SERIES IN COSMETIC AND LASER THERAPY

LASER HAIR REMOVAL

Second Edition

David J Goldberg

informa healthcare

LASER HAIR REMOVAL

Series in Cosmetic and Laser Therapy
Published in association with the *Journal of Cosmetic and Laser Therapy*

Already available

1. David Goldberg
   Fillers in Cosmetic Dermatology, ISBN 9781841845098
2. Philippe Deprez
   Textbook of Chemical Peels, ISBN 9781841844954
3. C William Hanke, Gerhard Sattler, Boris Sommer
   Textbook of Liposuction, ISBN 9781841845326
4. Paul J Carniol, Neil S Sadick
   Clinical Procedures in Laser Skin Rejuvenation, ISBN 9780415414135

Of related interest

1. Robert Baran, Howard I Maibach
   Textbook of Cosmetic Dermatology, ISBN 9781841843117
2. Anthony Benedetto
   Botulinum Toxin in Clinical Dermatology, ISBN 978184214244
3. Jean Carruthers, Alastair Carruthers
   Using Botulinum Toxins Cosmetically, ISBN 9781841842172
4. David Goldberg
   Ablative and Non-Ablative Facial Skin Rejuvenation, ISBN 9781841841755
5. David Goldberg
   Complications in Cutaneous Laser Surgery, ISBN 9781841842455
6. Nicholas J Lowe
   Textbook of Facial Rejuvenation, ISBN 9781841840956
7. Shirley Madhere
   Aesthetic Mesotherapy and Injection Lipolysis in Clinical Practice,
   ISBN 9781841845531
8. Avi Shai, Howard I Maibach, Robert Baran
   Handbook of Cosmetic Skin Care, ISBN 9781841841793
9. Antonella Tosti, Maria De Padova
   Atlas of Mesotherapy in Skin Rejuvenation, ISBN 9780415419949

LASER HAIR REMOVAL

Second Edition

DAVID J GOLDBERG MD JD
Clinical Professor of Dermatology
Mount Sinai School of Medicine
and
Skin Laser and Surgery Specialists of New York
and New Jersey, New York, NY, USA

With contributions from Tom Bialoglow and
Steven Mulholland MD

informa
healthcare

First edition published in the United Kingdom in 2000

Second edition published in the United Kingdom in 2008 by Informa Healthcare, Telephone House, 69-77 Paul Street, London, EC2A 4LQ. Informa Healthcare is a trading division of Informa UK Ltd. Registered Office: 37/41 Mortimer Street, London W1T 3JH. Registered in England and Wales number 1072954

Tel: +44 (0)20 7017 5000
Fax: +44 (0)20 7017 6699
Website: www.informahealthcare.com

A CIP record for this book is available from the British Library.

Library of Congress Cataloging-in-Publication Data

Data available on application

ISBN-10: 0 415 41412 1
ISBN-13: 978 0 415 41412 8

Distributed in North and South America by
Taylor & Francis
6000 Broken Sound Parkway, NW, (Suite 300)
Boca Raton, FL 33487, USA

Within Continental USA
Tel: 1 (800) 272 7737; Fax: 1 (800) 374 3401
Outside Continental USA
Tel: (561) 994 0555; Fax: (561) 361 6018
Email: orders@crcpress.com

Book orders in the rest of the world

Paul Abrahams
Tel: +44 207 017 4036
Email: bookorders@informa.com

Composition by Replika Press Pvt Ltd, India
Printed and bound in India by Replika Press Pvt Ltd

CONTENTS

PREFACE TO THE SECOND EDITION

My major goal in writing the first edition of *Laser Hair Removal* was to provide readers with a comprehensive review of the then available hair removal lasers and light sources. This second edition expands, and brings up to date, current research as it relates to the popular lasers and light sources used for hair removal. However, this book does much more. With increasing experience, all hair removal practitioners have begun to note nuances in their daily practice. This book places a major emphasis on the now recognized subtleties of the laser hair removal practice.

In addition to chapters on laser biology, various utilized laser/light source hair removal wavelengths, complications and marketing (written by Steven Mulholland, MD) – all expanded from the first edition – this book also has chapters on the treatment of ethnic skin, treatment of non-pigmented hair, laser hair removal approaches and the appropriate use of photography for laser hair removal (written by Tim Bialoglow).

The second edition of *Laser Hair Removal* is geared for both the beginner and the expert who wants the latest in this ever growing specialty.

David J Goldberg

ACKNOWLEDGMENTS

The author and publishers would like to thank Tom Bialoglow of Canfield Scientific, Fairfield, New Jersey, who kindly contributed the text and illustrations for Chapter 9, and Steven Mulholland MD, of Toronto, Canada, who kindly contributed Chapter 11.

1 HAIR BIOLOGY

KEY POINTS

(1) Human hairs exhibit various growth cycles
(2) Hair growth cycles can be impacted on by various factors including medications, seasonal changes, and varying hormonal changes
(3) Attempts at correlating treatment intervals with growth cycles have generally failed

ANATOMY AND PHYSIOLOGY

Hair follicles develop embryologically through a complex series of interactions between the epithelial components of the epidermis and the mesenchymal populations within the dermis. They maintain this essential and as yet largely mysterious and intricate relationship throughout life. The hair follicle has traditionally been described in terms of three distinct anatomic units: the infundibulum, the isthmus, and the inferior segment that includes the hair bulb. Unlike the considerable morphologic changes that the inferior aspect of the follicle undergoes during the course of the hair cycle, the upper permanent region, comprised of the infundibulum and the isthmus, maintains relative stability above the level of the insertion of the arrector pili muscle. Located in close proximity and largely enveloped by the hair bulb is the dermal, or follicular, papilla. Although not technically part of the follicle, this distinct dermal component holds great importance in the proper morphogenesis and cycling of the hair follicle.[1]

Located within the follicular bulb is a population of multipotent hair matrix cells, a pool of relatively undifferentiated epithelial cells, which through interaction with the dermal papilla, is responsible for the follicular growth and differentiation.[1–3] The hair matrix contains transit amplifying cells that demonstrate the highest proliferation rate in the entire human body, with a doubling time of 18–24 hours.[1]

These cells give rise to the trichocytes of the hair shaft and its surrounding internal root sheath.[3–5]

During the growing phase (anagen) of the hair cycle, the matrix cells proliferate. When the matrix cells cease to divide, the lower segment of the follicle regresses during the tightly controlled apoptosis-driven process called catagen. When the regression is complete, the follicle enters telogen, or a resting phase. The matrix cells then resume proliferation and produce a new hair bulb, thus reentering anagen and completing the hair cycle (Figure 1.1).[2–5]

The duration of the anagen phase is variable and can last up to 6 years, depending on the site. The relatively constant catagen phase is generally 3 weeks in duration, whereas the telogen phase lasts approximately 3 months. At any given time, the majority of hair follicles (80–90%) are in anagen and the remainder are either in the catagen phase (2%) or the telogen phase (10–15%). However, the duration of the anagen and telogen phases varies considerably from one anatomic site to another (Table 1.1).[1,6,7]

Despite variations in length, growing phases, and type of hair, all human hair growth is cyclical. During anagen, the matrix cells divide, moving superficially in the hair bulb. With this movement, they begin to differentiate into portions of the hair shaft, as well as the encasing inner root sheath. The outer root sheath, interlocked with the inner root sheath by their cuticles, provides further support, its innermost companion layer acting as a slippage plane that guides the growth of the hair towards the surface. At the end of the anagen growing phase, deeper matrix keratinocytes cease

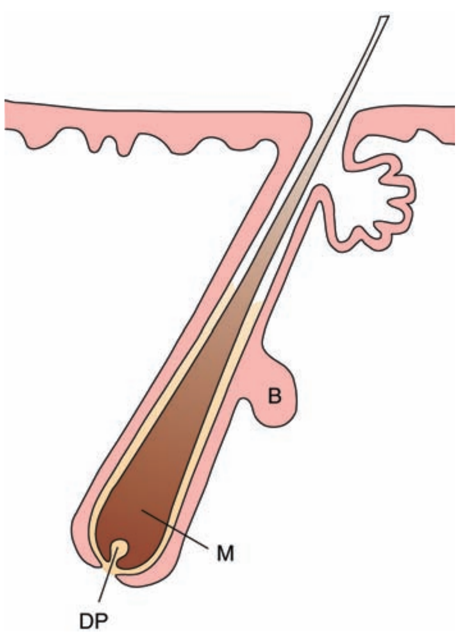

Figure 1.1 Stages of hair growth

Body area	Duration (months) Anagen	Telogen (mo)	% Telogen
Scalp	2–6 y	3–4	10–15
Eyelashes	1–1.5 mo	–	–
Eyebrows	1–2 mo	3–4	85–94
Moustache	2–5 mo	1.5	34
Beard	1 y	2.5	–
Chest	–	2.5	–
Axillae	–	–	31–79
Arms	1–3 mo	2–4	72–86
Thighs	1–2 mo	2–3	64–83
Legs	4–6 mo	3–6	62–88
Pubic hair	–	–	65–81

Table 1.1 Human hair cycles (derived from Olsen[40])

proliferation and undergo terminal differentiation. It is this process that results in the involution of the lower follicle. The melanization of hair ceases just before the conclusion of anagen. At this time, the follicular bulb begins to move upwards within the dermis.[1,2]

The mouse hair follicle shows similarities and differences when compared to the human hair follicle. In the mouse hair follicle, the hair growth cycle is a continuous process, where there are clearly defined growth cycles. The hair cycle has been traditionally divided into 3 stages: anagen, the period of activity; catagen, the period of regression; and telogen, the period of quiescence. Chase further divided the mouse anagen stage into 6 substages (I–VI). The studied mice were born with neither hair nor pigment in their skin. As the hair follicle buds enter anagen (days 1–17 of the cycle), melanin is produced and incorporated into the budding matrix.[8,9]

During the first 3 days of the anagen stage (anagen I–II), in this animal model, no melanin production is apparent and the skin remains pink. At this time, the base of the follicle is characteristically about 250 μm below the skin surface and at a quiescent level. In anagen II (days 3–4 of the cycle), the follicle attains its maximum depth at least 500 μm below the skin surface. The hair usually goes no deeper. Melanocytes appear along the papilla cavity, producing and transferring melanin granules to cells in the matrix, and the skin starts to turn gray. By anagen V (day 8 of the cycle), the tip of the hair has broken through the tip of the internal sheath and has grown to about the level of the epidermis. The activity of melanogenesis reaches a peak on days 8–l2 (anagen V–VI). Now the skin appears black. Thereafter, the skin begins to turn pink as melanogenesis decreases, whereas the depth of the hair follicle remains at its maximum. In both the mouse and human anagen stages, the hair shaft is fully pigmented for its entire length. This would explain the finding that laser thermal damage, by way of melanin absorption, has been noted along the entire length of an anagen follicle.[8,9]

When active growth ends, dramatic changes occur in the hair follicle throughout catagen. Catagen is a relatively brief transitional stage (days 18–19 of the mouse cycle). Melanin production and hair growth cease abruptly. The hair shaft, in the animal model, is entirely depigmented. Since most laser systems employ melanin as the major absorbing chromophore, no selective laser thermal damage along the entire length of catagen or telogen follicles would be expected during these stages. In this period, the lower hair follicle undergoes apoptosis and its base moves gradually upward to the resting position. As the hair follicle moves into telogen (days 20–24 of the cycle), hair growth and melanin production remain completely absent; stem cells remain largely quiescent.[9]

Anagen duration varies greatly depending on age, season, anatomic region, sex, hormonal levels, and certain genetic predispositions. These variations lead to the tremendous disparity in hair cycles reported by various investigators (Table 1.1).[1]

Examples of the variations are as follows:

(1) Scalp hair exhibits a decrease in anagen duration with age; there is also a corresponding prolongation of the interval between loss of the telogen hair and new anagen hair regrowth.
(2) There are seasonal changes in the percentage of anagen human scalp hairs.
(3) Men show a 54-day anagen hair cycle on their thighs; women have only a 22-day cycle.
(4) Male and female anagen scalp cycles are about the same. Although reports of anagen duration, telogen duration, and percentage of hairs in telogen represent an inexact science, it is clear that when one discusses the results following laser hair removal, one must take into account the different anatomic areas in terms of anagen and telogen cycles. Since all laser and light source systems can induce temporary hair removal, only the knowledge of the anagen/telogen cycle for a particular anatomic site will determine if that technology can induce long term changes in the growth of hair.[2–4]

Long term hair removal requires that a laser or light source impact on one or more growth centers within the hair. In order to do so, an appropriate target or chromophore must be identified. The major growth center has long been thought to reside within the hair matrix. However, research evaluating growth of new hair has revealed that the matrix is not the only growth center within the follicle.[3–5]

Although it has generally been assumed that matrix cells, through their interactions with the dermal papilla, play a central role in follicular growth and differentiation, it has been noted that a complete hair follicle can be regenerated after the matrix-containing hair follicle is surgically removed. In addition, the controlling mechanism responsible for the cyclic growth of hair has been enigmatic.[2,6]

Earlier theories on recapitulation of the anagen cycle focused on the necessary preservation of the hair matrix (the putative site of follicular stem cells), and the contiguous dermal papilla. However, we now know from the elegant transection experiments of Oliver on rat vibrissae, that if the dermal papilla and not more than the lower one-third of the follicle are removed, the hair follicle can regenerate. Oliver also found that when lengths of the lower third of the vibrissae follicle wall, but not lengths of the upper two-thirds of the follicle wall, were transplanted into ear skin, whiskers were again produced. From these experiments, it was clearly established that the outer root sheath and the adherent mesenchymal layer from the lower follicle were, in the absence of a matrix and dermal papilla, the essential elements in the regeneration of the hair follicle. Additional studies then addressed the issue of whether it was the outer root sheath cells in the upper third of the follicle that were incapable of supporting whisker growth or of stimulating papilla formation, or whether the mesenchymal cells at this level were incompetent to form a dermal papilla. Oliver evaluated the removal of different lengths of follicle so that less than or equal to half of the upper region of the follicle was left in situ. After the cut whisker shafts were plucked from these follicle remnants, the mouths of the follicular tubes left by the plucked whisker were left open, or isolated dermal papillae were placed there. Fourteen of 19 of the follicular segments with papilla implants produced whiskers versus none of the follicular segments without papilla implants. This confirmed that non-regeneration of papillae and whiskers from the upper two-thirds of the follicle arose from the inability of the mesenchymal layer to form papillae at this level and not from the incompetence of the outer root sheath to become organized for hair production. Another study from Oliver examined hair regeneration from the standpoint of papilla preservation as opposed to full follicle requirement. He found that isolated vibrissae papillae could induce follicle formation from ear epidermis.[10]

A key issue that must be addressed when one considers the homeostasis and differentiation of any self-renewing tissue such as the hair follicle is the location of the stem cells. Where and what these multipotential epithelium-derived cells may be has recently been a subject of great interest. Surprisingly, this location of cells is not in the matrix area of the bulb – the location of known follicular stem cell progeny. Cotsarelis et al. have determined that a group of specialized slow-cycling cells with follicular stem cell properties, including a relatively undifferentiated cytoplasm, is found in a fixed position within the bulge of Wulst, a specialized portion of the outer root sheath located in the lowest portion of the permanent follicular segment at the level of the insertion of the arrector pili muscle (Figure 1.2).[11] In embryonic hair, the bulge is a prominent structure, sometimes even larger than the hair bulb. It remains fairly inconspicuous in routine paraffin sections of adult human and animal follicles.[5] Reynolds et al. have identified a population of germinative epidermal cells in the lower end bulb region of anagen hair follicles in both rats and humans that are distinct from epidermal or outer root sheath cells. The cells remain quiescent in culture unless cultured in association with hair follicle

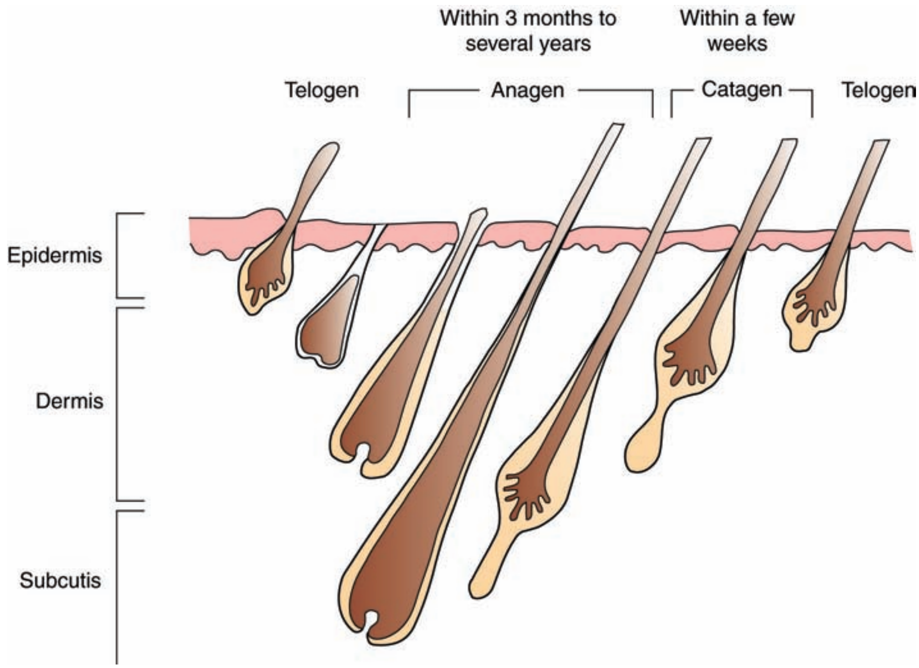

Figure 1.2 Hair follicle with dermal papilla (DP), matrix (M) and bulge (B)

dermal papilla cells. In this situation, they become proliferative, aggregate, and form organotypic structures. At telogen it is not clear whether these germinative cells remain as a permanent population or are replaced, or augmented by outer root sheath cells, perhaps from the bulge region.[12]

Kim and Choi; reported human hair transection experiments, with results similar to those of Oliver. They placed transected human occipital scalp hairs with reimplantation of transected hairs into non-scalp (forehead or leg) skin. Sectioning was done (1) just below the sebaceous gland (upper one-third of the follicle), (2) through the isthmus in the middle of the follicle, or (3) below the level of insertion of the arrector pili muscle bulge region (lower one-third of the follicle). Follicular transplants from the lower two-thirds, lower half, and upper two-thirds of the follicle developed into normal sized hairs. Transplants from the upper one-third and lower one-third of the follicle did not regenerate hair. Follicular transplants from the upper half of the follicle produced fine hairs. They concluded that the mid-follicle or isthmus portion of the follicle is necessary for regeneration of the hair follicle.[13]

Based on stem cell studies of the hemopoietic system and various epithelial systems, we know that stem cells possess the following properties:

(1) They are relatively undifferentiated both ultrastructurally and biochemically.
(2) They have a large proliferative potential and are responsible for the long-term maintenance and regeneration of the tissue.

(3) They are normally slow cycling, presumably to conserve their proliferative potential and to minimize DNA errors that could occur during replication.
(4) They can be stimulated to proliferate in response to wounding and certain growth stimuli.
(5) They are often located in close proximity to a population of rapidly proliferating cells.
(6) They are usually found in a well-protected, highly vascularized and innervated area.[1,5,14,15]

Although evidence clearly suggests several potential growth centers in hair, there are several biological advantages for follicular stem cells to be located in the bulge area instead of the lower bulb. First, unlike the hair bulb, which undergoes cyclic degeneration, cells in the bulge area are in the permanent portion of the hair follicle. Situated at the lower end of the permanent portion, bulge cells are in a strategically convenient position to interact, during late telogen, with the upcoming papilla, and to send out a new follicular downgrowth during early anagen. Second, basal cells of the bulge form an outgrowth pointing away from the hair shaft and are therefore safeguarded against accidental loss due to plucking. The bulb area, conversely, is vulnerable to damage from plucking. Finally, the bulge area is reasonably vascularized so that cells in this area are well nourished.[16,17]

Most authorities, therefore, agree that the pluripotent follicular epithelial stem cells, in fact, reside within the mid-follicular outer root sheath at the insertion of the arrector pili muscle within the bulge of Wulst. This population of pluripotent cells is believed to be the source of stem cells that directly form the outer root sheath, and indirectly the hair matrix, and ultimately the hair shaft.[4,6,7]

Regarding permanent hair removal, the aforementioned data are extremely important. Such data shift the potential target of destruction from only the hair matrix and dermal papilla to other more superficial areas of the hair follicle as well.

Although the histologic changes occurring during the growing anagen, regressing catagen, and resting telogen phases of the hair cycle are rather clear (Figure 1.3), the mechanistic basis underlying the cessation and reactivation of the follicular growth remains obscure. The recognition that hair follicle stem cells may reside in the bulge area would help to explain the critical events during the various phases of the human hair cycle.[2,3]

The precise mechanisms involved in the activation of the follicular bulge stem cells remain largely unknown to this day. However, a significant advance in the study has been achieved by the recently proposed ‘bulge activation hypothesis’, which states that the proximity of the dermal papilla and the bulge region of the late telogen follicle permits the activation of the quiescent bulge stem cells by a dermal papilla-derived diffusible growth factor and/or direct cell–cell contact. Such a sequence is known to occur during a comparable stage in embryonic hair formation. This activation of the normally slow-cycling bulge stem cells triggers proliferation that leads to the generation of the new stem cell progeny — the transient amplifying

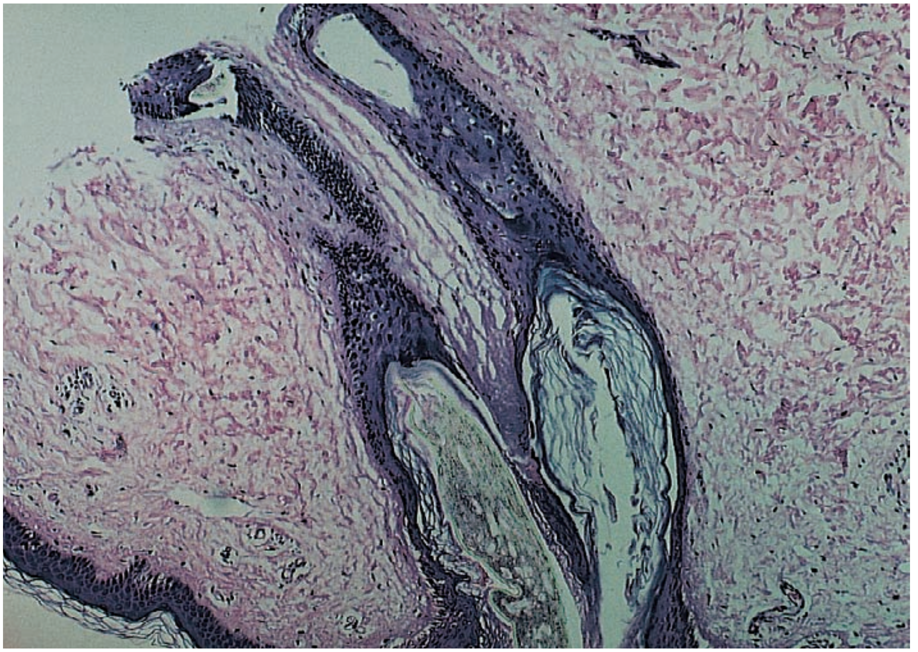

Figure 1.3 Histologic appearance of anagen hair on the left and catagen hair on the right

cells. The follicular downgrowth produced by these cells becomes associated with the dermal papilla, forming a new anagen hair bulb. As the anagen follicle grows, the stem cells within the bulge region become increasingly separated from the stimulatory influences within the dermal papilla, and revert to their previously quiescent state. Unlike their parent stem cells within the bulge, transit amplifying cells have a finite proliferative potential, which, when exhausted, is inevitably followed by terminal differentiation and regression of the lower two-thirds of the follicle that is characteristic of the catagen phase. As the dermal papilla of the catagen follicle migrates superficially, it, once again, approaches the bulge area, renewing the stimulatory influence on the quiescent stem cells in telogen.[5,18–21]

It has been shown that the bulge stem cell progeny has the potential to recapitulate most if not all cell types in the follicle and shaft, as well the sebaceous gland and the interfollicular epidermis, giving rise to the concept of a 'pilosebaceous epithelial unit'. leading some to describe the bulge as housing the 'ultimate epidermal stem cell'.[5,18–20]

Another cell population with high proliferative activity has been described within the telogen follicle that remains distinct from bulge stem cell progeny — the hair germ. Some authors propose that it is this cellular population located in close proximity to the dermal papilla throughout the hair cycle that plays the primary role in the induction of anagen. This supposition is supported by the observation that the hair germ cell population enters a proliferative phase during anagen I, in contrast to the stem cells within the bulge, which begin proliferating only in anagen

II and III. Also, the upregulation of bamacan, an important organizer of mesenchymal–epithelial interaction, has been noted within the hair germ and the dermal papilla during anagen I, supporting the importance of the interaction between these areas in early anagen.[22]

The dermal papilla, too, is known to undergo hair cycle-dependent changes. The volume, histologic appearance, and basement membrane composition of the dermal papilla determine the size of the follicular bulb and the diameter of the hair shaft, as well as the duration of anagen. During most phases of the hair cycle, the dermal papilla appears to be relatively dormant. However, during mid anagen, there is a burst of cell proliferation in the dermal papilla. Some of these replicating papillary cells are endothelial cells engaged in angiogenesis, which occurs in the perifollicular area. Possible consequences of this activation include the formation of new blood vessels that would undoubtedly facilitate rapid hair growth. Although the dermal papilla is clearly critical to growth, it can be replaced by the mesenchymal stem cells from the tissue sheath under follicular epithelial cell influence.[1]

The activation of the hair germ by the dermal papilla in anagen I is believed to be responsible for the induction of proliferation within the bulge. Thus, while the hair germ cell progeny develops into the ascending hair shaft with its surrounding internal root sheath, the bulge stem cells give rise to the descending outer root sheath.[19,22,23]

New evidence suggests that during the late anagen some stem cells from the bulge migrate downward within the basal layer of the outer root sheath, eventually taking residence in the 'lateral disc' at the periphery of the hair bulb, where they remain quiescent next to the proliferating neighboring hair matrix cells.[24] Subsequently, while the hair matrix cells undergo apoptosis during catagen, the apoptosis-resistant lateral disc cells come into direct contact with the dermal papilla and gradually transform into the hair germ as both are carried by the regressing follicle upward towards the bulge.[22–25]

Since almost 100% of matrix cells are involved in continuous replication, some believe that they are likely derived from the putative stem cells residing in the distant bulge area. According to this concept, stem cells can potentially live the entire life of a human being, and are slow cycling. After each stem cell division, on average one of the two (probably identical) daughter cells leaves the stem cell home — the bulge. Such cells ultimately become matrix cells. The matrix cells, by definition, have only a limited proliferative potential. They eventually become exhausted and undergo terminal differentiation — a new hair is born. The length of this now-starting anagen phase is an intrinsic trait of its beginning matrix cell. This may explain why, once started, the length of the growing phase is relatively insensitive to environmental factors. This anagen phase is then followed by catagen. During early catagen, the dermal papilla is condensed and becomes increasingly distant from the regressing matrix. They are still connected, however, by an epithelial sheath. Later, the dermal papilla is pulled upward, presumably through the contractile activities of the outer root sheath cells and/or the connective sheath cells that wrap around the dermal papilla. This upward movement of the dermal papilla apparently plays a critical role in the subsequent activation of cells in the bulge area.[1]

Other authorities, however, advocate the idea that the hair bulb matrix cells are not the direct progeny of the bulge stem cells, but are in fact produced by the hair germ. This hypothesis is supported by the observation that the proliferative capacity of the hair matrix cells is solely dependent on stimulatory factors from the dermal papilla. In contrast, the bulge stem cells do not require this close interaction with a mesenchymal component in cell culture to proliferate, and may respond to a variety of nonspecific factors. Furthermore, the authors maintain that the catagen–telogen interaction between the lateral disc and the dermal papillary fibroblasts endows the developing hair germ cells with high receptivity to the stimuli derived from the dermal papilla during subsequent anagen, predetermining them to form the hair shaft and the outer root sheath.[5,26–29]

Several signaling molecules have been identified as critical to proper follicular cycling. For instance, members of the wingless (WNT) protein family, noggin, signal transducer and activator of transcription factor 3 (STAT3) and the β-catenin pathway all play an important role in the induction of anagen. Sonic hedgehog, hepatocyte growth factor (HGF), fibroblast growth factor 7 (FGF 7), insulin growth factor 1 (IGF1), glial cell-derived neurotrophic factor (GDNF), and vascular endothelial growth factor (VEGF) have anagen-supporting properties. The hairless (Hr) transcription factor is critical for proper anagen–catagen transition. Transforming growth factor β1 (TGF β1), TGF β2, FGF5, neurotrophins NT3 and NT4, brain derived neutrophic factor (BDNF), and p75 all play a role in the induction of catagen. The dermal papilla, on the other hand, avoids the catagen-associated apoptosis due to the presence of anti-apoptotic transcription factor bcl-2.[27–32]

Anecdotal approaches have suggested that the pluripotential cells of the bulge, dermal papilla, and hair matrix must be treated in the anagen cycle for effective hair removal. If the damage is not permanent during this cycle, it has been suggested, follicles will move into the telogen stage as they fall out. Thus, all of the follicles may become synchronized after the first laser treatment. The hair follicle will then return to anagen based on the natural hair cycle. This cycle varies depending on the anatomic location. It is shortest on the face and longer on the body.[33–39]

Thus, whether hairs are in anagen or telogen is not only of academic interest. It has been traditionally thought that it is only anagen hairs that are especially sensitive to a wide variety of destructive processes — including laser and light source damage. It is this assault on the anagen hair that leads to a metabolic disturbance of the mitotically active anagen matrix cells. The response pattern is dependent both on the duration and intensity of the insult. Three patterns of damage have been noted:

(1) Premature anagen termination with subsequent start of telogen.
(2) Transition from a normal to dystrophic anagen.
(3) Acute matrix degeneration.

It should be noted that these changes, although well documented after a variety of physical and chemical insults, have not been well defined after laser treatment.[33–35]

Because of the depth of the hair growth centers, significant laser energies must be applied for effective hair removal. However, not only must each follicle be damaged, but also the surrounding tissue, especially the epidermis, must be protected from damage. This is required to reduce the chances of scarring and permanent pigmentary changes. Melanin, the only endogenous chromophore in the hair follicle of pigmented hair, can be effectively targeted by lasers and light sources throughout the visible light spectrum. Only the longer wavelengths seen with currently available hair removal lasers and light sources are effective in destroying hair because of their greater depth of penetration. Alternatively, an exogenous chromophore, such as carbon, can be applied to the skin. This chromophore will then be irradiated with laser energy of a wavelength that matches its absorption peak. Both of the aforementioned approaches have been shown to remove hair.[33–37]

Hair follicle destruction by a light source may be achieved by 3 main general mechanisms.

(1) The damage may result from direct photothermal destruction, whereby a light source emitting a wavelength in the absorption spectrum of the desired chromophore melanin (600–1100 nm) results in selective heating of the hair shaft, follicular epithelium, and hair matrix. However, the pulse duration theoretically should be equal to or shorter than the thermal relaxation time of the hair follicle (10–100 msec depending on the size) in order to maintain spatial confinement of the thermal damage. A cooling device may be used to limit thermal damage to the epidermis containing competing melanin chromophore, by means of a cooled glass chamber, cooled sapphire window, a cooled gel layer, or a pulsed cryogen spray. Available photothermal destruction methods include the normal-mode 694 nm ruby, normal-mode 755 nm alexandrite, 800–810 nm pulsed diode, long-pulsed Nd:YAG lasers, and filtered flashlamp technology.[33–38]

(2) Photomechanical destruction method relies on the damage induced by the photoacoustic shock waves generated when very short pulsed light source causes rapid heating of the melanin chromophore within the hair follicle, inducing trauma to the surrounding bulbar melanocytes without follicular disruption. Q-switched Nd:YAG laser and carbon suspension Q-switched Nd:YAG laser employ this method.[33–38]

(3) Photochemical destruction results when a photosensitizer is used in conjunction with a light source. In photodynamic therapy, aminolevulinic acid (ALA) becomes rapidly converted to protoporphyrin IX (PPIX) by epithelial cells. A photodynamic reaction occurs when a photon-activated PPIX reacts with molecular oxygen to form singlet oxygen species that result in oxidative cell damage.[34–38]

Central to the light-source hair removal technology is a concept of selective photothermolysis, according to which a thermal destruction of the target specified by a chromophore at a given wavelength is dependent upon the delivery of sufficient energy within a period less than or equal to the thermal relaxation time (TRT). TRT represents the time it takes for the target to transfer the acquired heat to its surroundings. In addition, the thermokinetic selectivity theory maintains that for a given chromophore, a longer pulse duration allows smaller targets (e.g. basal layer epithelium) to cool more rapidly than larger targets (e.g. follicular epithelium), which allows preferential destruction of the hair follicle with relative preservation of the interfollicular epidermis. Preferably, a pulse duration of between thermal relaxation times of epidermis and hair follicle would carry the least risk for surface epithelial damage while achieving a desirable hair removal result.[33,37]

According to the recently proposed concept of thermal damage time (TDT), the preferred pulse duration for medium to coarse hair removal may be longer than the TRT of the hair follicle, allowing for greater thermal diffusion for the relatively small melanin chromophore within a relatively large follicle, in order to achieve sufficient damage on stem cell population within the outer root sheath bulge region.[38]

Based on our current understanding of hair biology, knowledge of the hair cycle and especially the length of telogen, becomes essential for determining whether laser or light source treatment of unwanted hair is ‘temporary’ or ‘permanent’. Currently, there is no agreement on a definition for treatment induced permanent hair loss. Permanence, defined as an absolute lack of hair in a treated area for the lifetime of the patient, may be an unrealistic goal. Dierickx et al. have suggested a more practical approach. They defined ‘permanent’ hair loss as a significant reduction in the number of terminal hairs, after a given treatment, that is stable for a period longer than the complete growth cycle of hair follicles at any given body site. Telogen may last 3–7 months on the thighs and chest. After telogen, the follicle will then recycle into anagen. This will also last 3–7 months. Thus hair may be considered permanently removed from these locations if there is no recurrence after this complete time period. Olsen has suggested an even longer time period. She suggests that permanent hair reduction would be deemed to have occurred after the lapse of 6 months after 1 complete growth cycle. If no hair regrows after this time period, it can be assumed that the growth centers have no capacity to recover from injury.[39,40]

The timing of laser treatment of unwanted hair may be crucial. Selective photothermolysis requires absorption of a chromophore, such as melanin, by light. The hair shaft growth and pigmentation occurs only during anagen. In the lowest regions of the hair bulb, melanocytes of the hair follicle pigmentary unit actively transfer melanin to the dividing matrix cells. Factors involved in the regulation of pigmentation include the melanocortins, α-MSH and ACTH, as well as nerve growth factor, stem cell factor, and the hepatocyte factor.[1]

On the other hand, the bulb of a telogen, or club, hair is unpigmented because of the cessation of melanin production during the catagen stage. In fact, the cessation of melanin production is the first sign of catagen. As anagen progresses, the bulb and papilla descend deeply into the dermis so that late anagen hairs may also be somewhat laser resistant to treatment. It would seem, therefore, that it is in early anagen that hair follicles are most sensitive to laser induced injury. Since any injury, even a laser injury, may induce telogen, the timing of a second laser treatment after the first laser induced telogen formation, becomes critical. As the laser resistant terminal follicles now enter an anagen growth phase, after a first treatment, the second treatment may be more effective than the first. Conversely, a second treatment given too early, or too late, would be expected to have little effect.[39,41]

This time honored theory of optimal anagen treatment times has recently been challenged by Dierickx et al. She evaluated 100 subjects treated with a 3 msec 694 nm ruby laser and 5–20 msec 800 nm diode laser. She noted that 9 months after one treatment with either laser, 50% of the hairs lost were in anagen at the time of treatment, while 45% of the hairs lost were in telogen at the time of the initial treatment. These findings, if confirmed, would suggest that anagen/telogen cycling does not have the significant impact on laser induced response as was previously thought.[39]

It should be noted that there is a general consensus that hair removal results will always be affected by chosen anatomic site. Most investigators note a better response on chest, face, legs, and axilla. Lesser responses appear to occur on the back, upper lip, and scalp. In addition, terminal hairs, and not vellus hairs respond to laser treatment. This has been shown following ruby laser treatment, but presumably applies to other lasers and light sources as well. SACPIC staining is a marker for the growth phases of hair as well as hair shaft damage. When SACPIC staining is undertaken, damage following laser treatment is only seen in terminal hairs. P53 staining is used as a marker of cell death. When such markers are used to evaluate hair death after laser treatment, it is the hair's external root sheath that suffers the initial damage. This damage is associated with a 5–10°C rise in follicular temperature. This has been shown to be enough of a temperature rise to cause protein denaturation, with associated hair destruction.[42]

It is now widely accepted that almost any laser can induce temporary hair loss. Fluences as low as 5 J/cm^2 can induce this effect. The effect tends to last 1–3 months. The mechanism of action appears to be an induction of catagen and telogen. Permanent hair reduction, occurring at higher fluences is seen in 80% of individuals and is fluence dependent. Thus, the greater the delivered fluence, all else being equal, the better are the expected results.[36]

Understanding of hair biology leads to improved results when unwanted hair is treated with a laser. Many individuals seeking laser hair removal are within good health. However, alterations in human biology may also lead individuals to seek laser hair removal. The development of localized or diffuse unwanted excess hair may occur in association with many inherited syndromes, as well as with the use of certain medications (especially androgens), or in the presence of ovarian or adrenal tumors. Excess hair may also be seen as a normal genetic variant (Table 1.2). The

Virilizing disorders	
Tumors	
	Adrenal gland
	Ovary
Congenital adrenal hyperplasia	
Endocrine disorders	
Cushing's disease	
Medications	
Androgens	
Oral contraceptives	
Minoxidil	
Phenytoin	
Penicillamine	
Diazoxide	
Cyclosporine	
Corticosteroids	
Phenothiazines	
Haloperidol	
Syndromes	
Polycystic ovary syndrome (PCOS) (Stein-Leventhal syndrome)	
Malnutrition	
Porphyrias	
Anorexia nervosa	
Hypothyroidism	
Dermatomyositis	

Table 1.2 Causes of hirsutism and hypertrichosis

use of proper terminology is confusing, yet important, in describing excess hair growth. Hypertrichosis is the presence of increased hair in men and women at any body site. Hirsutism is defined as the presence of excess hair in women only at androgen dependent sites. Hirsutism is most commonly seen on the upper chin, chest, inner thighs, back, and abdomen.[43]

However, both hirsutism and hypertrichosis are ultimately believed to occur as a result of disturbances in the hair cycle. In both conditions, prolonged anagen phase is associated with the conversion of vellus to terminal hair.[2]

Hirsutism is caused by diseases of androgen excess or by the intake of certain medications. The most common causes are polycystic ovary syndrome (PCOS) and idiopathic hirsutism. The diseases of androgen excess are usually pituitary/adrenal or ovarian in source. Elevated ACTH levels, which increase the adrenal secretion of cortisol, aldosterone, and androgens, are a rare cause of hirsutism. Adrenal causes of hirsutism include virilizing types of congenital adrenal hyperplasia, and adrenal neoplasms. PCOS (Stein-Leventhal syndrome) is undoubtedly the most common cause of a disease-defined hirsutism. In the United States, 70% of patients who have PCOS have hirsutism. The severity of the androgen effect ranges from mild hirsutism to virilization. Hirsutism may also be caused by androgen-producing ovarian neoplasms. Since insulin stimulates ovarian androgen production, another ovarian cause of hirsutism is insulin resistance with the resultant hyperinsulinism. Idiopathic hirsutism is a diagnosis of exclusion. Total testosterone levels in idiopathic hirsutism may be normal, though free testosterone levels are high. Of note, emotional stress may cause idiopathic hirsutism. Anorexia nervosa and hypothyroidism may cause hypertrichosis. Patients with anorexia nervosa frequently develop fine, dark hair growth on the face, trunk, and arms, which at times is extensive. In hypothyroidism, the hair growth is of the long, fine, soft unpigmented (vellus) type. Although multiple drugs may cause hypertrichosis, the pathophysiology of drug induced hypertrichosis is unknown.[43,44]

All races have similar androgen and estrogen levels, despite the striking differences in amounts of body hair. Whites have more hair than do Blacks, Asians, and Native Americans. The number of hair follicles per unit skin varies among the ethnic groups (Mediterranean>Nordic>Asian). Asians rarely have facial hair or body hair outside the pubic and axillary regions. White women of Mediterranean background have heavier hair growth and a higher incidence of excess facial hair than do those of Nordic ancestry (blond, fair-skinned). Thus, a wide range of normal hair growth exists for men and women, largely based on racial and ethnic predisposition.[44]

EVALUATION OF THE HIRSUTE WOMAN

Although the overwhelming majority of patients seeking laser and light source hair removal are perfectly healthy, or present with idiopathic hirsutism, a clinical history must be undertaken to rule out those serious diseases that cause hirsutism. Historical data that suggest potential serious underlying disease include the onset of hirsutism that is not peripubertal; abrupt onset and/or rapid progression of hair growth; virilization with associated acne, male-pattern baldness, deepening of voice, increased muscle mass, decreased breast size, amenorrhea, clitoromegaly, or increased sexual drive. If such a history is provided, a full medical evaluation is mandatory. A careful drug history is also very important. Simple change in drug regimens may be all that is necessary to reverse unwanted new onset hair growth.

