition, there are reports of a higher failure rate in DCR patients who had routine intubation for PANDO [6]. It has been suggested that the higher failure rates are possibly a result of intubation-related granulomatous inflammation. Stenting of the nasolacrimal system is also associated with complications including punctal erosion and 'cheese-wiring' of the canaliculi [7].

Rationale for Intubation

Maintaining Canalicular Patency

The primary rationale used by many surgeons who perform routine intubation during DCR for primary acquired nasolacrimal duct obstruction is that it maintains patency of the common canalicular opening into the sac, preventing closure from inflammation or intraoperative trauma [2, 8–10]. It may also play a role in treating any undetected canalicular stenosis [8].

Prevention of Ostial Closure

An alternate reason for intubation that can be gathered from papers studying the DCR ostium is that the tubes maintain the ostium from the sac to the nose, probably acting as a guard against fibrosis [11–13]. Some surgeons also selectively intubate in scenarios where they believe there may be a higher risk of anatomical failure, such as small sacs, dacryocystitis and poor flaps in the belief the stent will assist in maintaining patency.

Rationale Against Intubation

Advocates against routine intubation believe there is no strong evidence in the literature to suggest improved anatomical patency in DCR for anatomical obstructions at either the canalicular or the ostial level. Furthermore, intubation-related morbidity such as punctal or canalicular cheese wiring, granuloma formation, nasal irritation, corneal erosions, nasal bleeds and displacements have been reported [14]. Intubation in DCR surgery also increases the cost and the duration of DCR surgery in addition to requiring removal at a later date.

Evidence Base for the Use of Intubation in DCR Surgery

The studies on behaviour of the postoperative ostium have shed important light on its evolution [11, 15, 16]. Advocates supporting intubation report an increased patency rate, due to maintenance of the ostium of the lacrimal sac into the

E.C. Figueira, F.R.A.N.Z.C.O.
Ophthalmic Plastics Surgery, Royal Adelaide Hospital, Adelaide, Australia

D. Brettell, M.D. • A. Zarkovic, F.R.A.N.Z.C.O.
S.N. Madge, F.R.C.Ophth.
Department of Ophthalmology, Wye Valley Trust, NHS, Hereford, UK
e-mail: drsimonmadge@googlemail.com

M.M. Marcet, M.D.
Department of Ophthalmology, University of Hong Kong, Cyberport, Hong Kong

D. Selva, F.R.A.N.Z.C.O. (✉)
Ophthalmology and Visual Sciences, University of Adelaide, Adelaide, Australia
e-mail: saioph@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_45

middle meatus and correction of presaccal stenosis. Older [17] reported a success rate of 94% with the routine use of silicone tubes in a series of 70 patients. Seven years later, Rosen et al. [14] presented a series of 253 cases with routine intubation. Although they acknowledged their success rate was not significantly higher than that reported with other techniques, they listed some advantages of silicone intubation. They found that the surgery was easier to complete in the presence of excessive bleeding or inadvertent mucosal tears and that the suturing of anterior flaps was easier with the tubes in place. They also commented that the stent can act as a support structure for torn anterior flaps [14].

In a retrospective review of 338 DCR cases that excluded patients with common canalicular pathology, Panday and colleagues [18] found intubation time of longer than 6 months was associated with better outcome compared with shorter intubation times.

Many lacrimal surgeons have advocated 'selective' silicone intubation in PANDO cases, where there is an intraoperative appearance of a tight common canaliculus [19, 20]. Other putative indications used by some surgeons include previous history of dacryocystitis, revision procedures, small sacs, narrow nasal cavities, excessive intraoperative haemorrhage and poor mucosal flap formation [3, 21, 22].

Evidence Base Against the Use of Intubation in Routine DCR

Many studies comparing the surgical success of endoscopic DCR with and without silicone intubation have reported that a functionally patent DCR can be achieved without the need for routine nasolacrimal stenting [23–29].

Gu et al. [28] in their meta-analysis of endoscopic DCR and simultaneous intubation retrieved 4 trials and could appraise only 2 trials involving 84 patients that met their inclusion criteria for analysis. There was no statistically significant heterogeneity between the studies. Their analysis revealed using the fixed-effects models, that the pooled risk ratio for DCR failure in the non-intubated group was 0.85 (95% confidence interval: 0.71–1.02). Feng et al. [30] in a meta-analysis that included five randomized controlled trials and four cohort studies reported that there was no benefit from silicone tube intubation in primary DCR cases. However, this meta-analysis had many potential limitations, which included analysis from follow-ups of different duration (4 months to 96 months) and inclusion of many clinical trials that were not randomized. Chong et al. [12] in a prospective randomized trial with a 12-month follow-up of bicanalicular silicone intubation in endonasal endoscopic mechanical dacryocystorhinostomy (EEM-DCR) for PANDO reported no statistical difference in the success rates between patients with (96.3%) and without (95.3%) intubation. The odds ratio of failure without silicone intubation was analysed to be 1.28 (95% confidence interval, 0.21–7.95). There was no difference in the incidence or the time taken to develop granulation tissue between the two groups of intubation and non-intubation [12].

In a single comparative study, Unlu et al. [29] described 91.7% anatomical success in intubated cases compared to 92.3% in their non-intubated subgroup. Smirnov et al. [27] in a 46-patient, randomized controlled, intubation versus non-intubation primary endo DCR study (absence of canalicular pathology confirmed in these cases) performed by three rhinologists reported a 100% anatomical and functional success in the non-intubated group, in comparison to 78% in the intubated subgroup, a difference that was statistically significant. In an another study by Unlu et al. [26] with postoperative endoscopic examination revealed the rhinostomy opening could be visible in 89.5% of the intubated cases and 94.7% without intubation. Cannon et al. [31] report a single surgeon prospective study of 163 endoscopic DCR with non-intubation cases and a zero incidence of canalicular closure at 12-month follow-up and found an anatomic patency rate of 98.5% and a combined anatomical and functional success rate of 90.7%.

Updates (2015–2016)

The most recent publications addressing the dilemma facing surgeons about the use of stents in dacryocystorhinostomy (DCR) for primary acquired nasolacrimal duct obstruction (PANDO) have done little to establish consensus.

Duration of Intubation

The practice with regards to the duration for intubation is quite variable and can usually range from 4 weeks to 6 months. However, recent evidence is building on the shorter durations (4–6 weeks). There are two main reasons for this developing shift. Firstly, multiple studies showed that the ostium size changes most in the first 4 weeks, and subsequently there is not much change even up to 2 years [15, 32]. Secondly, the development of biofilms and subsequent biomass buildup accelerates beyond 4–6 weeks, and the biofilms have the potential to encourage an inflammatory response which could have a negative influence on the DCR ostium [33, 34].

For the Use of Intubation in DCR Surgery

Fayers and Dolman [35] have recently published their prospective, randomized single-surgeon study of endoscopic DCRs which demonstrated a higher rate of success

in the group who received stents (94.7% vs 87.8%). This study of 300 patients noted a cumulative 8% risk of canalicular cheese-wiring or tube prolapse in the stented group. The overall failure rate was twice as high when the stents were not used (12.2% vs 5.3%). Malhotra et al. [36] described the results of their trainee surgeons performing endoscopic DCRs over a 3-year period. In their experience, the lowest rate of surgical success (54% vs 88–100%) coincided with the lowest use of lacrimal stents (31% vs 94–100%). A higher rate of mucosal trauma was noted in their trainee group, and the study's authors postulated that in this setting the placement of silicone tubes may be warranted. Few other studies that evaluated the surgeries of less experienced surgeons did not find such differences among the trainees, although all patients were uniformly intubated [37, 38].

Against the Use of Intubation in DCR Surgery

A recent Italian study by Longari et al. [39] on the use of silicone intubation in endoscopic DCR in PANDO found a lower rate of surgical success in the group with stents at 18-month follow-up (82.2% vs 88.6%, odds ratio [OR] 0.59). This retrospective study of 89 procedures in 84 patients also found a higher incidence of a reduced ostium size in the stented group due to higher risks of granuloma formation, scarring and turbinoseptal synechiae. In a review article, Kalin-Hajdu et al. [40] examined the evidence regarding the routine use of silicone intubation in DCR surgery and concluded that the practice of stenting routinely was not supported by the literature.

Several other studies published recently have demonstrated that the use of lacrimal stents in DCR is still common place in both primary and redo operations [41–46]. Encompassing both external and endoscopic approaches, these studies demonstrate that for many surgeons the use of intubation is still very much a part of routine surgery. Okuyucu et al. [47] performed a prospective, randomized trial examining the efficacy of silicone or polypropylene stents against an otologic T-tube, finding that the use of the stiffer T-tube led to a lower rate of surgical success (62.5% vs 87.5% or 84.4% for silicone and polypropylene, respectively).

Conclusion

There is currently no evidence basis for routine intubation in DCR for PANDO. Hence, it is the authors' belief that intubation should be limited to the setting of preoperatively or intraoperatively proven canalicular disease or in the presence of high-risk factors for failure. However, it is acknowledged that routine intubation for DCR in the context of PANDO remains widely practised.

References

1. Vicinanzo M, McGwin G, Long JA. The consequence of premature silicone stent loss after external dacryocystorhinostomy. Ophthalmology. 2008;115:1241–4.
2. Madge S, Selva D. Intubation in routine dacryocystorhinostomy: why we do what we do. Clin Exp Ophthalmol. 2009;37:620–3.
3. Madge S, Selva D, ANZSOPRS DCR Intubation Study Group. Canalicular intubation in routine dacryocystorhinostomy. Clin Exp Ophthalmol. 2009;37:533–44.
4. Griffiths J. Nasal catheter use in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 1991;7:177–86.
5. Mäntynen J, Yoshitsugu M, Rautiainen M. Results of Dacryocystorhinostomy in 96 patients. Acta Otolaryngol Suppl. 1997;529:187–9.
6. Allen K, Berlin AJ. Dacryocystorhinostomy failure: association with nasolacrimal silicone intubation. Ophthalmic Surg. 1989;20:486–9.
7. Anderson R, Edwards JJ. Indications, complications and results with silicone stents. Ophthalmology. 1979;86:1474–87.
8. Boboridis KG, Bunce C, Rose GE. Outcome of external dacryocystorhinostomy combined with membranectomy of a distal canalicular obstruction. Am J Ophthalmol. 2005;139:1051–5.
9. Smirnov G, Tuomilehto H, Terasvirta M, et al. Silicone tubing after endoscopic dacryocystorhinostomy: is it necessary? Am J Rhinol. 2006;20:600–2.
10. Zolli C, Shannon GM. Dacryocystorhinostomy: a review of 119 cases. Ophthalmic Surg. 1982;13:905–10.
11. Mann B, Wormald PJ. Endoscopic assessment of the dacryocystorhinostomy ostium after endoscopic surgery. Laryngoscope. 2006;116:1172–4.
12. Chong K, Lai FHP, Ho M, et al. A randomized trial on silicone intubation in endoscopic mechanical dacryocystorhinostomy (SEND) for primary nasolacrimal duct obstruction (report). Ophthalmology. 2013;120:2139–45.
13. Allen K, Berlin AJ, Levine HL. Intranasal endoscopic analysis of dacryocystorhinostomy failure. Ophthal Plast Reconstr Surg. 1988;4:143–5.
14. Rosen N, Sharir M, Moverman DC, et al. Dacryocystorhinostomy with silicone tubes: evaluation of 253 cases. Ophthalmic Surg. 1989;20:115–9.
15. Chan W, Selva D. Ostium shrinkage after endoscopic dacryocystorhinostomy. Ophthalmology. 2013;120:1693–6.
16. Linberg J, Anderson RL, Bumsted RM, et al. Study of intranasal ostium external dacryocystorhinostomy. Arch Ophthalmol. 1982;100:1758–62.
17. Older JJ. Routine use of a silicone stent in a dacryocystorhinostomy. Ophthalmic Surg. 1982;13:911–5.
18. Pandya VB, Lee S, Benger R, et al. External dacryocystorhinostomy: assessing factors that influence outcome. Orbit. 2010;29:291–7.
19. Callejas C, Tewfik MA, Wormald PJ. Powered endoscopic dacryocystorhinostomy with selective stenting. Laryngoscope. 2010;120:1449–52.
20. Walland M, Rose GE. The effect of silicone intubation on failure and infection rates after dacryocystorhinostomy. Ophthalmic Surg. 1994;25:597–600.
21. Rosser P. There is no use crying over spilt tears: the surgical management of primary acquired nasolacrimal duct obstruction. Aust N Z J Ophthalmol. 1999;27:95–100.
22. Choung H, Khwarg SI. Selective non-intubation of a silicone tube in external dacryocystorhinostomy. Acta Ophthalmol Scand. 2007;85:329–32.
23. Saeed B. Endoscopic DCR without stents: clinical guidelines and procedure. Eur arch Otorhinolaryngol. 2012;269:545–9.
24. Pittore B, Tan N, Salis G, et al. Endoscopic transnasal dacryocystorhinostomy without stenting: results in 64 consecutive procedures. Acta Otorhinolaryngol Ital. 2010;30:294–8.