Although the patient's cosmetic feelings about unwanted hair growth must be considered, the physician must always be alert to rule out medical causes of excess hair growth.

Prior to the advent of laser and light source technology, treatment options for hair excess included treatment of associated diseases, suppression or blockade of androgen production and action, and a variety of frustrating and/or protracted cosmetic measures (Table 1.3).

- Treatment of any underlying disease found
- Suppression of androgen overproduction
  - Oral contraceptives
  - Dexamethasone
- Blocking the effect of androgens
  - Anti-androgens
    - Spironolactone
    - Flutaniide
    - Cyproterone acetate
  - α-Reductase inhibitor
    - Finasteride
- Management of insulin resistance
  - Insulin-sensitizing agent
    - Metformin
    - Thiazolidinediones
  - Weight loss
- Hair synthesis inhibitor
    - Ornithine decarboxylase inhibitor
      - Eflornithine
- Cosmetic measures
  - Shaving
  - Bleaching with hydrogen peroxide
  - Chemical depilatories
  - Plucking
  - Waxing
  - Electrolysis

Table 1.3 Management options for patients with hirsutism

REFERENCES

1 Krause K, Foitzik K. Biology of the hair follicle: the basics. Semin Cutan Med Surg 2006; 25: 2–10.
2 Paus R, Foitzikk. In search of the “hair cycle clock”: a guided tour. Differentiation 2004; 72: 489–511.
3 Stenn KS, Paus R. Controls of hair follicle cycling. Physiol Rev 2001; 81: 449–94.
4 Ito M, Kizawa K, Hamada K, Costarelis G. Hair follicle stem cells in the lower bulge form the secondary germ, a biomedically distinct but functionally equivalent progenitor cell population, at the termination of catagen. Differentiation 2004; 72: 548–57.
5 Lavker RM, Sun TT, Oshima H et al. Hair follicle stem cells. J Investig Dermatol Symp Proc 2003; 8: 28–38.
6 Botchkarev VA, Paus R. Molecular biology of hair morphogenesis: development and cycling. J Exp Zoolog B Mol Dev Evol 2003; 298: 164–80.
7 Morris RJ, Liu Y, Marles L et al. Capturing and profiling adult hair follicle stem cells. Nat Biotechnol 2004; 22: 411–17.
8 Dry FW. The coat of the mouse. J Genet 1926; 16: 287–340.
9 Chase HB. Growth of the hair. Physiol Rev 1954; 34: 113–26.
10 Oliver RE. The induction of hair follicle formation in the adult hooded rat by vibrissa dermal papillae. J Embryol Exp Morphol 1970; 23: 219–36.
11 Cotsarelis G, Sun TT, Lavker RM. Label-retaining cells reside in the bulge area of pilosebaceous unit: implications for follicular stem cells, hair cycle and skin carcinogenesis. Cell 1990; 61: 1329–37.
12 Reynolds AJ, Lawrence CM, Jahoda CA. Human hair follicle germinative epidermal cell culture. J Invest Dermatol 1993; 101: 634–8.
13 Kim JC, Choi YC. Regrowth of grafted human scalp hair after removal of the bulb. Dermatol Surg 1995; 21: 312–13.
14 Akiyama M, Smith LT, Shimizu H. Changing patterns of localization of putative stem cells in developing human hair follicles. J Invest Dermatol 2000; 114: 321–7.
15 Fuchs E, Segre JA. Stem cells. A new lease on life. Cell 2000; 100: 143–55.
16 Blanpain C, Lowry WE, Geoghegan A, Polak L, Fuchs E. Self-renewal, multipotency, and the existence of two cell populations within an epithelial stem cell niche. Cell 2004; 118: 635–48.
17 Sun TT, Costarelis G, Lavker RM. Hair follicular stem cells: the bulge-activation hypothesis. J Invest Dermatol 1991; 96: 77S–8.
18 Taylor G, Lehrer MS, Jensen PJ, Sun TT, Lavker RM. Involvement of follicular stem cells in forming not only the follicle but also the epidermis. Cell 2000; 102: 451–61.
19 Lavker RM, Sun TT. Epidermal stem cells. Properties, markers, and location. Proc Natl Acad Sci USA 2000; 97: 13473–5.
20 Oshima H, Rochat A, Kedzia C, Kobayashi K, Barrandon Y. Morphogenesis and renewal of hair follicles from adult multipotent stem cells. Cell 2001; 104: 233–45.
21 Morris RJ, Potten CS. Highly persistent label-retaining cells in the hair follicles of mice and their fate following induction of anagen. J Invest Dermatol 1999; 112: 470–5.
22 Commo S, Gaillard O, Bernard BA. The human hair follicle contains two distinct K19 positive compartments in the outer root sheath: a unifying hypothesis for stem cell reservoir? Differentiation 2000; 66: 157–64.
23 Panteleyev AA, Mitchell PJ, Paus R, Christiano AM. Expression patterns of the transcription factor AP-2alpha during hair follicle morphogenesis and cycling. J Invest Dermatol 2003; 121: 13–19.
24 Panteleyev AA, Paus R, Christiano AM. Patterns of hairless (hr) gene expression in mouse hair follicle morphogenesis and cycling. Am J Pathol 2000; 157: 1071–9.

25 Panteleyev AA, Paus R, Sundberg JP, Christiano AM. The 'second wave' of hair growth in hairless mouse skin: a model to study mechanisms of anagen hair follicle induction. J Invest Dermatol 1999; 112: 631.
26 Hardy MH. The secret life of the hair follicle. Trends Genet 1992: 8: 55–61.
27 Millar SE, Willert K, Salinas PC et al. WNT signaling in the control of hair growth and structure. Dev Biol 1999; 207: 133–49.
28 Botchkarev VA, Botchkareva NV, Peters EM, Paus R. Epithelial growth control by neurotrophins: leads and lessons from the hair follicle. Prog Brain Res 2004; 146: 493–513.
29 Peters EM, Hansen MG, Overall RW et al. Control of human hair growth by neurotrophins: brain-derived neurotrophic factor inhibits hair shaft elongation, induces catagen, and stimulates follicular transforming growth factor β2 expression. J Invest Dermatol 2005; 124: 675–85.
30 Ellis T, Smyth I, Riley E et al. Overexpression of sonic hedgehog suppresses embryonic hair follicle morphogenesis. Dev Biol 2003; 263: 203–15.
31 Hibino T, Nishiyama T. Role of TGF-β2 in the human hair cycle. J Dermatol Sci 2004; 35: 9–18.
32 Oro AE, Higgins K. Hair cycle regulation of hedgehog signal reception. Dev Biol 2003; 255: 238–48.
33 Lepselter J, Elman M. Biological and clinical aspects in laser hair removal. J Dermatolog Treat 2004; 15: 72–83.
34 Warner J, Weiner M, Gutowski KA. Laser hair removal. Clin Obstet Gynecol 2006; 49: 389–400.
35 Wanner M. Laser hair removal. Dermatol Ther 2005; 18: 209–16.
36 Dierickx C. Laser-assisted hair removal: state of the art. Dermatol Ther 2000; 13: 80–9.
37 Ross EV, Ladin Z, Kreindel M, Dierickx C. Theoretical considerations in laser hair removal. Dermatol Clin 1999; 17: 333–55.
38 Rogachefsky AS, Silapunt S, Goldberg DJ. Evaluation of a new super-long-pulsed 810 nm diode laser for the removal of unwanted hair: the concept of thermal damage time. Dermatol Surg 2002; 28: 410–14.
39 Dierickx C, Campos VB, Lin WF, Anderson RR. Influence of hair growth cycle on efficacy of laser hair removal. Lasers Surg Med 1999; 11: 21.
40 Olsen EA. Methods of hair removal. J Am Acad Dermatol 1999; 40: 143–55.
41 Lin TY, Manuskiatti W, Dierickx CC et al. Hair growth cycle affects hair follicle destruction by ruby laser pulses. J Invest Dermatol 1998; 111: 107–13.
42 Topping A. Ruby Laser Hair Destruction, 2nd Annual European Society for Lasers in Aesthetic Surgery, Oxford, England, March 1999.
43 Randall VA, Lanigan S, Hamzavi I, Chamberlain James L. New dimensions in hirsutism. Lasers Med Sci 2006; 21: 126–33.
44 Moghetti P, Toscano V. Treatment of hirsutism and acne in hyperandrogenism. Best Pract Res Clin Endocrinol Metab 2006; 20: 221–34.

2 NORMAL MODE ALEXANDRITE LASER

KEY POINTS

(1) 755 nm visible light-near infrared wavelength
(2) Excellent melanin absorption, albeit somewhat less than the now rarely used ruby lasers
(3) Slightly less risk of post-treatment pigmentary changes as compared to older initial ruby lasers (risk is lessened with significant cooling or when longer pulse durations are utilized)

BACKGROUND

The Q-switched alexandrite laser, used for the treatment of pigmented lesions and tattoos, is a solid state laser, which emits light at 755 nm with pulse durations between 50 and 100 nsec. There are fewer published data about this laser as compared to the Q-switched ruby laser. However, because the wavelength and pulse durations are similar to those of the Q-switched ruby laser, the results are similar. A good response has been seen in the treatment of lentignes and cafe au lait macules. Dermal pigmented lesions, such as nevus of Ota, also respond. The 755 nm wavelength of this laser penetrates deeply enough to affect the growth centers of hair. In fact, the longer the wavelength is, the deeper the penetration. Thus, alexandrite laser wavelengths although not as well absorbed by melanin as compared to the ruby wavelength, do penetrate more deeply into the dermis (Figures 2.1, 2.2). Nevertheless, as with the Q-switched ruby lasers, there are no documented cases of long term hair removal induced by Q-switched alexandrite lasers.

When Q-switched alexandrite lasers are used to treat either pigmented lesions or tattoos, short-term hair removal can be seen. However, the nanosecond pulses of these systems are not long enough to induce the photothermal damage necessary

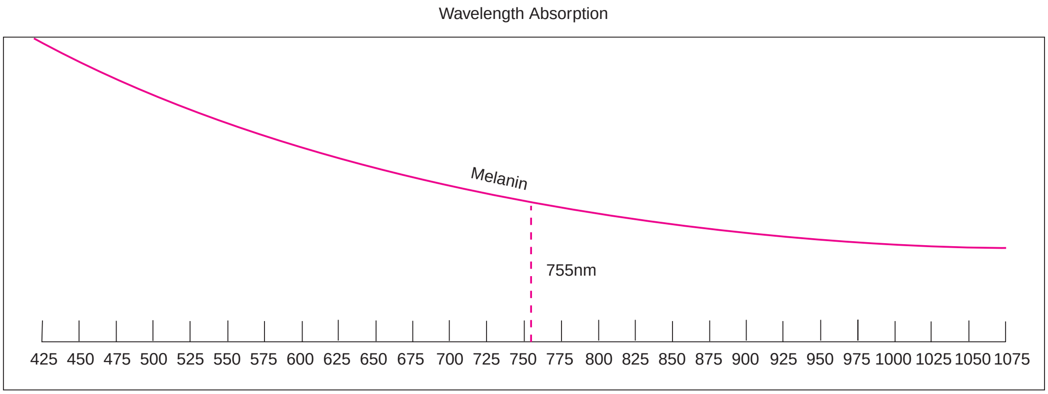

Figure 2.1 Melanin absorption curve of 755 nm alexandrite laser irradiation

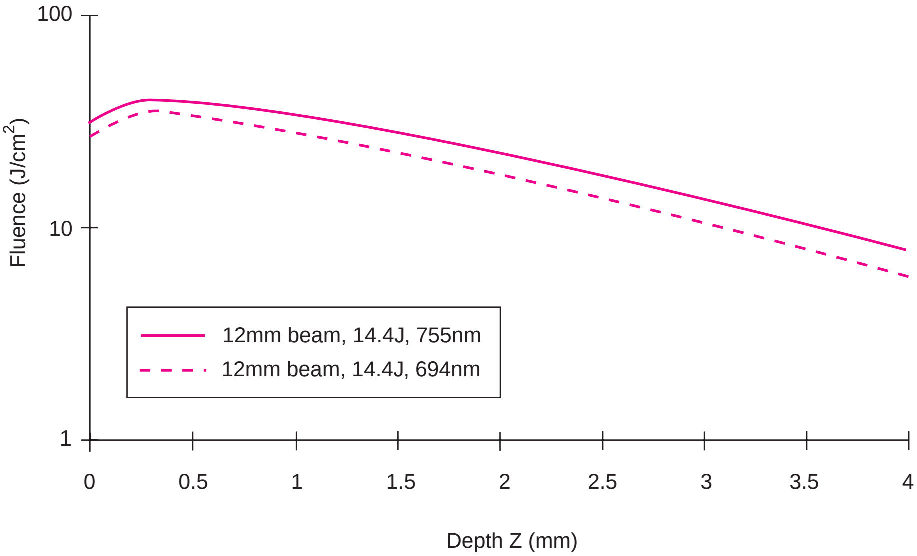

Figure 2.2 Relationship between fluence and dermal penetration depth of alexandrite 755 nm and ruby 694 nm laser irradiation

for effective permanent changes in hair. Normal mode non-Q-switched millisecond pulse duration alexandrite lasers do cause the requisite selective hair follicle damage required to see acceptable results (Figure 2.3).

When the alexandrite laser's longer wavelength is compared to 694 nm ruby laser irradiation, less light is scattered as it passes through the dermis. This, at equivalent fluences, then leads to deeper penetration into the dermis as compared to ruby laser irradiation (Figure 2.2). There may also be less risk of epidermal damage due to the slightly lower epidermal melanin absorption as compared to the ruby wavelength.

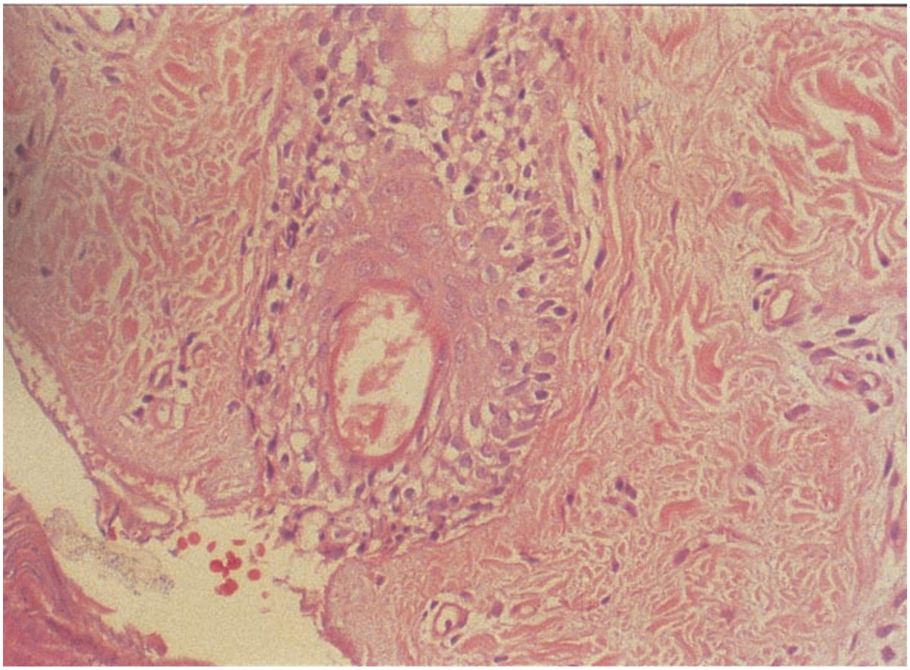

Figure 2.3 Distinct vacuolization of hair follicle immediately after treatment with an alexandrite laser

CLINICAL STUDIES

Finkel et al. were among the first group to evaluate the efficacy of the alexandrite laser in removing unwanted hair. They treated 126 patients (10 men, 116 women) with a 2 msec alexandrite laser. Among the 116 female patients, 77 individuals had facial hair treated (full face – 25; sideburns – 12; upper lip – 15; chin – 25); 15 individuals had bikini and leg hair treated; 4 individuals had axillae hair treated; 10 individuals had areolar hair treated; 10 individuals had abdominal hair treated. The 10 male patients had backs and/or chests treated. The study was undertaken over a 15-month period.[1]

All subjects were treated with a 2 msec alexandrite laser at 20–40 J/cm^2 (average of 25 J/cm^2) with a 7 mm spot size and 5 pulses per second. Cooling of the epidermis was accomplished with a topical cooling gel. The total number of treatments varied between 3 sessions on the sideburns, bikini line, legs and areolar areas of the breast to 5 sessions on the upper lip. Treatment intervals varied between 1 month on the upper lip to $2^1/_2$ months on the sideburn and chin. The interval between treatments was $1^1/_2$–2 months for the bikini region, axillae, men's backs and chests, areolar breast hair, and abdomen. The authors noted light erythema in 10% of treated patients. The erythema lasted up to several days. Superficial burns, and blistering, were noted in 6% of patients. Healing occurred within 10 days. Transient hypopigmentation was noted in 6% of individuals. Hypopigmentation lasted up to 3 months.

The average hair count taken before a second treatment was 65% of the hair as compared with the numbers present at baseline. However, the numbers varied in different anatomic areas. Fifty per cent of the hair was removed from the axillae, periareolar, and sideburn regions; 30% of the hair was removed from the full face, bikini, leg, men's back and chest, and abdomen regions; 20% of the hair was removed from the upper lip and chin regions.

As would be expected, there was progressive improvement with each laser hair removal session. The average amount of hair present 3 months after the final treatment was markedly less than that seen after the first session. An average of only 12% of hair persisted at the final analysis. The results varied from 95% of hairs removed from the sideburns; 90% of hairs removed from the upper lip, bikini, legs, axillae, and periareolar breast area; 85% of the hairs removed from the chin, male backs and chest areas; and 75% of the hairs removed from the abdomen.

The authors found that treatment with this particular 2 msec alexandrite laser was extremely fast because of the 5 pulse per second repetition rate. They also noted that it was important to avoid creating the expectation of permanent hair removal.

It should be emphasized that the complications reported in this study, although minimal, might be lessened with a strict regimen of epidermal cooling prior to treatment. This can, at times, be difficult with topical cooling gels.

Woo et al. treated some 392 patients with a 20 msec alexandrite laser and noted 44–58% hair loss 1 month after 1 treatment session. It is difficult to draw any conclusions from such a short follow-up period except that short-term hair removal is possible with the system utilized in this study.[2]

Of greater interest was a study by Narurkar et al., which evaluated both a 20 msec and 5 msec pulse duration alexandrite laser in skin phenotypes IV–V. All individuals were treated with less than 20 J/cm^2. In this study, better results were obtained with the 20 msec pulse duration. Thus, longer pulse duration laser hair removal systems may be more beneficial in darker complected individuals.[3]

These findings must be contrasted with the observations of Nanni and Alster. They also evaluated the hair removal efficacy of different alexandrite laser pulse durations. They noted that the ideal laser parameters and treatment candidates for photoepilation remain largely unknown. In their study, they examined the hair removal clinical efficacy and side effect profile of a 5, 10, or 20 msec duration pulsed alexandrite laser.[4]

Thirty-six subjects (9 men, 27 women, age range: 18–68 years, average: 31 years) were evaluated. Only terminal hairs were treated. Hair was treated from the upper lip, back, or lower extremities. All subjects had Fitzpatrick skin phototypes I–V. A total of 36 anatomic locations (4 upper lips, 7 backs, and 25 legs) were treated. Hair colors included brown and black in 32 subjects, gray in 4 subjects, and blond in 2 subjects.

All areas to be treated were cooled with a thin film of cooled gel. Fluences of 15–20 J/cm^2 (average of 18 J/cm^2) were delivered. Comparisons were made between the 5, 10 and 20 msec pulse durations. Exposed hair shafts were completely vaporized upon laser impact with evidence only of residual shaft remnants in the follicle. An immediate erythematous skin response was an observed end-point in the laser-irradiated sites.

All laser-treated areas displayed a significant delay in hair regrowth compared to a control area at 1 week, and 1 and 3 months. No significant differences were seen in hair regrowth rates between the use of 5 msec, 10 msec, and 20 msec pulse durations. An average of 66% hair reduction was recorded at the 1 month follow-up, 27% average hair reduction was observed at the 3 month follow-up, and only a 4% hair decrease remained at the 6 month follow-up visit. The authors noted that after the 1 treatment utilized in this study, there was on average no significant reduction in hair growth by the 6 month follow-up. Nevertheless, 3 individual subjects did experience a cosmetically visible reduction in hair density (hair reductions of 11%, 20%, and 18%) during this time period. These subjects were all noted to be Fitzpatrick skin phenotype III with brown hair. All received treatment to their lower extremities.

Complications were limited to immediate post-treatment erythema in 97% of treated sites, minimal intraoperative treatment pain in 85%, transient hyperpigmentation in 3%, and mild blistering in less than 1% (1 case) of treated subjects. Of note, although hyperpigmentation was observed at all pulse durations in certain individuals, it was generally of less severity and resolved more rapidly in the 20 msec pulse duration treated areas. These findings were consistent with those seen by Narurkar et al. Average duration of hyperpigmentation was 6 weeks.

The authors noted that all pulse durations resulted in equivalent hair removal. However, they acknowledged that this result might be due to the small sample size studied. Another plausible explanation is that laser hair removal efficacy is similar using a variety of millisecond pulse durations.

It is theoretically possible that a 20 msec pulse duration alexandrite laser could be less traumatic to epidermal melanosomes than is a shorter pulse duration system. Small cutaneous targets, such as melanosomes, being more severely damaged by shorter laser pulses would explain this. Larger cutaneous structures such as hair follicles, however, sustain greater injury at longer pulse durations. This is due to the longer time required for laser energy to be absorbed by these structures. An enhanced selectivity of the longer 20 msec pulse duration, therefore, might be best observed in study subjects who exhibited very mild post-treatment erythema and hyperpigmentation. What was not determined in this study was whether a slightly shorter pulse duration might be more effective in thinner hair, while a correspondingly longer pulse duration might be more effective in thicker, larger hairs.

It should be noted that higher fluences (up to 40 J/cm^2) are often necessary when the ruby laser is used to achieve long-term hair reduction. Because the alexandrite laser penetrates deeper into the dermis when compared to the ruby laser, such high fluences may not be required. Nevertheless, the fluences used in this study were conservative and may have led to a reduced rate of efficacy. Higher fluences may be required to maximize potential efficacy.

In the study of Nanni and Alster blond and gray hairs did not respond as well to alexandrite laser treatment as did brown or black hairs.[4] This is due to the reduced melanin content of these hair follicles. Whether higher fluences or additional laser sessions would be more successful in treating lighter hair colors has yet to be determined.

Overall, the authors noted that patients with brown hair, skin phenotype III, and lower extremity involvement responded best to treatment. This may suggest that there could be subgroups uniquely susceptible to laser hair removal. The authors also concurred that multiple sessions of treatment are required for optimal results.

Jackson et al. noted somewhat similar findings. They evaluated 8 subjects with Fitzpatrick skin phenotypes III–IV. Subjects with unwanted hair on the legs, beard, bikini, and axilla were treated with a 5 msec and 20 msec alexandrite laser and fluences between 14 and 20 J/cm^2. Both pulse durations led to equal hair removal efficacy. In addition, although there was histologic evidence of epidermal damage with both pulse durations, there was, as would be expected, less than 1 month of postinflammatory hyperpigmentation seen with the longer 20 msec pulse duration.[5]

The same authors then evaluated the effect of a 20 msec versus 40 msec alexandrite laser in similarly complected individuals. Fifteen subjects were treated with fluences varying between 12 and 17 J/cm^2. Although clinical response was similar, there were now greater pigmentary changes noted in the 20 msec group as compared to the 40 msec group. In addition, the authors noted greater pain when the longer pulse duration system was used.

Rogers et al. evaluated alexandrite laser hair removal in 15 subjects. All were Fitzpatrick skin phenotypes I–III; all had blond or brown hair. Only axillae were treated. A 20 msec alexandrite laser was utilized through a cooled gel. The laser was delivered with a 10–20% overlap, with a fluence of 22 J/cm^2. The authors found that 80% of treated individuals had post-laser erythema, which lasted on average 2–3 days; 47% showed perifollicular erythema which lasted on average 90 hours. At 2 months, 55% of the hair was absent. However, at 3 months only 19% of the hair was absent. It should be noted that the findings might have been improved if only darker hairs had been treated (D. Glaser, personal communication). The findings of Rogers et al. are consistent with those of Nanni et al. An identical alexandrite laser was used in both studies. None of the treated subjects in Rogers et al. were noted to have pigmentary changes. Scarring also did not occur.[6]

Touma and Rohrer evaluated a 3 msec alexandrite laser, used in conjunction with –30°C cryogen spray cooling. They evaluated 21 subjects, 12–15 months after 1 treatment with average fluences of 33 J/cm^2. The presumed permanent hair reduction was noted to be 30% at this period. In addition, the authors noted a 29% reduction in hair width of the remaining hairs.[7]

Avram in a somewhat similar study evaluated the same 3 msec alexandrite laser, used in conjunction with –30°C cryogen spray cooling. Using a variety of fluences, he noted a 40–60% hair reduction after 3 treatments performed at 4–8 week intervals. The follow-up intervals and treated anatomic sites varied in different individuals. Of great interest was the finding that 15% of treated individuals showed 80% hair reduction after 3 treatments and 15% of treated individuals showed less than 30% hair reduction after 3 treatments. This suggests that results can vary from individual to individual and from one anatomic region to the next. The findings are also consistent with anecdotal reports suggesting that there are rare individuals who, for unknown reasons, may not respond to laser hair removal.[8]

The study also showed that both hyper- and hypopigmentation were more common in Fitzpatrick skin phenotypes IV–V. However, blisters and transient pigmentary changes were also observed in Fitzpatrick skin phenotype II–III treated individuals with recent suntans. Erythema, although universally present at the time of treatment, lasted between 12 and 48 hours in less than 5% of individuals.

A study at our center compared the effect of pulse duration and multiple treatments on alexandrite laser hair removal efficacy. Fourteen subjects (3 men, 11 women) between the ages of 19 and 51 were studied. Treatment sites included the chin, neck, back, bikini, and lower leg; Fitzpatrick skin phenotypes were I–III. All subjects had black or brown terminal hairs.[9]

An alexandrite laser with a pulse duration of 2 msec, energy fluence of 25 J/cm^2, 7 mm spot size and a repetition rate of 5 pulses per second was compared with an alexandrite laser with a pulse duration of 10 msec, energy fluence of 25 J/cm^2, 7 mm spot size, and a repetition rate of 3 pulses per second. A cooled gel was applied to the skin prior to treatment. Consecutive treatment and evaluations occurred at 2–3 month intervals for a total of 3 treatment visits. Post treatment complications such as erythema, pigmentary changes, and scars were evaluated. The results of 2 msec and 10 msec laser treatments were compared, side by side, for a given anatomical site. Manual terminal hair counts were performed at baseline and compared with similar evaluations at 6 months following the final treatment. The percentage of hair loss was defined as the number of terminal hairs present after treatment compared with the number of terminal hairs present at baseline.

The average percentage of hair reduction was 33.1% for the 2 msec pulse duration and 33.9% for the 10 msec pulse duration alexandrite laser. There was a slightly greater, albeit statistically insignificant, loss of thicker hairs (such as those seen on the back of men) with the 10 msec alexandrite laser. The most common post treatment complication was perifollicular erythema. This developed immediately after treatment and resolved within 24–48 hours. No cutaneous pigmentary changes or scarring were noted 6 months after the final treatment.

This study was unique, in that it was the first to compare 2 different pulse durations after multiple treatments. It should be noted that our results showed a greater degree of improvement than that seen in the studies of both Nanni et al. and Rogers et al. This may be due to more treatment sessions or the slightly higher delivered fluences utilized in our study. We initially expected that the 10 msec alexandrite laser would be more effective because of the greater confinement of thermal damage to the follicle. The purported benefit of this longer pulse duration may be equaled, though, by the greater peak power seen with a 2 msec laser system. Although our study showed an overall reduction of hair counts, there was no significant difference between the different pulse durations. Despite this lack of clinical difference, the 2 msec pulse duration laser may ultimately be the better practical treatment alternative, when all other chosen parameters are equal, because of its faster speed (5 pulses per second versus 3 pulses per second). It should also be noted, though, that an even longer pulsed laser system might be safer in darker skin phenotypes not evaluated in this study.

There were 10 female and 8 male patients, with a mean age of 36 years. All skin types from Fitzpatrick classes I through VI were treated. The body areas treated consisted of the face, ears, neck, back, arms, upper thighs, bikini lines, legs, and breasts. One side of the body was treated with the short-pulse (2 msec) alexandrite laser (Sharplan Epitouch 5100). The other half was treated with a long-pulse (20 msec) alexandrite laser. Both lasers were set at the same fluence for each patient. Patients reported a 60–80% reduction in hair growth at 6 months. Both sides were identical with regard to return of hair growth and complications such as hypopigmentation.

Boss et al. conducted a similar study comparing the efficacy of the long-pulsed and short-pulsed alexandrite laser for hair removal in 18 patients with skin types I–VI. The authors reported similar results with both pulse durations while using a fixed fluence for any given patient, with participants reporting a 60–80% hair reduction at 6 months post-operatively, 13 of whom observed no difference between the 2 pulse durations (remaining 2 patients reported greater efficacy with short pulse and 3 with long pulse). Blistering and hypopigmentation were comparable between the 2 pulse durations.[10]

Lehrer et al. conducted a randomized controlled pilot study to determine the effect of wax epilation prior to long-pulsed alexandrite laser hair removal, demonstrating that the technique had a beneficial effect, with 12 out of 13 patients showing improved short-term reduction (1 month follow-up) in hairiness, compared with pre-operative shaving, in patients with skin types I–III when treating the back.[11]

In comparing the alexandrite laser treatment with electrolysis, Gorgu et al. found the former superior to the latter, with a 74% mean hair reduction measured 6 months following 3 treatments with alexandrite laser, compared to 35% mean reduction after the same period following 4 electrolysis treatments. Furthermore, the participants found the laser treatment less painful than electrolysis.[12]

Recently, in our own center, a large study was conducted involving 144 Asian patients with Fitzpatrick skin types III–V to compare the efficacy of multiple treatment sessions in comparison to a one-time therapy with alexandrite laser, using 40 msec pulse duration, 12.5 mm spot size, and fluences of 16–24 J/cm^2 at each session. Both short-term as well as long-term follow-up (up to 9 months) suggest greater benefit achieved by repeat therapy (44% and 55% overall hair reduction after 2 and 3 treatments, respectively, compared to 32% after a single treatment).[13]

A recent randomized controlled trial by Clayton et al., in which 88 hirsute female patients with polycystic ovary syndrome having skin types I–V participated (13 did not complete the study), comparing high fluence alexandrite laser (treated group: 14–13 J/cm^2; mean 4.8 treatments) with sham treatment (4.8 J/cm^2; mean 4.4 treatments), using 20 msec pulse duration and 12.5 mm spot size, found a significant improvement in the treated group in terms of self-reported facial hair reduction, time spent on hair removal, mean depression and anxiety scores, and psychological quality of life at 1–2 months following completion of treatment.[14]

The effect of spot size on the efficacy of alexandrite laser-assisted hair removal was investigated by Nouri et al. in a study involving 17 patients (6 did not complete the study), using 3 msec pulse duration and 16 J/cm^2 fluence. The authors reported no significant difference between the 18 mm spot size and 12 mm spot size, with 52% and 42% hair reduction, respectively.[15]

A randomized controlled trial by Handrick and Alster, comparing the efficacy of 3 treatments with alexandrite (2 msec pulse, 10 mm spot, 25 J/cm^2) to 3 treatments with diode laser (12.5–25 msec pulse, 9 mm spot, 25–40 J/cm^2) in 20 patients with skin types I–IV, showed comparable mean hair reduction at the 6 month follow-up (54–63%). The pain level reported by the study participants was mild to moderate with alexandrite, compared with moderate to severe with diode laser. There was slightly more hyperpigmentation and blistering associated with diode compared to alexandrite laser. No scarring or atrophy was reported for either laser system.[16]

Another study comparing the alexandrite and diode laser efficacy was undertaken by Eremia et al., showing comparable hair reduction (85% with 3 msec alexandrite and 84% with diode) after 4 treatments with 25–40 J/cm^2 fluences in 15 patients of skin types I–V, measured at 12 month follow-up.[17]

Recently, in our center, a study was conducted to compare the efficacy of 4 laser systems for hair removal: 755 nm alexandrite (18 J/cm^2, 3 msec), intense pulsed light with red and yellow filters (65 and 35 J/cm^2, 100 msec), and 810 nm diode laser (28 J/cm^2, 14 msec). A significant decrease in hair counts (~50%) and hair coverage (~55%) did not statistically differ between the 4 modalities, with a follow-up period of up to 6 months. The remaining hair length and diameter was not affected by any treatment method. It was noted also that the cryogen spray-based alexandrite laser showed the highest pain score, compared with the other contact cooling-based devices.[18]

Finally, McGill et al. conducted another study in 60 female patients with polycystic ovary syndrome to determine the efficacy of hair removal using the alexandrite laser, using 3 msec pulse duration, 15 mm spot size, and fluences of

18–25 J/cm^2 for skin types I–II and 8–14 J/cm^2 for skin type IV. The authors determined that following 6 treatments at 6 weekly intervals a mean hair reduction of 31 ± 38% (mean ± SD) was achieved. The authors postulated that the poorer response to treatment as compared to those reported in the literature for non-selected patients may relate to the possible relative refractoriness of the facial hair to laser hair removal techniques in this population, functionally approximating male-type facial hair growth. The authors also reported that a longer mean hair-free interval (HFI) resulted when the number of treatments increased beyond the original 6, with 31% of patients having a HFI longer than 6 weeks following 12 treatments, compared to 2.6% after 6 treatments. Despite the lower than expected mean hair reduction, 95% of patients were satisfied with treatment.[19]

AVAILABLE ALEXANDRITE LASERS

Company	Wavelength (nm)	Fluence	Pulse duration
Candela			
GentleLASE	755 nm	10–100 J/cm^2	3 ms
GentleMax	755 nm/1064 nm	up to 600 J/cm^2	0.25–300 ms
Cynosure			
Apogee	755 nm	25–50 J	0.5–300 ms
Elite	755 nm/1064 nm	25–100 J/35–300 J	0.5–300 ms/ 0.4–300 ms

Table 2.1 The most popular currently used alexandrite lasers for laser hair removal. It should be noted that the list is not meant to be exclusive

MY APPROACH

I have found the alexandrite lasers to be very useful in treating Fitzpatrick I and III skin phenotypes. Although it has been suggested that alexandrite lasers, with a longer 755 nm wavelength, are safer in treating darker complexions than are ruby lasers, I have not consistently found this to be the case. It would appear that the ability to treat darker complexions is more a factor of longer pulse durations or better cooling. Unless appropriate cooling is utilized, Fitzpatrick skin phenotype IV and even sun-tanned type II complected individuals tend to have postinflammatory pigmentary changes.

Alexandrite laser speed is helped by the availability of scanning devices or large delivered spot sizes. Unlike the bulkiness seen with older ruby laser articulated delivery systems, alexandrite laser irradiation is delivered through lightweight fiberoptic systems.

The treatment technique consists of preoperative shaving of the treatment site. This reduces treatment-induced odor, prevents long pigmented hairs lying on the skin surface from conducting thermal energy to the adjacent epidermis, and promotes transmission of laser energy down the hair follicle. In darkly pigmented or heavily tanned individuals, it may be beneficial to use topical hydroquinones and meticulous sunscreen protection for several weeks prior to treatment in order to reduce inadvertent injury to epidermal pigment. Postinflammatory pigmentary changes are still to be expected in some darker complected individuals.

The alexandrite laser, when used with almost all fluences, can lead to temporary hair loss at all treated areas. However, choosing appropriate anatomic locations, higher fluences, and treating hair multiple times will increase the likelihood of permanent hair reduction (Figures 2.4–2.38).

The ideal treatment parameters must be individualized for each patient, based on clinical experience and professional judgment. The novice may wish to deliver several individual test pulses at an inconspicuous site, with equivalent pigmentation, starting at an energy fluence of 15 J/cm^2 and slowly increase the delivered energy. As a general rule, somewhat lower fluences are required for effective hair removal than is required from the now rarely used ruby lasers. This may be related to the deeper penetration of the 755 nm wavelength. Undesirable epidermal changes such as whitening and blistering are to be avoided.

Prolonged and permanent hair loss may occur following the use of all normal mode alexandrite lasers; however, great variation in treatment results is often seen. Most patients with brown or black hair obtain a 2–6 month growth delay after a single treatment. There is usually only mild discomfort at the time of treatment. Pain may be diminished by the use of topical or injectable anesthetics.

Transient erythema and edema are also occasionally seen and irregular pigmentation of 1–3 months duration has also been described. Scarring and pigmentary changes can be induced by any laser or light source.

Figure 2.4 Chin before alexandrite laser treatment

Figure 2.5 Chin after alexandrite laser treatment

Figure 2.6 Thick terminal hairs on woman's chest. Good candidate for alexandrite laser hair removal

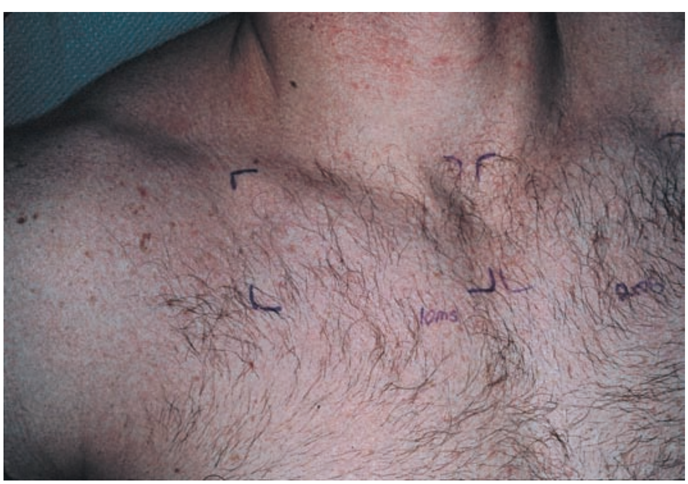

Figure 2.7 Upper chest before treatment with an alexandrite laser

Figure 2.8 Expected erythema immediately after alexandrite laser treatment

Figure 2.9 Beginning of hair regrowth 3 months after 1 alexandrite laser treatment

Figure 2.10 Right cheek before treatment with alexandrite laser

Figure 2.11 Right cheek 4 months after 3 alexandrite laser sessions. Note thinning of some hairs intermixed with areas of minimal regrowth

Figure 2.12 Neck before treatment with alexandrite laser

Figure 2.13 Neck 3 months after first alexandrite laser treatment

Figure 2.14 Left cheek before alexandrite laser treatment

Figure 2.15 Left cheek 5 months after 3 alexandrite laser treatments

Figure 2.16 Right shoulder before alexandrite laser treatment

Figure 2.17 Right shoulder 2 months after 1 alexandrite laser treatment

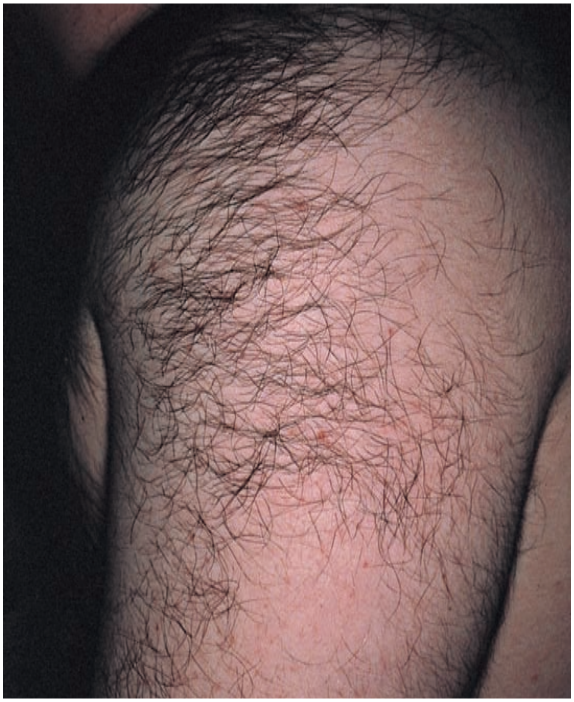

Figure 2.18 Left shoulder before alexandrite laser treatment

Figure 2.19 Left shoulder 1 month after 1 alexandrite laser treatment

Figure 2.20 Left shoulder 4 months after 1 alexandrite laser treatment. Note that almost all hairs have regrown after only 1 session

Figure 2.21 Lip and neck before treatment

Figure 2.22 Lip 6 months after 5 alexandrite laser treatments; neck 6 months after only 2 treatments

Figure 2.23 Back before alexandrite laser treatment

Figure 2.24 Back immediately after alexandrite laser treatment

Figure 2.25 Back 3 months after 1 alexandrite laser treatment

Figure 2.26 Back 4 months after third alexandrite laser treatment. Note some areas on upper back have regrown

Figure 2.27 Upper lip in Fitzpatrick IV complected individual before alexandrite laser treatment

Figure 2.28 Upper lip in Fitzpatrick IV complected individual immediately after alexandrite laser treatment. Treatment undertaken with extensive pre-treatment cryogen cooling. This lessened post-treatment epidermal blistering

Figure 2.29 Upper lip 3 months after 2 alexandrite laser sessions

Figure 2.30 Ideal axilla terminal hairs before alexandrite laser treatment

Figure 2.31 Left bikini before alexandrite laser treatment

Figure 2.32 Left bikini 6 months after 3 alexandrite laser treatments

Figure 2.33 Left bikini before alexandrite laser treatment

Figure 2.34 Left bikini 9 months after 2 alexandrite laser treatments

Figure 2.35 Left leg before alexandrite laser treatment

Figure 2.36 Left leg 2 months after alexandrite laser treatment

Figure 2.37 Right leg before alexandrite laser treatment

Figure 2.38 Right leg 3 months after second alexandrite laser treatment

REFERENCES

1 Finkel B, Eliezri YD, Waldman A, et al. Pulsed alexandrite laser technology for noninvasive hair removal. J Clin Laser Med Surg 1997; 15: 225–9.

2 Woo TY, Molnar G. Laser assisted hair removal using the Cynasure long pulse alexandrite laser. Lasers Surg Med 1998; 22(S10): 39.

3 Narurkar V, Miller HM, Seltzer R. The safety and efficacy of the long pulse alexandrite laser for hair removal in various skin types. Lasers Surg Med 1998; 22(S10): 39.

4 Nanni CA, Alster TS. Long-pulsed alexandrite laser-assisted hair removal at 5, 10, and 20 millisecond pulse durations. Lasers Surg Med 1999; 24: 332–7.

5 Jackson BA, Junkins-Hopkins J. Effect of pulse width variation on hair removal in ethnic skin. American Society for Dermatologic Surgery Meeting. May 1999, Miami Beach, FL.

6 Rogers CJ, Glaser DA, Siegfried EC, Walsh PM. Hair removal using topical suspension-assisted Q-switched Nd:YAG and long-pulsed alexandrite lasers: a comparative study. Dermatol Surg 1999; 25: 844–50.

7 Touma DJ, Rohrer TE. The 3 msec long pulse alexandrite laser for hair removal. American Society for Dermatologic Surgery Meeting. May 1999, Miami Beach, FL.
8 Avram M. Alexandrite laser hair removal. 8th International Symposium on Cosmetic Laser Surgery. March 1999, New Orleans, LA.
9 Goldberg DJ, Akhami R. Evaluation comparing multiple treatments with a 2 msec and 10 msec alexandrite laser for hair removal. Lasers Surg Med 1999; 25: 223–8.
10 Boss WK, Usal H, Thompson RC, Fiorillo MA. A comparison of the long-pulse and short-pulse alexandrite laser hair removal systems. Ann Plast Surg 1999; 42: 381–4.
11 Lehrer MS, Crawford GH, Gelfand JM, Leyden JJ, Vittorio CC. Effect of wax epilation before hair removal with a long-pulsed alexandrite laser: a pilot study. Dermatol Surg 2003; 29: 118–23.
12 Gorgu M, Aslan G, Akoz T, Erdogan B. Comparison of alexandrite laser and electrolysis for hair removal. Dermatol Surg 2000; 26: 37–41.
13 Hussain M, Polnikorn N, Goldberg DJ. Laser-assisted hair removal in Asian skin: efficacy, complications, and the effect of single versus multiple treatments. Dermatol Surg 2003; 29: 249–54.
14 Clayton WJ, Lipton M, Elford J, Rustin M, Sherr L. A randomized controlled trial of laser treatment among hirsute women with polycystic ovary syndrome. Br J Dermatol 2005; 152: 986–92.
15 Nouri K, Chen H, Saghari S, Ricotti CA, Jr. Comparing 18-versus 12 mm spot size in hair removal using a gentlease 755 nm alexandrite laser. Dermatol Surg 2004; 30: 494–7.
16 Handrick C, Alster TS. Comparison of long-pulsed diode and long-pulsed alexandrite lasers for hair removal: a long-term clinical and histologic study. Dermatol Surg 2001; 27: 622–6.
17 Eremia S, Li C, Newman N. Laser hair removal with alexandrite versus diode laser using four treatment sessions: 1-year results. Dermatol Surg 2001; 27: 925–30.
18 Amin SP, Goldberg DJ. Clinical comparison of four hair removal lasers and light sources. J Cosmet Laser Ther 2006; 8: 65–8.
19 McGill DJ, Hutchison E, McKenzie E, McSherry E, Mackay IR. Laser hair removal in women with polycystic ovary syndrome. J Plast Reconstr Aesthet Surg 2007; 60: 426–31.

3 DIODE LASER

KEY POINTS

(1) 800 nm near infrared wavelength
(2) Good melanin absorption, albeit less than that seen with ruby and alexandrite lasers
(3) Slightly less risk of post-treatment pigmentary changes as compared to alexandrite lasers (risk is lessened with significant cooling or when longer pulse durations are utilized)
(4) 800 nm wavelength penetrates deeper into dermis than 755 nm alexandrite lasers
(5) Reasonably transportable smaller laser systems

BACKGROUND

Semiconductor diode lasers are among the most efficient light sources available. Because such lasers tend to be smaller than flashlamp devices, they are well suited for clinical applications. The ruby, alexandrite, Nd:YAG lasers and intense pulsed light sources are all flashlamp-type devices. Thus, diode technology does represent a change from all other currently available hair removal devices. The currently available systems emit 800 nm pulsed light. The 800 nm wavelength is not as well absorbed by melanin as the 694 nm ruby and 755 nm alexandrite wavelengths (Figure 3.1). Conversely, though, the longer 800 nm wavelength penetrates deeper into the hair follicle with a correspondingly greater chance of injuring follicular growth centers.

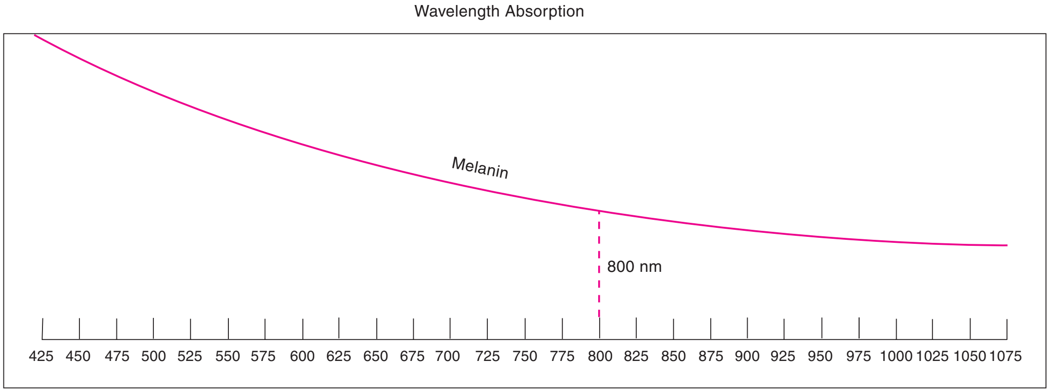

Figure 3.1 Melanin absorption curve of 800 nm diode laser irradiation

CLINICAL STUDIES

Diode lasers emit 800 nm laser light. These systems are among the newest available hair removal lasers. Dierickx, Grossman and others[3] evaluated the effectiveness and safety of a pulsed diode laser in the permanent reduction of unwanted hair. Ninety-five subjects were evaluated. Different hair colors and skin types (Fitzpatrick's skin types II to VI) were treated. The majority had Fitzpatrick II–III skin phenotypes and brown or black hair. Subjects were treated and examined at baseline, 1, 3, 6, 9, and 12 months after treatment. The objective of the study was not only to investigate effectiveness and safety of a pulsed diode laser in the permanent reduction of pigmented hair, but also to study the fluence–response relationship. The authors also evaluated 1 versus 2 treatments, and single versus multiple pulse treatments of the same area.

The device used was a semiconductor diode laser system that delivers pulsed, infrared light at a wavelength of 800 nm, pulse duration from 5 to 20 msec and fluences from 15 to 40 J/cm^2.

In this study, the laser handpiece contained a high-power diode array, eliminating the need for an articulated arm or fiber-optic beam delivery system. Laser energy was delivered over a 9 × 9 mm area. The handpiece contained an actively cooled convex sapphire lens that, when pressed against the subject's skin slightly before and during each laser pulse, provided thermal protection for the epidermis. The cooling lens allowed not only higher doses of laser energy to be safely and effectively delivered, but also permitted compression of the target area, placing hair roots closer to the laser energy. Treatment results demonstrated 2 different effects on hair growth: hair growth delay and permanent hair reduction. A measurable growth delay was seen in all patients (100%) at all fluence/pulse width configurations tested; this growth delay was sustained for 1–3 months.

Significant fluence-dependent, long-term hair reduction occurred at all fluences in 88% of subjects. Clinically obvious long-term hair reduction usually required ≥30 J/cm^2. After two treatments at 40 J/cm^2 with a 20 msec pulse duration, the average permanent hair reduction at the end of the study was 46%. Two treatments significantly increased hair reduction as compared to one treatment, with an apparently additive effect. At a fluence of 40 J/cm^2, the initial treatment removed approximately 30% of terminal hairs, and the second treatment given 1 month later removed an additional 25%. Triple pulsing of the same area did not significantly increase hair reduction over single pulsing, after 1 or 2 treatments. However, the incidence of side effects was higher for triple pulsing.

Of note, hair regrowth stabilized at 6 months at all fluences; there was no further hair re-growth between 6, 9, and 12 months in this study. This stabilizing of hair re-growth or hair count is consistent with the clinically accepted growth cycle of many hair follicles. It is also consistent with the definition of permanent hair reduction, being a significant reduction in the number of terminal hairs after treatment, which is stable for a longer period than the complete growth cycle of follicles at the body site tested.

In addition to statistically significant hair reduction, treatment with the laser also showed reduction in hair diameter and reduction in color of re-growing hairs. Re-growing mean hair diameter decreased by 19.9%. Optical transmission at 700 nm of hair shafts re-grown post-treatment was 1.4 times greater than transmission pre-treatment. Said differently, the hairs remaining after treatment were lighter and thinner.

Histologic analysis suggested 2 mechanisms for effective, permanent reduction of terminal hair: miniaturization of coarse hair follicles to vellus-like hair follicles, and destruction of the follicle with granulomatous degeneration with a fibrotic remnant. Immediately after treatment, hairs show evidence of thermal damage in follicles with large, pigmented shafts. Follicles with small vellus shafts showed no effect. Both pigmented and non-pigmented areas of terminal hair follicle epithelium showed thermal coagulation necrosis, with minimal or no damage to the adjacent dermis. Triple pulsing did not produce more follicular damage than single pulsing, although triple pulsing occasionally injured the dermis between closely spaced follicles. Sebaceous glands near the treated follicles showed no or minimal thermal damage. Sweat glands and dermal capillaries appeared normal.

As would be expected from any visible light, melanin-absorbing system, side effects with pulsed diode laser treatment were fluence and skin type dependent. Hyper- or hypopigmentation was minimal in fair skin, and increased with fluence and with darker skin type. At the highest delivered fluence of 40 J/cm^2, the incidence of hyper- or hypopigmentation was greater for patients with skin types III through VI. In addition, clinical experience has shown that these high fluences may elicit somewhat greater side effects in treatments of areas of high hair density.

The typical response of perifollicular erythema and edema was noted. Approximately 20% of patients exhibited pigment changes which resolved in 1–3 months. The vast majority of pigment changes were transient, but with darker skin types and higher fluences, some persistent pigment changes were noted. Triple pulsing, as mentioned earlier, increased the incidence of hyper- or hypopigmentation as compared to single pulsing, but did not significantly increase hair reduction.

It should be noted that in this study, all subjects with all skin types were treated with both low and high fluences. In clinical practice, fluence and pulse width can be adjusted for skin types. When this is done, the incidence of side effects would be expected to be very small.

Adrian[4] has noted that most patients receive greater than 60% long-term clearance (greater than 6 months) efficacy after 2 or 3 treatments. Post-operative complications were limited to epidermal crusting and temporary hypopigmentation in darker skin type patients. He noted, as would be expected, that fair skin type dark-haired subjects experienced excellent results; however, even skin type V patients could be treated safely with a longer 30 msec pulse duration, effective cooling, and slightly lesser fluences. Although no evidence of persistent pigmentary changes or textural changes were noted, the possibility of such complications from any laser or light source for hair removal must be considered.

In a 2000 study by Lou et al. of 50 patients having primarily skin types II and III treated with an 800 nm diode laser, using 10–40 J/cm^2 fluences, 5–30 msec pulse durations, and 9 mm spot size, followed for an average of 20 months after treatment, the investigators noted a 22–31% hair regrowth after 1 treatment at 1 month follow-up, stabilizing at 65–75% between 3 and 20 months. A longer growth delay and 47–66% hair regrowth beginning to stabilize at 6 months was noted following 2 treatments. The authors noted transient pigmentary alteration as the main side effect of treatment.[5]

The efficacy of the 800 nm diode laser in photoepilation was confirmed in a study by Baugh et al., in which 36 patients with skin types I–IV and brown to black hair received treatment with 24, 38, and 48 J/cm^2 fluences and examined 1 and 3 months following therapy. The investigators noted a fluence-dependent hair reduction that was significantly superior to that obtained by shaving.[6]

In 2000, Campos et al. conducted a study, in which 38 patients were treated with an 800 nm diode laser at 10–40 J/cm^2. The authors noted that 59% of subjects had only sparse growth at 4 month post-treatment follow-up. Furthermore, multiple treatments as well as higher fluences were associated with superior results. In the 7 patients with skin types V–VI treated by using 10–20 J/cm^2 long-pulsed diode laser, 5 experienced transient pigment alteration that resolved after an average of 3.2 months.[7]

In a study of 41 female patients (29 of whom completed the study) with skin types II–IV and brown to black hair, Fiskerstand et al. compared two available diode laser systems, the 810 nm Mediostar using 12 mm spot size, two 45 msec pulses at 35 J/cm^2, and the 800 nm LightSheer using 9 mm spot size, a 30 msec pulse at

35 J/cm^2. Six months after the third treatment to the upper lip, conducted at 6 to 8-week intervals, a 49% average hair reduction was noted with the MedioStar and 48% with LightSheer. The authors noted, however, that more intense erythema and significantly more burned hairs resulted from the LightSheer 800 nm laser.[8]

In 2002, Baumler et al. evaluated the effect of varying spot size for long-pulsed diode laser photoepilation. Twenty patients with skin types I–III were included in the study and received 3 diode laser treatments. At 3 month follow-up, mean hair reduction was 33% for 3 mm spot size, 46% for 12 mm spot size, and 45% for 14 mm spot size.[9]

The effect of treatment interval on the efficacy of photoepilation was investigated by Bouzari et al. A retrospect chart review study of 24 patients demonstrated that the 45-day interval group had significantly higher mean hair reduction of 78.1%, compared with 45.8% in the 60-day group which was also superior to the 28.7% in the 90-day interval groups.[10]

The use of the long-pulsed diode laser in patients with skin types V–VI was evaluated by Greppi, who utilized low 10 J/cm^2 fluence and long 30 msec pulse duration to treat 8 patients. Hair reduction of 75–90% was obtained following 8–10 treatments with only transient pigment alteration.[11]

Another study to evaluate diode laser photoepilation for treatment of pseudofolliculitis barbae (PFB) in patients with skin types V and VI was conducted by Smith and colleagues. The authors report that 10 of the 13 subjects who completed the study experienced improvement following treatment with super long-pulsed (450 msec) 810 nm diode laser at 26–29 J/cm^2 fluences.[12]

Wanner suggested that the risk of pigmentary changes in this group of patients can be reduced by the use of long pulse duration (e.g. 200 msec), low fluences in the first 4–6 months, as well as by sun avoidance and topical hydroquinone treatment from the outset of therapy.[13]

In order to investigate the theory of thermal damage time, a recent study performed at our center utilized super-long-pulsed (200–1000 msec) 810 nm diode laser in 10 female patients with skin types I–VI delivered at fluences of 23–115 J/cm^2. The patients were evaluated 6 months following the first treatment. Optimal hair reduction of 31% was achieved at a thermal diffusion time of 400 msec (at 46 J/cm^2), the pulse duration at which heat diffusion and thermal damage to the follicular stem cells reaches its peak. Highest complication rate was found at 1000 msec pulse duration and 115 J/cm^2 fluence.[14]

A randomized controlled trial by Handrick and Alster, comparing the efficacy of 3 treatments with alexandrite (2 msec pulse, 10 mm spot, 25 J/cm^2) to 3 treatments with diode laser (12.5–25 msec pulse, 9 mm spot, 25–40 J/cm^2) in 20 patients with skin types I–IV, showed comparable mean hair reduction at the 6 month follow-up (54–63%). The pain level reported by the study participants was mild to moderate with alexandrite, compared with moderate to severe with diode laser. There was slightly more hyperpigmentation and blistering associated with diode compared to alexandrite laser. No scarring or atrophy was reported for either laser system.[15]

Another study comparing the alexandrite and diode laser efficacy was undertaken by Eremia et al., showing comparable hair reduction (85% with 3 msec alexandrite and 84% with diode) after 4 treatments with 25–40 J/cm^2 fluences in 15 patients of skin types I–V, measured at 12 month follow-up.[16]

Chan et al. compared the efficacy and complication profile of the diode laser and long-pulsed Nd:YAG following 1 treatment in 15 Chinese patients with skin types IV–V. The authors report an increased pain level associated with therapy in the Nd:YAG laser compared with the diode laser. Nine months following treatment, a substantial and similar regrowth was noted for both laser systems.[17]

Galadari compared the efficacy and side effect frequency for diode, alexandrite, and Nd:YAG lasers in a study of 100 female patients with skin types IV–VI, 32 of whom received diode laser treatment, 33 alexandrite, and 35 Nd:YAG. Twelve months after the last of the 3–6 treatment sessions, the efficacy in hair removal was comparable (35–40%).[18]

A study comparing 3 treatments using the diode, alexandrite, and Nd:YAG laser systems, as well as a rotational method (single session by each of the 3 lasers) for hair removal in 20 female patients with skin type II, 17 of whom had dark-colored hair and 3 red or light-colored hair, was conducted by Rao et al. Three treatments were performed at 6 to 8-week intervals. LightSheer XC 810 nm diode laser with 30 msec pulse duration, 25 J/cm^2 fluence, and 12 mm spot size; Apogee 6200 755 nm alexandrite laser with 10 msec pulse duration, 18 J/cm^2 fluence, and 10–15 mm spot size; and Smartepil II 1064 nm Nd:YAG laser with 20 msec pulse duration, 75 J/cm^2 fluence and 7 mm spot size were utilized for treatment. The greatest hair reduction was achieved by the alexandrite and diode lasers (59.3 ± 9.7% and 58.7 ± 7.7%, respectively; no statistical difference between the two systems), compared with Nd:YAG and rotational methods (31.9 ± 11.1% and 39.8 ± 10.1%, respectively; statistical significance present between the two approaches). The patients with light- or red-colored hair experienced lower efficacy of treatment.[19]

Toosi et al. performed a similar study comparing the efficacy and side effect profile of diode and alexandrite lasers and IPL for laser hair removal. Participating in this study were 232 female patients with skin types II–IV. The investigators used Palomar 810 nm diode laser with a 9 mm^2 sapphire chill tip, using 12.5 msec pulse duration and fluences of 40–64 J/cm^2; a Cynosure 755 nm alexandrite laser with 10 mm spot size using 2 msec pulse duration and 16–20 J/cm^2 fluences; and Medical Bio Care IPL with cut-off filter of 650 nm with double pulse illumination, using 20 msec pulse duration and 22–34 J/cm^2 fluences with 10–40 msec between consecutive pulses. Six months after the last of the 3–7 treatments, no significant statistical difference was observed in the hair reduction between the 3 light sources (68.75 ± 16.92% for alexandrite, 66.96 ± 14.74% for IPL, and 71.71 ± 18.12% for diode), although diode was slightly superior to the other 2 systems. The occurrence of side effects, mainly transient pigment alteration, was significantly higher for the diode laser and lowest with the alexandrite, and rose with increasing Fitzpatrick skin type. The number of treatment sessions corresponded positively with the amount of hair reduction.[20]

Recently, in our center, a study was conducted to compare the efficacy of 4 laser systems for hair removal: 755 nm alexandrite (18 J/cm^2, 3 msec), intense pulsed light with red and yellow filters (65 and 35 J/cm^2, 100 msec), and 810 nm diode laser (28 J/cm^2, 14 msec). A significant decrease in hair counts (~50%) and hair coverage (~55%) did not statistically differ between the 4 modalities, with a follow-up period of up to 6 months. The remaining hair length and diameter, was not affected by any treatment method. It was noted also that the cryogen spray-based alexandrite laser showed the highest pain score, compared with the other contact cooling-based devices.[21]

Lask et al. recently investigated the use of pneumatic skin flattening (PSF) technology in reducing the pain associated with photoepilation by diode and intense pulse light-based systems. The authors showed that 30% higher energies may be utilized while at the same time ameliorating the discomfort and reducing the post-treatment erythema and edema. Hair removal efficacy was preserved or even enhanced by the use of this novel technology.[22]

AVAILABLE DIODE LASERS

Company	Wavelength (nm)	Fluence (Joules)	Pulse duration
Alma Lasers			
Soprano XL	810 nm	up to 120 J/cm^2	10–1350 ms
Lasering			
Velure S800	808 nm	10–600 J/cm^2	10–1000 ms
Lumenis			
LightSheer ET	800 nm	10–1000 J/cm^2	5–400 ms
LightSheer ST	800 nm	10–40 J/cm^2	5–100 ms
LightSheer XC	800 nm	10–100 J/cm^2	5–400 ms
Asclepion			
MeDioStar XT	808 nm	up to 90 J/cm^2	up to 500 ms
Syneron			
eLaser DSL	810 nm	up to 50 J/cm^2	N/A

Table 3.1 The most popular diode lasers currently used for hair removal. It should be noted that the list is not meant to be exclusive

MY APPROACH

I have found the diode laser very useful in treating Fitzpatrick I and IV skin phenotypes (Figures 3.2–3.3). The laser is always to be used with the contact-cooling device. When used with the longer 30–100 msec or longer pulse durations, darker

Figure 3.2 Fitzpatrick Type IV male with chest hair. Ideal candidate for treatment with diode laser

Figure 3.3 Lower abdominal/suprapubic hairs that will respond to diode laser hair removal

Fitzpatrick skin phenotypes can be treated with a lessening of postinflammatory pigmentary changes. Diode systems are small, portable, and very user friendly.

The treatment technique consists of preoperative shaving of the treatment site. This reduces treatment-induced odor, prevents long pigmented hairs lying on the skin surface from conducting thermal energy to the adjacent epidermis, and promotes transmission of laser energy down the hair follicle. In darkly pigmented or heavily tanned individuals, it may be beneficial to use topical hydroquinones and meticulous sunscreen protection for several weeks prior to treatment in order to reduce inadvertent injury to epidermal pigment. Postinflammatory pigmentary changes are still to be expected in some darker complected individuals. Transient perifollicular erythema and edema are also to be expected (Figure 3.4). Such findings are identical to those seen with the ruby and alexandrite lasers.

The diode laser, when used with almost all fluences, can lead to temporary hair loss at all treated areas. However, choosing appropriate anatomic locations, higher fluences, and treating hair multiple times will increase the likelihood of permanent hair reduction (Figures 3.5–3.47).

As a consequence, the ideal treatment parameters must be individualized for each patient, based on clinical experience and professional judgment. The novice may choose to deliver several individual test pulses at an inconspicuous site with equivalent pigmentation starting at an energy fluence of 20 J/cm^2 and slowly

Figure 3.4 Perifollicular erythema seen immediately after diode laser treatment. (Photo courtesy M Grossman, MD)

Figure 3.5 Dark neck hairs before treatment with the diode laser

Figure 3.6 Expected erythema seen immediately after treatment

Figure 3.7 Absence of neck hairs seen 5 months after two treatments with the diode laser

Figure 3.8 Male back hairs before treatment with the diode laser

Figure 3.9 Immediately post-treatment

Figure 3.10 Upper back 4 months after one treatment with the diode laser. Mid back 2 months after one treatment with the diode laser; lower back has yet to be treated

Figure 3.11 Hirsute chin prior to treatment with diode laser

Figure 3.12 Close-up of chin. Note both hairs, presence of folliculitis and post-inflammatory changes second to chronic inflammation

Figure 3.13 Immediately after treatment. Note the desired perifollicular erythema and edema

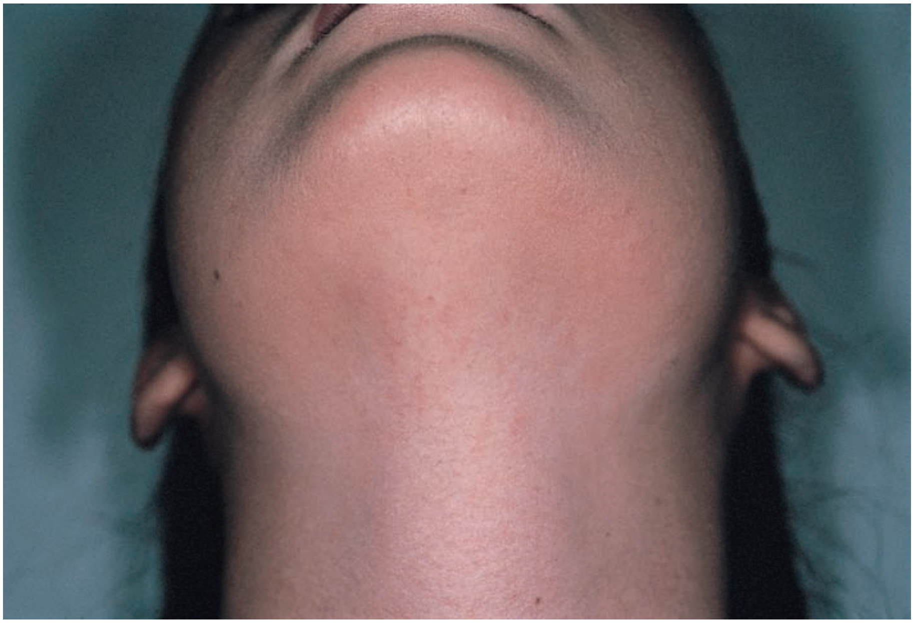

Figure 3.14 Five months after 2nd treatment. Only fine hairs have regrown. Some post-inflammatory hyperpigmentation persists

Figure 3.15 Chin hairs prior to diode laser treatment

Figure 3.16 Mild crusting occasionally noted after treatment. Utilized fluence was too high

Figure 3.17 Three months after laser treatment. Note some improvement

Figure 3.18 Six months after 3 sessions with the diode laser. Almost no hair has recurred

Figure 3.19 Chin hairs prior to treatment with the diode laser

Figure 3.20 Perifollicular erythema and edema noted immediately after treatment

Figure 3.21 Six months after 2 sessions of diode laser treatment. Only several fine hairs have re-grown

Figure 3.22 Fine upper lip hairs before treatment with the diode laser

Figure 3.23 Erythema after laser treatment

Figure 3.24 Three months after 1 session with the diode laser. All hairs have re-grown. More sessions are required

Figure 3.25 Fine upper lip hairs before treatment with the diode laser

Figure 3.26 Mild erythema after laser treatment

Figure 3.27 No regrowth 6 months after 4 diode laser sessions

Figure 3.28 Right cheek hairs and folliculitis in patient with polycystic ovary disease. Treatment with spironolactone orally and 7 sessions of electrolysis had minimal impact on hair growth

Figure 3.29 Marked improvement 5 months after 4 diode laser sessions

Figure 3.30 Cheek hairs and folliculitis prior to diode laser treatment

Figure 3.31 Erythema after laser treatment

Figure 3.32 Mild upper lip hairs prior to diode laser treatment

Figure 3.33 Expected erythema seen immediately after diode laser treatment

Figure 3.34 Bikini hairs prior to treatment with the diode laser

Figure 3.35 Expected perifollicular erythema and edema seen immediately after diode laser treatment

Figure 3.36 Bikini hairs prior to treatment with the diode laser. (Photo courtesy M Grossman, MD)

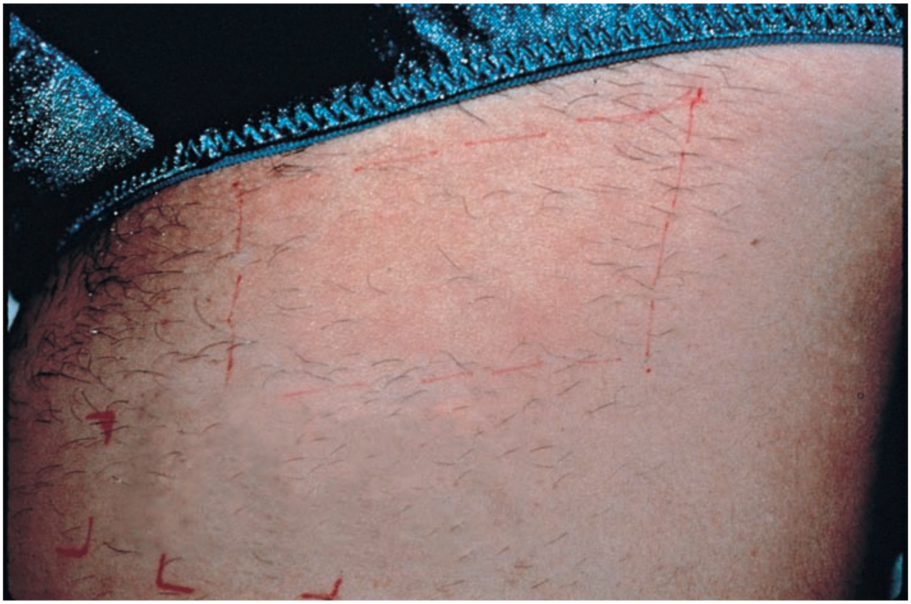

Figure 3.37 Bikini 5 months after 1 session with the diode laser. (Photo courtesy M Grossman, MD)

Figure 3.38 Bikini hairs prior to treatment with the diode laser

Figure 3.39 Expected erythema seen immediately after diode laser treatment

Figure 3.40 Bikini 6 months after 2 sessions with the diode laser. Some hairs have regrown. Hyperpigmentation present before treatment persists

Figure 3.41 Absence of hair regrowth 1 year after diode laser treatment. Hypertrophic scars are biopsy sites. (Photo courtesy M Grossman, MD)

Figure 3.42 Bikini before treatment with diode laser

Figure 3.43 Bikini area 1 year after 7 diode laser sessions

Figure 3.44 Axilla before treatment with diode laser

Figure 3.45 Axilla 6 months after 5 treatments with diode laser

Figure 3.46 Bikini before treatment with diode laser

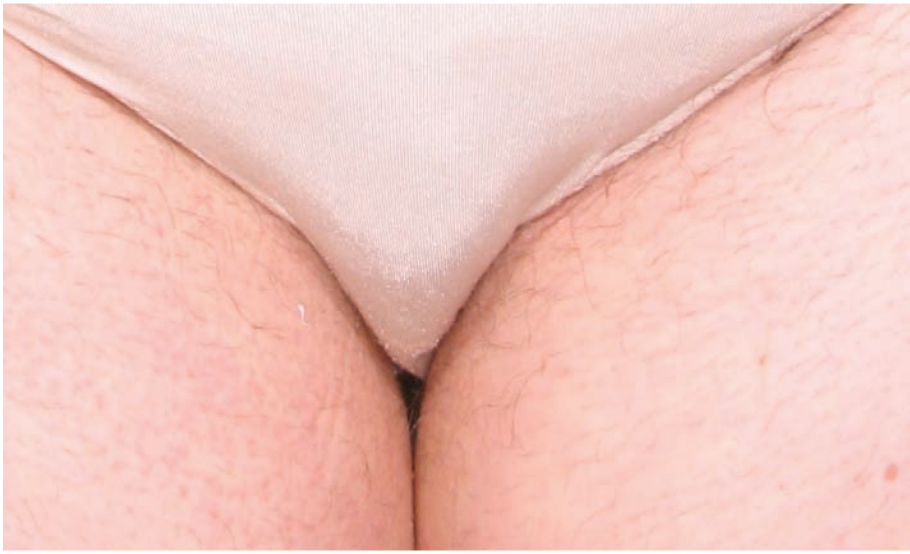

Figure 3.47 Bikini 1 year after 5 diode laser sessions

increasing the energy. As a general rule, somewhat lower fluences are required for effective hair removal than is required from the ruby lasers. This may be related to the deeper penetration of the 800 nm wavelength. Undesirable epidermal changes such as whitening and blistering are to be avoided. Scarring and pigmentary changes can be seen after use of any laser hair removal device.

Prolonged and permanent hair loss may occur following the use of the diode laser. Most patients with brown or black hair obtain a 2 to 6-month growth delay after a single treatment. Long-term hair reduction can be expected with multiple treatment sessions when appropriate fluences are utilized. There is usually only mild discomfort at the time of treatment. Pain may be diminished by the use of topical or injectable anesthetics.

REFERENCES

1 Dierickx CC, Grossman MC, Farinelli WA et al. Hair removal by pulsed infrared laser. Lasers Surg Med 1998; 22(S10): 42–3.
2 Dierickx CC, Grossman MC, Farinelli WA et al. Comparison between a long pulsed ruby laser and a pulsed, infrared laser system for hair removal. Lasers Surg Med 1998; 22(S10): 42–3.
3 Grossman MC, Dierickx CC, Quintana A, Geronemus R, Anderson R. Removal of excess body hair with an 800 nm pulsed diode laser. Lasers Surg Med 1998; 22(S10): 42.
4 Adrian R. Diode laser for hair removal. Coherent Medical (internal data).
5 Lou WW, Quintana AT, Geronemus RG, Grossman MC. Prospective study of hair reduction by diode laser (800 nm) with long-term follow-up. Dermatol Surg 2000; 26: 428–32.
6 Baugh WP, Trafeli JP, Barnette DJ, Ross EV. Hair reduction using a scanning 800 nm diode laser. Dermatol Surg 2001; 27: 358–64.
7 Campos VB, Dierickx CC, Farinelli W, Lin TYD, Manuskiatti W, Anderson RR. Hair removal with an 800-nm pulsed diode laser. J Am Acad Dermatol 2000; 43: 442–7.
8 Fiskerstrand EJ, Svaasand LO, Nelson JS. Hair removal with long pulsed diode lasers: a comparison between two systems with different pulse structures. Lasers Surg Med 2003; 32: 399–404.
9 Baumler W, Scherer K, Abels C et al. The effect of different spot sizes on the efficacy of hair removal using a long-pulsed diode laser. Dermatol Surg 2002; 28: 118–21.
10 Bouzari N, Tabatabai H, Abbasi Z, Firooz A, Dowlati Y. Hair removal using an 800-nm diode laser: comparison at different treatment intervals of 45, 60 and 90 days. Int J Dermatol 2005; 44: 50–3.
11 Greppi I. Diode laser hair removal of the black patient. Lasers Surg Med 2001; 28: 150–5.
12 Smith EP, Winstanley D, Ross EV. Modified superlong pulse 810 nm diode laser in the treatment of pseudofolliculitis barbae in skin types V and VI. Dermatol Surg 2005; 31: 297–301.
13 Wanner M. Laser hair removal. Dermatol Ther 2005; 18: 209–16.
14 Rogachefsky AS, Silapunt S, Goldberg DJ. Evaluation of a new super-long-pulsed 810 nm diode laser for the removal of unwanted hair: the concept of thermal damage time. Dermatol Surg 2002; 28: 410–14.
15 Handrick C, Alster TS. Comparison of long-pulsed diode and long-pulsed alexandrite lasers for hair removal: a long-term clinical and histologic study. Dermatol Surg 2001; 27: 622–6.
16 Eremia S, Li C, Newman N. Laser hair removal with alexandrite versus diode laser using four treatment sessions: 1-year results. Dermatol Surg 2001; 27: 925–30.

17 Chan HH, Ying S-Y, Ho W-S, Wong DSY, Lam L-K. An *in vivo* study comparing the efficacy and complications of diode laser and long-pulsed Nd: YAG laser in hair removal in Chinese patients. Dermatol Surg 2001; 21: 950–4.

18 Galadari I. Comparative evaluation of different hair removal lasers in skin types IV, V and VI. Int J Dermatol 2003; 42: 68–70.

19 Rao J, Goldman MP. Prospective, comparative evaluation of three laser systems used individually and in combination for axillary hair removal. Dermatol Surg 2005; 31: 1671–7.

20 Toosi P, Sadighha A, Sharifian A, Razavi GM. A comparison study of the efficacy and side effects of different light sources in hair removal. Lasers Med Sci 2006; 21: 1–4.

21 Amin SP, Goldberg DJ. Clinical comparison of four hair removal lasers and light sources. J Cosmet Laser Ther 2006; 8: 65–8.

22 Lask G, Friedman D, Elman M, Fournier N, Shavit R, Slatkine M. Pneumatic skin flattening (PSF): a novel technology for marked pain reduction in hair removal with high energy density lasers and IPLs. J Cosmet Laser Ther 2006; 8: 76–81.

4 ND:YAG LASER

KEY POINTS

(1) 1064 nm infrared wavelength
(2) Much less melanin absorption than seen with visible light wavelengths
(3) Significantly less risk of post-inflammatory pigmentary changes than seen with visible light
(4) Deeper penetration into the dermis than seen with visible light wavelengths
(5) Nanosecond pulse duration systems lead to only temporary hair reduction; newer millisecond pulse duration systems may lead to better results

BACKGROUND

The Q-switched Nd:YAG laser emits a 1064 nm wavelength beam with pulse duration of 10 ns. Melanin is not a good absorbing chromophore of 1064 nm wavelength (Figure 4.1). Thus, 1064 nm Q-switched Nd:YAG lasers have never been ideal for the treatment of benign pigmented lesions. Despite less melanin absorption of the 1064 nm wavelength, as compared to ruby, alexandrite, and diode wavelengths, the Nd:YAG laser's advantage lies in its ability to penetrate more deeply in the skin (up to 4–6 mm). The nanosecond Q-switched Nd:YAG laser's effect on hair is one of photomechanical damage. In order to induce a photothermal effect on treated hairs, a millisecond Nd:YAG laser must be used.

In order to cause selective hair damage, an innate and unique property of the follicle must be attacked. Although melanin is the most utilized chromophore, other proteins could theoretically be used. Alternatively, an agent capable of laser absorption may be placed in proximity to the hair. If an appropriate topical chromophore is applied, penetrates around the hair, and is then activated by laser light, heating of this chromophore would in turn heat and damage the surrounding

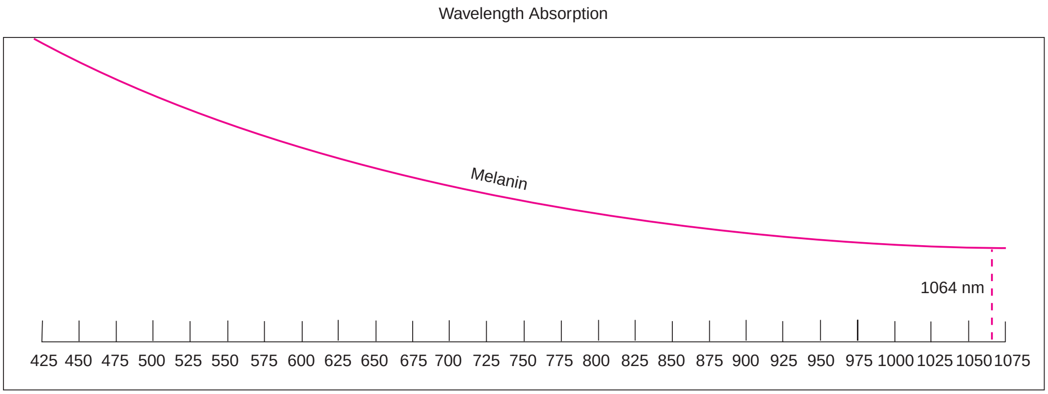

Figure 4.1 Melanin absorption by 1064 nm

Figure 4.2 Carbon particles surrounding hair

follicle. In one of the first available laser hair removal methods, this technique was utilized. In this technique a Q-switched Nd:YAG laser was utilized in conjunction with a topical carbon-based suspension in an attempt to target, damage, and decrease unwanted hair (Figure 4.2).