25. Ananth L, Hosamani P, Chary G. Efficacy of endonasal dacryocystorhinostomy, using 'cold steel' instruments without stenting, in treatment of distal nasolacrimal duct obstruction. J Laryngol Otol. 2011;125:590–4.
26. Unlu H, Gunhan K, Baser EF, et al. Long-term results in endoscopic dacryocystorhinostomy: is intubation really required? Otolaryngol Head Neck Surg. 2009;140:589–95.
27. Smirnov G, Tuomilehto H, Teräsvirta M, et al. Silicone tubing is not necessary after primary endoscopic dacryocystorhinostomy: a prospective randomized study. Am J Rhinol. 2008;22:214–7.
28. Gu Z, Cao Z. Silicone intubation and endoscopic dacryocystorhinostomy: a meta-analysis. Head Neck Surg. 2010;39:710–3.
29. Unlu H, Aslan A, Toprak B, et al. Comparison of surgical outcomes in primary endoscopic dacryocystorhinostomy with and without silicone intubation. Ann Otol Rhinol Laryngol. 2002;111:704–9.
30. Feng YF, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
31. Cannon P, Chan WO, Selva D. Incidence of canalicular closure with endonasal dacryocystorhinostomy without intubation in primary nasolacrimal duct obstruction. Ophthalmology. 2013;120:1688–92.
32. Ali MJ, Psaltis AJ, Ali MH, et al. Endoscopic assessment of the dacryocystorhinostomy ostium after powered endoscopic surgery: behaviour beyond 4 weeks. Clin Exp Ophthalmol. 2015;43:152–5.
33. Murphy J, Ali MJ, Psaltis AJ. Biofilm quantification on nasolacrimal silastic stents after dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31:396–400.
34. Ali MJ, Baig F, Lakshman M, et al. Scanning electron microscopic features of nasolacrimal silastic stents retained for prolong durations following dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2016;32:20–3.
35. Fayers T, Dolman PJ. Bicanalicular silicone stents in endonasal dacryocystorhinostomy: results of a randomized clinical trial. Ophthalmology. 2016;123:2255–9.
36. Malhotra R, Norris JH, Sagili S, et al. The learning curve in endoscopic dacryocystorhinostomy: outcomes in surgery performed by trainee oculoplastic surgeons. Orbit. 2015;34:314–9.
37. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes of primary powered endoscopic dacryocystorhinostomy: comparison between experienced versus less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.
38. Kamal S, Ali MJ, Nair AG. Outcomes of endoscopic dacryocystorhinostomy: experience of a fellowship trainee at a tertiary care center. Ind J Ophthalmol. 2016;64:648–53.
39. Longari F, Dehgani Mobaraki P. Endoscopic dacryocystorhinostomy with and without silicone intubation: 4 years retrospective study. Eur Arch Otorhinolaryngol. 2016;273:2079–84.
40. Kalin-Hajdu E, Cadet N, Boulos PR. Controversies of the lacrimal system. Surv Ophthalmol. 2016;61:309–13.
41. Akcay E, Yuksel N, Ozen U. Revision external dacryocystorhinostomy results after a failed dacryocystorhinostomy surgery. Ophthalmol Ther. 2016;5:75–80.
42. Chen S, Le CH, Liang J. Practice patterns in endoscopic dacryocystorhinostomy: survey of the American Rhinologic Society. Int Forum Allergy Rhinol. 2016;6(9):990–7.
43. Jung SK, Kim YC, Cho WK, et al. Surgical outcomes of endoscopic dacryocystorhinostomy: analysis of 1083 consecutive cases. Can J Ophthalmol. 2015;50:466–70.
44. Yuksel D, Kosker M, Akoz I, et al. Long-term results of simultaneous bilateral external dacryocystorhinostomy in cases with bilateral dacryostenosis. Semin Ophthalmol. 2015;30:20–4.
45. Chisty N, Singh M, Ali MJ, et al. Long-term outcomes of powered endoscopic dacryocystorhinostomy in acute dacryocystitis. Laryngoscope. 2016;126:551–3.
46. Ali MJ, Psaltis AJ, Murphy J, et al. Powered endoscopic dacryocystorhinostomy: a decade of experience. Ophthal Plast Reconstr Surg. 2015;31:219–21.
47. Okuyucu S, Gorur H, Oksuz H, et al. Endoscopic dacryocystorhinostomy with silicone, polypropylene, and T-tube stents; randomized controlled trial of efficacy and safety. Am J Rhinol Allergy. 2015;29:63–8.

The Great Debate: External Versus Endonasal Dacryocystorhinostomy

46

Andre Litwin and Raman Malhotra

Introduction

The principles of standard surgery for blockage of the lacrimal outflow tract probably dates back 1000 years now when the twelfth century Andalusian Oculist Mohammad Ibn Aslam Al Ghafiqi described a small spear-shaped instrument perforating the lacrimal bone in a nasal direction "*until blood flows through the nose and mouth with care given not to direct the instrument downward as this would be the incorrect direction*". The probe was then wrapped in cotton that was either *dry or soaked in ox fat*. This would then be exchanged every day in order to maintain the patency of the created fistula [1]. This principle remains the same to date as that for contemporary conjunctivo-dacryocystorhinostomy. Modern dacryocystorhinostomy (DCR), however, dates back to the dawn of the twentieth century [1–4]. In terms of anatomic goals, the aims of surgery are simple: the lacrimal sac is connected directly to the nose by removal of the separating bone and mucosa. A fistula is hence formed that allows tears to pass directly into the nasal vault through the lateral nasal wall. This must occur at a level above the mechanical obstruction in order to bypass it [5]. The traditional popular method has been through an external approach as described by Toti [3] and modified by Dupuy-Dutemps [4]. Although the endonasal approach was described perhaps prior to this [2], it is only in recent decades with the introduction and development of the endoscope that attention has turned to endoscopic DCR for both primary procedures and to revise failures [6]. DCR is indicated for patients with lacrimal sac or nasolacrimal duct obstruction (NLDO) causing either epiphora or dacryocystitis (infection).

Surgery may be performed through a cutaneous incision (*external DCR*) and although alternative ophthalmic approaches to avoiding skin scarring have been described, [7, 8] the only effective alternative remains an endonasal approach. While maintaining the same principles as an external approach, endonasal DCR simply describes an approach through the nose rather than a specific technique. Many endonasal techniques exist by either direct visualization [6], or more commonly, when viewed through an endoscope (*endoscopic DCR*). Endoscopic DCR has itself evolved over time. Endoscopic laser DCR progressed to mechanical endoscopic DCR [9] and powered endoscopic DCR. This shift toward "powered" instruments was because laser could not remove the thick bone of the frontal process of the maxilla and root of the middle turbinate, resulting in higher failure rates [10, 11]. The principles of the evolved "powered endoscopic DCR" have shifted forward ("back") to mechanical DCR, aiming to achieve full sac exposure while still creating mucosal flaps [12, 13].

Through dissection and manipulation of tissue, there is no reason why a skilled surgeon with the right tools cannot remove the same amount of bone from either approach [14]. Until the twenty-first century, external DCR was historically regarded as the "gold-standard." However, the reported success rate of both procedures in the modern literature is now similar when compared with endoscopic procedures that remove adequate bone for full lacrimal sac exposure, marsupialization, and mucosal flap apposition [11, 15–19].

Overview of the Procedures

DCR surgery can be performed under either local or general anesthesia. If local anesthesia is to be used, infratrochlear and infraorbital nerve blocks using bupivacaine 0.5% or lidocaine 2% with epinephrine are administered. Anesthetic may also be infiltrated along the lateral wall of the nose at the proposed osteotomy site, and nasal packs soaked in cocaine 4%, adrenaline 1:1000 or a mixture (e.g., Moffett's solution) may be applied, via packing, buds, or patties.

A. Litwin, F.R.C.S. • R. Malhotra, F.R.C.S. (✉)
Oculoplastic Surgery, Queen Victoria NHS Trust, London, UK
e-mail: raman@ramanmalhotra.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_46

External DCR

To perform an external DCR, a 15-mm skin incision is made medial to the medial canthus. A skin-muscle flap is formed to reveal the anterior limb of the medial canthal tendon. This is divided and the periosteum opened. The periorbita is elevated to displace the lacrimal sac and duct laterally. A 3-mm up-biting right-angled Kerrison rongeur is used to break through the thin bone of the lacrimal fossa, and a bony osteotomy is formed, initially proceeding anteriorly, inferiorly, and then posteriorly. An osteotomy of at least 15 mm in diameter is created. The lacrimal sac is then probed and opened longitudinally. Any grossly suspicious mucosa should be biopsied and submitted for pathologic review. The nasal mucosa is incised in a similar longitudinal fashion, with relieving incisions at either ends forming an "H" shape. A silicone stent is inserted and tied loosely to prevent cheese-wiring of the canaliculi. The posterior lacrimal sac flap is sutured to the posterior nasal flap, typically with a single continuous 6/0 Vicryl suture. Three sutures are then used to appose the anterior nasal mucosal and anterior lacrimal sac flaps. Where possible, these are suspended by attachment to the overlying orbicularis. The anterior limb of the medial canthal tendon is re-approximated, and the skin is typically closed with a 6-0 polypropylene suture.

Endonasal Non-endoscopic DCR

When carrying out endonasal, non-endoscopic DCR, surgeons often utilize a 20-gauge disposable vitrectomy light pipe threaded through the upper canaliculus to guide placement of the osteotomy [6]. After decongestion, an elliptical nasal mucosa incision down to bone, centered over the transilluminated light target, is made. Mucosa is stripped from underlying bone and peeled away. An osteotomy is fashioned with an attempt to rongeur sufficient bone superiorly and anteriorly to easily visualize the entire width and most of the length of the lacrimal sac and duct. Care is taken to remove sufficient bone superiorly to ensure that the target light pipe when held horizontally across the common canaliculus can be visualized tenting the lacrimal sac within the nose. A posteriorly hinged U-shaped oval flap is made and reflected posteriorly, and the lacrimal system is usually intubated.

Early Mechanical Endoscopic DCR

Standard functional endoscopic sinus surgery (FESS) scopes were commonly used in addition to keratomes, standard blades, Freers elevators, Blakesley forceps, and up-biting Kerrison rongeurs. Lacrimal probes or a light pipe passed into the lacrimal sac were often used to guide placement of the osteotomy. The nasal mucosa was incised and excised overlying the planned osteotomy site before carrying out the osteotomy with up-biting Kerrison ronguers. The inferior two-thirds (or less) of lacrimal sac was often all that was exposed. The sac was incised and its mucosa either reflected anteriorly and posteriorly or trimmed. Silicone tubes were passed, and the nose was often temporarily packed [15, 20, 21].