CLINICAL STUDIES

In one of the first laser hair removal studies 35 subjects (6 men, 29 women), ranging in age from 20 to 74 years, were treated.[1,2] Treatment sites included the upper lip, chin, cheeks, neck, and axilla. The hair was trimmed to a length of 1–2 mm. A topical carbon/mineral oil suspension was then massaged into the treatment sites and allowed to absorb for 5–10 minutes. The excess suspension was then wiped away followed by laser treatment with a 1064 nm Q-switched Nd:YAG laser. Laser energy was delivered with a 7 mm diameter spot, a fluence of 2–3 J/cm^2 and a 10 nsec pulse. Patients were assessed at 4 and 12 weeks.

At week 4, the investigators evaluated 68 sites on the 35 treated subjects. A total of 10% of the sites showed 0–25% reduction in hair; 44% showed 26–50% reduction in hair; 24% showed 51–75% reduction in hair; and 22% showed 76–100% reduction in hair. By 3 months, the degree of hair reduction had decreased. At week 12, evaluation of 55 treated sites showed 27% with 0–25% clearance; 42% with 26–50% clearance; 12% with 51–75% clearance; and 18% with 76–100% clearance.

In evaluating the data in a different manner, the authors noted greater than 25% hair reduction in 90% of subjects at week 4 and greater than 25% hair reduction in 73% of the subjects at week 12.

The only common reaction was erythema, seen immediately following treatment. Erythema resolved in all patients within 4–8 hours. One patient had mild hyperpigmentation, which had completely resolved at week 12. No patients showed any scars or texture changes.

It has been postulated that topical solution-assisted laser hair removal damages hair follicles in the following manner. Nd:YAG laser light is strongly absorbed by carbon (in contrast to other cutaneous chromophores such as melanin). As the topical carbon interacts with 1064 nm laser light, it undergoes a rapid temperature rise. The resulting photomechanical shock waves propel carbon particles in multiple directions. It is assumed that this effect, in some way, causes follicular damage with resultant delayed hair growth.

The authors suggested a potential melanin sparing advantage in using a Nd:YAG laser system. Although the melanin specific lasers are very useful for dark-haired individuals, patients with lighter or white hair respond poorly. The authors assumed that an exogenous chromophore coating these non-pigmented hairs would lead to better results. Furthermore, the longer 1064 nm near infrared wavelength leads to greater depth of follicular penetration with the potential for greater follicular damage. Finally, because of the relative melanin sparing capacity of 1064 nm Nd:YAG laser energy, darker Fitzpatrick skin phenotypes IV–VI might be successfully treated.

It should be noted that the authors used very low fluences in this study when compared to the typical energy densities required with Q-switched Nd:YAG laser tattoo removal. Less energy often translated into less pain. Even though topical carbon suspension assisted laser hair removal is not devoid of discomfort, most patients easily tolerate it. No patient in this study required a topical or local anesthetic. In addition, a lower fluence decreased the risk of adverse events. Permanent pigmentary changes were not seen in this study.

In a follow-up study, the results of a single topical carbon suspension assisted Q-switched Nd:YAG laser treatment was compared to the results seen after 3 treatments.[3] Patients were treated with similar parameters to those used in the first study. Twelve female subjects with unwanted bikini and axillary hair were treated 3 times. The study revealed that cumulative treatments led to better results.

It should be noted that all treated individuals in both the aforementioned studies had 1–2 mm hairs present at the time of treatment. In a variation on the technique utilized in these studies, hair has been also waxed prior to the laser procedure. This was done in an attempt to allow greater carbon access to the deeper follicular structures. There has been no scientific evidence that this technique leads to better results.

In a subsequent study, Nanni and Alster evaluated the effectiveness of topical carbon suspension assisted Q-switched Nd:YAG laser hair removal under varying pre-treatment protocols.[4] Laser-assisted hair removal was performed under 4 different pre-treatment conditions. Eighteen areas of unwanted body and facial hair from 12 study subjects were divided into 4 quadrants. Wax epilation followed by application of a carbon-based solution and exposure to Q-switched Nd:YAG laser radiation was performed on 1 quadrant. A second quadrant was wax epilated and exposed to Q-switched Nd:YAG laser radiation without prior carbon solution application. A third quadrant was exposed to laser radiation alone, and a final quadrant was wax epilated to serve as the control. Follow-up evaluations occurred at 1, 3, and 6 month intervals. The 12 subjects (3 men, 9 women) had a mean age of 32 years. The total of 18 anatomic sites included 6 backs, 3 upper lips, 1 chin, and 8 legs. Treated skin types included Fitzpatrick skin phenotypes I–IV. Only subjects with black or brown terminal hair were included in the study. A 1064 nm Q-switched Nd:YAG laser was used at a fluence of 2.6 J/cm^2, pulse duration of 50 nanoseconds, and a 7 mm spot size.

Follow-up evaluations consisted of manual hair counts and subjective hair-density estimates. The mean percentage of regrowth at 1 month was 39.9% for the wax-carbon-laser quadrants, 46.7% for the wax-laser quadrants, 66.1% for the laser-alone quadrants, and 77.9% for the wax control quadrants. At the 3 month follow-up, all laser-treated quadrants had significantly less hair regrowth than the control quadrant, with a mean regrowth of 79% (1% for the wax-carbon-laser quadrants, 85.2% for the wax-laser quadrants, 86.3% for the laser-alone quadrants, and full regrowth for the wax control quadrants). All hair regrew at all quadrants by 6 months.

Subjective hair density estimates reflected the objective hair count data. It should be noted that several subjects did note changes in their hair quality after laser treatment. The regrown hairs were finer in texture and lighter in color. Such an observation is consistent with laser induced damage to both the growth center and pigment production sites of treated hairs.

The results of this study suggested that after a single Q-switched Nd:YAG laser treatment, a change within the hair follicle is produced that results in a delay in hair regrowth. However, permanent hair reduction, the authors noted, was not achieved. The authors also found that although pre-treatment with wax epilation and topical carbon suspension resulted in significant hair removal, the protocol was not essential. All laser treated sites showed less hair regrowth at 3 months than the wax-epilated control sites. This suggested that the laser energy could be targeted in the follicle without an exogenous carbon chromophore. The authors were unable to determine the optimal pre-treatment protocol. They did suggest that when treating blond or white hair bearing areas, exogenous carbon application might lead to better results.

In a recent study, McDaniel evaluated the use of a 5 nanosecond Q-switched Nd:YAG laser, without the use of an exogenous carbon chromophore, for temporary hair removal (D. McDaniel, personal communication). He found that at 2 J/cm^2, there was little histologic damage to the dermis surrounding the treated hair follicle. In contrast there was obvious histologic damage to the hair shaft and follicular matrix. He noted that although 1064 nm laser irradiation is not as well absorbed by melanin, as are visible light wavelengths, the immediate whitening of treated hairs may reflect hair shaft melanosome destruction. The study suggested that the depilatory effect of a low fluence, nanosecond, photomechanical laser system is one of growth delay. There appeared to be premature telogen induction, rather than true photothermal damage, to the treated hair structure.

Bencini et al. were the first to evaluate hair removal efficacy with a long pulsed millisecond Nd:YAG laser.[5] Such a system theoretically combines the pigmentation safety of a near-infrared laser with the photothermal benefits of millisecond pulsed technology.

Two hundred and eight subjects were treated during an 11 month period. The subjects were divided into 3 groups; Group A consisted of 79 subjects (8 men, 71 women). This group included subjects with normal size and distribution of hairs. Group B contained 67 subjects, all women, with constitutional familial hypertrichosis. Group C contained 62 patients (51 women, 11 transsexuals) with hirsutism. Most of the females in this third group had polycystic ovary syndrome.

Subjects ranged in age from 18 to 56. Treated areas included the face and neck (30%), bikini (27%), lip (22%), abdomen (13%), legs (14%), chin (12%), arms (5%), and axilla (3%). Two hundred and three subjects were Fitzpatrick skin phenotypes II–IV while 5 were Fitzpatrick skin phenotype V. Hair colors were divided as follows: 124 subjects having dark hair, 2 with white hair, 78 with blond hair, and 4 with red hair.

The number of treatment sessions was determined solely by the subject's desire to achieve aesthethic and psychological satisfaction with the results. The goal of treatment was not necessarily to obtain a complete epilation in all subjects. Thus, some subjects were only treated once, others many times.

The laser treatment was performed with a long-pulsed Nd:YAG laser. Laser energy was delivered with 3 or 4 mm spot sizes and fluences between 23 and 56 J/cm^2, depending on hair type. The authors, as a general rule, used lower fluences for darker or finer hairs and higher fluences for lighter or thicker hairs.

The first session resulted in a 20–40% hair loss of the treated area, lasting over 24 weeks. These treatments were considered a success by 21 of the 79 patients with normal hair and normal anatomic distribution in Group A. Results were deemed satisfactory by all 67 patients of the constitutional hypertrichosis Group B. It should be noted that these individuals often sought only improvement and not complete epilation. Group C patients and 58 of the 79 patients of Group A usually desired a greater degree of epilation. Thus, after 4 weeks they had a second treatment with an incremental increase of 20–40% more hair loss. The authors noted a greater degree of improvement at higher fluences (40–56 J/cm^2 compared to 30–40 J/cm^2). Higher fluences, however, also caused more discomfort. This led the subjects often to choose comfort over greater efficacy in their treatments. Surprisingly, the authors noted a good response in blond hair at all utilized fluences. Red hair did not respond as well. White hair, as expected, did not respond to laser treatment. Biopsies from specimens obtained 6 hours after treatment revealed extensive necrosis of the hair follicle and sebaceous gland epithelium. Histologic findings in biopsies taken 3 months after the end of treatment showed complete disappearance of hair follicles with the occasional presence of arrector pili muscle and scattered focal fibrosis.

No patient showed any long term pigmentary changes. This was significant since 5 treated subjects were Fitzpatrick V skin phenotypes. Mild transient erythema was present in all patients after the treatment sessions. This generally regressed within 1–2 hours after treatment. Of note, no blistering was noted at any fluence, even in Fitzpatrick IV–V skin phenotypes.

The authors suggest that long pulsed Nd:YAG treatment produces effective prolonged epilation after several sessions, with no significant side effects. Unfortunately, nowhere in the manuscript do the authors describe the pulse duration of the utilized long pulsed Nd:YAG laser. Of note, the authors do suggest that with the 1064 nm wavelength, other chromophores besides melanin (?hemoglobin) may be absorbing laser energy.

In a recent study millisecond Q-switched Nd:YAG laser treatment was performed on 15 healthy, adult volunteers, ranging in age from 28 to 69 years of age.[6] Subjects were divided into 2 treatment groups: females with facial hair (group I), and females or males with non-facial hair (group II). Treatment sites included periorbital area (4 sites), cheeks (2 sites), sideburns (2 sites), bikini area (10 sites), back (6 sites), chest (3 sites), abdomen (1 site), and arms (1 site). Each patient, except for one, had 2 sites treated, resulting in a total of 29 treated areas. All subjects had Fitzpatrick I–III skin phenotypes with brown or black hair.

Topical anesthetic cream was applied to the treatment sites, if required. The sites were then shaved. Treatment, through a cooling device, was then undertaken using a millisecond 1064 nm Q-switched Nd:YAG laser. Laser energy was delivered through a 2 mm diameter spot size, 30 msec pulse duration and fluence of 125–130 J/cm^2 for facial hair and 150 J/cm^2 for non-facial hair. Post-treatment care consisted only of ice packs, if desired.

Both physician and subject evaluated several parameters immediately following treatment and at follow-up visits. The degree of hair reduction (on a scale of 0–100%) was judged by physician and subject at 1 week, 1 month, and 3 months after treatment. Patients also rated their satisfaction on a 5 point scale (1 = worse; 5 = excellent) at 1 week, 1 month, and 3 months. Adverse effects were monitored at each encounter. At 3 months, investigators determined if treatment was considered a success based on the following criteria: > 30% reduction in hair density, no unanticipated adverse effects, no unresolved symptoms or adverse effects, and satisfaction rating by subject of at least 3 out of 5.

The physician assessment of hair reduction showed an overall 31% reduction at day 7, 52% reduction at day 30, and 59% reduction at day 90. The subject assessment of hair reduction was 23% at day 7, 45% at day 30, and 50% at day 90. The overall satisfaction rating of the subjects on a scale of 1 to 5 showed a mean score of 2.6 on day 7, 3.2 on day 30, and 3.3 on day 90. In all of these assessments, the perceived reduction of facial hair was greater than that of non-facial hair, although the differences were not found to be statistically significant. No complications or adverse effects were reported at any of the follow-up examinations.

In a somewhat similar study, a millisecond Nd:YAG laser was evaluated using 15–30 msec pulse durations and fluences of 50–60 J/cm^2 (S. Kilmer, personal communication). Twenty-five subjects with 100 treatment sites were evaluated. Skin phenotypes I–V were evaluated; anatomic sites included the face, arms, legs, axilla, bikini, and back. Response was assessed 3 months after a single treatment. The median hair count reduction 3 months after a single treatment was 32% for treatment parameters of 60 J/cm^2 and 30 msec; 24% for the treatment parameters of 50 J/cm^2 and 15 msec. The epidermal response 1 day following treatment included erythema, edema, and infrequent blistering. At the 3 month follow-up visit, minimal hyperpigmentation was noted in only 5 of 100 treated sites. No hypopigmentation was noted.

Whether multiple session millisecond Nd:YAG laser treatment leads to long-term better results when compared to nanosecond Q-switched Nd:YAG laser treatment has yet to be determined.

In a 2003 study, Goh investigated the efficacy, as well as the role of wavelength selection, of long pulse Nd:YAG and intense pulse light, in photoepilation. The study involved 11 female patients with skin types IV to VI and black hair. Face, axilla, and legs were treated. A 1064 nm Nd:YAG laser with fluences of 35–42 J/cm^2, 20–25 msec pulse duration, and 10 mm spot size was used. This was compared with a 600–950 nm intense pulse light (IPL) with fluences of 12–14 J/cm^2, and pulse durations of 5–40 msec. Six weeks following treatment, hair removal efficacy was noted to be comparable between the 2 light source systems, with 73% of Nd:YAG-treated patients and 64% of IPL-treated patients reporting up to 20% reduction in hairiness. Post-inflammatory hyperpigmentation was noted in 45% of IPL-treated patients, compared to none in the Nd:YAG-treated group.[7]

In a study involving 12 patients with skin types I–IV and brown to black hair on the upper lip, chin, back, and legs, Nanni and Alster compared a single treatment of waxing with a single treatment of (1) waxing and Q-switched Nd:YAG; (2) waxing, topical application of carbon-based solution, and Q-switched Nd:YAG; and (3) Q-switched Nd:YAG alone. The study utilized1064 nm Q-switched Nd:YAG laser at 2.6 J/cm^2, 50 ns pulse duration, and 7 mm spot size. The patients were evaluated at 1, 3, and 6 months post-operatively. At 3 months postop, an overall 2–21% hair reduction was achieved, with the Q-switched Nd:YAG-treated group showing superior results to waxing alone (mean regrowth 66 and 86%, respectively, at 1 and 3 months for laser treatment, and 78 and 102% for waxing). Furthermore, preoperative waxing improved efficacy of laser treatment at 1 month (47% regrowth), but not at 3 months (85% regrowth). Six months postop, full hair regrowth was noted.[8]

Rogers et al. compared the efficacy of a 20 msec long-pulsed alexandrite laser with a fluence of 22 J/cm^2 to Q-switched Nd:YAG with topical carbon suspension in a study of 15 patients with skin types I–III with blond-brown hair. At 3 month follow-up, 19% hair reduction was achieved using the alexandrite laser, compared with 27% with the Nd:YAG laser. Two months following treatment, hair regrowth rate of 55% was observed for alexandrite and 73% for the Nd:YAG lasers. Three months postop, a hair reduction rate of 19% was noted for the alexandrite laser treated patients, compared with 27% for the Nd:YAG group.[9]

The efficacy of Nd:YAG laser was evaluated by Lorenz et al. The study involved 29 patients with skin types I–IV and blond to brown to black hair. One to 5 treatments were used. At 1 month follow-up, a greater than 50% hair reduction was observed in 44.9% of treated areas. With 5 treatments, hair reduction of 71.5% was noted. At 12–16 months follow-up, 1 treatment resulted in 100% of patients having less than 25% hair reduction. However, after 5 treatments, 40% of patients maintained greater than 50% hair reduction.[10]

Recently in our own center, the efficacy of a contact cooled long-pulsed 50 msec Nd:YAG laser was studied at fluences of 50, 80, and 100 J/cm^2. Fifteen patients were included in the study, having skin types II–IV and brown-black hair. Axilla and bikini regions were treated. Three months postop, the mean hair reduction rate was comparable: 29% at 50 J/cm^2, 29% at 80 J/cm^2, and 27% at 100 J/cm^2 fluence. The rate of side effects, mainly blistering was, however, proportional to the energy level. No pigmentary changes or scarring were observed.[11]

Fournier et al. utilized a 3.5 msec pulsed Nd:YAG laser at 25–80 J/cm^2 fluences for photoepilation in 14 patients with skin types I–IV. Hair reduction was

60% at 1 month follow-up and 24% at 3 months. No adverse reactions were observed.[12]

Chan et al. compared the efficacy and complication profile of the diode laser and long-pulsed Nd:YAG following 1 treatment in 15 Chinese patients with skin types IV–V. The authors reported an increased pain level associated with therapy in the Nd:YAG laser compared with the diode laser. Nine months following treatment, a substantial and similar regrowth was noted for both laser systems.[13]

Galadari compared the efficacy and side effect frequency for diode, alexandrite, and Nd:YAG lasers in a study of 100 female patients with skin types IV–VI, 32 of whom received diode laser treatment, 33 alexandrite, and 35 Nd:YAG. Twelve months after the last of the 3–6 treatment sessions, the efficacy in hair removal was comparable (35–40%).[14]

A study comparing 3 treatments using the diode, alexandrite, and Nd:YAG laser systems, as well as a rotational method (single session by each of the 3 lasers) for hair removal in 20 female patients with skin type II, 17 of whom had dark-colored hair and 3 red or light-colored hair, was conducted by Rao et al. Three treatments were performed at 6–8 week intervals. LightSheer XC 810 nm diode laser with 30 msec pulse duration, 25 J/cm^2 fluence, and 12 mm spot size; Apogee 6200 755 nm alexandrite laser with 10 msec pulse duration, 18 J/cm^2 fluence, and 10–15 mm spot size; and Smartepil II 1064 nm Nd:YAG laser with 20 msec pulse duration, 75 J/cm^2 fluence and 7 mm spot size were utilized for treatment. The greatest hair reduction was achieved by the alexandrite and diode lasers (59.3 ± 9.7% and 58.7 ± 7.7%, respectively; no statistical difference between the 2 systems), compared with Nd:YAG and rotational methods (31.9 ± 11.1% and 39.8 ± 10.1%, respectively; statistical significance present between the 2 approaches). The patients with light- or red-colored hair experienced lower efficacy of treatment.[15]

In a study of 29 patients, Levy and colleagues evaluated the efficacy of the 1064 nm Nd:YAG laser at 56–70 J/cm^2 and 4 msec pulse duration. The authors noted an average hair count reduction of 43% at 3 months, 36% at 6 months, and 46% at 9 months. The hair-free interval was 2–6-fold longer with laser treatment compared to self-applied methods.[16]

Recently, Tanzi and Alster evaluated the use of long-pulsed 1064 nm Nd:YAG laser in 36 patients with skin types I–VI at 30–60 J/cm^2 and 10 mm spot size. Ten, 20, and 30 msec pulse durations were studied. One month postop, 58–62% mean hair reduction was achieved on the face, and 66–69% on non-facial sites. Six months after treatment, the mean hair reduction was 41–46% on the face, and 48–53% on non-facial sites. The side effects noted by the authors included mild to moderate treatment pain, and transient erythema, as well as rare and transient pigmentary alteration with no scarring.[17]

In a recent review of the use of Nd:YAG laser for photoepilation in their center, Ferraro et al. noted an average regrowth rate of 40–65% at 36 months follow-up in 480 patients with red, brown, black, and blond hair. The authors utilized 1064 nm Q-switched Nd:YAG laser with fluences of 40–70 J/cm^2, pulse length of 4 msec, and spot size of 4–6 mm. The authors noted as side effects erythema, small blisters (11%), and hypo- (4%) or hyperpigmentation (2%).[18]

In a 2004 study by Raff et al., the authors utilized the 1064 nm long-pulsed Nd:YAG laser for photoepilation in 42 patients using 4 different treatment parameters. Superior results were obtained using the Lyra XP laser at 40 J/cm^2 fluence, 50 msec pulse duration, and 10 mm spot size (77% hair reduction at 1 month postop, 37% at 3 months, 55% at 6 months, and 49% at 12 months). The efficacy of the Smartepil II system (40–75 J/cm^2, 10–20 msec, 5–7 mm) produced 30–35% hair reduction at 12 months follow-up.[19]

AVAILABLE ND:YAG LASERS

Company	Wavelength (nm)	Fluence	Pulse duration
Cooltouch			
VARIA	1064 nm	500 J/cm^2	300 ms continuous
Cutera			
CoolGlide CV	1064 nm	10–100 J	10–100 ms
Cynosure			
Elite	755 nm/1064 nm	25–100 J/ 35–300 J	0.5–300 ms 0.4–300 ms
Acclaim	1064 nm	35–300 J	0.4–300 ms
Focus Medical			
NaturaLase LP	1064 nm	up to 400 J/cm^2	up to 100 ms
HOYA ConBio			
RevLite	1064 nm, 532 nm	Up to 12 J/cm^2	5–20 ns Q-switched
MedLite C6	1064 nm, 532 nm	Up to 12 J/cm^2	5–20 ns Q-switched

Table 4.1 The most popular Nd:YAG lasers that can be used for laser hair removal. It should be noted that the list is not meant to be exclusive

MY APPROACH

I have found the nanosecond Q-switched Nd:YAG lasers to be highly effective in inducing temporary short term hair removal. Although initially it was suggested that hair waxing aided in allowing the topical carbon suspension to penetrate deeper into hair follicles, there is no scientific proof that waxing plays any role in the final result. Skin cooling is not required when a nanosecond laser is used. This contrasts with the need for some form of epidermal cooling when virtually all millisecond lasers are used. The treatment technique with a nanosecond Q-switched Nd:YAG laser consists of preoperative shaving of the treatment site. This reduces treatment induced odor, prevents long pigmented hairs lying on the skin surface from conducting thermal energy to the adjacent epidermis, and promotes transmission of laser energy down the hair follicle. When the technique is utilized with a topical carbon suspension, there is often a greenish hue, seen through laser goggles, to the area being treated. This is presumably due to the interaction between the 1064 nm wavelength and the carbon chromophore. Wen the 1064 nm Q-switched Nd:YAG laser is used without topical carbon chromophore, treated dark terminal hairs often turn white on laser impact. Usually no post-treatment crusting is noted. Erythema may vary from non-existent to significant in its extent. It is quite safe to treat darker complected individuals with a nanosecond Q-switched Nd:YAG laser (Figures 4.3–4.7). Millisecond Nd:YAG lasers have now proved to be the treatment of choice for the darkest of skin types. Safe and effective results can be produced even in Fitzpatrick VI individuals. Results are longer lasting than those that are seen with Q-switched Nd:YAG lasers (Figures 4.8-4.18). Post-inflammatory pigmentary changes after treatment with these lasers may still occur in some darker complected individuals.

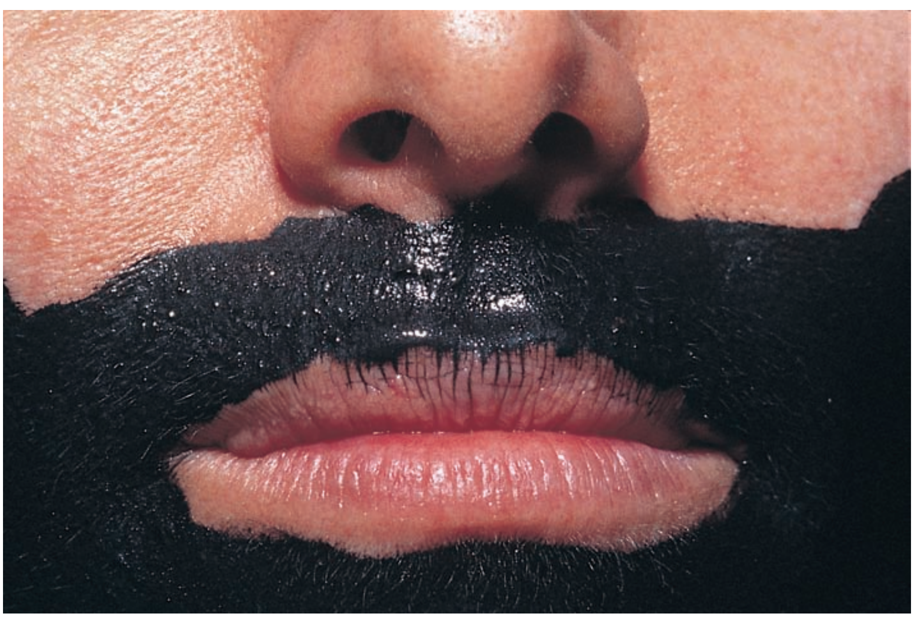

Figure 4.3 Carbon suspension applied to skin prior to laser irradiation with 1064 nm Q-switched Nd:YAG laser

Figure 4.4 Immediately after laser irradiation of carbon suspension

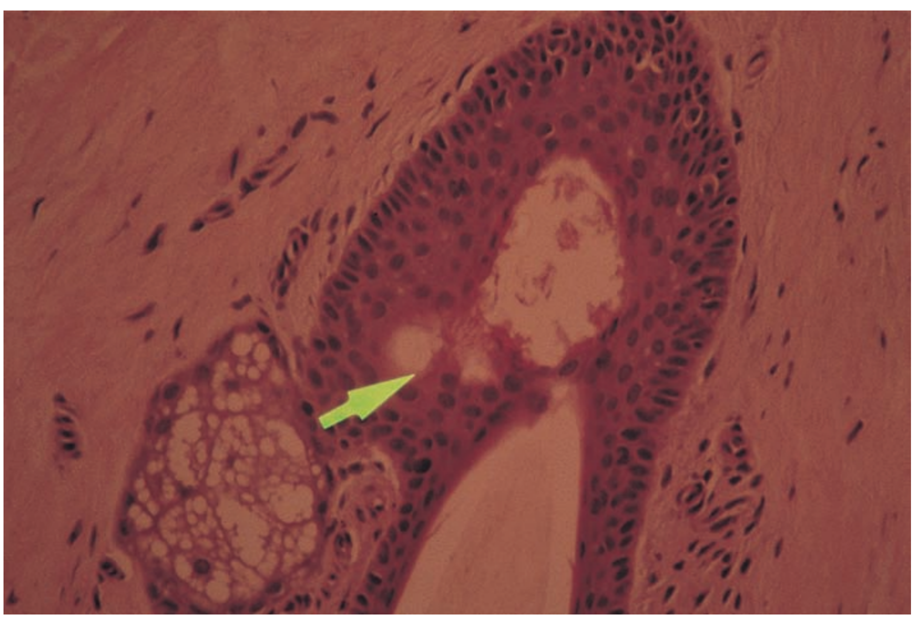

Figure 4.5 Vacuoles created within hair follicle after interaction of Q-switched Nd:YAG laser with topically applied carbon

Figure 4.6 Hair on upper lip prior to treatment with topically applied carbon assisted Q-switched Nd:YAG laser

Figure 4.7 Minimal hair present on upper lip 2 months after treatment

Figure 4.8 Chest hair in Fitzpatrick V individual. Good candidate for millisecond Nd:YAG laser treatment

Figure 4.9 Leg hair in Fitzpatrick VI individual. Ideal candidate for millisecond Nd:YAG laser treatment

Figure 4.10 Bikini hair in Fitzpatrick V individual. Good candidate for millisecond Nd:YAG laser treatment

Figure 4.11 Lip hair in Fitzpatrick V individual. Good candidate for millisecond Nd:YAG laser treatment

Figure 4.12 Chin hair in Fitzpatrick VI individual. Ideal candidate for millisecond Nd:YAG laser treatment

Figure 4.13 Chin hair in Fitzpatrick VI individual. Ideal candidate for millisecond Nd:YAG laser treatment

Figure 4.14 Chin hairs prior to treatment with millisecond Nd:YAG laser hair removal

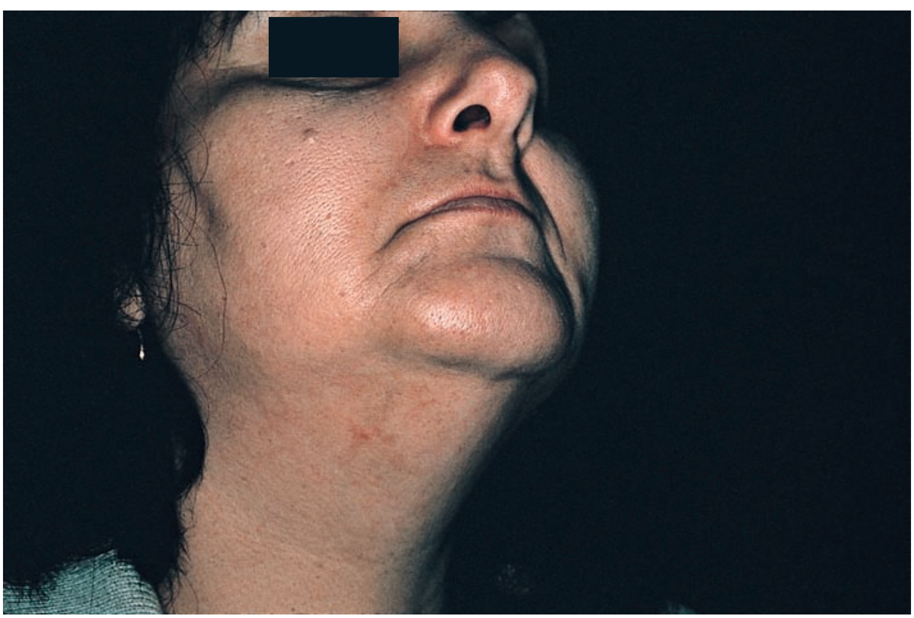

Figure 4.15 Chin 1 month after treatment with millisecond Q-switched Nd:YAG laser hair removal

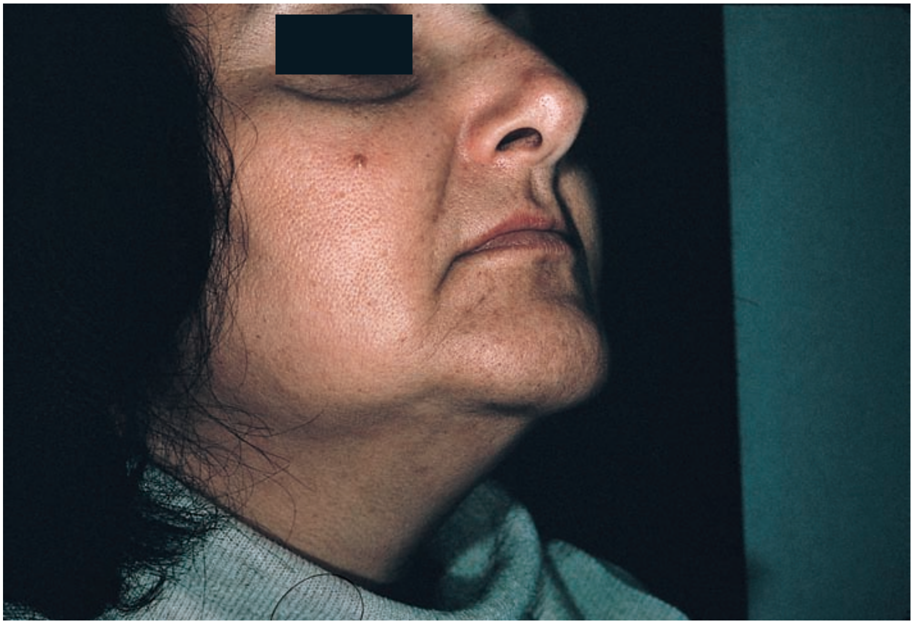

Figure 4.16 Chin 3 months after treatment with millisecond Q-switched Nd:YAG laser hair removal. No perceptible hairs are present

Figure 4.17 Upper lip hairs before treatment with millisecond Nd:YAG laser hair removal

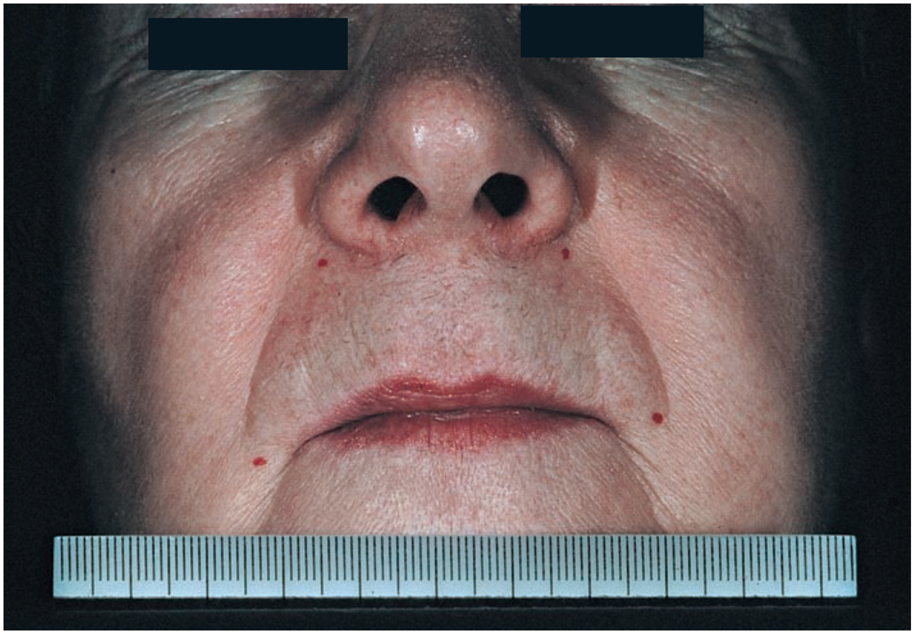

Figure 4.18 Absence of upper lip hairs 6 months after 5 millisecond Nd:YAG laser hair removal treatments

REFERENCES

1 Goldberg DJ, Littler C. Topical solution assisted laser hair removal. Lasers Surg Med 1995; 15(Suppl 7): 47.
2 Goldberg DJ, Littler CM, Wheeland RG. Topical suspension assisted Q-switched Nd:YAG laser hair removal. Dermatol Surg 1997; 23: 741–5.
3 Goldberg DJ. Topical suspension assisted laser hair removal: treatment of axillary and inguinal regions. Lasers Surg Med 1996; 16 (Suppl 8): 34.
4 Nanni CA, Alster TS. A practical review of laser-assisted hair removal using the Q-switched Nd:YAG, long-pulsed ruby, and long-pulsed alexandrite lasers. Dermatol Surg 1998; 24: 1399–1405.
5 Bencini PL, Luci A, Galimberti M et al. Long-term epilation with long-pulsed neodimium: YAG Laser. Dermatol Surg 1999; 25: 175–8.
6 Goldberg DJ. Laser hair removal with a millisecond Q-switched Nd:YAG laser. Lasers Surg Med 1999; 19(Suppl 11): 22.
7 Goh CL. Comparative study on a single treatment response to long pulse Nd:YAG lasers and intense pulse light therapy for hair removal on skin type IV to VI — is longer wavelengths lasers preferred over shorter wavelengths lights for assisted hair removal? J Dermatolag Treat 2003; 14: 243–7.
8 Nanni CA, Alster TS. Optimizing treatment parameters for hair removal using topical carbon-based solution and 1064-nm Q-switched neodymium: YAG laser energy. Arch Dermatol 1997; 133: 1546–9.

9 Rogers CJ, Glaser DA, Siegfried EC, Walsh PM. Hair removal using topical suspension-assisted Q-switched Nd:YAG and long-pulsed alexandrite lasers: a comparative study. Dermatol Surg 1999; 25: 844–50.
10 Lorenz S, Brunnberg S, Landthaler M, Hohenleutner U. Hair removal with the long pulsed Nd:YAG laser: a prospective study with one year follow-up. Lasers Surg Med 2002; 30: 127–34.
11 Goldberg DJ, Silapunt S. Hair removal using a long-pulsed Nd:YAG laser: comparison at fluences of 50, 80, and 100 J/cm^2. Dermatol Surg 2001; 27: 434–6.
12 Fournier N, Aghajan-Nouri N, Barneon G, Mordon S. Hair removal with an Athos Nd:YAG 3.5 ms pulse laser: a 3-month clinical study. J Cutan Laser Ther 2000; 2: 125–30.
13 Chan HH, Ying S-Y, Ho W-S, Wong DSY, Lam L-K. An in vivo study comparing the efficacy and complications of diode laser and long-pulsed Nd:YAG laser in hair removal in Chinese patients. Dermatol Surg 2001; 21: 950–4.
14 Galadari I. Comparative evaluation of different hair removal lasers in skin types IV, V and VI. Int J Dermatol 2003; 42: 68–70.
15 Rao J, Goldman MP. Prospective, comparative evaluation of three laser systems used individually and in combination for axillary hair removal. Dermatol Surg 2005; 31: 1671–7.
16 Lévy JL, Trelles MA, de Ramecourt A. Epilation with a long-pulse 1064 nm Nd:YAG laser in facial hirsutism. J Cosmet Laser Ther 2001; 3: 175–9.
17 Tanzi EL, Alster TS. Long-pulsed 1064-nm Nd:YAG laser-assisted hair removal in all skin types. Dermatol Surg 2004; 30: 13–17.
18 Ferraro GA, Perrotta A, Rossano F, D'Andrea F. Neodymium: yttrium-aluminum-garnet long impulse laser for the elimination of superfluous hair: experiences and considerations from 3 years of activity. Aesthetic Plast Surg 2004; 28: 431–4.
19 Raff K, Landthaler M, Hohenleutner U. Optimizing treatment parameters for hair removal using long-pulsed Nd:YAG-lasers. Lasers Med Sci 2004; 18: 219–22.

5 INTENSE PULSED LIGHT

KEY POINTS

(1) Non-laser light source
(2) Delivered wavelengths between 590 nm and 1100 nm
(3) Filters are used to choose delivered wavelengths
(4) Myriad choices of pulse durations
(5) Risk profile similar to visible light lasers
(6) Better intense pulsed light technologies produce identical results to those seen with lasers

BACKGROUND

Non-laser induced selective photothermolysis has become an accepted method of treating a wide gamut of vascular lesions. This non-coherent, polychromatic light source can be 'tuned' to provide a variety of wavelengths, fluences, and pulse durations. Non-laser induced selective photothermolysis for hair removal has also been utilized with a filtered flashlamp intense pulsed light source (IPL) (Figure 5.1). Such a light source, when used for hair removal, delivers non-coherent light in the 590–1200 nm range. The light is delivered in divided synchronized millisecond pulses separated by short thermal relaxation intervals for protection of epidermal melanin. The light is focused by a reflector and transmitted through a set of filters that determine its spectral characteristics. With non-laser light sources, a variety of parameters must be chosen. These include the spectrum of delivered wavelengths as determined by cutoff filters; number of delivered pulses; pulse duration in milliseconds; delay between pulses in milliseconds; and delivered fluence. The cutoff filters are utilized to tailor the spectrum of light to the skin type and hair color of the patient. The filter cuts off the emitted light, so that only wavelengths longer

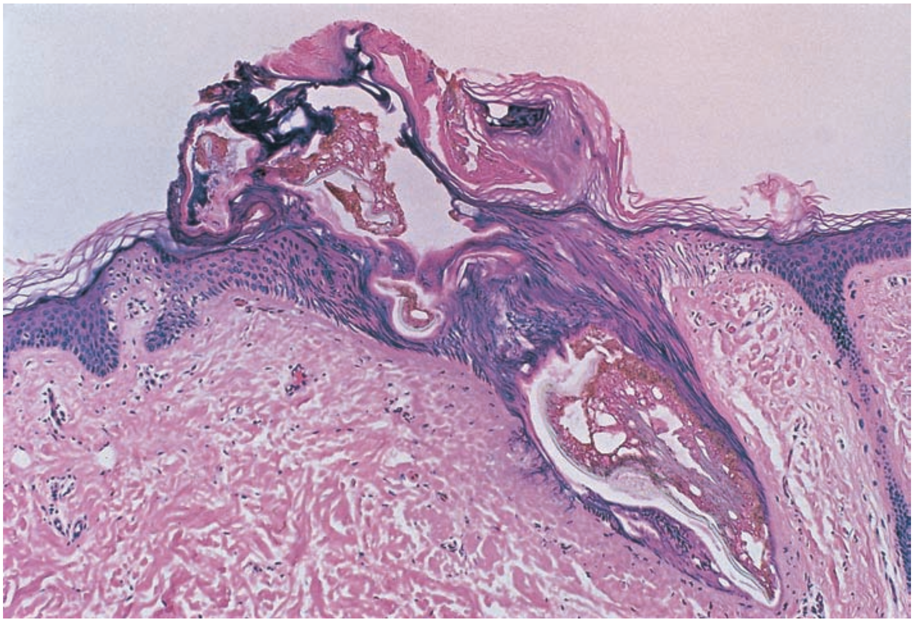

Figure 5.1 Histologic response immediately after IPL treatment. Significant thermal damage to follicle is noted with relative sparing of epidermis. No damage to surrounding dermis is noted

than the utilized filter value pass to the treated hair and skin. As an example, a 615 nm filter will only allow wavelengths greater than 615 nm to be emitted from the pulsed light source. In general, the higher cutoff filters are utilized in darker complected individuals. The light is usually applied to the skin through a rectangular light guide. Cool gel and a bracketed cooling device have been utilized to cool the skin.