Powered Endoscopic DCR

After decongestion, the nasal mucosa is usually infiltrated with 2 ml of lignocaine 2% with 1:80,000 epinephrine using a dental syringe above and anterior to the middle turbinate. A mucosal incision with a small-angled crescent blade is made on the lateral nasal wall, 2–3 mm posterior to the maxillary line, starting 8 mm above the insertion of the middle turbinate and extending vertically down to a level just below the body of the middle turbinate. Using a number 15 scalpel blade, two horizontal incisions are made, 8 mm above the insertion of the middle turbinate and just below the body of the middle turbinate, respectively. This creates the posterior nasal mucosal flap, which is reflected using a Freer elevator, exposing the junction of the hard frontal process of the maxilla and the thin lacrimal bone. The lacrimal bone is removed off the inferior half of the sac using a Freer elevator or a forward-biting up-cutting 40° Kerrison rongeur. The frontal process of the maxilla, overlying the anterior and inferior portions of the lacrimal sac, is removed and the osteotomy continued superiorly until it is no longer possible using the standard Kerrison. A burr or drill is utilized at this stage, exposing the fundus of the sac. The agger nasi air cell (the anterior most ethmoid cell) is often exposed as the fundus extends above the axilla of the middle turbinate [22].

The medial wall of the sac is then tented with a probe to ensure that all bone at least 5–10 mm above the common canalicular opening has been removed. The medial wall of the sac is incised vertically with a crescent blade to create large anterior and smaller posterior flaps. Small additional relieving incisions allow the flaps to be reflected onto the lateral nasal wall and sit "flat." Good mobility and marsupialization of the lacrimal mucosal flaps have been associated with better outcomes [23]. A silicone stent can be passed and tied loosely to protect the internal ostium.

Modern Non-powered Endoscopic DCR with Flaps

A posteriorly [12] or inferiorly hinged [13] nasal mucosal flap is formed along the frontal process of the maxilla. The mucosal flap (which will form the anterior nasal mucosal

flap) is elevated using a Freer elevator, maintaining the tip of the elevator on the bone, reflecting it out of the surgical field. The technique proceeds in the same as powered endoscopic DCR until the osteotomy can no longer be continued superiorly using a standard Kerrison rongeur. A modified bone nibbler may be used at this time to aid bone clearance at the fundus of the sac [13].

Considerations for Both Approaches

The goal of DCR surgery is to create a functioning fistula, by means of adequate bone removal to allow the lacrimal sac to be fully marsupialized into the lateral nasal wall. Primary intention wound healing of all mucosa should be the aim. Trauma to adjacent tissues should be avoided to minimize the scarring response and reduce the risk of closure of the *soft-tissue ostium* (the entire marsupialized lacrimal sac when viewed endonasally) or the internal ostium of the *common canaliculus*.

Anatomic Factors

In order to achieve an absolute cure, a large fistula between the lacrimal sac and the nose is required leaving the canaliculi as the only zone of residual tear resistance [24]. It is generally agreed that exposure of the inferior and superior parts of the lacrimal sac should be accomplished, usually requiring an osteotomy of at least 15 mm, even approaching 20 mm [22, 24, 25]. Whether the new *soft-tissue ostium* of the entire marsupialized lacrimal sac remains stable in size beyond the first few postoperative weeks is unclear. It appears to reduce a small amount, with one endoscopic study measuring an average soft-tissue ostium size 12 months after surgery of 10.1 × 6.6 mm [26]. This is most in-keeping with our own experience. Some have suggested that the soft-tissue ostium may shrink by 50% at 6 months or even smaller [27, 28]. Others have found no significant relationship between *bony ostium* size and outcomes of surgery [23].

Biological (Healing) Factors

The main cause of failure in DCR surgery is fibrosis of the intranasal soft-tissue ostium, both in external DCR and endonasal DCR [11]. For the surgery to be successful, the mucosa of the lacrimal sac must anastomose to the nasal mucosa with the fistula remaining patent. The natural response from a surgical insult means granulation tissue can grow over the surgical ostium, rendering the procedure a failure. In successful surgery, once the lacrimal and nasal epithelia have healed together, the signal for secondary intention healing is turned off [14]. In a recent article looking at 20 failed DCRs, all had rhinostomy sites that were closed with fibrous tissue. None had canalicular or common internal ostium obstructions before undergoing revision surgery [29]. Presuming we should aim for anatomic surgery, we can maximize the success of DCR surgery by any means that helps tip the balance toward primary intention healing of the mucosa and away from secondary intention granulation [14]. The benefits of anatomic surgery may be difficult to prove, with many studies comparing different techniques or simple flap removal, but the concept should be sensible to any contemplative surgeon. Many authors have found that creation of mucosal flaps does not seem to increase the success rate of endoscopic DCR and can be technically challenging or time consuming [5]. Others have described successful results with simple flap removal [30, 31]. It is only when endonasal DCR began to emulate the approach of external DCR that success rates improved [22].

Intubation

The evidence bases either in favor of or against the practice of routine intubation remains lacking [32]. Certainly, in experienced hands it does not appear to be necessary to intubate every patient, but until very recently, the majority of surgeons still routinely did [18, 32–35]. Silicone tubes are inserted with the aim of reducing the risk of fibrosis of the internal ostium of the common canaliculus, while epithelial migration and repair takes place. In the absence of definitive canalicular disease, there is no clear evidence that intubation in routine DCR is superior to non-intubation. In the setting of canalicular disease, non-intubation may not be appropriate [50]. Other situations prompting intubation, but for which evidence is also currently lacking, include previous acute dacryocystitis, poor flap creation, revision surgery, excessive bleeding, inflammatory disease, and small lacrimal sacs. [32] The intubation dilemma chapter in this text has in depth analyzed this adjunctive measure in DCR surgery.

Mitomycin C (MMC)

A retrospective study has attempted to compare surgical outcomes in a group of 48 endonasal laser DCR procedures without MMC were compared to outcomes in a group of 123 consecutive procedures in which MMC (0.5 mg/ml) was applied to the intranasal ostium for 5 min. The success rate in the MMC-treated group was statistically significantly greater than that of the controls (99% v 90%) [36]. Assessments of outcomes with or without MMC further blur true differences. MMC cannot always deliver success from a poor procedure and should not be regarded as the solution for poor primary surgery. “The MMC dilemma” chapter in this text has in depth analyzed the usefulness of MMC in DCR surgery.

Time Taken to Perform Surgery

It may be fair to say that in experienced hands, there is no significant difference in the time taken to perform a successful DCR. Any technique that inadequately removes bone and incompletely excises mucosa would be faster, hence, endoscopic laser DCR is arguably the quickest surgery [21].

Efficacy

Success rates for external DCR have historically been quoted as over 90% [37] and often over 95% [11, 16]. These high success rates are similar for both anatomical patency and resolution of patient symptoms. Early mechanical endoscopic DCR could not match these figures: in an early series of 123 patients, 83% success was reported [38]. Subsequent smaller series claimed to have improved upon this (86–100%) [39, 40].

Due to the perceived inferiority and technical complexities of endoscopic DCR, it remained unpopular with ophthalmologists when compared to external DCR [41]. The development of surgical lasers was thought to hold the key, as a less invasive form of lacrimal surgery that would improve success. Despite early promise (100% success in ten patients) [42], it became accepted that success was much lower than conventional surgery (77–83%) [41, 43]. The high failure rate of endoscopic laser DCR was attributed to scarring (nasal and medial lacrimal sac mucosa was excised or obliterated) and the small size of the bony osteotomy. It is not possible to remove the thick bone of the frontal process of the maxilla with most lasers, leading to a small and inadequate osteotomy [44]. This led others to focus on mechanical means of creating a larger osteotomy, with slightly greater success (86%) [45, 46].

Modern endoscopic DCR respects anatomic surgical principles key to all successful DCR surgery. A large osteotomy is created with preservation of mucosa so that flaps can be fashioned to achieve a mucosal anastomosis with the lacrimal sac, minimizing secondary intention healing and scarring response [22]. Endoscopic anatomical success could finally be achieved and replicated at other centers in 95% (or more) of cases [10, 13].

Long-term analyses have reported 91% success with external DCR (437 cases, average follow-up 71 months) [47]. Long-term studies of endoscopic DCR describe 82–94% success (108 and 165 cases, average follow-up 49 and 92 months) [48, 49]. Grouping endoscopic DCR as a single entity, one can see, is unhelpful. It does not distinguish between types of endoscopic techniques, nonstandard osteotomy, or flap formation. There are many individual variations. Published success rates, therefore, do not allow direct comparison of techniques. Success itself is a loosely applied term. Subjective dependence on symptoms is unreliable, and some early papers based their outcomes on this [50]. It is rare for symptoms to completely resolve in elderly patients, yet these papers report a high level of symptom "resolution."

Attempts to be more objective by incorporating syringing or irrigation into the assessment do not necessarily provide a straightforward "black or white" success or failure. Irrigation is not physiological, and papers that report "obstructed" or "completely patent" may either have excluded those with minimal (10–20%) degrees of regurgitation on irrigation or are ignoring subtleties before or after surgery. Other objective tests such as fluorescein dye retention testing or functional endoscopic dye test have been inconsistently utilized. Patient selection is not standard. It is easy to offer and predict a good outcome for patients with complete obstruction but less so for those with partial obstruction, canalicular disease, or that overused and loosely defined term, the group with "functional epiphora." [51] The lack of agreed or standardized outcome measures or even duration of follow-up highlights how difficult comparisons actually are.

Resolution of mucocele or dacryocystitis is probably the only true outcome measure that is absolute and not relative. The symptoms and findings of stenosis lie more along a spectrum. The most practical measure of success is the control of symptoms, although this can be at odds with anatomic outcome [24]. Should we therefore be purists and ignore symptoms as a marker of success? Is this defying the initial indication and aim of surgery?

Comparative studies have tried to tackle some of these inconsistencies but often failed to demonstrate a significant difference between techniques [19]. This is not surprising, considering to adequately power a study seeking a 5% difference (e.g., 90% v 95% success), a sample size of approximately 900 patients would be required [52]. Of the published studies, anatomic success of endoscopic DCR has therefore been found to be similar to that of external DCR (97%) [11], although occasional comparative series have suggested higher success rates for endonasal DCR [5].

This means we are left with other ways of deciding where the role of external and endoscopic DCR lies.

Advantages of External DCR

External DCR is an ideal option for elderly patients not suitable for general anesthesia. Although many centers perform endoscopic DCR under local anesthetic with sedation, there is valid concern that sedation reduces or dampens the gag reflex and raises the risk of aspiration during the procedure.

External DCR avoids potential need for a septoplasty in patients with narrow nasal passages. An external approach allows lacrimal sac masses to be biopsied prior to osteotomy and may also be preferred if there is previous fracture with abnormal bone anatomy [53].

In patients with proximal or mid-canalicular disease, external DCR has an obvious advantage, allowing for retrograde intubation. This will alleviate or reduce epiphora in the majority of patients and could also spare a proportion of patients from requiring Jones canalicular bypass tubes [54].

Disadvantages of External DCR

Risks common to all forms of DCR surgery include bleeding, wound infection, and damage to the lacrimal punctae by silicone stents. Cerebrospinal fluid leaks occur exceedingly rarely in DCR, with only a few case reports in the literature [55].

Noticeable scar is a potential complication unique to external DCR. In a survey of 263 patients who underwent external DCR, visible scars were reported by 19%, with 10% describing their scars as cosmetically significant [56].

Damage to the facial nerve during external DCR is also a proven risk [57]. This complication is likely to be caused by an insult to peripheral fibers of the zygomatic and buccal branches of the facial nerve as they course in the medial canthal area and provide innervation to the upper eyelid orbicularis muscle in a subset of individuals. Among a cohort of 215 patients, 7% demonstrated abnormalities of eyelid closure (lagophthalmos or hypometric blink), 20% of which were permanent [57]. This risk should be included when counseling patients as to which approach is suitable.

Advantages of Endoscopic DCR

Advantages of endoscopic DCR include the absence of any skin incision and lack of significant trauma to orbicularis. This results in a faster soft-tissue recovery, with preservation of the lacrimal pump mechanism. It also allows nasal or paranasal sinus abnormalities to be addressed at the same time (e.g., septoplasty may be of help where patients have problems breathing through one side of the nose) [49].

In the setting of dacryocystitis, endoscopic DCR offers rapid resolution of symptoms, converting an anaerobic abscess cavity into an aerobic cavity through noninfected tissue planes with associated drainage and long-term control of epiphora [44, 58, 59].

Given a common cause for failed DCR is formation of membranous scarring at the internal ostium (at the common canalicular opening), it appears to make logical sense that the most direct means of addressing this problem would be endoscopically. Good success rates have been safely demonstrated through both endoscopic and external approaches [29, 60, 61].

Disadvantages of Endoscopic DCR

Risks of endoscopic DCR surgery include damage to the nasal mucosa with adhesion formation, orbital fat prolapse, and rarely a potential damage to the medial rectus muscle. The latter complications would only occur where a surgeon mistakenly loses orientation of the location of the sac and operates posterior to it. This is a risk for any procedure that removes bone behind the sac and inadvertently breaches the periorbita.

A historic disadvantage of endoscopic DCR is the suggestion that biopsy of the lacrimal sac is not achievable. Although the rate of unsuspected sac tumors is low [62, 63], it is possible to take a sac biopsy (or nasal mucosal biopsy) when performing an endoscopic DCR [11]. Blakesley or fine nasal biopsy forceps can be used to submit nasal or lacrimal mucosa to pathology, dacryoliths, or pus can also be sent for culture [6].

Update (2015–2016)

Since the previous edition, additional papers on external and endonasal DCR have been published, covering topics as wide as reported outcome measures, long-term results, training, management of dacryocystitis, and revision surgery. Some of these have been covered in detail in respective chapters; however, the aim of this update is to provide an overview of these approaches as they stand in 2017.

Patient reported outcome measures are increasingly being used to evaluate health gains after surgical treatment. The use of validated quality of life questionnaires helps doctors to better understand the physical, social, and emotional impact of the interventions we offer. A symptom score based on the social impact of lacrimal symptoms (Lac-Q) [64] has now been used to assess the outcomes of powered endoscopic endonasal DCR [65].

Efficacy

Since 2014, studies have confirmed functionally good success rates (approximately 85–90%) for revision DCR surgery, both endonasal and externally. Anatomical success could be achieved in up to 100% of cases [66–70].

The advantages of an endonasal approach in acute dacryocystitis have been previously described. Longer-term functional success has now been demonstrated in 81–90% of cases of endoscopic endonasal DCR [71, 72]. Good outcomes using both external and non-endoscopic techniques are reported when carried out by experienced surgeons [73].

Pediatric endonasal DCR surgery, both endoscopic and non-endoscopic is still reported to be an effective approach to DCR surgery following failed probing [74].

Anatomic Developments

Further work has looked at changes to the ostium over the healing process. Sixty ostia were measured at visits up to 2 years after powered endoscopic endonasal DCR. Little change in size (average 10% reduction) was found after 4 weeks when reviewed up to 2 years after surgery [75]. Evaluation of the DCR ostium at regular intervals is important for surgeons to understand how surgical techniques affect the healing and hence procedure success. A scoring system (such as the DCR ostium scoring system or DOS) [76] can help with the routine clinical evaluation of ostia following DCR surgery.

External DCR Developments

Skin scarring is an issue in a minority of external DCR patients [77, 78]. Pediatric patients and darker-skinned patients appear to have a greater tendency for visible scars. Predictably, the use of a monofilament nonabsorbable suture for skin closure (such as Prolene 6-0) has been found to be associated with less scarring. However, no study has yet used a validated scar evaluation system (e.g., Patient and Observer Scar Assessment Scale) [79], for the assessment of long-term appearance after an external DCR surgery.

Endonasal DCR Developments

While learning endonasal DCR, we published factors identified by trainee surgeons that we believe helped to encourage good outcomes. These include suggestions for techniques of holding the video endoscope; positioning of the operating table as low as possible (in reverse-Trendelenburg's position) and elbow support to rest the non-dominant elbow to reduce arm strain; first learning to infiltrate local anesthesia into the nasal mucosa; techniques to minimize mucosal contact, trauma, and bleeding; paying particular attention to the removal of bone superiorly and supero-posteriorly; posterior lacrimal sac flap reflection and apposition. When training surgeons in endoscopic endonasal DCR, we have suggested that one should try to allow up to 90 min of total theater time for each case [80].

There appears to be a trend toward improved outcomes and reduced granulation in groups where nasal mucosal and lacrimal flaps are preserved, with no evidence of increased complication rates with mucosal sparing techniques [81]. Several articles have highlighted the importance of surgical access to successful endonasal DCR surgery [82–84].Septoplasty or an anterior middle turbinectomy are often required. Adjunctive nasal procedures were found to be performed in 53% of patients in a tertiary rhinology practice [83].

The large series reports of ultrasonic endoscopic endonasal DCR using newer generation machines have been published [85]. As against the conventional belief, the time taken by the piezoelectric system was found to be comparable to standard techniques [86].

Intubation

Based upon the outcome data of endonasal DCR carried out by surgeons in training, we have suggested that routine intubation in such patients may help to reduce the potential for early internal ostium obstruction [17]. There have been reports for [80, 87, 88] and against [89–91] intubation. However, the lack of consensus continues.

Other Interesting Developments

The simple air bubble test [92], now has reported reliability indices [93]. The air bubble test showed a sensitivity of 82% and specificity of 100% for anatomical success and 84% and 75% for functional success after external DCR.

One center published an interesting reminder that equipment can have alternative uses. In this practice, a direct otoscope was found to allow nasal examination of the nasolacrimal anastomosis in the majority of patients undergoing DCR surgery [94].

Finally, should we be considering the prior administration of radioactive iodine (RAI) therapy a risk factor for failure of our DCR surgeries? [95–97]. By means of logistic regression analysis of 1083 cases, the odds ratio for failure of DCR surgery was found to increase to 4.18 (confidence interval 1.579–11.044) when there was history of RAI [97]. Iodine uptake is thought to occur in the epithelial cells lining the nasolacrimal system. This can result in inflammation, tissue swelling, or fibrosis; with resultant occlusion, sometimes years after RAI administration. In the above series, patients who had unsuccessful surgery were much more likely to have a history of RAI (24% v 7%, $p = 0.009$). Guidelines on screening and evaluating nasolacrimal duct obstruction in patients taking RAI have been proposed [98].

Conclusion

Despite recent acceptance of equivalent success between external and endoscopic DCR [66, 84], more surgeons still prefer and perform greater numbers of external procedures, while reporting higher success rates [99]. Is the tide turning among ophthalmologists? Approaches to DCR surgery may no longer represent such a great debate but a division of experience and training between generations of surgeons!

References

1. Al-Ghafiqi M.. Ophthalmic guide. Madrid, Spain: El-Escorial Museum; 1165 AD.
2. Caldwell GW. A new operation for the radical cure of obstruction of the nasal duct. N Y Med J. 1893;58:476.
3. Toti A. Nuovo metodo conservatore di cura radicale delle suppurazioni croniche del sacco lacrimale (dacriocistorinostomia). Clin Mod Firenze. 1904;10:385–7.
4. Dupuy-Dutemps L, Bourguet M. Procede plastique de dacryocystorhinostomie et ses results. Ann Ocul. 1921;158:241–61.
5. Ben Simon GJ, Joseph J, Lee S, et al. External versus endoscopic dacryocystorhinostomy for acquired nasolacrimal duct obstruction in a tertiary referral center. Ophthalmology. 2005;112:1463–8.
6. Dolman PJ. Comparison of external dacryocystorhinostomy with nonlaser endonasal dacryocystorhinostomy. Ophthalmology. 2003;110:78–84.
7. Adenis JP, Robert P-Y. Retrocaruncular approach to the medial orbit for dacryocystorhinostomy. Graefes Arch Clin Exp Ophthalmol. 2003;241:725–9.
8. Robert M-C, Maleki B, Boulos PR. Endocanalicular laser dacryocystorhinostomy with mucosal flaps. Ophthal Plast Reconstr Surg. 2013;29:294–7.
9. McDonogh M, Meiring JH. Endoscopic transnasal dacryocystorhinostomy. J Laryngol Otol. 1989;103:585–7.
10. Tsirbas A, Wormald PJ. Mechanical endonasal dacryocystorhinostomy with mucosal flaps. Br J Ophthalmol. 2003;87:43–7.
11. Tsirbas A, Davis G, Wormald PJ. Mechanical endonasal dacryocystorhinostomy versus external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2004;20:50–6.
12. Codère F, Denton P, Corona J. Endonasal dacryocystorhinostomy: a modified technique with preservation of the nasal and lacrimal mucosa. Ophthal Plast Reconstr Surg. 2010;26:161–4.
13. Patel V, Ross JJ, Malhotra R. Early experience using a new modified bone nibbler for superior osteotomy during endonasal dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2011;27:15–20.
14. Goldberg RA. Endonasal dacryocystorhinostomy: is it really less successful? Arch Ophthalmol. 2004;122:108–10.
15. Whittet HB, Shun-Shin GA, Awdry P. Functional endoscopic transnasal dacryocystorhinostomy. Eye. 1993;7:545–9.
16. Tarbet KJ, Custer PL. External dacryocystorhinostomy. Surgical success, patient satisfaction, and economic cost. Ophthalmology. 1995;102:1065–70.
17. Shun-Shin GA. Endoscopic dacryocystorhinostomy: a personal technique. Eye. 1998;12:467–70.
18. Cokkeser Y, Evereklioglu C, Er H. Comparative external versus endoscopic dacryocystorhinostomy: results in 115 patients (130 eyes). Otolaryngol Head Neck Surg. 2000;123:488–91.
19. Woog JJ, Kennedy RH, Custer PL, et al. Endonasal dacryocystorhinostomy: a report by the American academy of ophthalmology. Ophthalmology. 2001;108:2369–77.
20. Häusler R, Caversaccio M. Microsurgical endonasal dacryocystorhinostomy with long-term insertion of bicanalicular silicone tubes. Arch Otolaryngol Head Neck Surg. 1998;124:188–91.
21. Malhotra R, Wright M, Olver JM. A consideration of the time taken to do dacryo-cystorhinostomy (DCR) surgery. Eye. 2003;17:691–6.
22. Tsirbas A, Wormald PJ. Endonasal dacryocystorhinostomy with mucosal flaps. Am J Ophthalmol. 2003;135:76–83.
23. Davies MJ, Lee S, Lemke S, et al. Predictors of anatomical patency following primary endonasal dacryocystorhinostomy: a pilot study. Orbit. 2011;30:49–53.
24. Rose GE. The lacrimal paradox: toward a greater understanding of success in lacrimal surgery. Ophthal Plast Reconstr Surg. 2004;20:262–5.
25. Patrinely JR, Anderson RL. A review of lacrimal drainage surgery. Ophthal Plast Reconstr Surg. 1986;2:97–102.
26. Mann BS, Wormald PJ. Endoscopic assessment of the dacryocystorhinostomy ostium after endoscopic surgery. Laryngoscope. 2006;116:1172–4.
27. Linberg JV, Anderson RL, Bumsted RM, et al. Study of intranasal ostium external dacryocystorhinostomy. Arch Ophthalmol. 1982;100:1758–62.
28. Ezra E, Restori M, Mannor GE, et al. Ultrasonic assessment of rhinostomy size following external dacryocystorhinostomy. Br J Ophthalmol. 1998;82:786–9.
29. Takahashi Y, Nakamura Y, Kakizaki H. Dacryoendoscopic findings in the lacrimal passage in failed dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2013;29:373–5.
30. Türkcü FM, Oner V, Taş M, et al. Anastomosis of both posterior and anterior flaps or only anterior flaps in external dacryocystorhinostomy. Orbit. 2012;31:383–5.
31. Katuwal S, Aujla JS, Limbu B, et al. External dacryocystorhinostomy: do we really need to repair the posterior flap? Orbit. 2013;32:102–6.
32. Madge SN, Selva D. Intubation in routine dacryocystorhinostomy: why we do what we do. Clin Experiment Ophthalmol. 2009;37:620–3.
33. Saiju R, Morse LJ, Weinberg D, et al. Prospective randomised comparison of external dacryocystorhinostomy with and without silicone intubation. Br J Ophthalmol. 2009;93:1220–2.
34. Cannon PS, Chan W, Selva D. Incidence of canalicular closure with endonasal dacryocystorhinostomy without intubation in primary nasolacrimal duct obstruction. Ophthalmology. 2013;120:1688–92.
35. Chong KK, Lai FH, Ho M, et al. Randomized trial on silicone intubation in endoscopic mechanical dacryocystorhinostomy (SEND) for primary nasolacrimal duct obstruction. Ophthalmology. 2013;120:2139–45.
36. Camara JG, Bengzon AU, Henson RD. The safety and efficacy of mitomycin C in endonasal endoscopic laser-assisted dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2000;16:114–8.
37. Hartikainen J, Grenman R, Puukka P, et al. Prospective randomized comparison of external dacryocystorhinostomy and endonasal laser dacryocystorhinostomy. Ophthalmology. 1998;105:1106–13.
38. Jokinen K, Kärjä J. Endonasal dacryocystorhinostomy. Arch Otolaryngol. 1974;100:41–4.
39. Rice DH. Endoscopic intranasal dacryocystorhinostomy results in four patients. Arch Otolaryngol Head Neck Surg. 1990;116:1061.
40. McDonogh M. Endoscopic transnasal dacryocystorhinostomy. Results in 21 patients. S Afr J Surg. 1992;30:107–10.
41. Kong YT, Kim TI, Kong BW. A report of 131 cases of endoscopic laser lacrimal surgery. Ophthalmology. 1994;101:1793–800.
42. Massaro BM, Gonnering RS, Harris GJ. Endonasal laser dacryocystorhinostomy. A new approach to nasolacrimal duct obstruction. Arch Ophthalmol. 1990;108:1172–6.
43. Woog JJ, Metson R, Puliafito CA. Holmium:YAG endonasal laser dacryocystorhinostomy. Am J Ophthalmol. 1993;116:1–10.
44. Madge SN, Chan W, Malhotra R, et al. Endoscopic dacryocystorhinostomy in acute dacryocystitis: a multicenter case series. Orbit. 2011;30:1–6.
45. Weidenbecher M, Hosemann W, Buhr W. Endoscopic endonasal dacryocystorhinostomy: results in 56 patients. Ann Otol Rhinol Laryngol. 1994;103:363–7.
46. Sprekelsen MB, Barberán MT. Endoscopic dacryocystorhinostomy: surgical technique and results. Laryngoscope. 1996;106:187–9.
47. Erdöl H, Akyol N, Imamoglu HI, et al. Long-term follow-up of external dacryocystorhinostomy and the factors affecting its success. Orbit. 2005;24:99–102.
48. Zenk J, Karatzanis AD, Psychogios G, et al. Long-term results of endonasal dacryocystorhinostomy. Eur Arch Otorhinolaryngol. 2009;266:1733–8.
49. Onerci M, Orhan M, Ogretmenoğlu O, et al. Long-term results and reasons for failure of intranasal endoscopic dacryocystorhinostomy. Acta Otolaryngol. 2000;120:319–22.