CLINICAL STUDIES

The first published report of IPL, used for hair removal, documented successful long-term removal of terminal beard hairs in two transsexual patients.[1] Biopsies demonstrated atrophy of entire follicles with no scarring at the skin surface. At 6 months, following a large number of treatments (13 and 41 respectively), no pigmented or textural skin changes were noted. Hair was found to be virtually absent.

Gold et al. published the first significant series of patients treated with IPL.[2] They evaluated hair removal efficacy in 31 subjects (3 men, 27 women, 1 transsexual). Patients ranged in age from 14 to 74 years. The majority of treated individuals were between 30 and 50 years of age. A total of 37 treated sites were evaluated. All sites were treated once and evaluated 2, 4, 8, and 12 weeks after treatment. Although a variety of anatomic sites were treated, the most common areas were the neck (27%), lip (22%), and chin (19%).

Utilized treatment parameters varied according to the pigmentation of the skin and treated hair. Four cutoff filters were used. They included 590, 615, 645, and 695 nm. Delivered fluences ranged between 34 and 55 J/cm^2. Energy was delivered in sequences of between 2 and 5 pulses, each pulse varying between 1.5 and 3.5 msec in length. Interpulse delay time varied between 20 and 50 msec. Generally, longer interpulse delays and multiple delivered pulses were used with higher fluences so as to better cool the skin between the pulses. In addition, larger number pulse sequences were used in darker complected individuals for the same reason.

The study evaluated both immediate and later treatment responses. Included immediate parameters were eliminated hair count, erythema, edema, purpura, burn, and post-treatment hair density. At follow-up visits, the authors analyzed the aforementioned parameters in addition to regrowth, change in hair color, scarring, textural changes, and pigmentary alteration.

Hair clearance was analyzed by placing responses into 4 quadrants: 0–25% clearance; 25–50% clearance; 50–75% clearance; and 75–100% clearance. Approximately one-third of the treated patients showed no clearance immediately after treatment. The remaining individuals were divided into the other 3 groups. Approximately one-fifth of the group was in the top 2 quadrants.

At 2 weeks, there was a net shift of 10% of the population from the bottom quadrant to the top quadrant. This progression continued at the 4 week follow-up visit. At 4 weeks, only about 10% of the population was included in the lowest quadrant. The top 2 quadrants now represented about two-thirds of the population. The 8 week results were similar to those of 4 weeks. Approximately 60% of patients were in the top 2 quadrants. Finally, at 12 weeks, the top 2 quadrants included 70% of the population.

The authors noted immediate post-treatment erythema in 70% of the patients. The only other immediate finding was edema noted in 8% of the population. Two weeks after treatment, 3 cases of resolving blisters were reported. One case of hyperpigmentation was noted. No other complications were observed.

The authors only followed patients for 12 weeks. Thus, there could be no claim of long term hair removal. In addition, patients were treated only once. It would be expected that the results would be improved after multiple treatments. Of note, the authors did not delineate which Fitzpatrick skin phenotypes were treated. It might be expected that the complication rate would rise if darker skin types were treated.

Weiss et al. expanded the aforementioned evaluation of the IPL's hair removal efficacy. The authors looked at not only the 3 month results after 1 treatment, but also hair removal efficacy 6 months after 2 treatments.[3]

Twenty-eight sites on 23 subjects, with Fitzpatrick skin types I–III, were enrolled in a study using a single IPL treatment. They were followed for 3 months. Another 56 sites on 48 subjects, with Fitzpatrick skin types I–V, were treated twice, with 1 month intervals between the 2 treatments. These individuals were followed for 6 months. Anatomic sites included in the double treatment protocol were facial regions (chin, submental, neck, lip, ear, cheek, and preauricular locations) and non-facial regions (back, bikini, thigh, shoulder, abdomen, and forearm). Treatment sites on the face averaged 25 cm^2 in size whereas treatment sites on the trunk averaged 50 cm^2. Large areas could be treated due to the large spot size utilized (8×33 mm or 10×45 mm) delivered with each pulse.

IPL treatment parameters utilized were a 2.8–3.2 millisecond pulse duration for 3 pulses, with thermal relaxation intervals between pulses of 20–30 milliseconds. The 615 nm or 645 nm cutoff filters were utilized based on skin type. Fitzpatrick types I and II subjects received treatment with the 615 nm filter; types III and above with the 645 nm filter. The triple pulses delivered a total fluence of 40–42 J/cm^2. For the double treatment protocol, delivered fluences were increased only if the response to the first treatment was minimal. All other parameters remained unchanged.

The authors claimed to have used very conservative fluences for the single treatment protocol. At the first visit, immediate post-treatment mean hair clearance of 16% was recorded. This improved to 56% at weeks 2 and 4, 54% at week 8, with a final 63% reduction at 12 weeks. These findings, suggestive of effective temporary hair removal, were consistent with those seen by Gold.[2] Of greater significance were the findings in the second study. In the double treatment protocol, immediate post-treatment clearance of 64% was achieved. These better results may be explained by the more aggressive parameters utilized in this second treatment protocol. At week 8, a 42% hair reduction was noted. At 6 months hair reduction was found to be 33%. In addition, many residual hairs were reduced in diameter. It is observations such as these that emphasize the importance in looking beyond simple hair counts in determining hair removal efficacy. Simple hair counts alone may be deceptive. Some patients in the study of Weiss et al. appeared to be excellent clinical responders even with hair counts reduced only by 33%.[3] Because observed hairs were often much smaller in hair shaft diameter, they were less visible.

The expected erythema following treatment, in the second study, was seen in 92% of patients. Urticarial edema around the hair follicles was noted immediately in 72% of treated individuals. Two sites developed a vesicle, which healed with no sequelae, but led to several weeks of hypopigmentation. Approximately 12% of patients experienced some areas of crusting lasting several days to 1 week. Resultant hypo- and hyperpigmentation, lasting for 4–8 weeks, occurred as a result of the crusting. This cleared within 2 months in all cases. Of note, patients who previously underwent electrolysis reported far less pain with IPL.

Examination of both study groups revealed maximal hair count reduction, at all sites, between 2 and 3 months after treatment. Partial regrowth of hair was observed at 6 months at all body sites. The authors suggested that this could be explained by the well-recognized, non-synchronous cyclical hair growth seen at different body locations. Another plausible explanation could also be invoked. It may be that the hair growth centers are merely damaged by IPL, or laser treatment, but not destroyed. It is also possible that some hairs simply do not respond to treatment.

Selim et al. have compared the results of IPL delivered in 3 different manners.[4] In one study, IPL treatment was delivered with a machine whose software, although designed for spider vein treatments, could be utilized to treat unwanted hair. In the second study, a similar IPL device, whose software was designed specifically to treat unwanted hair, was utilized. In addition, the authors, in a third study, evaluated the effect of a particular bracketed cooling device during the treatments.

All subjects were Fitzpatrick skin phenotypes II–III. The first group consisted of 82 subjects; the second group consisted of 58 subjects; the third group contained 20 subjects. Treatment areas included the face, neck, axilla, legs, bikini, and back. All patients received 1 or more treatments. A variety of cutoff filters were utilized to optimize appropriate wavelength use. Fluences varying between 32 and 45 J/cm^2 were utilized and delivered in double or triple pulses.

In the first study, 82 subjects (13 men, 60 women, 9 transgender), ranging in age between 19 and 69 years (mean age of 35), were treated. From this group, 56 were seen in 1–5 months follow-up, while 13 were seen from 6–16 months after treatment. The investigators noted better clearance in the 6–16 month group in Fitzpatrick skin type II (28% average clearance) as compared to the Fitzpatrick skin type III group (16% average clearance). There was also an increase in clearance with subsequent treatments. In addition, hair removal was most efficient in darker hairs as compared to lighter hairs. Legs and bikini areas showed the most clearance, the back the poorest results. One patient developed hyperpigmentation and one developed hypopigmentation. In both instances the pigmentary changes resolved within 6 months.

In the second study, 58 subjects (11 men, 41 women, and 6 transgender) were treated. The age range was 20 to 72 years (mean age of 38 years). Thirty-three subjects were seen in 1–5 months follow-up, while 17 subjects were seen at a 6–16 month interval. In this study, similar to the first study findings, the investigators also noted greater clearance in Fitzpatrick skin type II as compared to Fitzpatrick skin type III. However, the degree of clearance in this study was very different. Fitzpatrick skin type II subjects showed 64% clearance; skin type III showed 36% clearance. The reason for the disparity between the 2 sets of data was not provided. Nevertheless, greater improvement was again noted with increasing treatments. In addition, increased hair loss was noted with darker hair colors. The bikini was again the anatomic area showing the best response; the back showed poorer results. The neck and face also showed good results; the axilla showed poor results. The authors also noted a change in hair texture from coarse darker hair to thin lighter hair. No pigmentary alterations were noted.

When the investigators, in the third study, evaluated the effect of an IPL bracketed cooling device, they noted a substantial reduction in treatment discomfort. However, the cooling device had no effect on actual efficacy of treatment. There was also less blistering when the cooling device was utilized. Such a finding would be expected from any cooling device that protects the epidermis from thermal damage.

The aforementioned studies were all performed with IPL devices developed by ESC Medical. In a somewhat related IPL device available in some parts of the world, but not the United States, Bjerring noted 46.8% hair reduction 6 months after 3 treatments given at 2 month intervals.[5] These results, with the Ellipse IPL, compared to only a 6.3% reduction following similar treatments with a normal mode ruby laser.

In 2004, Bedewi examined the efficacy of IPL for photoepilation in 210 patients with skin types III–V using fluence ranging from 25 to 40 J/cm^2, pulse duration between 50 and 80 msec, and a cut-off filter of 615 nm with doubled pulse illumination. After 3–5 treatments, the mean hair reduction at 6 month follow-up was 80%. Eighty percent hair reduction was attained in patients with skin type III, and 70% hair reduction was achieved in the patients with skin types IV and V. The author noted a superior response (80–85% hair reduction) when treating extremities, axillae, and bikini areas, compared with face, back, and chest. Side effects in a few patients included mild pain after treating the upper lip, and transient erythema and mild perifollicular edema. However, no post-inflammatory pigment alteration or scarring was observed.[6]

Following up on their earlier study in 1999, Gold et al. examined the long-term result of a single IPL treatment for photoepilation at 1 year in 24 of the original 31 patients who participated in their earlier 3 month follow-up study. The authors observed a long-term hair reduction of 75% in this group of individuals. Evaluating the effect of IPL treatment on the cutaneous histology, the authors report miniaturization of the hair follicles with minimal damage to the perifollicular tissue.[7]

Sadick et al. evaluated the long-term efficacy of IPL in the removal of superfluous hair and the effect of anatomic site and skin type on the success of the treatment. The study included 34 patients with skin types II–V and light brown to black terminal hair in the treated areas of the face, lip, chin, mandible, chest, abdomen, back, and the bikini area. Broad-spectrum 615–695 nm noncoherent IPL light source delivered in macropulses divided into 2–5 minipulses was used. Fluences ranged from 34 to 42 J/cm^2, pulse durations from 2.6 to 3.3 msec, with a 10×45 mm exposure field. Mean hair reduction of 76% was noted after a mean of 3.7 treatments, with greater than a 50% reduction attained at more than 94% of the treatment sites. Anatomic site did not significantly impact on the hair removal efficacy (HRE), with mean torso HRE of 78% not statistically significantly differing from the HRE of 72% on the face. Furthermore, no statistically significant variation was observed among the patients of various Fitzpatrick skin types or between different hair colors, nor between groups receiving a different number of treatments (75% for 1–3 versus 77% for 4–7 treatments). Long-term (greater than 12 months, with mean of 20 months) follow-up of 14 patients within the study demonstrated an HRE of 83% after a mean of 3.9 treatments, further improving to 92% ± 12% at 30 months. The authors report a 9% rate of temporary hyperpigmentation and a 6% rate of self-limited and non-scarring superficial crusting, both of which did not significantly vary among patients of different skin types. Eighty-three percent of patients reported moderate to great satisfaction with treatment (with 52% greatly satisfied), and 10% remained unsatisfied.[8]

Recently, Lee et al. investigated the effects of wavelength and pulse width on the photoepilation results achieved by IPL. In a study of axillary photoepilation in 28 Asian women with skin types II–IV using the Ellipse Flex IPL system, the authors found that restricting the emitted spectrum of IPL light source by 45 nm by using a 645–950 nm, as opposed to a 600–950 nm, filter, and by using a longer pulse duration of 25–50 msec, compared with 20–40 msec, a greater hair reduction (83.4% versus 52.8%) was obtained. Fluences of 14.9 ± 2.0 J/cm^2 in the 600–950 nm filter group and 17.1 ± 0.6 J/cm^2 in the 645–950 nm filter group were used. Two cases of postinflammatory pigment alteration were observed in the non-restricted IPL filter group, compared to none in the restricted filter group. Furthermore, the pain level was also lower in the 645–950 nm filter group.[9]

In a 2005 study, Fodor et al. evaluated patient satisfaction with IPL treatment in their 108 consecutive patients with skin types II–V. The number of treatments varied from 1 to 13, but most received between 2 and 6. The authors reported that 1–3 treatments were superior to more than 7 treatments with regards to patient satisfaction. Although 67% of individuals reported no complications, prolonged erythema lasting more than a week was reported by 16.25%, blistering by 6.25%, temporary hyperpigmentation by 8.75% of patients, with 1 case of leukotrichia and 1 case of persistent hypopigmentation. The greater incidence of side effects in the higher skin type, although not statistically significant, may account for a decreasing level of satisfaction with increasing skin type.[10]

Lask et al. recently investigated the use of pneumatic skin flattening (PSF) technology in reducing the pain associated with photoepilation by diode and intense pulse light-based systems. LightShear 810 nm diode laser with 30 msec pulse duration was tested with and without the use of the PSF vacuum chamber device at fluences of 38–42 J/cm^2. The authors showed that 30% higher energies may be utilized while at the same time ameliorating the discomfort and reducing the post-treatment erythema and edema. Hair removal efficacy was preserved or even enhanced by the use of this novel technology.[11]

Bjerring et al. have compared the photoepilation efficacy of IPL and ruby laser after 3 treatments in a study of 31 patients with skin types II–IV in the chin and neck areas. At the 6 month follow-up, 94% of patients in the IPL group achieved hair reduction, the hair count decreasing by a mean of 49%, compared with 55%

of patients in the ruby laser group and 21% mean hair reduction. Interestingly, additional 36% hair reduction was achieved by following the ruby laser treatment course with 3 additional treatments with IPL to a total of 57%, whereas only a marginal 7% improvement in hair reduction to 56% was obtained after a total of 6 IPL treatments.[12]

Recently, Toosi et al. performed a study comparing the efficacy and side effect profile of diode and alexandrite lasers and IPL for laser hair removal. Participating in this study were 232 female patients with skin types II–IV. The investigators used Palomar 810 nm diode laser with a 9 mm^2 sapphire chill tip, using 12.5 msec pulse duration and fluences of 40–64 J/cm^2; a Cynosure 755 nm alexandrite laser with 10 mm spot size using 2 msec pulse duration and 16–20 J/cm^2 fluences; and Medical Bio Care IPL with cut-off filter of 650 nm with double pulse illumination, using 20 msec pulse duration, and 22–34 J/cm^2 fluences with 10–40 msec between consecutive pulses. Six months after the last of the 3–7 treatments, no significant statistical difference was observed in the hair reduction between the 3 light sources (68.75 ± 16.92% for alexandrite, 66.96 ± 14.74% for IPL, and 71.71±18.12% for diode), although diode was slightly superior to the other 2 systems. The occurrence of side effects, mainly transient pigment alteration, was significantly higher for the diode laser and lowest with the alexandrite, and increased with increasing Fitzpatrick skin type. The number of treatment sessions corresponded positively with the amount of hair reduction.[13]

Similarly, Goh compared the efficacy, as well as the role of wavelength selection, in the photoepilation involving IPL and long pulse Nd:YAG laser. The study involved 11 female patients with skin types IV to VI and black hair. Face, axilla, and legs were treated. A 1064 nm Nd:YAG laser with fluences of 35–42 J/cm^2, 20–25 msec pulse duration, and 10 mm spot size was used. This was compared with a 600–950 nm intense pulse light with fluences of 12–14 J/cm^2, and pulse durations of 5–40 msec. Six weeks following treatment, hair removal efficacy was noted to be comparable between the 2 light source systems, with 73% of Nd:YAG-treated patients and 64% of IPL-treated patients reporting up to 20% reduction in hairiness. Postinflammatory hyperpigmentation was noted in 45% of IPL-treated patients, compared to none in the Nd:YAG-treated group.[14]

Finally, recently, in our own center, a study was conducted to compare the efficacy of 4 laser systems for hair removal: 755 nm alexandrite (18 J/cm^2, 3 msec), intense pulsed light with red and yellow filters (65 and 35 J/cm^2, 100 msec), and 810 nm diode laser (28 J/cm^2, 14 msec). A significant decrease in hair counts (~50%) and hair coverage (~55%) did not statistically differ between the 4 modalities, with a follow-up period of up to 6 months. The remaining hair length and diameter, on the other hand, were not affected by any treatment method. It was noted also that the cryogen spray-based alexandrite laser showed the highest pain score, compared with the other contact cooling-based devices.[15]

AVAILABLE INTENSE PULSED LIGHT SYSTEMS

Company	Wavelength (nm)	Fluence	Pulse duration
DermaMed International, Inc.			
Quadra Q4 Series	500–1200 nm	up to 20 J/cm^2	10–110 ms
Lumenis			
Lunenis One	515–1200 nm	10–40 J/cm^2	3–100 ms
Radiancy			
SkinStation	400–1200 nm	up to 65 J/cm^2	10 ms
Palomar			
StarLux LuxY	525–1200 nm	up to 45 J/cm^2	1–500 ms
StarLux LuxR	650–1200 nm	up to 70 J/cm^2	5–500 ms

Table 5.1 The most popular currently used IPL sources for light based hair removal. It should be noted that the list is not meant to be exclusive

MY APPROACH

I have found intense pulsed light sources to be very useful in treating Fitzpatrick I and IV skin phenotypes. The IPL technique can also be used to improve hair-induced folliculitis (Figures 5.2–5.50). Although some IPLs have been FDA cleared in the US for Fitzpatrick skin phenotype V, I have found the incidence of post-inflammatory changes may be too high for practical use in some of these individuals. Because red hair, with its associated pheomelanin, absorbs visible light best in the 400–600 nm range, a lower filter is used in these patients so as to allow wavelengths 590 nm and above to be released. Fitzpatrick skin phenotypes II and III with dark terminal hair can be treated with a variety of filters. Finally, Fitzpatrick IV individuals are treated with a higher filter. Such a filter skews emitted light toward the 800–900 nm range for greater safety in these darker complected individuals. When choosing emitted pulse durations, shorter pulse durations anecdotally are more helpful for finer hairs, while longer pulse durations appear to have greater efficacy in treating thicker hairs. In addition, longer pulse durations, because of their epidermal pigment sparing capacity, are chosen for darker skin phenotypes. The choice of the pulsing mode and interpulse times are also dictated by skin complexions. Darker complexions are usually treated with a double/triple pulse and longer interpulse times as compared to the parameters chosen with lighter

Figure 5.2 Axilla before IPL treatment

Figure 5.3 Axilla 6 months after 3 IPL treatments

Figure 5.4 Male back before treatment with IPL

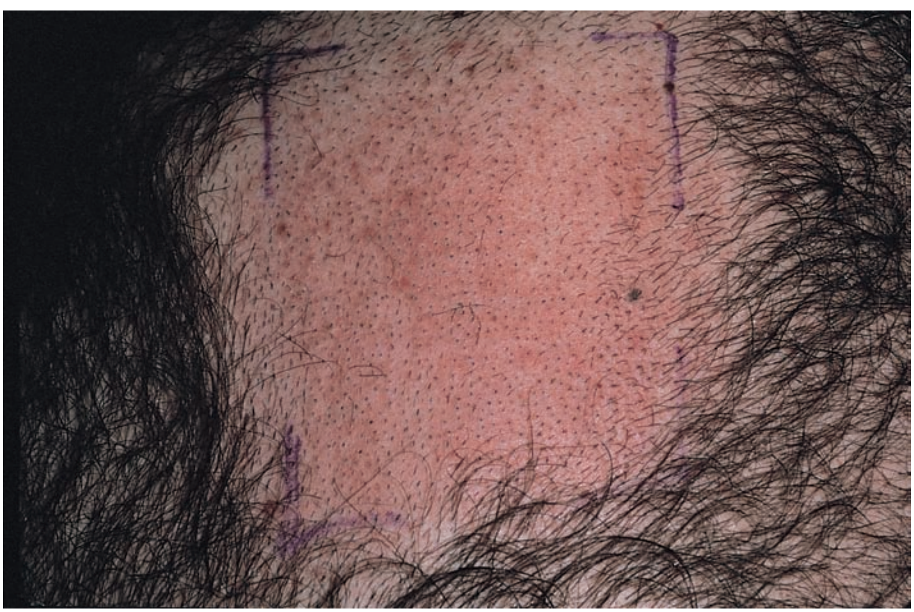

Figure 5.5 Male back immediately after treatment with IPL. Note expected post-treatment erythema

Figure 5.6 Hirsute chin before treatment with IPL

Figure 5.7 One month after treatment with IPL. Hairs usually fall out over the course of 1 month after treatment

Figure 5.8 Post-menopausal woman before treatment with IPL. Note black and white hairs on chin

Figure 5.9 Post-menopausal woman 3 months after 1 treatment with IPL. Note most of the black hairs are gone. As would be expected, there is little response in non-pigmented hairs

Figure 5.10 Dark terminal hairs on female chin

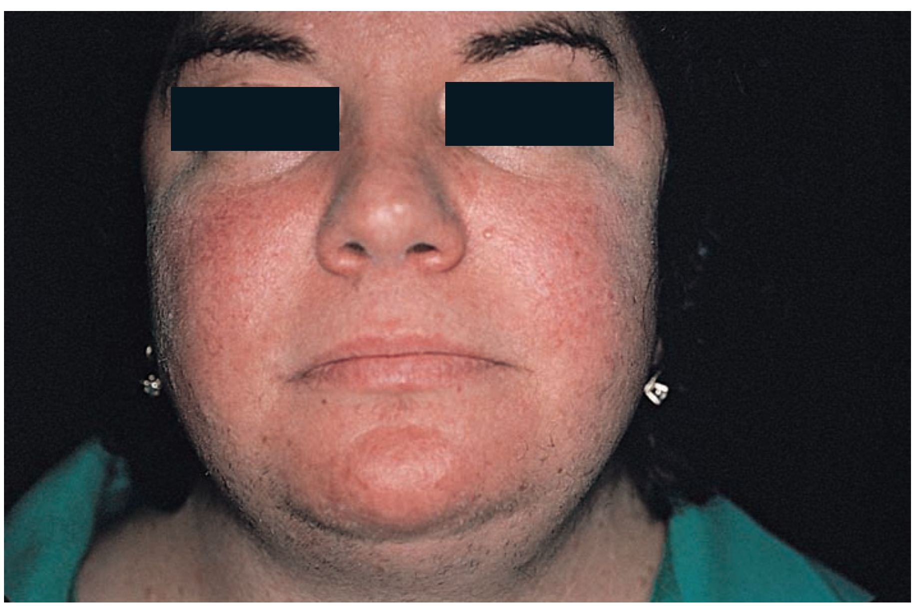

Figure 5.11 Excellent response 5 months after 2 treatments with IPL

Figure 5.12 Male ear with dark terminal hairs

Figure 5.13 Some hair thinning noted 2 months after 1 treatment with IPL

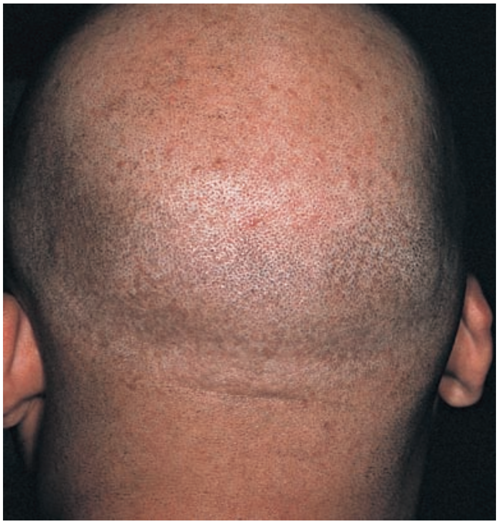

Figure 5.14 Type V male scalp hair before treatment with IPL

Figure 5.15 Mild thinning of hair noted 4 months after 1 session with IPL. As would be expected some post-inflammatory hyperpigmentation is seen

Figure 5.16 Right female breast hairs before treatment with IPL

Figure 5.17 Right female breast 3 months after 2 sessions with IPL

Figure 5.18 Left female breast hairs before treatment with IPL

Figure 5.19 Left female breast 3 months after 1 session with IPL. Almost no improvement is seen. Multiple sessions are required

Figure 5.20 Left female breast 3 months after 2 sessions with IPL. Almost no improvement is seen. Multiple sessions are required

Figure 5.21 Left female breast three months after 3 sessions with IPL. Improvement is now obvious

Figure 5.22 Left female breast 6 months after 5 sessions with IPL. Only thin, lightly pigmented hairs persist

Figure 5.23 Right cheek hairs prior to treatment with IPL

Figure 5.24 Right cheek 1 month after 2 treatments with IPL

Figure 5.25 Right cheek 3 months after 2 treatments with IPL

Figure 5.26 Right cheek 6 months after 2 treatments with IPL

Figure 5.27 Neck before treatment with IPL. Note erythema from topically applied anesthetic cream

Figure 5.28 Neck 9 months after 4 sessions with IPL. No hairs persist

Figure 5.29 Several small hairs present immediately inferior to lip in this post-menopausal woman

Figure 5.30 No hairs seen immediately inferior to lip in this post-menopausal woman 3 months after 1 treatment with IPL

Figure 5.31 Red hairs present on cheek

Figure 5.32 Marked thinning of hairs 6 months after 3 treatments with IPL using a 590 nm cutoff filter

Figure 5.33 Hirsute female chest prior to treatment with IPL

Figure 5.34 Erythema and perifollicular edema seen after treatment with IPL

Figure 5.35 Minimal amount of hair present 2 months after treatment with IPL

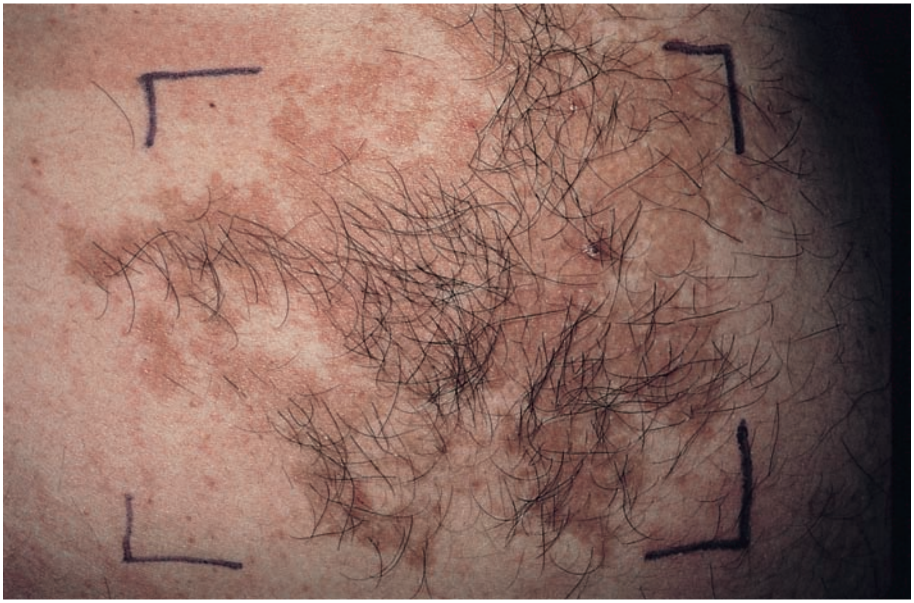

Figure 5.36 Hairs of Becker's nevus prior to treatment with IPL

Figure 5.37 Erythema noted immediately after treatment with IPL

Figure 5.38 Six months after 1 treatment with IPL. All hairs appear to have regrown but are thinner than prior to treatment

Figure 5.39 Six months after second treatment with IPL

Figure 5.40 Six months after 3rd treatment with IPL. Note progressive improvement

Figure 5.41 Left bikini hairs prior to treatment with IPL

Figure 5.42 Left bikini 5 months after 3 treatments with IPL

Figure 5.43 Right bikini hairs prior to treatment with IPL

Figure 5.44 Perifollicular erythema and edema noted immediately after treatment with IPL

Figure 5.45 Right bikini hairs 4 months after 1 treatment with IPL. Minimal improvement was noted

Figure 5.46 Right bikini hairs 6 months after 2 treatments with IPL. Most of the hairs have regrown

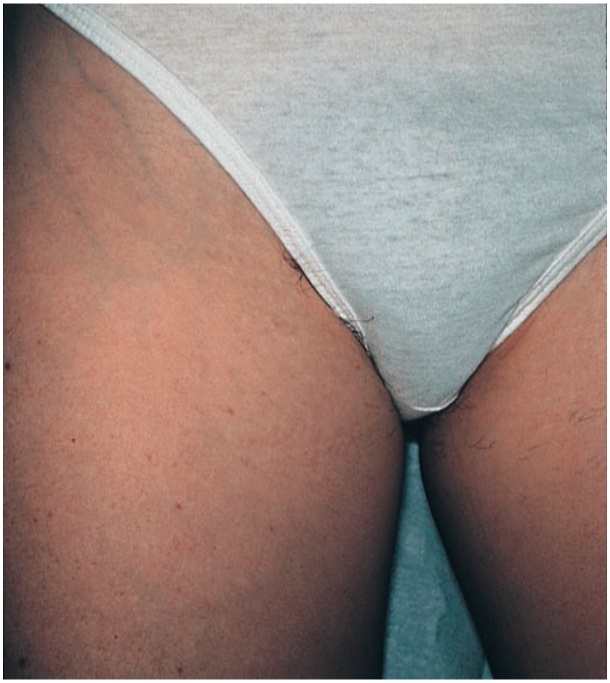

Figure 5.47 Right bikini hairs 6 months after 4 treatments with IPL. Almost no hair is present

Figure 5.48 Right bikini hairs 12 months after 4 treatments with IPL. Only a small number of fine hairs are noted

Figure 5.49 Significant folliculitis, post-inflammatory hyper- and hypopigmentation in Fitzpatrick VI skin phenotype prior to treatment with IPL

Figure 5.50 Mild improvement in folliculitits after 2 treatments with IPL. Pigmentary changes persist

skin complexions. As is true with all lasers used for hair removal, the higher the utilized fluences, the better the results. The fluence chosen should be as high as is tolerated without creating an epidermal blister.

The treatment technique consists of preoperative shaving of the treatment site. This reduces treatment-induced odor, prevents long pigmented hairs lying on the skin surface from conducting thermal energy to the adjacent epidermis, and promotes transmission of laser energy down the hair follicle. My experience with IPLs has shown that the greatest safety is achieved when appropriate epidermal cooling is used. Usually, post-operative perifollicular edema and erythema is noted. The treated hairs sometimes appear darker after treatment and usually fall out of the treated follicle 1–4 weeks after treatment. Re-treatments are usually undertaken at 2–5 month intervals. In darkly pigmented or heavily tanned individuals, it may be beneficial to use topical hydroquinones and meticulous sunscreen protection for several weeks prior to treatment in order to reduce inadvertent injury to epidermal pigment. Individuals with recent suntans should not be treated until at least 1 month of pre-treatment hydroquinones has been utilized. Postinflammatory pigmentary changes are still to be expected in darker complected individuals.

IPL, when used with almost all fluences, can lead to temporary hair loss at all treated areas. However, choosing appropriate anatomic locations, utilizing higher fluences, and providing multiple treatments will increase the likelihood of permanent hair reduction. Even though permanent hair loss is not to be expected in all treated individuals, lessening of hair density and thickness is a common finding.

The ideal treatment parameters must be individualized for each patient, based on clinical experience and professional judgment. The novice, when treating darker complected individuals, may wish to undertake several individual test pulses at an inconspicuous site with a lesser fluence. The delivered energies may then be slowly increased. Undesirable epidermal changes such as whitening and blistering are to be avoided.

Prolonged and permanent hair loss may occur following the use of the intense pulsed light device. However, as with lasers, great variation in treatment results can be seen. Scarring, and IPL induced pigmentary changes can be seen with any device utilized.

REFERENCES

1 Raulin C, Werner S, Hartschuh W, Schonermark MP. Effective treatment of hypertrichosis with pulsed light: A report of two cases. Ann Plast Surg 1997; 39: 169–73.

2 Gold MH, Bell MW, Foster TD, Street S. Long-term epilation using the EpiLight broadband, intense pulsed light hair removal system. Dermatol Surg 1997; 23: 909–13.

3 Weiss RA, Weiss MA, Marwaha S, Harrington AC. Hair removal with a non-coherent filtered flashlamp intense pulsed light source. Lasers Surg Med 1999; 24: 128–32.

4 Selin MM, Flor ME, Johnson TA, Zelickson BD. Personal communication.
5 Bjerring P. Ellipse pulsed light hair removal. 2nd Annual European Society for Lasers in Aesthetic Surgery. Oxford, England, March 1999.
6 Bedewi AFE. Hair removal with intense pulsed light. Lasers Med Sci 2004; 19(1): 48–51.
7 Gold MH, Bell MW, Foster TD, Street S. One-year follow-up using an intense pulsed light source for long-term hair removal. J Cutan Laser Ther 1999; 1: 167–71.
8 Sadick NS, Weiss RA, Shea CR, Nagel H, Nicholson J, Prieto VG. Long-term photoepilation using a broad-spectrum intense light source. Arch Dermatol 2000; 136: 1336–40.
9 Lee JH, Huh CH, Yoon HJ, Cho KH, Chung JH. Photoepilation results of axillary hair in dark-skinned patients by IPL: a comparison between different wavelength and pulse width. Dermatol Surg 2006; 32: 234–40.
10 Fodor L, Menachem M, Ramon Y et al. Hair removal using intense pulsed light (EpiLight): patient satisfaction, our experience, and literature review. Ann Plast Surg 2005; 54: 8–14.
11 Lask G, Friedman D, Elman M, Fournier N, Shavit R, Slatkine M. Pneumatic skin flattening (PSF): a novel technology for marked pain reduction in hair removal with high energy density lasers and IPLs. J Cosmet Laser Ther 2006; 8: 76–81.
12 Bjerring P, Cramers M, Egekvist H, Christiansen K, Troilius A. Hair reduction using a new intense pulsed light irradiator and a normal mode ruby laser. J Cutan Laser Ther 2000; 2: 63–71.
13 Toosi P, Sadighha A, Sharifian A, Razavi GM. A comparison study of the efficacy and side effects of different light sources in hair removal. Lasers Med Sci 2006; 21: 1–4.
14 Goh CL. Comparative study on a single treatment response to long pulse Nd:YAG lasers and intense pulse light therapy for hair removal on skin type IV to VI — is longer wavelengths lasers preferred over shorter wavelengths lights for assisted hair removal? J Dermatolog Treatment 2003; 14: 243–7.
15 Amin SP, Goldberg DJ. Clinical comparison of four hair removal lasers and light sources. J Cosmet Laser Ther 2006; 8: 65–8.

6 LASER HAIR REMOVAL IN ETHNIC SKIN

KEY POINTS

(1) Laser hair removal in ethnic skin types requires greater caution
(2) The safest lasers in Fitzpatrick skin types may be Nd:YAG lasers
(3) Because epidermal melanin competes with follicular melanin, effective cooling is mandatory when treating darker skin types

BACKGROUND

Laser hair removal was first approved by the FDA in 1995 and has become an increasingly popular procedure over the past several years. According to the American Society for Aesthetic Plastic Surgery, there were over 1.5 million laser hair removal procedures performed in 2005, an increase of more than 300% over 5 years ago. It is the second most commonly performed nonsurgical cosmetic procedure, and the most common procedure for individuals 18 years and younger. Initial laser and light based technology was designed for the treatment of dark hair on light skin.

Although the indications for hair removal are mostly considered cosmetic, in darker skinned patients hair removal may relieve chronic folliculitis or pseudofolliculitis barbae. This condition is common in dark skinned patients with spiral shaped hair, and may cause pruritus and discomfort, in addition to permanent scarring and pigment alteration in severe cases. It is often very difficult to treat, and the use of lasers has shown promising results.[1–3]

THEORY OF LASER USE FOR HAIR REMOVAL

The use of laser or light sources to remove unwanted hair is based on the theory of selective photothermolysis.[4] This concept allows the user to transfer light energy into heat and destroy the hair follicle with minimal to no effect on surrounding tissue. The target of the laser or light source is endogenous melanin present in hair follicles. The absorption spectrum for melanin is broad, and ranges from ultraviolet (400 nm) to infrared light (1200 nm). In theory, any of these wavelengths could be used to destroy the target melanin, however, melanin absorption is greatest with shorter wavelengths, and decreases as longer wavelengths are utilized.[5]

In order to selectively target melanin within the hair follicle and avoid epidermal injury, the laser or light source will ideally be able to reach deeper into the skin to the level of the bulge area of the hair follicle, as well as the dermal papilla or bulb. The bulge portion of the outer root sheath of the hair follicle is thought to contain epithelial stem cells responsible for regenerating follicles in the anagen stage.[6] The bulb is the lowermost portion of the hair follicle where the matrix cells exist and proliferate. Pigment in the hair shaft is produced by melanocytes interspersed among the matrix cells. Targeting both the bulge and bulb will theoretically provide permanent hair reduction. The bulb is approximately 4 mm from the skin surface, and the bulge is approximately one-third the distance from the surface of the skin to the bulb. Longer wavelengths such as the 1064 nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser will reach approximately 5 mm below the skin surface, which roughly corresponds to the level of the hair follicle bulb.[7]

In addition to selecting the appropriate wavelength, other parameters may be adjusted to selectively target deeper hair follicles while minimizing damage to the epidermis. According to the principle of selective photothermolysis, selective thermal destruction will occur if sufficient energy is delivered at a wavelength well absorbed by the target within a time period less than or equal to the thermal relaxation time of the target.[4] The thermal relaxation time is the time it takes for the target to cool to half of its baseline temperature by transferring the heat to surrounding structures. Tanned or darkly pigmented skin has greater melanin content and more melanin distributed throughout the epidermis and stratum corneum than white, nontanned skin. Tanning from ultraviolet exposure also causes epidermal thickening. Thus, thermal relaxation time of the absorbing epidermal layer can vary from 100 µs for white nontanned skin to as much as 25 ms for a thick epidermis in the case of tanned or darkly pigmented skin.[8]

The pulse duration is the amount of time laser energy is applied to the surface, and can range from nanoseconds to milliseconds. It is an important determinant of efficiency and morbidity associated with hair removal procedures. The pulse duration used in laser hair removal is approximately equal to the thermal relaxation time of the hair follicle. If the pulse duration exceeds the thermal relaxation time of the basal cell layer (approximately 0.1 ms) or the entire epidermis (approximately 10 ms), these structures will cool as they are heated during the laser pulse.[9] Larger targets such as hair follicles with longer thermal relaxation times (approximately 40 ms), can be selectively injured more than these smaller targets even though they contain the same target melanin. Longer pulse durations allow the hair follicles whose diameter is larger than the epidermal thickness and which contain heavy concentrations of melanin, to accumulate heat. Simultaneously, the epidermis with its shorter thermal relaxation time than the hair follicles, is essentially allowed to cool down.