50. Walland MJ, Rose GE. Factors affecting the success rate of open lacrimal surgery. Br J Ophthalmol. 1994;78:888–91.
51. Chan W, Malhotra R, Kakizaki H, et al. Perspective: what does the term functional mean in the context of epiphora? Clin Experiment Ophthalmol. 2012;40:749–54.
52. Vicinanzo MG, McGwin G, Boyle M, et al. The consequence of premature silicone stent loss after external dacryocystorhinostomy. Ophthalmology. 2008;115:1241–4.
53. Ali MJ, Gupta H, Honavar SG. Acquired nasolacrimal duct obstructions secondary to naso-orbito-ethmoid fractures. Patterns and outcomes. Ophthal Plast Reconstr Surg. 2012;28:242–5.
54. Wearne MJ, Beigi B, Davis G, et al. Retrograde intubation dacryocystorhinostomy for proximal and midcanalicular obstruction. Ophthalmology. 1999;106:2325–8.
55. Limawararut V, Valenzuela AA, Sullivan TJ, et al. Cerebrospinal fluid leaks in orbital and lacrimal surgery. Surv Ophthalmol. 2008;53:274–84.
56. Sharma V, Martin PA, Benger R, et al. Evaluation of the cosmetic significance of external dacryocystorhinostomy scars. Am J Ophthalmol. 2005;140:359–62.
57. Vagefi MR, Winn BJ, Lin CC, et al. Facial nerve injury during external dacryocystorhinostomy. Ophthalmology. 2009;116:585–90.
58. Lee TS, Woog JJ. Endonasal dacryocystorhinostomy in the primary treatment of acute dacryocystitis with abscess formation. Ophthal Plast Reconstr Surg. 2001;17:180–3.
59. Wu W, Yan W, MacCallum JK, et al. Primary treatment of acute dacryocystitis by endoscopic dacryocystorhinostomy with silicone intubation guided by a soft probe. Ophthalmology. 2009;116:116–22.
60. Tsirbas A, Davis G, Wormald PJ. Revision dacryocystorhinostomy: a comparison of endoscopic and external techniques. Am J Rhinol. 2005;19:322–5.
61. Hull S, Lalchan S-A, Olver JM. Success rates in powered endonasal revision surgery for failed dacryocystorhinostomy in a tertiary referral center. Ophthal Plast Reconstr Surg. 2013;29:267–71.
62. Anderson NG, Wojno TH, Grossniklaus HE. Clinicopathologic findings from lacrimal sac biopsy specimens obtained during dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2003;19:173–6.
63. Salour H, Hatami M-M, Parvin M, et al. Clinicopathological study of lacrimal sac specimens obtained during DCR. Orbit. 2010;29:250–3.
64. Mistry N, Rockley TJ, Reynolds T, et al. Development and validation of a symptom questionnaire for recording outcomes in adult lacrimal surgery. Rhinology. 2011;49:538–45.
65. Ali MJ, Iram S, Ali MH, et al. Assessing the outcomes of powered endoscopic dacryocystorhinostomy in adults using the lacrimal symptom (Lac-Q) questionnaire. Ophthal Plast Reconstr Surg. 2017;33:65–8.
66. Ali MJ, Psaltis AJ, Wormald PJ. Long-term outcomes in revision powered endoscopic dacryocystorhinostomy. Int Forum Allergy Rhinol. 2014;4:1016–9.
67. Akcay E, Yuksel N, Ozen U. Revision external dacryocystorhinostomy results after a failed dacryocystorhinostomy surgery. Ophthalmol Ther. 2016;5:75–80.
68. Yarmohammadi ME, Ghasemi H, Jafari J, et al. Teamwork endoscopic endonasal surgery in failed external dacryocystorhinostomy. J Ophthalmic Vis Res. 2016;11:282–6.
69. Baek JS, Jeong SH, Lee JH, et al. Cause and management of patients with failed endonasal dacryocystorhinostomy. Clin Exp Otorhinolaryngol. 2016 (Epub).
70. Park J, Kim H. Office-based endoscopic revision using a microdebrider for failed endoscopic dacryocystorhinostomy. Eur Arch Otorhinolaryngol. 2016;273:4329–34.
71. Chisty N, Singh M, Ali MJ, et al. Long-term outcomes of powered endoscopic dacryocystorhinostomy in acute dacryocystitis. Laryngoscope. 2016;126:551–3.
72. Kamal S, Ali MJ, Pujari A, et al. Primary powered endoscopic dacryocystorhinostomy in the setting of acute dacryocystitis and lacrimal abscess. Ophthal Plast Reconstr Surg. 2015;31:293–5.
73. Jain S, Ganguly A, Singh S, et al. Primary non-endoscopic endonasal versus delayed external dacryocystorhinostomy in acute dacryocystitis. Ophthal Plast Reconstr Surg. 2016 (Epub).
74. W Chan, G Wilscek, R Ghabrial, et al. Paediatric endonasal dacryocystorhinostomy – a multicentre series of 116 cases. Orbit. 2017;36:311–6.
75. Ali MJ, Psaltis AJ, Ali MH, et al. Endoscopic assessment of the dacryocystorhinostomy ostium after powered endoscopic surgery: behaviour beyond 4 weeks. Clin Experiment Ophthalmol. 2015;43:152–5.
76. Ali MJ, Psaltis AJ, Wormald PJ. Dacryocystorhinostomy ostium: parameters to evaluate and DCR ostium scoring. Clin Ophthalmol. 2014;8:2491–9.
77. Waly MA, Shalaby OE, Elbakary MA, et al. The cosmetic outcome of external dacryocystorhinostomy scar and factors affecting it. Indian J Ophthalmol. 2016;64:261–5.
78. Ng DS, Chan E. Techniques to minimize skin incision scar for external dacryocystorhinostomy. Orbit. 2016;35:42–5.
79. Draaijers LJ, Tempelman FR, Botman YA, et al. The patient and observer scar assessment scale: a reliable and feasible tool for scar evaluation. Plast Reconstr Surg. 2004;113:1960–5.
80. Malhotra R, Norris JH, Sagili S, et al. The learning curve in endoscopic dacryocystorhinostomy: outcomes in surgery performed by trainee oculoplastic surgeons. Orbit. 2015;34:314–9.
81. Green R, Gohil R, Ross P. Mucosal and lacrimal flaps for endonasal dacryocystorhinostomy (DCR): a systematic review. Clin Otolaryngol. 2016 (Epub).
82. Fayet B, Katowitz WR, Racy E, et al. Endoscopic dacryocystorhinostomy: the keys to surgical success. Ophthal Plast Reconstr Surg. 2014;30:69–71.
83. Ali MJ, Psaltis AJ, Wormald PJ. The frequency of concomitant adjunctive nasal procedures in powered endoscopic dacryocystorhinostomy. Orbit. 2015;34:142–5.
84. Ali MJ, Psaltis AJ, Murphy J, et al. Powered endoscopic dacryocystorhinostomy: a decade of experience. Ophthal Plast Reconstr Surg. 2015;31:219–21.
85. Ali MJ, Singh M, Chisty N, et al. Endoscopic ultrasonic dacryocystorhinostomy: clinical profile and outcomes. Eur Arch Otorhinolaryngol. 2016;273:1789–93.
86. Ali MJ, Ganguly A, Ali MH, et al. Time taken for superior osteotomy in primary powered endoscopic dacryocystorhinostomy: is there a difference between an ultrasonic aspirator and a mechanical burr? Int Forum Allergy Rhinol. 2015;5:764–7.
87. Fayers T, Dolman PJ. Bicanalicular silicone stents in endonasal dacryocystorhinostomy: results of a randomized clinical trial. Ophthalmology. 2016;123:2255–9.
88. Ali MJ, Psaltis AJ, Murphy J, et al. Outcomes of primary powered endoscopic dacryocystorhinostomy: comparison between experienced versus less experienced surgeons. Am J Rhinol Allergy. 2014;28:514–6.
89. Longari F, Dehgani Mobaraki P. Endoscopic dacryocystorhinostomy with and without silicone intubation: 4 years retrospective study. Eur Arch Otorhinolaryngol. 2016;273:2079–84.
90. Kalin-Hajdu E, Cadet N, Boulos PR. Controversies of the lacrimal system. Surv Ophthalmol. 2016;61:309–13.
91. Okuyucu S, Gorur H, Oksuz H, et al. Endoscopic dacryocystorhinostomy with silicone, polypropylene, and T-tube stents; randomized controlled trial of efficacy and safety. Am J Rhinol Allergy. 2015;29:63–8.
92. Mulligan NB, Ross CA, Francis IC, et al. The Valsalva DCR bubble test: a new method of assessing lacrimal patency after DCR surgery. Ophthal Plast Reconstr Surg. 1994;10:121–3.

93. Kashkouli MB, Jamshidian-Tehrani M, Shahrzad S. Reliability of air bubble test in assessment of anatomical and functional success after external dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2014;30:381–3.
94. Yazici B, Sabur H, Orucov N. Use of direct otoscope for intranasal examination after dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2016;32:116–7.
95. Morgenstern KE, Vadysirisack DD, Zhang Z, et al. Expression of sodium iodide symporter in the lacrimal drainage system: implication for the mechanism underlying nasolacrimal duct obstruction in I-131 treated patients. Ophthal Plast Reconstr Surg. 2005;21:337–44.
96. Sun GE, Hatipoglu B. Epiphora after radioactive iodine ablation for thyroid cancer. Thyroid. 2013;23:243–5.
97. Jung SK, Kim YC, Cho WK, et al. Surgical outcomes of endoscopic dacryocystorhinostomy: analysis of 1083 consecutive cases. Can J Ophthalmol. 2015;50:466–70.
98. Ali MJ. Iodine-131 therapy and nasolacrimal duct obstructions: what we know and what we need to know. Ophthal Plast Reconstr Surg. 2016;32:243–8.
99. Barmettler J, Erlich R, Lelli G, et al. Current preferences and reported success rates in dacryocystorhinostomy amongst ASOPRS members. Orbit. 2013;32:20–6.

Quality of Life and Patient Satisfaction in Lacrimal Disorders

47

Mohammad Javed Ali and Adel Al Suhaibani

Introduction

Lacrimal disorders need not necessarily always have only a physical or a functional dimension; there may be emotional, social, and economic or a combination of these aspects to them. Understanding the different facets of patient and the caregiver's perspectives of the disease before and after medical or surgical interventions contributes significantly to overall patient satisfaction. Rather than objective anatomical outcomes of a surgery alone, patient satisfaction is what all the surgeons should ideally aim for. It is in this context that the validated quality of life (QOL) questionnaires help the health-care providers. They are also a very useful tool for clinical research and standardization of outcomes.

CNLDO: Patient and Parental Quality of Life

Congenital nasolacrimal duct obstruction or CNLDO is the commonest pediatric lacrimal disorder that effects up to 20% of the newborns with spontaneous resolution in vast majority [1]. The symptomatology or the success rates have been largely assessed using isolated elementary questionnaires that included both parental perception and examinations [2, 3]. Holmes et al. [4] published a novel and comprehensive parental questionnaire addressing symptoms and health-related quality of life in CNLDO. The questionnaire included 17 questions with the first three questions having four subtypes each. All the questions were evaluated on five parameters (always, often, sometimes, rarely, and never) with scoring for each parameter. The questionnaire is briefly listed in Table 47.1. Holmes et al. [4] enrolled 87 children 56 with and 31 without NLDO. The Cronbach's values were impressive for not only the overall questionnaire (0.95) but also for its two subscales, namely, symptoms scale (0.95) and health-related quality of life (HRQL) scale (0.85). The CNLDO patients had worse scores for both the scales as compared to normal children, and the affected eye had worse score as compared to the normal fellow eye. Both these scales showed improvement in scores following intervention in the form of probing. The study found that the questionnaire is very useful in quantifying parental perception of symptoms and HRQL in CNLDO.

The author's group has compared the parental quality of life (QOL) in CNLDO children who were successful following intervention versus complex CNLDO with poor outcomes. However, we did not include the last two (16, 17) questions. The early analysis has shown the Holmes questionnaire to be very useful for comparisons within the CNLDO group as well.

Quality of Life After DCR Surgery

The quality of life after a DCR surgery has been usually assessed using the Glasgow Benefit Inventory or GBI Questionnaire which was developed by Robinson et al. [5] for evaluating otorhinolaryngology procedures. This questionnaire is well known and validated in many studies across subspecialties of otology and rhinology [6, 7]. It consists of 18 questions, each assessed on a five-point Likert scale. Twelve questions are related to general perception of well-being and three each for physical health and social parameters. A positive GBI score represents a beneficial effect. The range of scoring extends from −100 (maximal negative benefit) to 0 (no change) to +100 (maximum positive benefit). Table 47.2 lists briefly the 18 questions that constitute the GBI.

Bakri et al. [8] assessed the benefits of external DCR versus endoscopic laser-assisted DCR and found no statistical difference in GBI scoring between the two groups.

M. Javed Ali, F.R.C.S., F.R.C.G.P. (✉)
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Hyderabad 34, India
e-mail: drjaved007@gmail.com

A. Al Suhaibani, F.R.C.S.
Department of Ophthalmology, King Abdul Aziz University Hospital, Riyadh, Saudi Arabia

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_47

Table 47.1 Brief Holmes Questionnaire for CNLDO

1. Tears "well up" in my child's eye(s) (has four subtypes and five parameters to score)
2. Tears run down my child's cheek
3. My child has gunk in the corner of the eye(s)
4. My child's eye(s) looks glassy
5. The skin around my child's eye(s) is red
6. My child's eyeball is red
7. My child rubs his or her eye(s)
8. The appearance of one or both of my child's eyeballs bothers me
9. The appearance of one or both of my child's eyelids bothers me
10. Child is bothered by his or her eye(s)
11. Child's eye condition interferes with his or her daily activities
12. Child's eye condition interferes with my daily activities
13. I feel fine about my child's eye(s)
14. I worry about my child's eye(s)
15. Other people comment about my child's eye(s)
16. I feel fine about the way my child's eye(s) appears in photos
17. Other children tease my child about his/her eye(s)

Table 47.2 Brief Glasgow Benefit Inventory Questionnaire

1. Has the result of operation/intervention affected the things you do?
2. Has the result of the operation made your overall life better or worse?
3. Since your operation, have you felt more or less optimistic about the future?
4. Since your operation, do you feel more or less embarrassed when with people?
5. Since your operation, do you have more or less self-confidence?
6. Since your operation, do you find easier or harder to deal with company?
7. Since your operation, do you have more or less support from your friends?
8. Have you been to your family doctor, more or less since operation?
9. Since your operation, do you feel more or less confident about job opportunities?
10. Since your operation, do you feel more or less self-conscious?
11. Since your operation, are there more or fewer people who really care about you?
12. Since you had the operation, do you catch colds or infections much or less often?
13. Have you taken more or less medicine for any reason, since your operation?
14. Since your operation, do you feel better or worse for any reason?
15. Since your operation, do you have more or less support from your family?
16. Since your operation, are you more or less inconvenienced by health problem?
17. Since your operation, have you participated in more or fewer social activities?
18. Since your operation, are you more or less inclined to withdraw from social situations?

Mansour et al. [9] studied the long-term patient satisfaction following an external DCR and concluded that long postoperative times negatively affect the exact subjective symptom scoring after surgery. Yeniad et al. [10] compared the patient satisfaction between external and transcanalicular laser DCR and found that the mean symptoms scoring reduced from 24.2 ± 4.6 at baseline to 3.5 ± 1.8 in the external group and 22.8 ± 3.4 to 3.37 ± 1.2 in the transcanalicular group (p = 0.67). The GBI scoring was similar and did not reach statistical significance in either group. However there were concerns regarding follow-ups [11].

Ho et al. [12] studied the impact of endonasal DCR on quality of life and found GBI scores of +34 in successful cases as compared to −19 in failed cases. The mean total GBI for endoscopic DCR in another study was +15.04 (95% CI: 9.74–20.35). Hii et al. [13] compared patient satisfaction between external versus endonasal DCR and found no difference. The patients who underwent external DCR on one side and endonasal on the other side, retrospectively, reported preference for endonasal DCR [14, 15]. Jutley et al. [16] reported improved GBI scores following endoscopic DCR but felt it may be difficult for all patients to complete the 18 questions of GBI without appropriate guidance. In cases of bilateral NLDO, simultaneous bilateral DCR was shown to confer significant improvement of quality of life with a statistically significant GBI score difference between 1 month and 3 months post operatively [10].

Quality of Life in FNLDO and Minimally Invasive NLDO Treatments

Functional nasolacrimal duct obstruction is an under diagnosed entity [17]. Epiphora in the presence of a patent lacrimal pathway and absence of alternative etiology could be the simplest description. Cheung et al. [18] conducted a detailed study on 33 FNLDO patients and studied their symptoms in relation to the vision, reading, driving, moods, work, and embarrassment. All these parameters were affected specifically vision, reading, and embarrassment, resulting in lower quality of life. Overall symptom scores significantly reduced after dacryocystorhinostomy (DCR) from a mean preoperative score of 3.50 (SD = 2.07) to 2.0 (SD = 1.65) in the postoperative period ($p < 0.05$).

Kabata et al. [19] studied the effects of silicone intubation using Nunchaku-style tube on vision-related quality of life in patients with lacrimal passage obstructions. They used the 25 item National Eye Institute Visual Function Questionnaire (NEI-VFQ). Silicone intubation showed a significant improvement in NEI-VFQ composite score (p = 0.0001), ocular pain score ($p < 0.0001$), and mental health score (p = 0.0003).

Specific Lacrimal QOL Questionnaires—The Way Forward

Most of the questionnaires used so far in lacrimal surgery are of general nature, and most are administered postoperatively. The morbidity with lacrimal obstructions should ideally not be assessed using questionnaires that were designed for more general conditions where systemic morbidity may change a lot of parameters. This need for lacrimal specific questionnaires has resulted in two new models, one for NLDO and other for DCR. Smirnov et al. [20] conceptualized the NLDO-symptom score survey (NLDO-SS) which has six parameters that need to be scored on a scale of 0 (no symptoms) to 10 (severe symptoms). The timing of administration can be individualized based on the follow-up protocols of each surgeon but is usually carried out at 1 week, 1 month, and 3 months. Five of these parameters are symptoms related to NLDO. Hence this is not only more specific but also simpler to use once validated. Table 47.3 lists the parameters in the NLDO-SS questionnaire.

Mistry et al. [21] reviewed 100 consecutive patients of lacrimal duct obstruction and studied their symptomatology and subsequently developed Lac-Q questionnaire. The questions were specific to lacrimal disorders (four questions with multiple subparameters) including their social impact (five questions). They showed that not only is Lac-Q useful in pre- and postoperative comparisons but also correlates well with objective methods of assessment. Table 47.4 lists the parameters of the Lac-Q questionnaire.