For any given wavelength, increasing pulse duration allows the delivery of higher fluences in dark skin types.[10] Fluence is the total energy delivered per unit area and is measured in joules per centimeter squared (J/cm^2). Higher fluences have been shown to be more effective at achieveing permanent hair reduction. Therefore, the goal is to deliver the highest fluence possible without causing epidermal injury. Fluence is the main parameter causing adverse effects by overheating the surrounding tissue of the hair follicle or of the pigmented epidermis, and must be adjusted cautiously.

The biology of the hair follicle also influences the effectiveness of the laser. Human hair grows in a cyclical pattern. The growth phase, or anagen phase, is followed by a degradative phase, or catagen phase, and then by a resting period when no growth occurs, the telogen phase.[6] It is thought that for the laser treatment to be most effective, the hair must be in the anagen growth phase. This may be due to the higher concentration of melanin within the hair follicle at this stage. Approximately 80–85% of hairs are in the anagen phase at any one time depending on location, age, and gender; the remainder are in catagen (2%), or telogen (10–15%).[9] Table 6.1 shows the percentage of hair follicles in anagen according to location, as well as hair density and follicle depth which are also site dependent, and important considerations in laser hair removal.

Body site	**% anagen hairs**	**Density (cm^2)**	**Follicle depth (mm)**
Scalp	85	350	3–5
Beard	70	500	2–4
Upper lip	65	500	1–2
Axilla	30	65	3–4
Groin	30	70	3–4
Legs	20	60	2–3

(Modified from Lepselter J. and Elman, M.[5])

Table 6.1 Hair follicle characteristics

Four clinical responses may occur after light exposure.[11] Heat induced destruction of the hair shaft without damage to the germinative area may cause the hair shaft to fall out and then regrow at the next scheduled anagen cycle. Partial injury to the germinative zone of the hair follicle may result in trichoregulatory dysfunction, telogen-shock response, prolonged telogen dropout, and eventual regrowth of normal hair once the anagen phase begins again, or may lead to the development of thinner, finer hairs with variable hypopigmentation. Ideally after therapeutic light exposure, total germinative zone injury results in long term hair loss.

Laser hair removal is generally considered safe; however, as with any procedure, there are risks involved. Side effects may include erythema, edema, vesiculation, hypopigmentation, hyperpigmentation, growth of thinner or paler hair, induction of hair growth, and scar formation. These risks are much higher in individuals with darker skin types. New methods and technologies are under development that will aid in the safe treatment of darker skin types. Before treating an individual with type V or VI skin, a strong understanding of the principles of laser technology, as well as a consideration of available cooling devices, will be useful. The following discussion will assist the provider in the use of laser therapy for hair removal in types V and VI skin.

PROBLEMS IN TREATING DARKER SKIN

The most apparent problem in treating darker skin types is the amount of epidermal melanin present. This melanin acts as a competing chromophore for the laser or light energy. If a significant amount of energy is absorbed by the epidermal melanin, acute problems such as blistering and crusting, as well as long term complications such as scarring and dyspigmentation, may occur.

Melanosomes in black skin are not only increased in number compared to white skin, but are distributed throughout the entire epidermis, including the stratum basale, granulosum, lucidum, and corneum.[12] The melanosomes are larger, individually dispersed, and have a higher melanin content than the smaller, aggregated melanosomes with less melanin found in white non-tanned skin.[13] These melanosomes are able to absorb more light and therefore less light reaches the intended chromophore within the hair follicle, making the procedure essentially ineffective.

As mentioned above, the majority of black patients have spiral shaped hair and the follicles themselves are curved. Together, this makes black patients more prone to the condition of pseudofolliculitis barbae. Other differences in hair follicles have been studied, and perhaps not surprisingly, black hair is more heavily pigmented compared to white hair. Melanosomes are present in both the outer root sheath and in the bulb of vellus hairs in black patients, but not in white patients.[12]

The total hair density and total number of terminal hair follicles is significantly lower in African Americans compared with white subjects.[14] This is particularly important in hair removal, as a higher density of hair follicles leads to more thermal energy absorption and therefore a greater risk for adverse effects.

Although studies assessing the thickness of the epidermis and dermis find no difference between white and black skin,[15] there is a difference in composition of the dermis. Fibroblasts are larger and increased in number compared to white skin. The collagen fiber bundles are smaller and more closely stacked in black skin. Although we are unsure of the importance of these findings, there may be some contribution to the higher incidence of keloid formation seen in darker skinned individuals.[16]

AVAILABLE WAVELENGTHS TO TREAT DARKER SKIN

The pulsed ruby laser was among the first commonly used lasers for hair removal. This wavelength has extremely high melanin absorption and is therefore not useful for dark-skinned (Fitzpatrick skin types V–VI) patients. A study done by Elman et al., treating 16 patients with type IV skin, used the ruby laser with a long pulse duration of 20 ms and fluence of 15–21 J/cm^2.[17] Even with long pulses, patients developed post-treatment hyperpigmentation. This ultimately resolved in all patients, but clearly would be a significant risk for those with even darker type V and VI skin. Liew et al. treated 24 patients with type V skin with a pulse width of 500 μs and a fluence of 13.1 J/cm^2.[18] Eight percent of patients experienced blistering, hypopigmentation, and hyperpigmentation. Finally, in a study conducted by Nanni et al., 15 patients were treated with a 3 ms pulse duration, at a mean fluence of 10.5 J/cm^2.[19] Of patients with type V skin, 37.8% experienced side effects including blistering and crusting as well as hypopigmentation, hyperpigmentation, and purpura.

The wavelength of the alexandrite laser is 755 nm and therefore penetrates more deeply, and is considered safer in darker skin types. In 150 dark-skinned patients (skin types IV–VI, 70 of which were types V and VI) treated with the alexandrite laser (18 J/cm^2, 40 ms), side effects occurred in about 3% of cases, and included blistering, folliculitis, transient hyperpigmentation, and transient hypopigmentation.[20] More severe reactions such as blistering were associated with type VI skin. Galadari evaluated 100 patients with types IV–VI skin using a pulse duration of 40 ms and a fluence of 20–40 J/cm^2.[21] Side effects included redness, superficial burn, scarring, hyperpigmentation, and hypopigmentation. Superficial burns occurred in 60%, pigmentary alteration in 48%, and scarring in 15% of patients. Nanni et al. treated 18 patients with the alexandrite laser with a 10 ms pulse duration and 10.8 J/cm^2 mean fluence. Side effects occurred in 37.7% of patients including blistering and crusting, as well as hypopigmentation, purpura, and hyperpigmentation.[19] This is similar to the side effect profile experienced with the use of the pulsed ruby laser.

Diode lasers have longer wavelengths ranging from 800 nm up to 1000 nm and are therefore even safer for use in dark skin types. Galadari treated 100 patients with types IV–VI skin with the diode laser with a 40 ms pulse duration, and a fluence of 20–40 J/cm^2.[21] Side effects included superficial burns in 30%, scarring in 6%, and dyspigmentation in 36%. Adrian et al. treated 40 patients with type V and VI skin with the 800 nm diode with a pulse duration of 30 ms and a fluence of 15–25 J/cm^2.[10] Only mild crusting and transient hyperpigmentation were observed. Greppi treated 8 patients with an 810 nm diode laser with a 30 ms pulse duration and a fluence of 10 J/cm^2.[22] Two patients experienced blistering, crusting, and hypopigmentation, while 3 experienced hyperpigmentation. Rogachefsky et al. reported the use of a super-long-pulsed 810 nm diode laser on 2 patients with type V and VI skin using a range of pulse durations and fluences. Acutely, blistering and the Nikolsky sign were only seen in the most aggressively treated areas (1000 ms pulse duration, 115 J/cm^2). Scarring was not observed, however hyperpigmentation and hypopigmentation developed in aggressively treated areas.[23]

The Q-switched Nd:YAG laser has a much longer wavelength of 1064 nm. The absorption of melanin at this wavelength is poor, and higher fluences must be used for effective hair removal. However, because of the deeper penetration by the laser, it is much safer to use in individuals with the darkest skin types. The Nd:YAG can penetrate 5–10 mm into the dermis, almost twice that of the 694 ruby laser. Galadari treated 100 patients with type IV–VI skin with a 9.5 ms pulse duration and fluence ranging from 30–120 J/cm^2.[21] Fourteen percent of patients experienced a superficial burn, while only 2% experienced scarring and hyperpigmentation. Alster et al. treated 20 patients with types IV–VI skin with a pulse duration of 50 ms and a fluence of 40–50 J/cm^2.[7] Adverse effects included vesiculation in 1.5%, and pigmentary alteration in 5%. Nanni and Alster evaluated 38 patients with type V skin with a 50 ns pulse duration and a mean fluence of 2.37 J/cm^2.[19] Adverse effects occurred in 25.2% of patients and included folliculitis, hypopigmentation, and hyperpigmentation. Tanzi and Alster treated patients with type V and VI skin with 30 ms pulse duration and fluences ranging from 30–60 J/cm^2.[24] Only transient hyperpigmentation was observed in 1% of the patients.

Finally, the intense pulsed light (IPL) system uses a xenon flashlamp to produce an incoherent multiwavelength pulsed light (550–1200 nm). By attaching one of a series of 4 filters (590 nm, 615 nm, 645 nm, 695 nm), shorter wavelengths are eliminated, and the treatment can be tailored to the skin type and hair color of the patient. Johnson and Dovale treated type VI patients with a 695 nm cut off filter, using fluences ranging from 34–45 J/cm^2 and a pulse duration of 3.6 ms and 110, 120, 130 ms delay between pulses.[25] They also treated a group of type VI patients with 645, 695, and 755 nm cut off filters, fluences ranging from 28–34 J/cm^2 and pulse durations of 3.6, 5, and 5.5 ms with an 80 or 90 ms delay between pulses. Some patients experienced burn pigmentation after the first treatment. Sadick et al. used a 695 nm cut off filter with a fluence of 38–40 J/cm^2, and pulse duration of 2.6 ms with 30 ms delay between pulses.[11] Temporary hyperpigmentation and superficial crusting were noted in patients with type V skin.

Although the reported results in the treatment of unwanted hair in darker skin types have been impressive, the overall effectiveness of laser hair removal in darker skin types seems to be lower than in lighter skin types. Garcia et al. reported a 40% reduction at 6 months after 3 treatments with the alexandrite laser.[20] Galadari reported a 50–60% reduction at 6 months with the use the alexandrite, diode, and Nd:YAG lasers.[21] Tanzi and Alster reported a 41–53% reduction depending on body site after 3 treatments at 6 months, with the long pulse Nd:YAG.[24] Previous reports of laser hair removal in skin types I–IV have shown approximately 71–85% hair reduction with the use of the alexandrite laser and 74–84% hair reduction with the diode laser.[26–29] The therapeutic discrepancy between white and darkly pigmented skin may be overcome by additional treatment sessions as demonstrated by Greppi who was able to achieve 75–90% hair reduction with 7–10 treatments with the diode laser.[22]

DISCUSSION OF COOLING

Light absorption by melanin leads to the release of heat and subsequent thermal damage to the epidermis. This may clinically result in dyspigmentation and scarring if the epidermis reaches a temperature above its threshold for denaturation (60–65°C).[30] Although often temporary, these results are undesirable. Higher fluences, which correlate with higher effectiveness, unfortunately lead to the generation of more heat, and therefore more potential for epidermal injury. A way to minimize this damage to the epidermis is through the use of cooling devices on the skin. There are many different cooling devices available depending on the laser or light system selected. The most important endpoint of these cooling devices is ability to cool the basal layer of the epidermis, as this is the most heavily pigmented area of the epidermis, and is therefore the most susceptible to injury.[8] With the use of cooling devices, higher fluences can be delivered to the hair follicle, increasing the effectiveness of the hair removal procedure.

These cooling devices can be divided into contact cooling devices and non contact cooling devices, based on whether there is direct contact with the skin surface.

Direct contact of the skin allows for the application of pressure to the surface which decreases the distance from the epidermis to the deeper follicular structures. The pressure also blanches the underlying vessels, minimizing the absorption of the laser energy by hemoglobin.

The most commonly used contact cooling device is the cooled sapphire tip. This material is nearly ideal because it is close to transparent in the 0.2–5 μm wavelength range, and is similar to metal with respect to its thermal conductivity.[8] Because of its high thermal conductivity relative to the low conductivity of the epidermis, the sapphire acts as a heat sink. It therefore mitigates heat produced by 2 different methods, first by actually chilling the skin, and second by absorbing heat after delivery of the pulse. In a study performed by Klavuhn and Green the tip was cooled to 5°C and pressed directly onto the skin surface overlying the target structure.[31] The tip remained on the skin surface for approximately 250–500 ms prior to the administration of the laser or light, and remained in contact with the skin for approximately 1 s after the pulse was delivered. During the precooling period the sapphire cooled the basal layer of the skin from 30 to 16°C. During the post-pulse period, the sapphire increased the rate at which the basal layer returned to its normal temperature. In the same study, patients that were treated with a room temperature tip held above the skin surface experienced significant pain and epidermal devitalization. In the case of 30–100 ms laser pulses, precooling of the skin by contact cooling for 0.5 to 1 s has been shown to provide adequate epidermal protection.[30]

The most common non-contact cooling device is cryogen spray cooling (also referred to as dynamic cooling). Tetrafluoroethane is the only cryogenic compound currently approved by the FDA for use in dermatologic surgery. It has a boiling point of –26°C at atmospheric pressure and is a nonflammable, nontoxic, and nonchlorinated Freon substitute. The liquid is dispersed into a fine spray onto the skin surface prior to the light pulse. In an analysis performed by Svaasand et al., precooling with cryogen spray is the only efficient technique for laser pulses less than 10 ms.[32] Cryogen spray may also be used for postcooling. Again, Svaasand et al. found this to be the most efficient method of shortening the time the epidermis remains at higher temperatures.

Forced air cooling is also a non-contact cooling device, but is much less efficient in cooling the epidermis effectively. Forced air cooling essentially blows precooled air onto the surface of the skin at temperatures as low as –30°C. In order for this to effectively cool the epidermis, several seconds of cooling time are needed to cause significant temperature reductions in the basal layer.[30]

As mentioned above, the skin may be pre-cooled, parallel cooled, or post-cooled, or any combination of the above. With very short pulse durations, pre-cooling is very important. For longer pulse durations, such as those used in laser hair removal, parallel cooling is more important. Post-treatment cooling may also be of some value, particularly in the relief of any pain and post-treatment swelling or edema associated with the procedure.

EMERGING TECHNOLOGY

A device combining IPL with radio frequency has been shown to have potential in treatment of darker skin patients as well as treating terminal white hairs.[33,34] The theory behind the device is the combined use of radiofrequency energy, which allows the use of less optical energy. The lower optical energy allows for the safer treatment of darker pigmented individuals. The radiofrequency energy is delivered using bipolar electrodes applied to the skin surface. The applied energy results in volumetric heating of the tissue and is measured in J/cm^3. The current generated follows the lowest impedance route between the two electrodes, independent of target chromophores. The cooled epidermis has higher impedance than the target follicle that is preheated by a light pulse, and therefore the epidermis conducts a lower current and has less heat transferred to it. The optical energy is chromophore-sensitive as with all laser or light sources. By heating the hair follicle deeper in the dermis it decreases the impedance, and allows for greater flow of radiofrequency energy. The depth of penetration of the radiofrequency current is half the distance between the electrodes (4 mm in this prototype). This depth allows for heat generation around the hair follicle.

CONCLUSIONS

Laser hair removal has become an increasingly popular procedure among all ethnic groups. Its efficacy arises by the preferential ablation of melanin bearing follicular cells in anagen phase, a process known as selective photothermolysis. Efficacy and safety in lighter skin types is well documented with a variety of laser types including pulsed ruby, alexandrite, diode, Q-switched Nd:YAG, and IPL. Fitzpatrick type V and VI skin poses special challenges, however, and clinical results in these patients may be less impressive than those seen in lighter skinned individuals. Contributing factors include, but are probably not limited to, the increased number and more diffuse distribution of epidermal melanin, and the spiral geometry of the hairs and their follicles. In particular, these patients are more likely to experience post-treatment burns, crusting, purpura, hyper- and hypopigmentation, and scarring. The use of longer pulse durations coupled with good parallel cooling devices allow the procedure to be performed with minimal risks. In the future, there may be technology that relies less on pigmentation as a target, and is therefore less risky for treating the darkest skin types.

REFERENCES

1 Yamauchi PS, Kelly AP, Lask GP. Treatment of pseudofolliculitis barbae with the diode laser. J Cutan Laser Ther 1999; 1: 109–11.
2 Smith EP, Winstanley D, Ross EV. Modified superlong pulse 810 nm diode laser in the treatment of pseudofolliculitis barbae in skin types V and VI. Dermatol Surg 2005; 31: 297–301.
3 Parlette EC, Kroeger N, Ross EV. Nd:YAG laser treatment of recalcitrant folliculitis decalvans. Dermatol Surg 2004; 30: 1152–4.
4 Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983; 220: 524–7.
5 Lepselter J, Elman M. Biological and clinical aspects in laser hair removal. J Dermatolog Treat 2004; 15: 72–83.
6 Paus R, Cotsarelis G. The biology of hair follicles. N Engl J Med 1999; 341: 491–7.
7 Alster TS, Bryan H, Williams CM. Long-pulsed Nd:YAG laser-assisted hair removal in pigmented skin. Arch Dermatol 2001; 137: 885–9.
8 Zenzie HH, Altshuler GB, Smirnov MZ, Anderson RR. Evaluation of cooling methods for laser dermatology. Lasers Surg Med 2000; 26: 130–44.
9 Ross EV, Ladin Z, Kreindel M, Dierickx C. Theoretical considerations in laser hair removal. Dermatol Clin 1999; 17: 333–55.
10 Adrian RM, Shay KP. 800 nanometer diode laser hair removal in African American patients: a clnical and histologic study. J Cutan Laser Ther 2000; 2: 183–90.
11 Sadick NS, Weiss RA, Shea CR et al. Long-term photoepilation using a broad-spectrum intense pulsed light source. Arch Dermatol 2000; 136: 1336–40.
12 Montagna W, Carlisle K. The architecture of black and white facial skin. J Am Acad Dermatol 1991; 24: 929–37.
13 Kaidbey KH, Agin PP, Sayre RM, Kligman A. Photoprotection by melanin-a comparison of black and Caucasian skin. J Am Acad Dermatol 1979; 1: 249–606.
14 Sperling LC. Hair density in African Americans. Arch Dermatol 1999; 135: 656–8.
15 Whitmore SE, Sago NJ. Caliper-measured skin thickness is similar in white and black women. J Am Acad Dermatol 2000; 42: 76–9.
16 Taylor SC. Skin of color: biology, structure, function, and implications for dermatologic disease. J Am Acad Dermatol 2002; 46: S41–62.
17 Elman M, Klein A, Slatkine M. Dark skin tissue reaction in laser assisted hair removal with a long-pulse ruby laser. J Cutan Laser Ther 2000; 2: 17–20.
18 Liew SH, Grobbelaar A, Gault D et al. Hair removal using the ruby laser: clinical efficacy in Fitzpatrick skin types I-V and histological changes in epidermal melanocytes. Br J Dermatol 1999; 140: 1105–9.
19 Nanni CA, Alster TS. Laser-assisted hair removal: side effects of Q-switched Nd:YAG, long-pulsed ruby, and alexandrite lasers. J Am Acad Dermatol 1999; 41: 165–71.
20 Garcia C, Alamoudi H, Nakib M, Zimmo S. Alexandrite laser hair removal is safe for Fitzpatrick skin types IV-VI. Dermatol Surg 2000; 26: 130–4.
21 Galadari I. Comparative evaluation of different hair removal lasers in skin types IV, V, and VI. Int J Dermatol 2003; 42: 68–70.
22 Greppi I. Diode laser hair removal of the black patient. Lasers Surg Med 2001; 28: 150–5.
23 Rogachefsky AS, Silapunt S, Goldberg DJ. Evaluation of a new super-long-pulsed 810 nm diode laser for the removal of unwanted hair: the concept of thermal damage time. Dermatol Surg 2002; 28: 410–14.
24 Tanzi EL, Alster TS. Long-pulsed 1064-nm Nd:YAG laser-assisted hair removal in all skin types. Dermatol Surg 2004; 30: 13–17.

25 Johnson F, Dovale M. Intense pulsed light treatment of hirsutism: case reports of skin phototypes V and VI. J Cutan Laser Ther 1999; 1: 233–7.
26 Lloyd JR, Mirkov M. Long-term evaluation of the long-pulsed alexandrite laser for the removal of bikini hair at shortened treatment intervals. Dermatol Surg 2000; 26: 633–7.
27 Eremia S, Li C, Newman N. Laser hair removal: long-term results with a 755nm alexandrite laser. Dermatol Surg 2001; 27: 920–4.
28 Eremia S, Li C, Newman N. Laser hair removal with alexandrite versus diode laser using four treatment sessions: 1-year results. Dermatol Surg 2001; 27: 925–30.
29 Lou WW, Quintana AT, Geronemus RG et al. Prospective study of hair reduction by diode laser (800 nm) with long-term follow-up. Dermatol Surg 2000; 26: 428–32.
30 Svaasand LO, Nelson JS. On the physics of laser-induced selective photothermolysis of hair follicles: influence of wavelength, pulse duration, and epidermal cooling. J Biomed Opt 2004; 9: 353–61.
31 Klavuhn KG, Green D. Importance of cutaneous cooling during photothermal epilation: theoretical and practical considerations. Lasers Surg Med 2002; 31: 97–105.
32 Svaasand LO, Randeberg LL, Aguilar G et al. Cooling efficiency of cryogen spray during laser therapy of skin. Lasers Surg Med 2003; 32: 137–42.
33 Yaghamai D, Gargen JM, Bakus AD et al. Hair removal using a combination radio-frequency and intense pulsed light source. J Cosmet Laser Ther 2004; 6: 201–7.
34 Goldberg DJ, Marmur ES, Hussain M. Treatment of terminal and vellus non-pigmented hairs with an optical/bipolar radiofrequency energy source-with and without pre-treatment using topical aminolevulinic acid. J Cosmet Laser Ther 2005; 7: 25–8.

7 LASER HAIR REMOVAL OF NON-PIGMENTED HAIRS

KEY POINTS

(1) Photoepilation of light hair is significantly more challenging than that of dark hair
(2) The application of exogenous liposomal melanin may temporarily augment the naturally occurring follicular melanin chromophore, and thus enhance laser photoepilation
(3) The use of radiofrequency technology in conjunction with a light-based source system provides enhanced epilation by combining the principles of selective photothermolysis and electrothermolysis
(4) Phototodynamic therapy (PDT) may provide the best chance of removing non-pigmented hairs

BACKGROUND

The use of laser and light devices has revolutionized the treatment of unwanted hair in the last decade. Various systems have been found effective for photoepilation of black to brown hair. However, for a particular segment of the population with light, blond, and red hair, safe and effective hair reduction has been difficult to achieve using the current technology. The reason for this challenge is the premise for photoepilation. Most available systems operate on the basis of the principle of selective photothermolysis. Discriminate targeting of the hair follicle apparatus by laser and non-laser light sources is achieved when optical energy of sufficient quantity to produce thermal damage is selectively absorbed by the follicle by virtue of the chromophore differential between it and the surrounding cutaneous tissue. The chromophore in this case is melanin found within the hair shaft, follicular epithelium, and the hair matrix. Nevertheless, the surrounding tissue may be heated significantly in the process of dissipation of this optical energy. Thus, the effectiveness of any system depends largely on the amount of melanin present within the follicle, and its safety or the relative lack thereof in the surrounding skin. Consequently, the selectivity becomes increasingly elusive as the target hair considered for epilation becomes comparably less melanized in comparison with the surrounding skin.

In order to overcome this difficulty, the area with superfluous hair growth may be pre-treated with a liposomal melanin preparation to augment the naturally occurring melanin chromophore within the follicular structures.

In addition, a new technology has been introduced that employs an electrical, rather than optical, energy to target the hair follicle that does not rely on melanin as a chromophore. The principle guiding this system is selective electrothermolysis. This type of system utilizes a radiofrequency (RF) current delivered to a tissue between a single treatment electrode and a ground electrode positioned far removed from the treatment area in a unipolar system, or between two treatment electrodes in a bipolar system. The heating produced by this technology depends on the electrical properties of the treated tissue, rather than on the absorption by a chromophore.[1–4]

Recently, the principles of photothermolysis and electrothermolysis have been combined in a technology that delivers both light energy in the form of non-coherent intense pulsed light (IPL) and electrical energy in the form of RF. The premise for combining the 2 forms of energy is based on the fact that increasing the temperature of the follicle by a light source via melanin chromophore heating decreases its impedance to electrical current, thus concentrating the delivered RF energy and producing a more targeted follicular heating. Furthermore, the RF energy is diverted downward and away from the epidermis as a result of surface cooling provided by the system's applicator tip. Therefore, heat-related epidermal damage is minimized.[1–4]

Whereas chromophore-based photoepilation heats up the follicle in an outward fashion beginning at the hair shaft, chromophore-independent RF is concentrated in the 20–40 micron area around the hair, which includes the outer root sheath and the bulge area, an important target for achieving hair reduction. The RF-generated heat wave then proceeds inward toward the center of the follicle.[1–4]

Another advantage of RF, compared with light-based technologies, is the lack in the former of reflection and scattering, permitting greater control over the amount of energy delivered to the tissue. The continuous measurement of current and electric potential between the electrodes of the RF system allows the delivery of a precise amount of energy to the treated area.[2–5]

Combining the light and electrical technologies allows for lower energy levels to be provided by either system to achieve epilation, thus minimizing toxicity to the surrounding tissue resulting from non-selective heat transfer. Thus, the combined light/RF system can more effectively produce epilation in less melanized lighter hair, while at the same time providing greater safety when treating excessive hair growth in patients with darker skin.[1,3,5]

CLINICAL STUDIES

In their 1999 study of the long-pulsed Nd:YAG laser for photoepilation, Bencini et al. included 2 patients with white hair, 78 patients with blond hair, and 4 patients with red hair. The subjects received 3–6 monthly treatments with a long-pulsed Nd:YAG laser at 23–56 J/cm^2 of energy with 3–4 mm spot size. Hair reduction of 30–40% was noted for patients with blond hair, 20–30% for those with red hair. No hair reduction was observed for white hair. The authors also noted that significantly less burning sensation was experienced by the subjects with white, red, and blond hair, despite the higher fluences used in this group, compared with patients having darker hair. The authors contributed the relative success of photoepilation using the long-pulsed Nd:YAG laser in the treatment of light hair to an as of yet unknown melanin chromophore-independent factor.[6]

In their study of long-pulsed Nd:YAG laser for photoepilation involving 42 subjects with Fitzpatrick skin types I–IV, Raff et al. had included 12 persons with blond hair. Hair counts were performed at 1 year following 5 monthly treatments. The following hair reduction rates were noted for a given set of treatment parameters: 37% at 40 J/cm^2 of fluence, 50 msec pulse duration, and 10 mm spot size; 25% at 40 J/cm^2 of fluence, 10 msec pulse duration, and 5 mm spot size; 33% at 40 J/cm^2 of fluence, 20 msec pulse duration, and 5 mm spot size; 13% at 75 J/cm^2 of fluence, 20 msec pulse duration, and 5 mm spot size; and 37% at 40 J/cm^2 of fluence, 20 msec pulse duration, and 7 mm spot size. The authors concluded that greater hair reduction may be expected with the use of longer pulse durations and larger spot sizes. The authors also noted that changes in the parameters did not affect the incidence of side effects.[7]

In 2005, Rao and Goldman conducted a prospective study where they compared the use of the diode, alexandrite, and Nd:YAG lasers for photoepilation of axillary hair. Of the 20 female subjects with Fitzpatrick skin type II enrolled in the study, 3 had red or light-colored hair. Systems used in the study included the 810 nm diode laser with fluence of 25 J/cm^2, pulse duration of 30 msec, and a 12 mm spot size; a long-pulsed 755 nm alexandrite laser with fluence of 18 J/cm^2, pulse duration of 10 msec, and a 12.5 mm spot size; and a long-pulsed Nd:YAG laser with fluence of 75 J/cm^2, pulse duration of 10 msec, and a spot size of 7 mm. Three months post-treatment, the authors noted that the red and light-colored hair removal was 5–15% less effective compared with that of the 755 nm alexandrite (59.3 ± 9.7%), 810 nm diode (58.7 ± 7.7%), 1064 nm Nd:YAG (31.9 ± 11.1%), and the rotational regimens (39.8 ± 10.1%). No dyspigmentation or scarring was reported in the study.[8]

Sand et al. performed a randomized, controlled, double-blind study in 2007 to determine whether melanin-encapsulated liposomal spray application improves the efficacy of laser hair removal of blond, white, and gray hair. Two 16-patient groups of both female and male subjects with Fitzpatrick skin type II received 3 treatments with 800 nm diode laser at 8 week intervals, with fluences of 22–36 J/cm^2 and pulse duration of 30 msec, with contact cooling. Each group was randomized to receive either the liposomal melanin spray (Lipoxome; Dalton Medicare B.V., Zevenbergschen Hoek, The Netherlands) or the 0.9% NaCl saline solution, with 6 morning and 6 evening applications for 8 weeks prior to each laser treatment. The authors observed a mean hair reduction of 17% at 8 weeks post-therapy in the treatment group, compared with 13% in the control group. Six months following therapy, a 14% reduction was noted in the treatment group when compared with 10% hair reduction in the control group. Although both differences were statistically significant ($p < 0.05$), the authors note that the 2 groups exhibited clinically comparable results. The incidence of minor side effects (56%) in the treatment group, including small perifollicular urticae (12.5%), mild erythema (31%), and folliculitis (12.5%), was significantly greater than in the control group (12.5% with mild erythema). No permanent pigment alteration or scarring was noted in either group.[9]

In 2004, Sadick and Laughlin conducted a study to evaluate the efficacy of a combined IPL and bipolar RF device in photoepilation of white and blond hair. Thirty-six female subjects 38–83 years of age with Fitzpatrick skin types I–V having either blond or white hair, underwent 4 treatments over a 9–12 month period to the chin or the upper lip areas. The authors utilized a 680–980 nm IPL device with fluences of 24–30 J/cm^2 and pulse duration up to 120 msec, combined with a bipolar RF device with energy of 20 J/cm^3 and pulse duration up to 120 msec with current delivery at 4 mm of depth. The investigators found an average clearance of 48%, observed at 6 months following the final treatment. Photoepilation was noted to be slightly better in the subjects with blond hair (52%) compared with those with white hair (44%). The authors attributed this difference in efficacy to augmentation of the chromophore-independent RF heating by the IPL-associated optic targeting of the low-melanin chromophore in the blond hair, which is absent in the white hair that lacks melanin completely. The authors also observed a decreased response in 2 older patients with coarse white hair, which may be explained by the larger surface area that must be heated by the RF component to provide an effective photoepilation.[4]

In 2004, Sadick and Shaoul reported on the efficacy and safety of photoepilation using a combined intense pulsed light/bipolar radiofrequency technology (IPL/RF). Forty subjects with Fitzpatrick skin types II–V and various hair colors participated in the study. The authors treated a total of 5 sites containing blond hair, 3 sites with red hair, and 3 sites with white hair. Four treatments were given at 8–12 week intervals over 9–12 months. Light energy ranged from 15 to 26 J/cm^2, while RF energy varied from 10 to 20 J/cm^3. Higher optical energies were used for lighter skin and hair color. Radiofrequency energies of 18–20 J/cm^3 were generally used for most treatment areas, except non-facial sites or areas with dense hair, where reduced RF energies (10–14 J/cm^3) were applied. The device provided 200 msec-long pulses, with RF current penetration of 4 mm in depth. Contact cooling (5°C) was also utilized. The authors note a progressive decrease in hair density with each treatment, with maximal hair reduction occurring at 6–8 weeks post-treatment. Light hair clearance was 60% for blond and red hair, and 40% for white hair. This compared to 80 and 85% for brown and black hair, respectively. The efficacy of photoepilation was independent of the Fitzpatrick skin type. Mild erythema resolving within 24 hours was noted in 20% of patients.[10]

Similarly, Del Giglio and Shaoul have conducted a multicenter study to determine the efficacy of photoepilation using combined IPL/RF technology. Of the 60 patients with Fitzpatrick skin types II–V with various hair colors enrolled in the study, 12 patients had white or blond hair. Treated areas included the face, axillae, and legs. The system delivered optical energies of 15–28 J/cm^2 and RF energies of 10–120 J/cm^3. The subjects received a total of 3 treatments at 6–8 week intervals. The authors reported maximal hair reduction at 2–8 weeks post-treatment. At 6 month follow up, average clearance of blond and white hair was 52%. The treatments were well tolerated by the patients. The authors reported only transient post-treatment erythema disappearing within hours as the only side complication.[11]

In 2005, Goldberg et al. conducted a study involving 15 adult female subjects, 10 of whom had white terminal hairs and 5 of whom had fine facial vellus hairs. Two treatments at 4–6 week intervals to the entire face were performed using the combined pulsed light bipolar radiofrequency device at optical fluences of 24–30 J/cm^2 and RF energy of 20 J/cm^3. One half of each subject's face was pre-treated 1 hour prior with 20% 5-aminolevulinic acid (ALA). At 6 month follow-up, average hair removal was 35% for terminal white hair not pre-treated with ALA, compared with 48% for that pre-treated with the solution. No hair removal was achieved for subjects with vellus hair. Mild erythema lasting less than 24 hours was reported in 20% of areas not pre-treated with ALA, and lasting 48–72 hours in 60% of areas pre-treated with ALA. No blistering, scarring, or long-term dyspigmentation was reported. The authors proposed that some melanin pigment within the hair follicle must be present, even if not within the hair shaft itself, as in the case of white hair, for effective epilation. They further noted that although RF energy alone does not seem to provide epilation, the synergistic combination of RF and light energies augments the effects of light energies alone. Furthermore, ALA could represent a valuable exogenous photosensitizer in the photoepilation of hair beyond its application in the white hair treatment.[12]

Similar results have now been observed with a variety of laser and lights sources — even without the use of RF. Such a photodynamic phototherapeutic (PDT) approach may ultimately represent the best approach to treat non-pigmented hair.

In 2006, Schroeter et al. reported a study that involved 17 patients (mean age 57.4 years) with Fitzpatrick skin types I–II having blond hair, who received a mean of 4–12 treatments (mean 8.5) with the combined RF light based device with optical energies ranging from 21 to 26 J/cm^2 (mean 23.2 J/cm^2) and radiofrequency energies in the range of 10–20 J/cm^3 (mean 18.6 J/cm^3). The authors reported hair reduction of between 0 and 95% (mean 57.4%). Although no correlation was noted between percent hair reduction and light/RF energies utilized, the authors noted a positive trend in hair removal with increasing number of treatments. The authors reported no major side effects associated with treatment.[5]

In a 2004 study by Yaghmai et al., 7 patients with blond hair were treated once with the combined IPL-RF system, at 680–980 nm wavelength range, using optical energy fluences of 14–30 J/cm^2 (mean 24 J/cm^2) and RF energies of 10–20 J/cm^3 (mean 15 J/cm^3). Pulse durations used were 25 msec for IPL and 200 msec for RF. Contact cooling at 5°C was used. Mean hair reduction reported by the authors 3 months post-treatment was 35%. This compared with 43% for black, and 49% for brown hair also treated in this study.[13]

CONCLUSIONS

A variety of methods have been used to treat non-pigmented hairs, none with results that compare to those seen with the treatment of pigmented hairs. It may be that either combined RF/IPL or PDT treatment may represent the best approach for the treatment of non-pigmented hairs.

REFERENCES

1 Sadick NS. Combination radiofrequency and light energies: electro-optical synergy technology in esthetic medicine. Dermatol Surg 2005; 31: 1211–17.
2 Sadick NS, Sorhaindo L. The radiofrequency frontier: a review of radiofrequency and combined radiofrequency pulsed-light technology in aesthetic medicine. Facial Plast Surg 2005; 21: 131–8.
3 Sadick NS, Makino Y. Selective electro-thermolysis in aesthetic medicine: a review. Lasers Surg Med 2004; 34: 91–7.
4 Sadick NS, Laughlin SA. Effective epilation of white and blond hair using combined radiofrequency and optical energy. J Cosmet Laser Ther 2004; 6: 27–31.
5 Schroeter CA, Sharma S, Mbonu NC, Reineke T, Neumann HAM. Blond hair removal using ELOS systems. J Cosmet Laser Ther 2006; 8: 82–6.
6 Bencini PL, Luci A, Galimberti M, Ferranti G. Long-term epilation with long-pulsed neodymium:YAG laser. Dermatol Surg 1999; 25: 175–8.
7 Raff K, Landthaler M, Hohenleutner U. Optimizing treatment parameters for hair removal using long-pulsed Nd:YAG-lasers. Lasers Med Sci 2004; 18: 219–22.
8 Rao J, Goldman MP. Prospective, comparative evaluation of three laser systems used individually and in combination for axillary hair removal. Dermatol Surg 2005; 31: 1671–7.
9 Sand M, Bechara FG, Sand D, Altmeyer P, Hoffmann K. A randomized, controlled, double-blind study evaluating melanin-encapsulated liposomes as a chromophore for laser hair removal of blond, white, and gray hair. Ann Plast Surg 2007; 58: 551–4.
10 Sadick NS, Shaoul J. Hair removal using a combination of conducted radiofrequency and optical energies — an 18-month follow-up. J Cosmet Laser Ther 2004; 6: 21–6.

11 Del Giglio A, Shaoul J. Hair removal using a combination of electrical and optical energies — multiple treatments clinical study six months follow up. Yokneam (Israel): Syneron Medical Ltd; 2002. (http://www.syncron.com/assets/downloads/pdf/elosHairClinical.pdf)
12 Goldberg DJ, Marmur ES, Hussain M. Treatment of terminal and vellus non-pigmented hairs with an optical/bipolar radiofrequency energy source — with and without pre-treatment using topical aminolevulinic acid. J Cosmet Laser Ther 2005; 7: 25–8.
13 Yaghmai D, Garden JM, Bakus AD et al. Hair removal using a combination radio-frequency and intense pulsed light source. J Cosmet Laser Ther 2004; 6: 201–7.

8 LASER HAIR REMOVAL APPROACHES

KEY POINTS

(1) No method of consistent 100% hair removal exists
(2) The ideal interval between laser hair removal sessions remains unclear
(3) The ideal number of laser hair removal sessions remains unknown
(4) Surprisingly few guidelines exist regarding pre-laser site preparation in patients undergoing laser hair removal

INTRODUCTION

The desire to effectively remove unwanted body hair is a trend that continues to become more prevalent in our society, and photoepilation by laser or other light-based technology is one of the fastest growing procedures in cosmetic dermatology.[1] Excess hair growth ranges in severity and may present as hypertrichosis or hirsutism.[2] Hirsutism refers to abnormal hair growth in women in androgen-dependent sites while hypertrichosis is excess hair growth in any body site. There are many methods that temporarily treat unwanted hair, including: bleaching, plucking, shaving, waxing, and chemical depilatories.[3,4] These methods can be inconvenient and tedious, and they may produce unwanted side effects such as irritation and infection of the skin. Electrolysis offers a more permanent hair removal by inserting a fine needle deeply into the hair follicle and using electricity to destroy the follicle, but is monotonous and the efficacy in achieving permanent hair removal is variable. Tolerance is variable among patients.[5] Side effects of these methods vary significantly and are operator dependent.

To date, no method of 100% permanent hair eradication is available. The United States Food and Drug Administration (FDA) has defined permanent hair removal as: 'the long-term, stable reduction in the number of hairs re-growing after a treatment regime, which may include several sessions. The number of hairs regrowing must be stable over time greater than the duration of the complete growth cycle of hair follicles, which varies from four to twelve months according to body location. Permanent hair reduction does not necessarily imply the elimination of all hairs in the treatment area' (http://www.fda.gov/cdrh/consumer/laserfacts.html). Laser hair removal offers 'permanent hair loss' in the sense that lasing leads to a significant reduction in the number of terminal hairs after a given treatment, thereby giving a clinical appearance of considerable hair reduction without affecting the actual number of hair follicles. Most of the devices in use today produce a partial reduction in hair growth and short-term data on laser and light source hair removal suggest a temporary loss lasting at least 3 months.[6] It is important for patients to have realistic expectations for long-term results from laser hair removal. To date, there are no long-term studies (beyond 2 years) regarding efficacy of laser hair removal.[2]

Laser treatment has quickly become the treatment of choice for removal of unwanted hair; however, the recommended treatment parameters remain vague. As described throughout this text, the various techniques that are currently available for photo-epilation operate in the red or near-infrared wavelengths and include alexandrite laser (755 nm), diode laser (800–810 nm), Nd:YAG (neodymium:yttrium-aluminum-garnet) laser (1064 nm), and myriad intense pulsed lights (IPL) (590–1200 nm).[7–10] The ruby laser, although among the first to be used for laser hair removal, is now of mostly historical interest.

MECHANISM OF HAIR GROWTH

In order to better understand the mechanism of laser hair removal, one must first examine the hair growth cycle. The human hair follicle grows in 3 successive phases: active growth (anagen), regression (catagen), and resting (telogen). During anagen, mitotic activity occurs in the hair matrix, and hair is generated by these proliferating cells.[11] The dermal papilla undergoes a burst of cell proliferation during this phase.[12] Almost 100% of the matrix cells are involved in continuous replication; these transient amplifying cells eventually become exhausted and undergo terminal differentiation, resulting in catagen.[13] Therefore, the length of anagen is directly related to the function of the matrix cells.[14] During late telogen or early anagen the slow-cycling cells of the bulge area are activated by dermal papilla cells, leading to a proliferation of some cells in the bulge area, which forms a downgrowth.[15] The dermal papilla is pushed away from the bulge, and as this occurs, the bulge stem cells return to their normal quiescent, slow-cycling state in midanagen.

The percentage of hair follicles in the anagen and telogen phases varies among different parts of the body. It is hypothesized that growth delay and permanent hair loss may be caused by telogen induction, and miniaturization of terminal hair follicles. Approximately 85% of the scalp hairs, 56–76% of the facial hairs, and only 42–51% of the hairs on the limbs are in the anagen phase. The length of the hair cycles also differs depending on location. The cycle is a few years for scalp hairs and 4 to 10 months on other parts of the body.[16]

Recent evidence suggests that most stem cells reside in the bulge region of the hair follicle.[14,15,17] There are biological advantages for follicular stem cells to be located in the bulge area instead of the lower bulb. Cells in the bulge area are in the permanent region of the hair follicle and do not undergo cyclic degeneration as the hair bulb does. The position of the bulge cells allows convenient interaction with the upcoming dermal papilla as well as the new follicular downgrowth during early anagen. Finally, the basal cells of the bulge form an outgrowth that points away from the hair shaft and this safeguards against accidental loss due to plucking.[14] The average length of the adult hair follicle is approximately 3.85 mm and the bulge region exists at approximately two-thirds of the way down the follicle, or about 2.56 mm depth.[17]

MECHANISM OF LASER HAIR REMOVAL

Light can destroy hair follicles via 3 mechanisms: thermal (due to local heating), mechanical (via shock waves or violent cavitation), and photochemical (through generation of toxic mediators like singlet oxygen or free radicals).[18] Laser hair removal is thought to work through selective damage to the hair follicles and this mechanism is based on the principles of selective photothermolysis.[19] Melanin acts as the chromophore for targeting hair follicles, and the lasers or light sources that are used for hair removal lie within the optical window of the electromagnetic spectrum where absorption by melanin and deep penetration into the dermis are combined. Within the 600–110 nm region, deep and selective heating of the hair shaft, hair follicle epithelium, and hair matrix is possible while selective cooling of the epidermis minimizes epidermal injury and damage to epidermal melanin.[20] Appropriate selection of wavelength, pulse duration, and fluence are important in optimizing the hair removal while minimizing any potential side effects. A laser pulse that is too long can cause heat damage to the surrounding tissues, resulting in permanent scarring.[21]

The normal mode ruby laser (NMRL) is one of the lasers that have been used as a depilatory. This laser only penetrates approximately 2 mm and the bulge region of the hair follicle lies deeper than 2 mm, therefore, it may be suggested that the lack of penetration to this area contributes to the poor depilatory results of this laser. An energy loss of up to 50% may occur as the laser penetrates through the first 1 mm of skin, and Topping et al. postulate that approximately 50% of the incident fluence reaches both the bulge region and the hair bulb.[22]

When choosing treatment parameters, several factors must be considered. The hair cycle is important as the frequency of treatment must be timed to treat the hair in the anagen cycle when hair is more heavily melanized, however, as discussed below, there is controversy as to whether or not the hair cycle phase truly impacts laser hair removal effectiveness. Additionally, the hair diameter affects the optimal thermal relaxation time and pulse width.[23] In order to obtain spatial confinement of thermal damage, the pulse duration must be shorter than or equal to the thermal relaxation time of the hair follicle; a thicker hair follicle will have a longer thermal relaxation time than a thinner hair. Thermal relaxation times of human terminal hair follicles are estimated to vary between 10–50 msec.[24-26] Q-switched lasers operate within the nanosecond domain; therefore, they have a very small spatial scale of thermal confinement. Because of this property, these lasers damage individual pigmented cells within the hair follicles and confine heat. This property prevents any effective hair loss by Q-switched lasers. The depth of hair root (which impacts on the chosen wavelength, spot size, and energy) as well as the color of hair (which is directly related to the amount of melanin present) will also help in determining the most effective treatment parameters.[23]

Prior to treatment, the possibility of adverse effects must be discussed with patients. Adverse events include, but are not limited to: hyperpigmentation, hypopigmentation, erythema, edema, scarring, pain, and blistering.[27]

Beyond understanding the basic mechanics of laser hair removal, physicians seek to determine what the recommendations are regarding the ideal interval between sessions, what is the ideal number of sessions, should patients pluck, wax, or shave prior to undergoing laser hair removal, and what are the recommendations regarding sun exposure before and after treatment. Additionally, there are areas that should not be treated with laser hair removal. These guidelines are important in order to optimize treatment results and patient satisfaction while minimizing potential side effects.

WHAT IS THE IDEAL INTERVAL BETWEEN SESSIONS?

The most appropriate hair cycle phase for treatment and which elements within the follicular unit should be targeted are still a matter of debate. Traditional thought is that only anagen hairs respond to laser or intense light pulses.[28] This has been partially attributed to the fact that anagen hair bulbs contain the highest concentration of melanin,[29] and in humans, the melanin within the pigmented hair shaft serves as the dominant chromophore;[1,30] hair follicles contain a greater density of melanocytes and larger melanosomes when compared to the epidermis. As the hair follicles enter catagen, melanogenesis ceases, thereby reducing pigmentation of the subsequent telogen-stage bulbs. This reduction in melanin concentration is proposed to make the telogen hairs less susceptible to laser pulses.[29,31,32] Kolinko et al. confirmed this theory with the use of a Q-switched Nd:YAG laser. After treatment, areas with high numbers of anagen hairs had a greater decrease in hair density than areas with lower anagen counts. They also showed that total hair loss after treatment is less than anagen hair loss, and that there was an apparent lack of response in telogen hairs following laser treatment. It is important to note that untreated hairs have asynchronous growth cycles. In order to be effective, the laser or light source should damage one or more of the growth centers of the hair including the bulge cells, the dermal papilla, and the hair matrix.[1]

Anagen follicles may convert to telogen hairs after lasing, however the hairs may or may not fall out soon after this conversion. Anagen hairs can grow for a week or more before converting to telogen.[29] Histologically, it has been demonstrated in long-term follow up that there are an identical number of hairs when comparing the control and laser-treated sites, however, in the laser-treated sites, there is a significant reduction in the number of large terminal hairs and a reciprocal increase in the number of small vellus hairs.[28]

Another proposed mechanism of laser hair removal is through destruction of follicular stem cells that regenerate the epidermis and its adnexal structures; there is experimental evidence to suggest that selective destruction of follicular stem cells alone will prevent hair regrowth[33] because the bulge region of the follicle contributes to the newly forming hair matrix after induction by the dermal papillae during late telogen. Follicular stem cells reside in the bulge region of the hair follicle. A recent study[34] examined the effects of laser-mediated hair removal (using a diode laser or an Nd:YAG laser) on immunohistochemical staining properties of hair follicles. Investigators found that the external root sheath and hair bulb were essentially intact. There was mild but variable thinning of the follicular epithelium at the isthmus and infundibulum. The hair shaft itself showed a thinned and shriveled appearance, and many follicles were entirely devoid of a hair shaft after treatment. Some specimens demonstrated focal alteration of the internal root sheath. Using cytokeratins 15 and 19 as biomarkers for follicular stem cells, and CD34, which is a surface protein in the suprabulbar outer root sheath and is either very low or entirely absent in the bulge region of human hair follicles, the authors examined the properties of the follicle following laser treatment. They found that the immunohistochemical markers for the cells of the bulge region had a similar staining pattern before and after laser treatment, thereby suggesting that if the follicular stem cells are altered by the treatment, the changes are not detectable immunohistochemically. The authors postulated that there may be a functional change that results or that the laser may target other areas of the hair follicle. Additionally, since the stem cells play an important role in wound healing and epithelial regeneration, the fact that these cells are not destroyed by laser treatment supports the safety of laser hair removal. There is debate as to whether or not the hair follicle is able to regenerate from the bulge area if the papilla is destroyed.

There are differences in anagen:telogen ratio depending on the area that is treated. For example, the axillae and bikini areas have a higher anagen:telogen ratio than the legs, arms, and chest;[29,35] therefore, it may be suggested that these areas would respond better to laser hair removal with more noticeable differences in hair density. Telogen may last a few months on the face and for several months on the legs and thighs; scalp hair remains in anagen for 2–5 years.[23] There are also seasonal variations in hair growth. Beard hair grows faster during the months leading from winter to summer and slower during the months leading from summer to winter.[36] Additionally, there are differences in hair growth rates between men and women secondary to hormones and underlying genetic susceptibilities.[37] All of these factors must be taken into account when selecting the interval between treatments.

In a study by Chana et al., the median hair-free interval after the final treatment in 346 patients was 8 weeks. There was no overall difference in the hair-free period between males and females except in regard to facial hair. The median hair-free interval on males was 3.6 weeks as opposed to 8.8 weeks on female faces.[16] There was a progressive increase in the hair-free period after repeat treatments. The authors concluded that the hair-free interval is helpful in assessing treatment efficacy, and that in a significant number of patients, laser treatment may not cause permanent depilation but it may prolong the telogen phase of hairs.

Bouzari et al. studied 24 females who received laser hair removal with an 800 nm diode laser to the face or neck areas after ceasing any other hair removal methods for 2 months prior to laser treatment.[9] The patients received between 2 and 3 sessions of laser hair removal and were treated at intervals of 45 days, 60 days, or 90 days. The patients were seen in follow-up 5 months after receiving the laser treatments. The authors found that the shorter the treatment interval, the more the hair was reduced. The mean hair reduction was 78.1%, 45.8%, and 28.7% for the 45, 60, and 90 day interval groups respectively.

The ideal treatment interval remains a matter of debate. Bouzari et al. suggested that a shorter treatment interval is more effective.[9] However, their study was confounded by differences in total number of treatments among the groups (2 or 3 treatments). In the guidelines set by the European Society for Laser Dermatology, Drosner and Adatto recommended treatments every 4–8 weeks.[39] In conclusion, most clinicians recommend an interval of 6–8 weeks in general; however, this may vary depending on the region of the body that is being treated.

WHAT IS THE IDEAL NUMBER OF SESSIONS?

To date, there has been no formal recommendation regarding the ideal number of sessions, and formal studies in this area are limited. It is likely that the number of sessions will vary depending on the area and individual hair growth characteristics, body site, and type of laser; however, further research is needed. All investigators agree that efficacy is improved when repetitive treatments are given, and this is discussed in further detail below. Repeated treatments may synchronize the anagen phase by induction and/or shortening of the telogen phase which could lead to increased effectiveness of hair removal at each consecutive treatment.[5,31] Alternatively, the follicle may show growth arrest after one shortened anagen cycle.[40,41]

The alexandrite and diode lasers produce good long-term hair reduction (84–85%) 12 months postoperatively after 4 repetitive axillary treatments.[42]

In one study, 3 treatments with the alexandrite laser produced a mean 74% reduction in hair compared to 4 treatments of electrolysis, which produced only a 35% mean reduction 6 months postoperatively).[43] A large study (n = 144) in an Asian population evaluated hair removal efficacy up to 9 months postoperatively and found significantly increased short-term and long-term clearing after 2 and 3 treatments (overall 55% reduction) compared to a single treatment (overall 32% reduction) with the alexandrite laser.

Another study using the alexandrite laser involved a retrospective study of 313 consecutive alexandrite hair removal treatments on a total of 23 patients (22 women, 1 man) on 58 anatomic areas. The patients had skin types III and IV. The patients were divided into 4 groups depending on the number of hair removal treatments they had received (group I < or = 4, group II = 5, group III = 6, group IV > or = 7). Hair counting was performed through digital photos, and the treatment was defined as successful if there was more than 50% hair reduction and an absence of adverse effects. The authors found a positive correlation between hair reduction and number of treatments. The success rates were: 25% for patients receiving 4 or fewer treatments, 76% for 5 treatments, 58% for 6 treatments, and 15% for 7 treatments. The lower rates of success in the 6 and 7 treatments groups is attributed to a higher incidence of side effects such as hyper- and hypopigmentation, blister, and folliculitis.[44]

With regard to the diode laser, a study (n = 50) of laser hair removal in 8 different body sites found that 2 treatments produced relatively longer growth delays (hair regrowth beginning at 6 months after treatment and ranging from 47 to 66% over subsequent follow-ups) compared to 1 treatment (hair regrowths from 22 to 31% at the 1 month follow-up then remaining stable between 65 and 75% starting at the 3 month follow-up through the end of the study).[45] Toosi et al. found similar results, in that efficacy of diode laser hair removal (n = 76) on facial and neck hair was significantly related to the number of treatment sessions as increased number of sessions improved the results; the number of treatments ranged from 3 to 7 with a mean of 4.29.[46]

The long-pulsed ruby laser has also demonstrated efficacy in hair removal. A study of 25 patients with 48 areas of unwanted facial and body hair showed that the mean percent regrowth was 65.5% after the first treatment, 41% after the second treatment, and 34% after the third treatment. Overall, regardless of skin type or targeted body region, patients who underwent 3 treatment sessions demonstrated an average 35% regrowth in terminal hair count 6 months after initial therapy compared to baseline pretreatment values.[8]

Repetitive treatments have been shown to be more effective than single treatments with regard to the Nd:YAG laser as well. A study by Lorenz et al. studied hair removal on the lower leg with long pulsed Nd:YAG laser (n = 29) and showed that with multiple treatments, there was an improvement in short-term effectiveness of hair removal and in the duration of epilation success.[41] After 4 and 5 treatments, the rate of >95% hair removed was 4% and 12% respectively at 13 and 12 months post-treatment. In this same study, greater than 50% hair reduction was obtained in 44.9% of the areas 1 month after a single treatment, and with 2 treatments, this percentage increased to 71.5%.

Although most studies support the efficacy of having more than one treatment for laser hair removal, there has been some evidence that there is no benefit in additional treatments beyond the first treatment. A study by Gold et al. found that when using IPL for hair removal, there were no statistically significant differences in hair counts after single versus multiple treatments.[10] Allison et al. studied patients who underwent laser hair removal with a 694 nm ruby laser.[47] The patients were divided into several treatment areas: 25 patients underwent treatment on the top lip, 25 females underwent treatment in the axilla, and 19 patients underwent treatment on the leg. The patients received 2 laser treatments on 1 side and 3 laser treatments on the other side. The authors found that all patients experienced significant hair reduction after 1 treatment (61–75%) and that the reduction persisted throughout the 8 months of study follow-up. Interestingly, data after 12 months showed no appreciable difference. Furthermore, they found that having a second or third treatment did not seem to significantly increase the initial reduction. The reduction was sustained over the 8 month follow-up period, and the addition of a third treatment only prolonged the hair reduction significantly during the first 2 months after that treatment's end.[7]

Although there is some discordance regarding the appropriate number of treatments, most authors agree that regardless of the type of laser used, multiple treatments are usually required in order to produce satisfactory results.[1] Based on my experience, and the studies available to date, I recommend an initial 5 treatments. After reevaluation, most patients require additional maintenance treatments.

WHAT ARE THE RECOMMENDATIONS FOR SHAVING, PLUCKING, WAXING, ETC. BEFORE LASING?

To date, surprisingly few guidelines exist regarding preoperative site preparation in patients undergoing laser hair removal. Sunscreen and/or sun avoidance is universally recommended prior to laser hair removal because melanin is the principal chromophore for laser hair removal; a bleaching cream such as hydroquinone may be considered in patients with darker skin types. It is intuitive that hair at the surface should be shaved or removed in some way so that melanin within hair above the skin surface does not absorb laser energy and allows that energy to reach its target in the hair follicle within the dermis. Most practitioners have traditionally advised against mechanical epilation (plucking or waxing) prior to laser treatment[6,48] due to the observation that plucking of hairs just prior to treatment reduced the efficacy of hair removal with a ruby laser.[19] Theoretically, waxing immediately before a laser treatment would remove the chromophore (melanin) that is required for laser hair removal to be effective. Lehrer et al., however, used wax epilation to synchronize groups of hair follicles into anagen and found that areas that were waxed 2 weeks prior to laser hair removal (long-pulsed alexandrite laser) were clearer when compared to areas that were not waxed.[49] Wax epilation converts normally telogen hairs into anagen and therefore increases the susceptibility of these hairs to thermal damage. During anagen, keratinocytes are dividing rapidly to create the hair shaft. These rapidly dividing tissues are more susceptible to the extreme heat and the oxidative products created during laser treatment.

In a small patient sample, Dierickx et al. looked at the effect of shaving prior to laser treatment. At 1 year and 2 years post-laser treatment, significantly less hair was found only in the shaved sites for all evaluated laser fluences, when compared with the unshaved control sites.[28]

Ornithine decarboxylase is an important regulatory enzyme in the hair follicle.[50] Eflornithine (Vaniqa®, SkinMedica, Carlsbad, CA) is an irreversible inhibitor of ornithine decarboxylase and causes inhibition of cell division associated with hair growth. Clinical studies have shown that eflornithine cream is safe and effective in reducing the growth and appearance of facial hair.[51] In one study, the efficacy of eflornithine cream plus laser was evaluated versus laser alone in efficacy of hair removal. This study was conducted using a long-pulsed 755 nm alexandrite laser at 10–40 J/cm^2; the patients were treated on their upper lips. Preliminary results demonstrated that eflornithine plus laser was more effective than laser alone in producing a rapid hair removal response.[23]

Another study to investigate the efficacy of eflornithine cream plus laser versus laser alone in hair removal of the upper lip or the chin was performed by Smith et al.[52] This study was performed at 2 investigational sites: one used a 1064 Nd:YAG laser (Laserscope Corp, San Jose, CA) and the other used a 755 nm alexandrite laser (Candela Corp, Wayland, MA). Each site enrolled 32 female participants. Physician grading showed a difference between the 2 sides of the lip at week 34 for 26 of the 54 subjects: 12 of these subjects showed less unwanted facial hair on the side of the lip treated with eflornithine cream, while the remaining 14 subjects showed less unwanted facial hair on the side of the lip treated with the vehicle cream. Likewise, 30 of the 54 subjects showed a difference between sides of the chin: 15 subjects showed less unwanted facial hair on the side of the chin treated with eflornithine cream and 15 subjects showed less unwanted facial hair on the side of the chin treated with vehicle. The subjects consistently favored the side treated with eflornithine cream compared to the vehicle side in terms of efficacy of hair reduction. In summary, there was no benefit seen with eflornithine cream use compared to vehicle use in laser hair removal efficacy when evaluated by physicians; however, the subjects felt there was significantly more efficacy on the eflornithine treated side compared to the vehicle treated side.

The evidence is controversial as to what pretreatment methods of hair removal will help achieve the most effective laser hair removal. In the guidelines set forth by the European Society for Laser Dermatology, Drosner and Adatto recommended avoiding any pretreatment plucking, waxing, or electrolysis because the light needs the melanin in the hair shaft as a chromophore in order to produce successful photoepilation.[39] They also stated that cutting, shaving, or using a depilatory cream are all acceptable prior to treatment. I routinely recommend that patients avoid plucking or waxing initially prior to laser hair removal treatment; I also recommend that patients cut or shave hair prior to treatment to minimize absorption of laser energy by melanin above the surface of the skin.

WHAT ARE THE RECOMMENDATIONS FOR SUN EXPOSURE BEFORE AND AFTER LASER TREATMENT?

Some of the most frequent complications following laser use are persistent erythema and pigmentary change.[53] Inflammation of the skin is a common cause of acquired hyperpigmentation, and postinflammatory hyperpigmentation is more common in patients with darker skin types. There is a paucity of controlled studies examining pre- and postoperative sun exposure in regard to frequency of complications following laser treatment. For many years, cosmetic surgeons have advised their patients to avoid sun exposure prior to and following laser treatment, believing, based on empiric data, that it leads to postinflammatory hyperpigmentation. Hyperpigmentation of the skin is typically related to stimulation of the melanocytes while hypopigmentation results from melanocyte destruction, suppression of melanogenesis, or melanin redistribution in the keratinocytes.[48] Therefore, it is reasonable to conclude that sun avoidance would prevent further stimulation of the melanocytes,[54] thereby reducing the risk of postinflammatory pigmentary changes. Some authors have recommended sun avoidance for up to 3 months following laser treatment to minimize additional inflammation of the treated area, however there are no formal recommendations regarding sun exposure before and after laser treatment. Such recommendations are particularly difficult in warmer, sunny climates.

Hasan et al. reported a case of a Latin woman with skin type III–IV who presented for several laser hair removal treatments with a normal mode alexandrite laser, she had no hyperpigmentation after her initial treatments. Following her third treatment, the patient had sunlight exposure on the treated sites during the week following her laser treatment and then developed hyperpigmented patches on her inner thighs. Wood's lamp exam revealed the presence of epidermal pigment.[53]

Weisberg and Greenbaun reported 7 cases of patients with skin types III–IV who were treated with the normal mode alexandrite laser[55] and experienced hyper- or hypopigmentation following treatment, but the authors did not note any specific patient factors that are predictive of complications. The authors speculated that the pigmentary changes may be directly related to the heat injury from the laser or the cold injury from the cryogen. They did not comment on any associated sun exposure prior to or following laser treatment in these patients.

ARE THERE AREAS THAT SHOULD NOT BE TREATED WITH LASER HAIR REMOVAL?

In general, laser hair removal remains a very safe and effective treatment; however, there are some areas where the risks of laser hair removal outweigh any benefits. Interestingly, there have been several reports of hair growth that was induced by laser treatment.[56–59] Berstein reported using an 810 nm pulsed diode laser in a 24-year-old white male (who was not on any medications) to perform a test spot prior to laser hair removal on the back. The patient returned 14 weeks later with dramatically increased hair growth in the area of the test spot. Subsequent laser treatments were performed to the hypertrichotic area. Following the third treatment, an annulus of hair appeared surrounding the treated area which was then treated by electrolysis. The author speculated that the complex mechanism of laser hair reduction may incite a reaction that actually stimulates localized hair growth.[56]

Bouzari et al. noted the conversion of vellus hairs to terminal hairs following laser treatment. In their study, they note that 27%, 12%, and 3% of patients receiving treatment with the Nd:YAG, alexandrite, and diode lasers respectively experienced terminalization; overall, 10% of patients experienced this side effect in their study. The authors hypothesized that in these cases, the produced heat is less than the temperature necessary for thermolysis and that the heat shock may induce follicular stem cell differentiation and growth via increased heat shock proteins and other growth factors.[9,44]

Moreno-Arias et al. described a 'paradoxical effect' following IPL treatment of facial hirsutism in 10.2% of patients undergoing IPL photoepilation.[58,59] They define the paradoxical effect as the growth of fine dark hair in an untreated area in close proximity to the treated area. The authors speculated that sublethal doses of IPL may have induced activation of dormant follicles. A separate study by the authors sought to analyze the factors that may induce this paradoxical effect; they found that ovarian hyperandrogenism and polycystic ovary syndrome (PCOS) were present in all of the patients who experienced the paradoxical effect.

Finally, Vlachos and Kontoes described the development of terminal hair in areas treated by intense pulsed light. This was reported in 2 patients: one receiving IPL treatments to a tattoo on his back, and one who was receiving IPL to a port-wine stain on her lateral neck. Both of the patients developed terminal hairs in areas that had previously had only vellus hairs. The authors speculated that the inflammatory reaction induced by the IPL treatment can potentially induce hair growth.[57]

Extreme caution must be used when using lasers for hair removal around the eye. Brilakis and Holland reported diode-laser-induced cataracts and iris atrophy as a complication of eyelid hair removal. The authors advised avoidance of periocular laser treatment; if treatment is necessary, they advocated the use of ocular shields.[60]

In summary, when performing laser hair removal around the eye, extreme caution must be used; physicians must take proper precautions (i.e. eye shields for their patients) if treatment is needed in this area. Besides the periorbital area, we have not found that there is a specific area not to treat. Although there have been a few reports of paradoxical hypertrichosis following laser hair removal treatment, this is not the usual scenario.

Laser hair removal is still an evolving treatment. There remain a limited number of studies regarding recommendations before, during, and after treatment.

REFERENCES

1 Lepselter J, Elman M. Biological and clinical aspects in laser hair removal. J Dermatolog Treat 2004; 15: 72–83.
2 Haedersdal M, Wulf HC. Evidence-based review of hair removal using lasers and light sources. J Eur Acad Dermatol Venereol 2006; 20: 9–20.
3 Lanigan SW. Management of unwanted hair in females. Clin Exp Dermatol 2001; 26: 644–7.
4 Shapiro J, Lui H. Treatments for unwanted facial hair. Skin Therapy Lett 2005 Dec–2006 Jan; 10(10): 1–4.
5 Richards RN, Meharg GE. Electrolysis: observations from 13 years and 140,000 hours of experience. J Am Acad Dermatol 1995; 33: 662–6.
6 Warner J, Weiner M, Gutowski KA. Laser hair removal. Clin Obstet Gynecol 2006; 49: 389–400.
7 Bencini PL, Luci A, Galimberti M, Ferranti G. Long-term epilation with long-pulsed neodinium:YAG laser. Dermatol Surg 1999; 25: 175–8.
8 Williams R, Havoonjian H, Isagholian K, Menaker G, Moy R. A clinical study of hair removal using the long-pulsed ruby laser. Dermatol Surg 1998; 24: 837–42.
9 Bouzari N, Tabatabai H, Abbasi Z, Firooz A, Dowlati Y. Laser hair removal: comparison of long-pulsed Nd:YAG, long pulsed alexandrite, and long-pulsed diode lasers. Dermatol Surg 2004; 498–502.
10 Gold MH, Bell MW, Foster TD et al. Long-term epilation using the EpiLight broad band, intense pulsed light hair removal system. Dermatol Surg 1997; 23: 909–13.

11 Philpott MP, Green MR, Kealey T. Human hair growth in vitro. J Cell Sci 1990; 97: 463–71.
12 Pierard GE, de la Brassinne M. Modulation of dermal cell activity during hair growth in the rat. J Cutan Pathol 1975; 2: 35–41.
13 Straile WE, Chase HB, Arsenault C. Growth and differentiation of hair follicles between periods of activity and quiescence. J Exp Zool 1961: 205–16.
14 Cotsarelis G, Sun TT, Lavker RM. Label-retaining cells reside in the bulge area of pilosebaceous unit: implications for follicular stem cells, hair cycle, and skin carcinogenesis. Cell 1990; 61: 1329–37.
15 Chase HB. Growth of the hair. Physiol Rev 1954; 34: 113–26.
16 Chana JS, Grobbelaar AO. The long-term results of ruby laser depilation in a consecutive series of 346 patients. Plast Reconstr Surg 2002; 110: 254–60.
17 Rochat A, Kobayashi K, Barrandon Y. Location of stem cells of human hair follicles by clonal analysis. Cell 1994; 76: 1063–73.
18 Dierickx C. Laser-assisted hair removal: state of the art. Dermatol Ther 2000; 13: 80–9.
19 Grossman MC, Dierickx C, Farinelli W, Flotte T, Anderson RR. Damage to the hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996; 35: 889–94.
20 Mandt N, Troilius A, Drosner M. Epilation today: physiology of the hair follicle and clinical photo-epilation. J Investig Dermatol Symp Proc 2005; 10: 271–4.
21 Dawber RPR. Guidance for the management of hirsutism. Curr Med Res Opin 2005; 21: 1227–34.
22 Topping A, Gault D, Grobbelaar A, Sanders R, Green C, Linge C. Does low penetration of human skin by the normal mode ruby laser account for poor permanent depilatory success rates? Lasers Med Sci 2001; 16: 224–9.
23 Randall VA, Lanigan S, Hamzavi I, James, LC. New dimensions in hirsutism. Lasers Med Sci 2006; 21: 126–33.
24 Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983; 220: 524–7.
25 Van Gemert MJC, Welch AJ. Time constants in thermal laser medicine. Lasers Surg Med 1989; 9: 405–21.
26 Anderson RR. Laser-tissue interactions. In: Goldman MP, Fitzpatrick RE, eds. Cutaneous laser surgery: the art and science of selective photothermolysis. St Louis: Mosby-Year Book, 1994: 1–18.
27 Lim SPR, Lanigan SW. A review of the adverse effects of laser hair removal. Lasers Surg Med 2006; 21: 121–5.
28 Dierickx CC, Grossman MC, Firnelli WA, Anderson RR. Permanent hair removal by normal-mode ruby laser. Arch Dermatol 1998; 134: 837–42.
29 Kolinko VG, Littler CM, Cole A. Influence of the anagen:telogen ratio on Q-switched Nd:YAG laser hair removal efficacy. Lasers Surg Med 2000; 26: 33–40.
30 Soden CE, Smith K, Skelton H. Histologic features seen in changing nevi after therapy with an 810 nm pulsed diode laser for hair removal in patients with dysplastic nevi. Int J Dermatol 2001; 40: 500–4.
31 Lin TY, Manuskiatti W, Dierickx CC et al. Hair growth cycle affects hair follicle destruction by ruby laser pulses. J Invest Dermatol 1998; 111(1): 107–13.
32 Lask G, Elman M, Slatkine M, Waldman A, Rozenburg Z. Laser-assisted hair removal by selective photothermolysis. Preliminary results. Dermatol Surg 1997; 23: 737–9.
33 Ito M, Liu Y, Yang Z et al. Stem cells in the hair follicle bulge contribute to wound repair but not to homeostasis of the epidermis. Nat Med 2005; 11: 1351–4.
34 Orringer JS, Hammerberg C, Lowe L et al. The effects of laser-mediated hair removal on immunohistochemical staining properties of hair follicles. J Am Acad Dermatol 2006; 55: 402–7.
35 Seago SV, Ebling FJ. The hair cycle on the human thigh and upper arm. Br J Dermatol 1985; 113: 9–16.

36 Randall VA, Ebling FJG. Seasonal changes in human hair growth. Br J Dermatol 1991; 124: 146–51.
37 Hughes CL. Hirsutism. In: Olsen EA, ed. Disorders of hair growth: diagnosis and treatment. McGraw-Hill: New York, 1994; 337–50.
38 Bouzari N, Firooz AR. Lasers may induce terminal hair growth. Dermatol Surg 2006; 32: 460.
39 Drosner M, Adatto M. Photo-epilation: guidelines for care from the European society for laser dermatology. J Cosmet Laser Ther 2005; 7: 33–8.
40 Bouzari N, Tabatabai H, Abbasi Z, Firooz A, Dowlati Y. Hair removal using an 800 nm diode laser: comparison at different treatment intervals of 45, 60, and 90 days. Int J Dermatol 2005; 44: 50–3.
41 Lorenz S, Brunnberg S, Landthaler M, Hohenleutner U. Hair removal with the long-pulsed Nd:YAG laser: a prospective study with one year follow-up. Lasers Surg Med 2002; 30: 127–34.
42 Eremia S, Li C, Newman N. Laser hair removal with alexandrite versus diode laser using four treatment sessions: 1-year results. Dermatol Surg 2001; 27: 925–30.
43 Gorgu M, Aslan G, Akoz T, Erdogan B. Comparison of alexandrite laser and electrolysis for hair removal. Dermatol Surg 2000; 26: 37–41.
44 Bouzari N, Nouri K, Tabatabai H, Abbasi Z, Firooz A, Dowlati Y. The role of number of treatments in laser-assisted hair removal using a 755 nm alexandrite laser. J Drugs Dermatol 2005; 4: 573–8.
45 Lou WW, Quintana AT, Geronemus RG, Grossman MC. Prospective study of hair reduction by diode laser (800 nm) with long-term follow-up. Dermatol Surg 2000; 26: 428–32.
46 Toosi P, Sadighha A, Sharifian A, Razavi GM. A comparison of the efficacy and side effects of different sources in hair removal. Lasers Med Sci 2006; 21: 1–4.
47 Allison KP, Kiernan MN, Waters RA, Clement RM. Evaluation of the ruby 694 Chromos for hair removal in various skin sites. Lasers Med Sci 2003; 18: 165–70.
48 Liew SH. Laser hair removal, guidelines for management. Am J Clin Dermatol 2002; 3: 107–15.
49 Lehrer MS, Crawford GH, Gelfand JM, Leyden JJ, Vittorio CC. Effect of wax epilation before hair removal with a long-pulsed alexandrite laser: a pilot study. Dermatol Surg 2003; 29(2): 118–23.
50 Soiler AP, Gilliard G, Megosh LC, O'Brien TG. Modulation of murine hair follicle function by alterations in ornithine decarboxylase activity. J Invest Dermatol 1996; 106(5): 1108–13.
51 Balfour JA, McClellan K. Topical eflornithine. Am J Clin Dermatol 2001; 2(3): 197–201.
52 Smith SR, Piacquadio DJ, Beger B, Littler C. Eflornithine cream combined with laser therapy in the management of unwanted facial hair growth in women: a randomized trial. Dermatol Surg 2006; 32: 1237–43.
53 Hasan AT, Eaglstein W, Pardo R. Solar-induced postinflammatory hyperpigmentation after laser hair removal. Dermatol Surg 1999; 25: 113–15.
54 Pathak MA, Stratton K. Free radicals in human skin before and after exposure to light. Arch Biochem Biophys 1968; 123: 468–76.
55 Weisberg NK, Greenbaum SS. Pigmentary changes after alexandrite laser hair removal. Dermatol Surg 2003; 29: 415–19.
56 Bernstein EF. Hair growth induced by diode laser treatment. Dermatol Surg 2005; 31: 584–6.
57 Vlachos SP, Kontoes PP. Development of terminal hair following skin lesion treatments with an intense pulsed light source. Aest Plast Surg 2002; 26: 303–7.
58 Moreno-Arias G, Castelo-Branco C, Ferrando J. Paradoxical effect after IPL photoepilation. Dermatol Surg 2002; 28: 1013–1016.
59 Moreno-Arias G, Castelo-Branco C, Ferrando J. Side-effects after IPL photoepilation. Dermatol Surg 2002; 28: 1131–4.
60 Brilakis HS, Holland EJ. Diode-laser-induced cataract and iris atrophy as a complication of eyelid hair removal. Am J Ophthalmol 2004; 762–3.

9 PHOTOGRAPHIC IMAGING IN LASER HAIR REMOVAL

Tom Bialoglow

KEY POINTS

‘*Cameras don’t take bad photos; people take bad photos.*’

(1) Photography has become an important tool in managing laser hair removal patients, perhaps now more so than ever as competition for patients is greater than ever

(2) Photographically documenting the patient’s baseline and monitoring interval change is important in documenting efficacy, monitoring progress, marketing, and ensuring patient satisfaction. Photography has, in fact, been the lynchpin for FDA approval for many laser hair-removal devices

(3) Photographic methods in laser hair removal may include global or overview photos, macro or close-up photos, and epiluminescence photos

GLOBAL (OVERVIEW) PHOTOGRAPHY

Global or overview photographs are the most important, and indeed, in many practices the only images taken. Global photos are important as they capture the overall appearance of the patient and the distribution and apparent density of hair across the region of interest. Global photos are most likely to be used for a quick assessment of progress at each patient visit and to prove efficacy to patients. Good global photos will save the practice time as efficacy of therapy and patient progress can often be assessed with but a cursory glance.

Global photographic methods range from point and shoot camera snap shots through serial photos where distance, focal length (zoom), lighting, and photographic technique are all standardized.

Global Photography: consistency and reproducibility

Mastering the variables could very well be the title of this subsection as that is the key in consistent and reproducible clinical photography. The variables we must master are as follows:

- Distance
- Focal length (zoom)
- Lighting/White balance
- Photographic technique

Distance can be standardized by simply marking spots where both photographer and patient stand for global photos.

Focal length can be simply standardized with digital SLRs by selecting a fixed focal length (non-zoom) lens. With point and shoot cameras, zoom to approximately the same spot on your camera status bar as possible (turn off any digital 'zoom'). If using a 3 × or 4 × lens, zoom to full telephoto for global views.

Lighting reproducibility is achieved by simply using a flash for *all* your global photos.

White balance, therefore, should always be set to the camera's flash white balance. Post treatment erythema can be difficult to quantify when the wrong white balance or inconsistent white balance is selected.

Photographic technique encompasses aperture, shutter speed, ISO, and white balance. Space precludes a detailed discussion of the meaning and effect of each of these terms. Suffice it to say, that the camera you choose for your clinical photos should feature the ability to set these parameters yourself to ensure consistency and reproducibility. Don't turn the camera to Auto Mode and hope for the best, as cameras rarely make good decisions when taking clinical photos.

Global Photography: positioning and views

Positioning includes anatomy and how it is framed in the image, plus the actual position of the patient. Positioning can be standardized by creating an internal photo-standard illustrated with views to be acquired, and featuring photos to be referred to as canonic standards. To standardize the angle of patient rotation in the Z-axis, a patient-posing mat can be created or purchased as illustrated (Figure 9.1). For headshots, use the ears as landmarks to minimize rotation; if one ear is showing much more than the other, chances are the patient is rotated. Rotation of the head in the X-axis (tilt) is best managed by using an anatomic standard Frankfurt Line (Figure 9.2). The Frankfurt Line runs from the external auditory meatus to the inferior orbital rim. Pay attention too to the angle at which you take your images. In most cases you will want the lens perpendicular to the anatomy you are

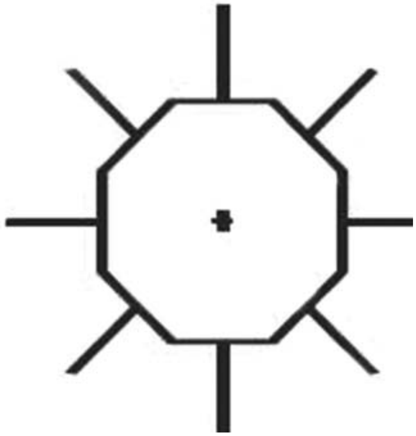

Figure 9.1

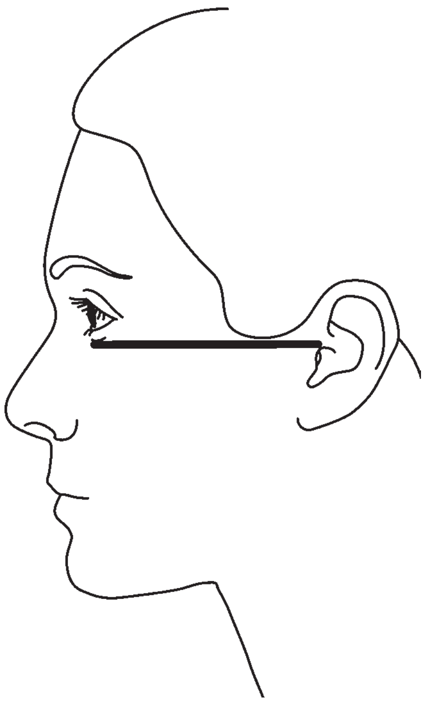

Figure 9.2

photographing. Have the patient sit or get up on a photo stage rather than angling the camera and distorting anatomy.

Views can be kept to a minimum. Position the subject and camera so that the region of interest is as close as possible to parallel to the capture plane. For specific regions as requested by the patient, always check the pre-procedure photo so as to duplicate the view post treatment. For many common hair removal sites, views can

Figure 9.3

be standardized. Often, a simple photo with the patient facing you or turned 180 degrees will suffice (Figures 9.3, 9.4 & 9.5). For facial photos, always capture a tight headshot and a close-up of the area of interest (Figures 9.6 & 9.7). For the axilla, have the patient place the palm of the hand on the back of the neck while rotating the patient 30 degrees anteriorly (Figure 9.8). For the bikini area, have the patient face you, one foot pointed forward, the other rotated 90 degrees externally. The feet should be about 10″ apart, the externally rotated leg slightly flexed (Figure 9.9). This view must be captured with each leg rotated in turn. For the neck and submental region, the patient stands, and tilts the head back 30 degrees off the Frankfurt Line (Figure 9.10).

Global Photography: photographic hardware & lighting

There are really 3 options for your global photos in laser hair removal: point and shoot cameras, SLRs, and studio systems. If choosing a point and shoot camera, choose a camera that allows for a mode that lets you set the aperture white balance and ISO. Pick a zoom no greater than 6× (ignore digital zoom).

Should you choose an SLR, choose a fixed aperture and fixed focus lens of a focal length equivalent to ~80 mm to 105 mm. Use an external flash to provide more homogeneous lighting. Macro twin flashes (Figure 9.11) are especially suited to clinical photography.