Table 47.3 The NLDO-Symptom Score (NLDO-SS) parameters

1. Tearing (0–10 scale scoring for each)
2. Irritation
3. Pain
4. Discharge
5. Swelling
6. Visual acuity

Table 47.4 The brief "Lac-Q" questionnaire parameters

Lacrimal parameters	Social parameters
1. Watery eye	1. Watery eye comment by family or friends
2. Soreness of eyelids	2. Watery eye causing embarrassment
3. Sticky eye	3. Watery eye interfering with daily activities
4. Swelling at medial canthus	4. Watery eye causing blurred vision
	5. Medical consultation for watery eye

Updates (2015–2016)

Impact of Epiphora on Vision-Related Quality of Life

A stable tear film is essential for maintaining optical quality and visual clarity. Epiphora may disturb the tear stability leading to a potentially suboptimal vision. The Ocular Surface Diseased Index (OSDI) questionnaire aims to evaluate common vision-related symptoms that affect performing of daily activities and comprises three sub-measurements: vision-related functions, eye symptoms, and environmental risk factors [22]. Shin et al. [23] conducted a study to evaluate subjective vision-related discomfort using ten vision-related parameters of the OSDI (Table 47.5) for 342 patients with epiphora, of which 115 had bilateral epiphora. In their study, the analysis on age and interpersonal relations showed a statistically significant negative correlation ($p = 0.048$), which reflected younger patients feeling greater discomfort. Females were found to have higher scores for household activities, outdoor activities, and interpersonal relations than males. Epiphora significantly influenced outdoor activities. Patients with complete obstruction of lacrimal drainage showed higher symptom scores than those who had patent lacrimal systems. Interestingly, one-sided and two-sided epiphora patients showed no significant differences in QOL scores. This indicates that the symptom of epiphora itself creates significant discomfort in daily life without regards to laterality. There were significant improvements of scores following surgical interventions.

Assessing the Outcomes of Powered Endoscopic Dacryocystorhinostomy in Adults Using the Lacrimal Symptom (Lac-Q) Questionnaire

A specific symptom-based social and lacrimal (Lac-Q) questionnaire was used by Ali et al. [24] to evaluate the quality of outcomes of powered endoscopic DCR. The Lac-Q questionnaire was administered preoperatively, at 4 weeks and 16

Table 47.5 The Ocular Surface Diseased Index (OSDI) questionnaire parameters

1. Reading
2. Daytime driving
3. Night time driving
4. Working at a computer
5. Watching
6. Work-related activities
7. Household activities
8. Outdoor activities
9. Interpersonal relations
10. General happiness

weeks (SI) following the surgery for all the 50 patients who participated in the study.

The mean preoperative total score was 12.5. Interestingly, the range of preoperative score was 5–16 for unilateral cases and 21–27 for bilateral cases. Following surgery, the total score significantly improvement to 1.59 at 4 weeks ($p \leq 0.001$) and 1.0 at 16 weeks ($p \leq 0.001$). Among the 50 participants in the study, one patient had anatomical and functional failure, and three additional patients had functional failure in the presence of anatomical patency at the 16th week follow-up. Minimal improvement in the scores was observed for patients with failed DCR (4/50); however, the social impact and total scores remained significantly high compared to patients with successful surgical outcomes.

Change in Quality of Life of Patients Undergoing Silicone Stent Intubation for Nasolacrimal Duct Stenosis Combined with Dry Eye Syndrome

Epiphora may occur as a result of different etiologies, and multiple mechanisms may coexist in the same patient. Inflammatory conditions, such as dry eye syndrome, and allergic conjunctivitis may impede lacrimal drainage by causing punctal stenosis and canalicular stenosis along with ocular irritation and reflex tearing.

Oh et al. [25] used the GBI to subjectively measure and evaluate vision-related QOL for 30 patients diagnosed with nasolacrimal duct stenosis combined with reflex tearing due to dry eye syndrome. All patients were initially treated with lubricants but the epiphora did not improve.

Silicone stent intubation was then performed to treat the nasolacrimal duct stenosis which resulted in relieving of tearing in 23 of 30 patients at 6 months of follow-up. The surgical success was measured by the subjective assessment of patients and the GBI scores. The preoperative total score in young patients (<58.5 years) was +19.38 (range, 10.10–28.67) and in older patients was +14.68 (range, −2.52 to 31.89). The total postoperative score in successful outcomes was +27.54 (range, 20.85–34.23) and in failed cases was −16.83 (range, −24.69 to −8.97). Apart from the therapeutic significance of silicone intubation, this study also demonstrates the utility of assessing the surgical outcomes using the GBI scores.

References

1. MacEwen CJ, Young JD. Epiphora during the first year of life. Eye. 1991;5:596–600.
2. Sturrock SM, MacEwen CJ, Young JD. Long term results after probing for congenital nasolacrimal duct obstruction. Br J Ophthalmol. 1994;78:892–4.
3. Lee DH, Fudemberg SJ, Davitt BV, et al. Success of simple probing and irrigation in patients with nasolacrimal duct obstruction and otitis media. J AAPOS. 2005;9:192–4.
4. Holmes JM, Leske DA, Cole SR, et al. A symptom survey and quality of life questionnaire for nasolacrimal duct obstruction in children. Ophthalmology. 2006;113:1675–80.
5. Robinson K, Gatehouse S, Browning GG. Measuring patient benefit from otorhinolaryngological survey and therapy. Ann Otol Rhinol Laryngol. 1996;105:415–22.
6. Fahy C, Nikolopoulos TP, O'Donoghue GM. Acoustic neuroma surgery and tinnitus. Eur Arch Otorhinolaryngol. 2002;259:299–301.
7. Salhab M, Matai V, Salam MA. The impact of functional endoscopic sinus surgery on health status. Rhinology. 2004;42:98–102.
8. Bakri SJ, Carney AS, Robinson K, et al. Quality of life outcomes following dacryocystorhinostomy: external and endonasal laser techniques compared. Orbit. 1999;18:83–8.
9. Mansour K, Sere M, Oey AG, et al. Long term patient satisfaction of external dacryocystorhinostomy. Ophthalmologica. 2005;219:97–100.
10. Yeniad B, Uludag G, Kozer-Bilgin L. Assessment of patient satisfaction following external versus transcanalicular dacryocystorhinostomy with a diode laser and evaluation if change in quality of life after simultaneous bilateral surgery in patients with bilateral nasolacrimal duct obstruction. Curr Eye Res. 2012;37:286–92.
11. Ali MJ, Honavar SG. Assessment of patient satisfaction following external versus transcanalicular dacryocystorhinostomy. Curr Eye Res. 2012;37:853.
12. Ho A, Sachidananda R, Carrie S, et al. Quality of life assessment after non-laser endonasal dacryocystorhinostomy. Clin Otolaryngol. 2006;31:399–403.
13. Hii BW, McNab AA, Friebel JD. A comparison of external and endonasal dacryocystorhinostomy in regard to patient satisfaction and cost. Orbit. 2012;31:67–76.
14. Ibrahim HA, Batterbury M, Banhegyi G, et al. Endonasal laser dacryocystorhinostomy and external dacryocystorhinostomy outcome profile in a general ophthalmic service unit: a comparative, retrospective study. Ophthalmic Surg Lasers. 2001;32:220–7.
15. Dolman PJ. Comparison of external dacryocystorhinostomy with non-laser endonasal dacryocystorhinostomy. Ophthalmology. 2003;110:78–84.
16. Jutley J, Karim R, Joharatnam M, et al. Patient satisfaction following endoscopic endonasal dacryocystorhinostomy: a quality of life study. Eye. 2013;27:1084–9.
17. Chan W, Malhotra R, Kakizaki H, et al. Perspective: what does the term functional mean in the context of epiphora? Clin Experiment Ophthalmol. 2012;40:749–54.
18. Cheung LM, Francis IC, Stapleton F, et al. Symptoms assessment in patients with functional and primary acquired nasolacrimal duct obstruction before and after a successful dacryocystorhinostomy surgery: a prospective study. Br J Ophthalmol. 2007;91:1671–4.
19. Kabata Y, Goto S, Takahashi G, et al. Vision-related quality of life in patients undergoing silicone tube intubation for lacrimal passage obstruction. Am J Ophthalmol. 2011;152:147–50.
20. Smirnov G, Tuomilehto H, Kokki H, et al. Symptom score questionnaire for nasolacrimal duct obstruction in adults – a novel tool to assess the outcomes after endoscopic dacryocystorhinostomy. Rhinology. 2010;48:446–51.
21. Mistry N, Rockley TJ, Reynolds T, et al. Development and validation of a symptom questionnaire for recording outcomes in adult lacrimal surgery. Rhinology. 2011;49:538–45.
22. Schiffman RM, Christianson MD, Jacobsen G, Hirsch JD, Reis BL. Reliability and validity of the ocular surface disease index. Arch Ophthalmol. 2000;118:615–21.
23. Shin JH, Kim YD, Woo KI, et al. Impact of epiphora on vision-related quality of life. BMC Ophthalmol. 2015;15:6.
24. Ali MJ, Iram S, Ali MH, et al. Assessing the outcomes of powered endoscopic dacryocystorhinostomy in adults using the lacrimal symptom (Lac-Q) questionnaire. Ophthal Plast Reconstr Surg. 2017;33:65–8.
25. Oh JR, Chang JH, Yoon JS, et al. Change in quality of life of patients undergoing silicone stent intubation for nasolacrimal duct stenosis combined with dry eye syndrome. Br J Ophthalmol. 2015;99:1519–22.

Future Directions in Lacrimal Disorders and Their Management

48

Mohammad Javed Ali

Introduction

If we wish to make a new world we have the material ready. The first one, too, was made out of chaos.

This quote by Robert Quillen perhaps is applicable to lacrimal surgery at this point of time. The enormous explosion in the knowledge we had in the last decade and newer developments in terms of instrumentations, diagnostics, surgical techniques, and molecular biology techniques augur well for the future of dacryology. This chapter would discuss some of the current trends and what is the possible future direction related to those trends. The ideas to future directions are innumerable and the author has highlighted those that strike him! This list is by no means comprehensive or exhaustive and many more can be added.

Etiopathogenesis of PANDO

Exact etiopathogenesis of PANDO has remained a big question for quite some time now. Inflammation, disturbances in helical structure of NLD, and cavernous bodies have been implicated; however, the accurate understanding is still elusive [1]. Future directions in this regard include careful studies of the vascular plexus surrounding the NLD, the possible protective role of tear duct-associated lymphoid tissue, cytokine expression in obstructed ducts, developing diagnostic modalities to recognize early inflammation, and possible specific pharmacological blockers.

Lacrimal Passage Recanalization

Recanalization of obstructed lacrimal passage under guidance is one of the current hot topics [2–6]. It is now recognized as a major therapeutic challenge. Although good success rates are occasionally reported, the long-term results are unclear, and skepticism is well justified at this stage. The major hurdle is our understanding of the etiopathogenesis. The future directions include characterizing the cytokine expressions during a scar formation, understanding the complete tissue response to recanalization, and possibly developing pharmacological blockers of undesirable molecular communications.

Mitomycin C (MMC)

Mitomycin C is commonly used to reduce the cicatrix in DCR, especially the high-risk ones and thus may prevent failures. The MMC meta-analysis has shed a good light on the role of MMC in DCR surgery [7]. Possible optimal concentration and duration have recently been identified in vitro [8]. The future direction is to standardize the appropriate concentration and duration by further basic studies like collagen contractility assays and clinical validation of these results. Standardized treatments of MMC will to a large extend make the clinical results comparable and objectively assessable, and this would further help in knowing the clinical benefits of MMC in DCR.

Lacrimal Intubation

The major question on lacrimal intubation is "Does it really help?" It has been a controversial topic although a recent meta-analysis has helped straighten a few curves [9]. Major questions to explore with the use of intubation include the appropriate retention duration, significance of biofilms on stents, and the feasibility of antiproliferative drug-coated stents.

M. Javed Ali, F.R.C.S., F.R.C.G.P.
Govindram Seksaria Institute of Dacryology, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad 34, India
e-mail: drjaved007@gmail.com

M. Javed Ali (ed.), *Principles and Practice of Lacrimal Surgery*, https://doi.org/10.1007/978-981-10-5442-6_48

Lacrimal Drainage-Associated Lymphoid Tissue (LDALT)

LDALT is a term used to describe the specific lymphoid tissue of the lacrimal drainage system. It is known to possibly influence the local immunity as well as ocular surface immune integrity [10]. Numerous derangements of LDALT have been noted in dacryocystitis [11]. The future directions would be to study LDALT in well-established ovine models of lymphocyte homing and recirculation. Changes in conjunctival-associated lymphoid tissues (CALT) following dacryocystectomy could be studied to decipher CALT and LDALT interactions and how the ocular surface influences lacrimal system and vice versa. LDALT of the nasolacrimal duct should be further investigated to assess whether it confers any protective effect against symptomatic dacryostenosis.

Diagnostic and Therapeutic Dacryoendoscopy

Dacryoendoscopy is gaining firm ground and increasing popularity for expanding indications in lacrimal disorders thus having many diagnostic and potential therapeutic implications [12–14]. Today, we can study every part of the lacrimal system in detail, and it has helped us in some cases to avoid more cumbersome diagnostic techniques like DCG and CT or MR-DCG. The future directions possibly include improved instrumentation for better clarity of images, better intraluminal mobility, less traumatic adjunctive instruments, and newer minimally invasive intraluminal surgical techniques.

Lacrimal Embryology

A thorough insight of lacrimal embryology is essential for advancing lacrimal science in terms of fundamental reasoning and developing minimally invasive interventions. Newer terminologies and description of embryonic conditions have been noted recently [15, 16]. The future direction is to study the cellular mechanism of mesenchymal condensation around the lacrimal primordium during Carnegie stage of embryonic development and create models to assess the effects of its dysregulation.

Lacrimal Microbiology

The microbes involved in acute and chronic lacrimal passage inflammation are well known [17, 18]. However their exact roles are unknown. The concept of Microbiome is picking up which essentially studies the microbial diversity and its abundance in a specified environment using molecular biology techniques [19]. The future is to establish the microbiome of the lacrimal system in detail and study the secretomes of the suspects and its mucosal barrier effects, biofilms on stents and their significance, and the role of appropriate antibiotics if any.

Electron Microscopy

Transmission electron microscopy (TEM) is being increasingly used to study the subcellular effects in lacrimal disorders and pharmacological response of tissues to medications [20, 21]. However the normative data is inadequate. The future direction would be to map the entire lacrimal system with both the TEM and scanning microscopes, establish a large normative data, and subsequently study the ultrastructural changes in common lacrimal disorders.

Revisiting the Dead!

Current trends and studies in cadavers had a paradigm shift effect in our understanding of lacrimal anatomy with regard to topography, Horner's muscle, medial canthal structures, and canalicular-lacrimal sac mucosal folds (CLS-MF) [22–24]. The crucial studies should be replicated across various races to validate their significance. The future directions perhaps should direct toward studying the embryos and stillborn cadavers up to cellular level to unravel the pathogenesis of congenital anomalies. It would also be interesting to take the CLS-MF fold concept further and study its characteristics and implications dacryocystitis and DCR surgery.

Stem Cells

Stem cell is a buzzword across the specialties. The possibilities of managing lacrimal disorders through stem cells should definitely be a long-term goal. Stem cells have been isolated and characterized within the lacrimal gland earlier [25]. The future direction could be to explore the stemness within the lacrimal system followed by its characterization, the cell-cell interactions, and the distant goal of regrowing the entire lacrimal system in vitro!

Quality of Life in Lacrimal Diseases

Most of the questionnaires used so far in lacrimal surgery are of general nature, and most are administered postoperatively [26]. The morbidity with lacrimal obstructions should ideally not be assessed using questionnaires that were designed

for more general conditions where systemic morbidity may change a lot of parameters. This need for lacrimal-specific questionnaires has resulted in two new models, the NLDO symptom score or the NLDO-SS questionnaire and "Lac-Q" questionnaire for DCR [27, 28]. The future direction would be to validate these in more clinical studies and add lacrimal disorder-specific morbidities and specific psychosocial impacts.

Translational Research and Collaborations

As enumerated earlier on in the text on numerous occasions, the research of future would increasingly focus on its translational values. The lacrimal surgeons today are increasingly focused on addressing questions which can have immediate or early translational value. Good forethought, planning, and meaningful collaborations contribute enormously toward this goal. The future lacrimal surgeons should intensely collaborate with appropriate people and systems, work on questions of immediate concern both in the clinics and lab, and always keep an eye on the larger picture of the impact of their research and how it is going to benefit mankind at large.

Cross-Specialization

Lacrimal drainage system traverses a good distance in the lateral wall of the nose. It is imperative to know both the nasal anatomy as well as surgical interventions through the nasal cavities. A resurgence of the EENT (eye, ear, nose, and throat) doctors, as was in past, may not be practical owing to the vast nature of each specialty; however, the benefits of limited cross-specialization are numerous. The future lacrimal surgeons should cross specialize into Rhinology and be as efficient as any ENT surgeon while managing lacrimal disorders.

The Clinician-Scientist

This breed of doctors is on the edge. The future largely belongs to the basic science approach to understand and manage diseases. The best people to take the clinical problems to the lab are clinicians themselves. Their participation with basic science research should be equal on the field. The future lacrimal surgeons should acquire knowledge of the basic sciences and related techniques and dedicate a specific time in labs on a routine basis. The results in the labs should be carefully analyzed by the clinician and if suitable brought back to the clinic for validation.

Conclusion

The 15 points elucidated in this chapter are just a few among the many more ideas. As discussed in the epilogue, the lacrimal surgeons had a glorious past, an exciting present era, and all looks set for a bright future. Constant discussions, meaningful collaborations, and working as a community to make the life of patient with lacrimal disorders comfortable could well be a legacy we want to hand over to subsequent generations.

Take the opportunity by beard as it is bald behind.

—Bulgarian proverb

References

1. Paulsen FP, Thale AB, Maune S, et al. New insights into the pathophysiology of primary acquired dacryostenosis. Ophthalmology. 2001;108:2329–36.
2. Liarakos VS, Boboridis KG, Mavrikakis E, et al. Management of canalicular obstructions. Curr Opin Ophthalmol. 2009;20:395–400.
3. Chen D, Li N, Wan P, et al. A novel procedure to treat canalicular obstruction by recanaliculisation and bicanalicular intubation. Br J Ophthalmol. 2012;96:366–9.
4. Ali MJ, Naik MN. Efficacy of endoscopic guided anterograde 3 mm balloon dacryoplasty with silicone intubation in treatment of acquire partial nasolacrimal duct obstruction in adults. Saudi J Ophthalmol. 2014;28:40–3.
5. Chen D, Ge J, Wang L, Gao Q, et al. A simple and evolutional approach proven to recanalize the nasolacrimal duct obstruction. Br J Ophthalmol. 2009;93:1438–43.
6. Javate R, Pamintuan FG, Cruz RT, et al. Efficacy of endoscopic lacrimal duct recanalization using microendoscope. Ophthal Plast Reconstr Surg. 2010;26:330–3.
7. Feng YF, Yu JG, Shi JL, et al. A meta-analysis of primary external dacryocystorhinostomy with and without mitomycin C. Ophthalmic Epidemiol. 2012;19:364–70.
8. Ali MJ, Mariappan I, Maddileti S, et al. Mitomycin C in dacryocystorhinostomy: the search for the right concentration and duration—a fundamental study on human nasal mucosa fibroblasts. Ophthal Plast Reconstr Surg. 2013;29:469–74.
9. Feng YF, Cai JQ, Zhang JY, et al. A meta-analysis of primary dacryocystorhinostomy with and without silicone intubation. Can J Ophthalmol. 2011;46:521–7.
10. Knop E, Knop N. Lacrimal drainage-associated lymphoid tissue (LDALT): a part of the human mucosal immune system. Invest Ophthalmol Vis Sci. 2001;42:566–74.
11. Ali MJ, Mulay K, Pujari A, et al. Derangements of lacrimal drainage associated lymphoid tissue (LDALT) in human chronic dacryocystitis. Ocul Immunol Inflamm. 2013;21:417–23.
12. Kakizaki H, Takahashi Y, Sa HS, et al. Congenital dacryocystocele: comparative findings of dacryoendoscopy and histopathology in a patient. Ophthal Plast Reconstr Surg. 2012;28:e85–6.
13. Sasaki T, Nagata Y, Sugiyama K. Nasolacrimal duct obstruction classified by dacryoendoscopy and treated with inferior meatal dacryorhinotomy: Part II. Inferior meatal dacryorhinotomy. Am J Ophthalmol. 2005;140:1070–4.
14. Emmerich KH, Steinhauer J, Meyer-Rüsenberg HW, et al. Dacryoendoscopy—current status. Ophthalmologe. 1998;95:820–2.
15. Ali MJ, Mohapatra S, Mulay K, et al. Incomplete punctal canalization: the external and internal punctal membranes. Outcomes of membranotomy and adjunctive procedures. Br J Ophthalmol. 2013;97:92–5.

16. Ali MJ, Naik MN. Canalicular wall dysgenesis: the clinical profile of canalicular hypoplasia and aplasia, associated systemic and lacrimal anomalies and clinical implications. Ophthal Plast Reconstr Surg. 2013;29:464–8.
17. Ali MJ, Motukupally SR, Joshi SD, Naik MN. The microbiological profile of lacrimal abscess: two decades of experience from a tertiary eye care center. J Ophthalmic Inflamm Infect. 2013;3:57–61.
18. Kaliki S, Ali MJ, Honavar SG, et al. Primary canaliculitis: clinical features, microbiological profile and management outcomes. Ophthal Plast Reconstr Surg. 2012;28:355–60.
19. Boase S, Foreman A, Cleland E, et al. The microbiome of chronic rhinosinusitis: culture, molecular diagnostics and biofilm detection. BMC Infect Dis. 2013;13:210–8.
20. Ali MJ, Mishra DK, Baig F, et al. Punctal stenosis: histopathology, immunology and electron microscopic features. A step towards unraveling the mysterious etiopathogenesis. Ophthal Plast Reconstr Surg. 2015;31(2):98–102.
21. Ali MJ, Baig F, Lakshman M, et al. Electron microscopic features of nasal mucosa treated with topical and circumostial injection of mitomycin C (COS-MMC): implications in dacryocystorhinostomy. Ophthal Plast Reconstr Surg. 2015;31(2):103–7.
22. Kakizaki H, Ichinose A, Takahashi Y, et al. Anatomical relationship of Horner's muscle origin and posterior lacrimal crest. Ophthal Plast Reconstr Surg. 2012;28:66–8.
23. Park J, Takahashi Y, Nakano T, et al. The orientation of the lacrimal fossa to the bony nasolacrimal canal: an anatomic study. Ophthal Plast Reconstr Surg. 2012;28(6):463.
24. Zoumalan CI, Joseph JM, Lelli GJ, et al. Evaluation of canalicular entrance into the lacrimal sac: an anatomical study. Ophthal Plast Reconstr Surg. 2011;27:298–303.
25. Tiwari S, Ali MJ, Balla MM, et al. Establishing human lacrimal gland cultures with secretory function. PLoS One. 2012;7:e29458.
26. Ho A, Sachidananda R, Carrie S, et al. Quality of life assessment after non-laser endonasal dacryocystorhinostomy. Clin Otolaryngol. 2006;31:399–403.
27. Smirnov G, Tuomilehto H, Kokki H, et al. Symptom score questionnaire for nasolacrimal duct obstruction in adults – a novel tool to assess the outcomes after endoscopic dacryocystorhinostomy. Rhinology. 2010;48:446–51.
28. Mistry N, Rockley TJ, Reynolds T, et al. Development and validation of a symptom questionnaire for recording outcomes in adult lacrimal surgery. Rhinology. 2011;49:538–45.