Figure 9.4

Figure 9.5

Figure 9.6

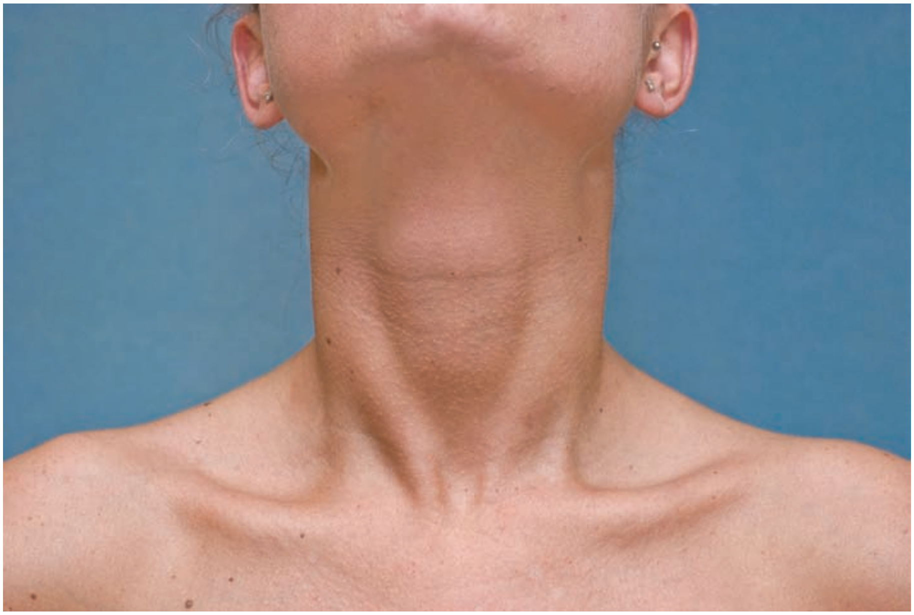

Figure 9.7

Figure 9.8

Figure 9.9

Figure 9.10

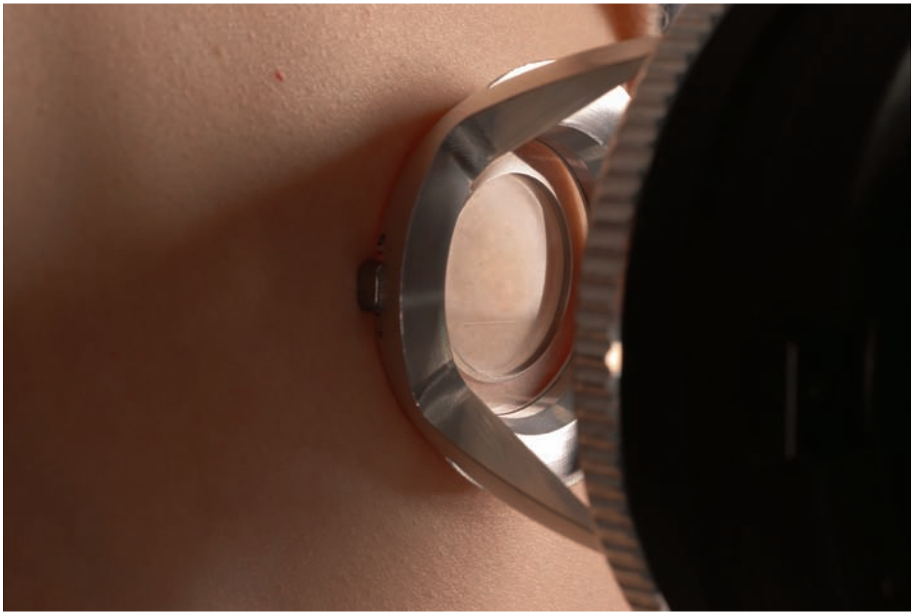

Figure 9.11

Figure 9.12

In the studio realm, you can have a medical imaging professional design a solution customized to a room dedicated to that purpose. Choose someone with a track record in clinical photography for best results. Recent innovations like Canfield Imaging System's IntelliStudio (Figure 9.12) further the pursuit to standardize photos by remembering the settings from one time point to the next and allowing you to superimpose the current video preview atop the baseline photo for incredible reproducibility. Its raked lighting system also helps visualize very fine and pale hairs.

MACRO (CLOSE-UP) PHOTOGRAPHY

As with global photography, good macro photography requires you to master the variables (see above) to ensure consistency and reproducibility. Despite this, macro photography is a different animal and good macro photos are rarer than good global photos.

SLRs have superior optics, easier manual focusing, TTL metering and external macroflash options, which make them a better choice for good macro photography than point and shoot cameras.

With point and shoot cameras, metering for macro images is difficult – they tend to overexpose if you get in too close to the subject matter. Turn on your macro function (the little flower), step back and zoom in. If you get in much closer than about 10″ (25 cm), the chances are your photo will be over-exposed. If you need to see more detail, good image management software will allow you to zoom in afterwards for review.

Cameras rely on contrast to auto-focus. When the camera is in very close to the anatomy and you are blocking the light the camera needs to focus, the lens may move back and forth in a fruitless effort to focus. With an SLR, switching to manual focus and turning the lens to some preset number on the lens (distance, reproduction ratio) will allow you to move the camera slightly forward and aft, shooting when the anatomy is in focus. This body focusing[1] helps to standardize your field of view too. With a point and shoot camera, it may help to add some artificial contrast to the image, a mm sticker for instance. You can also slip a cotton swab into the field of view, depress the shutter, let the camera focus, withdraw the cotton swab and depress the shutter the rest of the way to take the photo.

Macro Photography: photographic hardware & lighting

If choosing a point and shoot camera, be sure it has a macro setting. Also ensure a manual focusing option is available. Close-up scales (Figure 9.13) can be purchased to standardize distance, introduce a frame of reference, and minimize overexposure.

If choosing an SLR, purchase a fixed aperture & focal length macro lens. The same lens can be used for your global photos. Close-up scales can be purchased to standardize distance and introduce a frame of reference. Macro twin flashes are a good option for macro work as the built-in flash may be partially blocked by the lens.

Macro Photography: positioning and views

Macro views are always taken along with a global view. For the macro image, pick a landmark or skin feature that you can see on the global view. In clinical trials, a

Figure 9.13

tattoo is often used to mark the center of the area designated for macro imaging. This is not the case in private practice imaging. For precise imaging in the absence of tattooing, a sheet of acetate with a cut-out in the center can be employed. Two landmarks outside the field of view are marked (mole, scar, vein, etc.) on the acetate sheet and the sheet is positioned over these landmarks for pre/post treatment photos.

Macro Photography: special techniques — epiluminescence microscopy

In use as a tool to better image melanocytic nevi the epiluminescence microscopy (ELM) technique can also be used to better document very fine and/or fair hair. ELM employs a light source close to the skin and a glass contact plate (Figure 9.14). Fluid (isopropyl alcohol, hand gel, etc.) is sprayed or spread on the skin, care being taken to minimize the creation of bubbles. The glass contact plate is then placed against the skin and the photo taken. The fluid optically couples the glass plate to the skin, minimizing reflection and refraction, so that hair and follicle can be more clearly visualized (Figures 9.15 & 9.16).

Figure 9.14

Figure 9.15

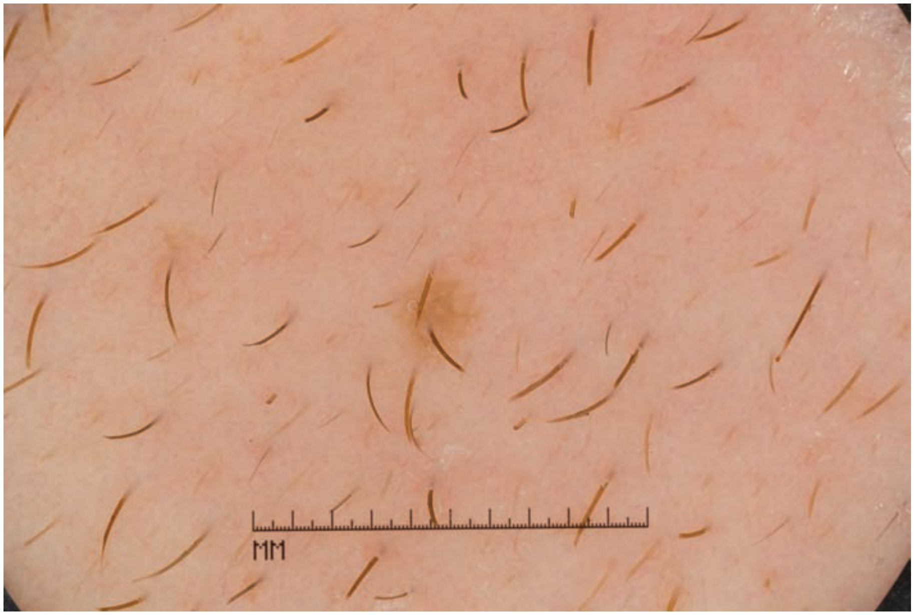

Figure 9.16

COMPUTER-AIDED ANALYSIS

Software analysis can be useful in quantifying hair density prior to and after treatment. For computer-aided density counts, the field of view needs to be standardized or a distance scale included on all photos. Capture of the same anatomic area is essential for recording meaningful data. Once an image is captured and validated, a density-count in hairs/cm^2 can be recorded by simply clicking on all the hairs in follicles included in the field of view.

IMAGE MANAGEMENT

Without the right medical image management software, much time can be lost searching for patient images and comparing pre and post laser hair removal photographs. The proper software package will also include tools for quickly calculating density counts. The medical software application you choose should include the following:

- Patient search
- Search by database attribute (diagnosis, procedure, anatomic location, utilized decice) and a customizable database

- Security functions to manage personal medical history in a confidential manner
- Quick side by side viewing of pre/post procedure photos
- A robust zoom function
- Camera tethering
- World class technical support
- Tools for hair density counts

SUMMARY

With some attention to detail, and the right photographic systems and hardware, you can take good, standardized photos of your laser hair removal patients. Both global and macro photos are required for managing this patient population. Good photos are an important resource for marketing your practice, illustrating your technical acumen, and ensuring patient satisfaction. Good clinical photos will help you retain patients as clients for other aesthetic procedures as the field of aesthetic medicine grows ever more crowded.

REFERENCE

1 Slue WE, Paglialunga A, Neville J et al. Better dermatologic photography: getting started. Cutis, 1994; 54 (3): 177–8.

10 COMPLICATIONS

KEY POINTS

(1) Complications can occur with any laser/light source hair removal system
(2) Longer wavelengths and longer pulse durations are associated with a lower risk profile
(3) Darker skin types are associated with a higher risk of complications
(4) Scarring and pigmentary changes are the most commonly noted complications

PATHOGENESIS OF COMPLICATIONS

Melanin, in the form of eumelanin, is the major cutaneous chromophore used as a target for hair removal lasers and light sources. Most individuals demonstrate greater melanin density in their hair as compared to their epidermis such that the absorption coefficient of the hair shaft and bulb is roughly 2–6 times that of the epidermis.[1] Optimally, one would want no absorption by any skin components except the targeted pigmented hair. Unfortunately, such a situation does not exist. The advantage of choosing melanin as a hair absorbing target is that it is already present in both the hair follicle and shaft. However, in terms of complications, melanin is found not only in the hair follicle, but in the epidermis as well. Light must initially pass through the epidermis in order to get to the deeper hair follicle and is therefore potentially absorbed first in the epidermis. This may have several consequences. Absorption of light in the epidermis results in possible adverse effects such as vesiculation, crusting, burns, and dyspigmentation.

The incidence of cutaneous adverse effects, after laser hair removal, is both patient and wavelength dependent.[2] Patients with darker colored skin, especially skin types V and VI, are more likely to experience cutaneous adverse effects related to the abundance of melanin in their epidermis. It should be noted that such complications are not limited to patients with genetically determined dark skin. They may also be seen in patients with darker skin due to other reasons, such as sun-tanning and lentiginous photoaging. A constitutionally higher reactivity to a variety of trauma in these darker skin types may be the reason for this observed effect.

Factors that could theoretically impact on the incidence of adverse effects include utilized wave length, fluence, pulse duration, utilized hand piece spot size, and the use of appropriate cooling. A laser with a longer wave length and longer pulse duration is less likely to be absorbed by epidermal melanin. While it is true that wavelengths with lower absorption coefficients will decrease the amount of light absorbed by epidermal melanin, these longer wavelengths also decrease the amount of light absorbed in hair and hair shaft containing melanin. With this occurring, the amount of heat producing delivered light must be increased to obtain the desired effect. Similarly, increasing the pulse duration will decrease the rate of heat generation in both the epidermis and in the hair follicle, again requiring an increased amount of light to be delivered to obtain the desired result. Variations in these parameters can either be beneficial or detrimental. Thus, in the end, the laser parameters need to be chosen to limit thermal diffusion to the size of the hair follicles, and limit its diffusion into surrounding tissue.

Effective laser hair removal requires an appropriately delivered spot size of energy. The smaller the spot size, the more rapid is the scattering of photons away from the treated follicle. Using a larger spot size leads to more efficient light penetration, greater depth of penetration, and a lower required threshold fluence. By requiring a lower fluence, less collateral heat is delivered lessening undesired thermal damage.

Appropriate cooling has become mandatory with today's high powered laser technology. Greater utilized fluences lead to greater heat deposition in the hair and hair shaft — a desired effect. However the same heat induction can lead to epidermal blistering and a diffuse thermal effect — an undesired effect that is lessened with current cooling devices.

PIGMENTARY CHANGES

There is a remarkable variation in the reported incidence of post-treatment pigmentary changes after laser hair removal. Unfortunately these studies have not been carried out under standardized conditions. Different laser parameters have been used; the follow up period has varied from 90 days to 2 years; the preoperative skin characteristics were not standardized (hair color, skin pigmentation, anatomical region); and the majority of studies estimated the incidences of side effects by subjective clinical evaluations.

In one study,[3] skin reflectance measurements were documented by the presence of sub-clinical postoperative pigmentary changes. These changes generally depended on the degree of pre-treatment pigmentation. The postoperative reflectance-determined skin pigmentation differed from the preoperative skin pigmentation in 47 out of 51 treated areas; yet clinically visible pigmentary changes were only seen in 6 of the treated areas. No linear dose–response relationship was observed. However, this may be due to non-homogenicity in the treated patient's skin characteristics (hair color and density, collagen density).

Anecdotally, many clinicians have noted that light-pigmented skin types experience more postoperative sub-clinical hyperpigmentation. Darker pigmented skin types experience more postoperative sub-clinical hypopigmentation. This finding might occur because laser light in dark-pigmented skin types is strongly absorbed by epidermal melanin. This absorption might lead to damage of melanocytes.[4] In contrast, thermal effects in fairly pigmented skin may stimulate postinflammatory hyperpigmentation.

Hypopigmentation

Hypopigmentation, though generally transient, can be unpleasant for the cosmetic laser hair removal patient. This loss of pigment may last for many months. Transient post treatment hypopigmentation occurs in 10–17% of treated patients.[5–7] The exact etiology of post-laser hair removal induced hypopigmentation is unclear. This hypopigmentation may be related to destruction of melanocytes, suppression of melanogenesis, or the redistribution of melanin in the keratinocytes.

Recent research has shown[8] that the number of melanocytes with tyrosinase activity (the first enzyme in the synthesis pathway of melanin) decreases dramatically immediately after laser treatment. Yet, the absolute number of S-100 positive melanocytes remains constant. In addition, there appears to be no definite alteration in the distribution of melanosomes in keratinocytes after treatment. It is therefore likely that the hypopigmentation seen after laser treatment is related to the suppression of melanin synthesis, rather than a change in the number of melanocytes in the basal layer of the epidermis. The mechanism of tyrosinase block is unknown. It could be due to the effect of heat, as tyrosinase enzymatic activity is normally suppressed by high temperature. It could also be due to the mechanical disruption of melanosomes following laser irradiation. The subdisruptive damage sustained by the patients' melanocytes may lead to a reparative process, which causes a delaying halt in tyrosinase activity. This is all consistent with the general clinical finding of reversibility of skin hypopigmentation after laser assisted hair removal.[8,9] This observation is generally true for all degrees of epidermal pigmentation and fluences used. However, in those circumstances where melanocytes in the periglandular and perifollicular areas are destroyed or significantly disabled, the

Figure 10.1 Hypopigmentation after long-pulsed ruby laser hair removal

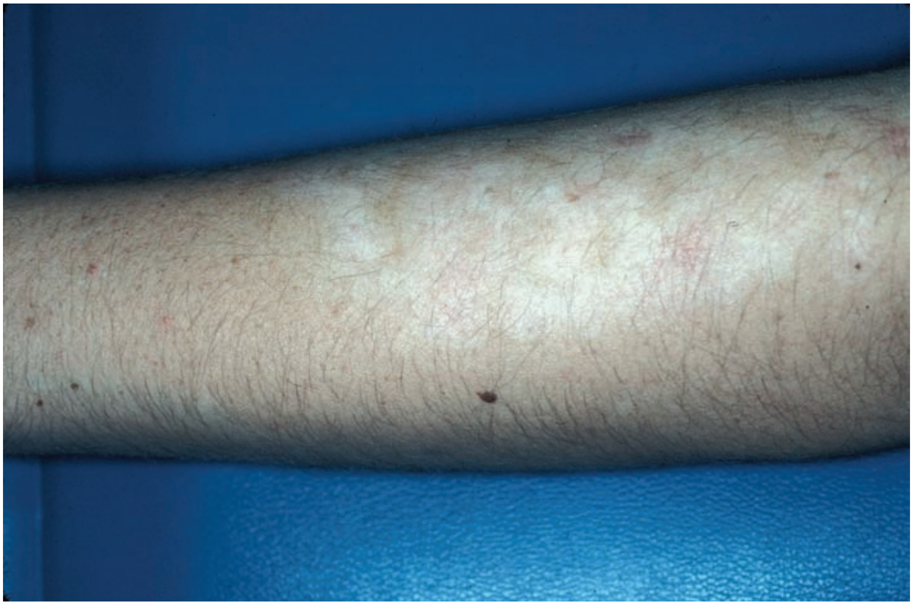

Figure 10.2 Hypopigmentation after long-pulsed alexandrite laser hair removal

mechanisms of trauma induced pigmentary changes may be different. Permanent loss of pigment is very rare (Figures 10.1 & 10.2).

Some authors have also suggested that some cases of hypopigmentation may be induced by cold injury associated with some laser/light source associated cooling devices. Patients presenting with this complication seem to show a similar pattern of initial hyperpigmented rings that subsequently develop into a thin wafer-like crust followed by hypopigmentation with a gradual return to normal skin color.

In trying to analyze the possible etiologies for this occurrence, some authors have suggested several possibilities.[10] One possibility would be a malfunctioning of the machine. This seems to be quite unlikely because today's lasers have multiple incorporated safety features that tend to prevent pulsing outside of the normal chosen parameters. Additionally, investigators have suggested, that if such hypopigmentation was machine malfunction related, one would expect a consecutive number of patients to be affected. This has not been the case in our series. Instead, affected patients seem to be treated on different dates with numerous patients being treated between these occurrences.

In analyzing the complication of hypopigmentation, it is important to note that current hair removal lasers tend to operate with 2 diametrically opposed forces. There is heat that is generated as a result of selective photothermolysis, which is meant to heat, and thereby damage, the hair follicle. There is also cooling that is designed to protect the epidermis as the laser beam penetrates the skin surface en route to deeper structures. Both the delivered heat and cold can generate pigmentary dyschromia. Some have suggested that the pattern of pigmentary change would suggest cold as the underlying cause. The rings of hypopigmentation generally correspond to the size and shape of the end of cryogen cooling associated distance gauges that contact the skin.

Other authors suggest that today's laser associated cooling devices are not the cause of such hypopigmentation.[11] They suggest that skin dyspigmentation occasionally observed after laser-assisted hair removal in combination with cryogen cooling is not cryo-injury, but rather laser-induced thermal injury. Currently available laser devices incorporate epidermal cooling to improve the margin of safety by increasing the threshold for epidermal damage, which allows the use of higher fluences, permits treatment of darker skin types, and decreases patient discomfort. However, to be effective and safe, the cooling medium must completely cover the skin surface before laser irradiation. When epidermal protection is incomplete, thermal injury is likely to result, particularly during the use of higher fluences in patients with darker skin types.

These authors note that cryogen cooling associated epidermal protection is complete only when the handpiece is held perpendicular to the skin surface. If the handpiece is angled from perpendicular, incomplete cryogen coverage of the laser spot occurs and a crescent-shaped burn can be observed. This can also be noted if the cryogen nozzle is misaligned in the handpiece, which may occur with moving of the laser from room to room or between office locations.

In order to lessen the risk of such hypopigmentation, 3 suggestions have been made:

(1) When larger spot sizes are used, selection of greater degrees of cooling will ensure complete cooling coverage of the irradiated skin surface.
(2) In the case of cryogen cooling, cryogen coverage can be quickly confirmed before each procedure or after changes of cooling/laser parameters by firing the beam onto a porous surface such as ordinary cardboard. If thermal injury is noted when the handpiece is held perpendicularly and adequate cryogen spurt duration has been chosen, the spray nozzle may be misaligned and require adjustment.
(3) Finally, care should be taken to hold the handpiece perpendicularly to the skin surface throughout the entire procedure, as indicated in the manufacturer's guidelines. This may require special attention, particularly during treatment of curved anatomic surfaces.

Hyperpigmentation

The exact pathogenesis of posttreatment hyperpigmentation is also obscure. Hyperpigmentation of the skin after most cutaneous skin injuries is related to melanocytic stimulation. In addition, arachadonic acid metabolites and histamine, which are found in increased amounts in inflamed skin, are thought to play a key role in post-injury pigmentary changes. Transient post treatment hyperpigmentation occurs in 14–25% of laser hair removal patients.[5–7]

The causes of hyperpigmentation include delayed tanning, epidermal injury, or an immediate pigment darkening phenomenon resulting from photo-oxidation of pre-existing melanin. This darkening is usually transient, lasting only 3–4 weeks and resolving spontaneously without sequelae.[12,13]

A potentially more serious hyperpigmentation resulting from epidermolysis and blistering can occur at energy thresholds higher than those associated with immediate pigment darkening. Although immediate pigment darkening always resolves, this second type of hyperpigmentation has the potential for permanent dyschromia, both in very dark-skinned individuals and darkly tanned individuals (Figures 10.3–10.8).

BLISTERING

Blistering or crusting may occur in 10–15% of patients.[14] Histologic *subepidermal* necrosis is seen in all patients with clinical blistering of the skin after laser hair irradiation. These changes, as described above, are typical for those seen after a

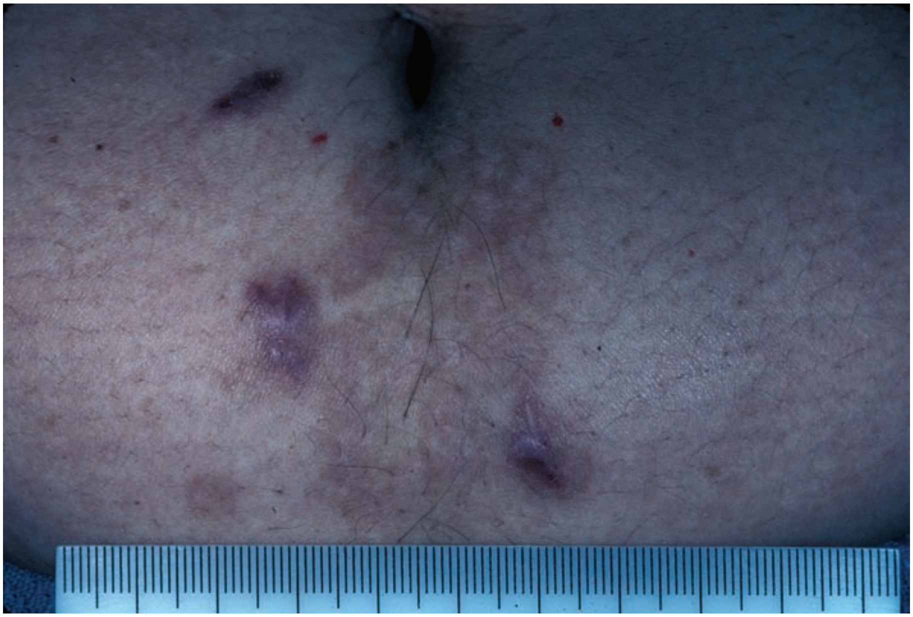

Figure 10.3 Hyperpigmentation after intense pulsed light hair removal

Figure 10.4 Hyper- and hypopigmentation after Nd:YAG laser hair removal

Figure 10.5 Hyperpigmentation after intense pulsed light hair removal

Figure 10.6 Hyperpigmentation after 810 nm diode laser hair removal

Figure 10.7 Hyperpigmentation after Nd:YAG laser hair removal

Figure 10.8 Hyperpigmentation after Nd:YAG laser hair removal

superficial burn.[15,16] The noted effects are thought to be due to a direct thermal injury. In general the maximum tolerated fluence leading to the end point of a burn is greater for a smaller spot size than is seen with a larger spot size. That is, a lower fluence may lead to a burn when a larger spot size is used; yet the same parameters with a smaller spot size would not create the same effect.[17]

SCARRING AND TEXTURAL CHANGES

Despite the presence of severe macroscopic cutaneous damage, collagen and elastin networks in the dermis are found to be normal in the majority of patients after laser hair removal.[18]

Type 1 collagen constitutes the major type of collagen in the dermis. It has a tendency to change its fibrillar form at temperatures between 60°C and 70°C.[19] Collagen's normal appearance and distribution in the dermal layer after laser hair removal support the clinical evidence that if laser assisted hair removal is performed correctly, scar formation rarely occurs.

The normal appearance and distribution of both collagen and elastin in laser-treated skin also suggest that textural changes in skin are unlikely after laser assisted hair removal except in cases of over-aggressive treatment, inadequate cooling, or post operative infection (Figures 10.9–10.12).

Figure 10.9 Scarring after Nd:YAG laser hair removal (no cooling)

Figure 10.10 Scarring after Nd:YAG laser hair removal (no cooling)

Figure 10.11 Scarring after Nd:YAG laser hair removal (no cooling)

Figure 10.12 Thermal damage induced hypertrophic scarring after diode laser treatment

INFECTIONS

Herpes simplex

Herpes simplex outbreaks are uncommon after laser and light sources treatment of hair removal, but may occur especially in patients with a strong history of outbreaks. Such infections are most commonly seen on, or around, the lip.

Bacterial infection

Although the risk of bacterial infection is extremely low, it may occur following epidermal damage induced by any form of trauma, including aggressive laser hair removal.

PARADOXICAL INCREASED HAIR GROWTH

Paradoxical increased hair growth has been noted after both laser and intense pulsed light (IPL) hair removal treatments. Although paradoxical hair growth following IPL treatment has been reported in almost 10% of treated patients, such studies have focused on patients undergoing hormonal treatment, something not seen in most office laser settings.

Most patients appear to be Fitzpatrick skin type III or higher.[20,21] Onset of paradoxical hair growth appears to be at the earliest 4 months after beginning treatment, and at the latest 20 months after beginning treatment. Most have had a minimum of 2 and a maximum of 8 treatments before the paradoxical growth appeared. All seem to have the paradoxical effect of hair growth in an adjacent untreated area in close proximity to treated areas. In general, affected patients show dramatic hair growth following laser treatment for hair reduction and a less than average response to hair laser treatment in another site. The etiology of this complication is unclear.

RETICULATE ERYTHEMA

Reticulate erythema is a rare reported complication after laser hair removal. This complication appears to be the result of cumulative laser fluences associated with multiple episodes of laser hair removal. The complication is generally subtle and often missed.[22]

UVEITIS AND IRITIS

There have been several observed cases of uveitis and iritis after laser hair removal of terminal eyebrow hair. In general the complication occurs with longer wavelength systems. It is thought to result from light scatter after treatment, and associated iris melanin absorption and thermal damage (Figure 10.13).

CONCLUSION

Complications following laser hair removal are rare.[23] However, they can occur. Most commonly one sees transient hyper- or hypopigmentation which improves with time.

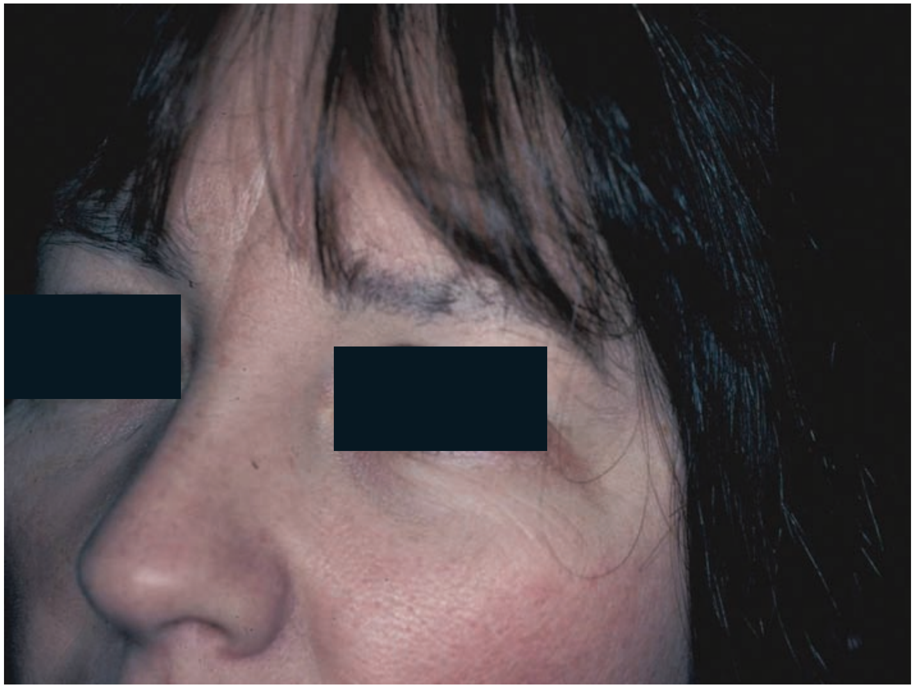

Figure 10.13 Damage to the iris after laser hair removal of eyebrow hairs

REFERENCES

1 Ross EV, Ladin Z, Kreindel M, Diereckx C. Theoretical considerations in laser hair removal. Dermatol Clin 1999; 17: 333–55.
2 Liew SH. Laser hair removal: guidelines for management. Am J Clin Dermatol 2002; 3: 107–15.
3 Haedersdal M, Egekvist H, Efsen J, Bjerring P. Skin pigmentation and texture changes after hair removal with the normal-mode ruby laser. Acta Derm Venereol 1999; 79: 465–8.
4 Anderson RR. Laser-tissue interactions. In: Baxter SH, ed. Cutaneous laser surgery. The art and science of selective photothermolysis. St. Louis, Missouri: Mosby, 1994: 1–19.
5 Grossman MC, Diereckx C, Farnilli W, Flotte T, Anderson RR. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996; 35: 889–94.
6 Bjerring P, Zachariae H, Lybecker H, Clement M. Evaluation of the free-running ruby laser for hair removal. Acta Derm Venereol 1998; 78: 48–51.
7 Williams R, Havoonjian H, Isagholian K, Menaker G, Moy R. A clinical study of hair removal using the long-pulsed ruby laser. Dermatol Surg 1998; 24: 837–42.
8 Liew SH, Grobbelaar AO, Gault DT et al. Ruby laser hair removal: Clinical efficacy in Fitzpatrick skin type I–V and histological changes in epidermal melanocytes. Br J Dermatol 1999; 140: 1105–9.
9 Liew SH, Grobbelaar AO, Gault DT et al. Ruby laser-assisted hair removal : Repeated treatments and clinical efficacy. Eur J Plast Surg 2000; 23: 121–6.
10 Weisberg NK, Greenbaum SS. Pigmentary changes after alexandrite laser hair removal. Dermatol Surg 2003; 29: 415–19.

11 Kelly KM, Svasand LO, Nelson S. Further investigation of pigmentary changes after alexandrite laser hair removal in conjunction with cryogen spray cooling. Dermatol Surg 2004; 30: 581–2.
12 McDaniel DH. Clinical usefulness of the hexascan. J Dermatol Surg Oncol 1993; 19: 312–17.
13 Wheeland RG. Clinical uses of lasers in dermatology. Lasers Surg Med 1995; 16: 2.
14 Nanni CA, Alster TS. A practical review of laser-assisted hair removal using the Q-switched Nd:YAG, long-pulsed ruby, and long-pulsed alexandrite lasers. Dermatol Surg 1998; 24: 1399–1405.
15 Foly FD. Pathology of cutaneous burns. Surg Clin N Am 1970; 50: 1210–20.
16 Kennedy CTC. Reactions to mechanical and thermal injury. In: Campion RH, Burton JL, Ebling FJG, eds. Textbook in dermatology. Oxford, UK Blackwell Scientific Publications, 1992: 808–18.
17 Eremia S, Newman N. Topical anesthesia for laser hair removal: Comparison of spot sizes and 755 nm vs 800 nm wavelengths. Dermatol Surg 2000; 26: 667–9.
18 Liew SH, Cerio R, Sarathchandra P et al. Ruby laser-assisted hair removal: An ultrastructural evaluation of cutaneous damage. Br J Plast Surg 1999; 52: 636–43.
19 Anderson RR. Laser-tissue interactions. In: Goldman MP, Fitzpatrick RE, eds. Cutaneous laser surgery. The art and science of selective photothermolysis. St. Louis: Mosby Year Book, Inc., 1984: 1–18.
20 Bernstein EF. Hair growth induced by diode laser treatment. Dermatol Surg 2005; 31(5): 584–6,
21 Alajlan A, Shapiro J, Rivers JK et al. Paradoxical hypertrichosis after laser epilation. J Am Acad Dermatol 2005; 53: 85–8.
22 Lapidoth M, Shafirstein G, Ben Amitai D et al. Reticulate erythema after diode laser-assisted hair removal. J Am Acad Dermatol 2004; 51: 774–7.
23 Goldberg DJ. Laser hair removal. London; Dunitz, 2000.

11 MARKETING A LASER HAIR REMOVAL PRACTICE

Steven Mulholland

INTRODUCTION

As one reflects on the marketing of a laser hair removal practice, 2 striking observations become self-evident. First, laser services are no longer ancillary in any cosmetic practice. The revenue streams from a full service cosmetic surgery practice and an aesthetic laser hair removal clinic can be equal. Because in many locations laser hair removal is delegated, this has been a tremendous addition to many practices. It expands the revenue base without the physician having to perform the services herself. Any time one can develop such 'multipliers' in a business, there is a powerful opportunity to maximize revenue or free oneself to do other things. Secondly, the attendance at laser hair removal seminars and courses has shifted to include, in addition to the traditional aesthetic medical specialists, internists, family physicians, obstetricians and gynecologists, practitioners of complementary medicine, neurologists, and non-medical practitioners such as dentists, oral surgeons, chiropractors, aestheticians, homeopaths, and nurses.

Why have both the demographics of the attendees shifted, and the popularity of laser hair seminars increased? Simply because of population shift and economic reality! At the same time that an increasingly affluent population enters into its prime spending years, all of medicine and allied health services have witnessed a major contraction in traditional insurance and health care reimbursements. The explosion in cosmetic surgery, laser skin care, and aesthetic services has created an attractive market and source of additional revenue for all medical, allied health, and non-medical practitioners.

Unfortunately, as more medical practitioners have entered into the laser hair removal business, so have more non-physician medical aesthetic practitioners. In fact, in 2007, most laser hair removal is performed in 'non-medical' office settings. So how do we doctors compete? — !

The marketing principles outlined in this chapter are general enough to benefit any practitioner who wants to augment a laser hair removal practice. They are also specific enough that any practitioner who has purchased a laser or intense pulsed light (IPL) hair removal system can benefit immediately.

WHAT IS MARKETING?

Most physicians starting a laser hair removal practice equate marketing with advertising. Most doctors are very good at spending money on advertising to make the phone ring but are very poor at marketing. Anyone can spend money to make the phone ring. That's not marketing, that's the easy part. Marketing is a summation of all the activities and procedures that a physician as the provider of a product (your aesthetic services) must perform/implement to deliver the product into the hands of the consumer. Advertising may only represent a very small or non-existent component of a practice's marketing plan. There are many yardsticks by which to measure a successful marketing plan, but profitability and Return On Investment (ROI) are the most important for practitioners of aesthetic laser services. Concepts of medical marketing can be condensed into the following 10 Ps of Medical Marketing.

10 Ps of Aesthetic Medical Marketing	
1. Physician	6. Price
2. Product	7. Precision
3. Plan	8. Predictability
4. People	9. Profitability
5. Place	10. Pleasure

PHYSICIAN

In medicine, unlike some businesses, promotion can not be substituted for quality. The most important aspect of a profitable practice, and marketing that practice, is a quality physician. As doctors, our product is not a disposable plastic toy, where quality can be variable; ours must only be measured in excellent client outcomes. We have an ethical and moral obligation to our clients, as physicians, to deliver quality aesthetic health care and above all else 'do no harm'. Most businesses and their products are not bound by such intimate and ethical standards. We, as physicians delivering an aesthetic service, can never compromise the well-being of our clients with our products.

Part of our role, as physicians delivering a laser hair removal service, is to know the product well. We must learn the basics of laser medicine, laser safety, wound healing, and hair biology. We must also keep up-to-date on the latest developments by going to meetings, reading journals, and maintaining our continuing medical education. We never must lose sight of our role as physicians. If we do, then all the other Ps of practitioner marketing are worthless.

PRODUCT

Once one becomes a high quality laser physician, the next step is the delivery of a quality hair removal product to the laser hair removal client. Deciding upon the right technology can be a very difficult decision. There are many difficult questions such as optimum fluence, pulse duration, wavelength(s), and skin cooling. It is inevitable that there will continue to be technological advances in optimizing the removal of unwanted hair. Features of laser or IPL systems that are important include:

(1) **Speed:** The faster the system (Hertz and spot size dependent), the more effectively you can compete, and the more affordable your product will be for your clients. The ability to offer laser hair removal quickly and affordably for large zones (backs and legs) has been a tremendous advance. It has opened a whole new market that has been relatively unavailable to electrolysis.
(2) **Accuracy:** There is no point being very fast with a system if you, or your assistant, miss large areas which require re-treatment, as these additional sessions will have to be offered to the client free of charge. Systems that employ computer generated scanners or large delivered spot sizes offer tremendous accuracy. Both will minimize your missed zone re-treatment rate.
(3) **Service:** You will want to choose a laser company that will still be doing business in a year, provide quality service in the field, and whose technology has an excellent track record. Realistically, all systems will have some down time for repair and maintenance.

PLAN

An excellent physician with a good laser hair removal system needs a plan. If one 'fails to plan – then one plans to fail'. Short of an actual business plan, there are 3 simple questions one must answer as part of a plan to implement laser hair removal into a practice.

Market Analysis

If one is an obstetrician, dermatologist, or primary care physician with 10,000–20,000 clients in your roster, then you are in an enviable position to implement laser hair removal. Your initial market is your own large client roster. For other physicians, the practice base may not be large enough, or there are one-time clients. One may need to consider actively recruiting clients, through promotion, into the hair removal practice. There may be a need to conduct a quick (and easy) marketing analysis to determine the viability of your enterprise. Your target market is women between 20 and 65 years old, making over $30,000 per year (for simplicity, all monetary units in this chapter are expressed in US dollars). To find out how many demographic matches live in your locale, simply call up any medium that you might be interested in advertising with (radio, newspapers, magazines or television) and they will gladly send the market breakdown for your area (as they have already paid for this marketing analysis themselves). This is the least expensive and most valuable 'free' tool you have.

The following is an example of the simple analysis you will require.

(1) **City population:** 2 million
(2) **Demographic matches** (target market):
Women, 20–65 years, making over $30,000, say for example 680,000
(3) '**2.5% Rule**': This is an advertising assumption, which states that, of a susceptible target market for a product, only 1/40 (2.5%) might respond to advertising for this product.
(4) **680,000 ÷ 40** = 17,000 potential clients; however, there will be other clinics, possibly 30, performing laser hair removal in your locale.
(5) **17,000 ÷ 30** = 567 clients = market share: the number of potential clients in your region that can be obtained from your advertisements. This does not include potential clients that may come from other hair removal clinics.

If the potential market share is 300 people or greater, then the region is not saturated. A profitable hair removal practice should result.

Financial Modeling

If there are 500 clients in the clinic's market share, the average amount spent by clients is approximately $500 per visit. The average client returns 4 times: 500 clients × $500 × 4 treatments = $1,000,000. Thus, if the laser hair removal clinic is converting optimally all potential clients into treatments, re-treatments, and word of mouth referrals, then a $1 million dollar/year laser hair removal practice should result. However, because physicians never convert anywhere near the optimal rate (100%), most physicians will earn between $50,000 and $100,000 after expenses.

Marketing Plan

All the Ps in this chapter must be implemented for a successful marketing plan. A good marketing plan will keep the laser hair clinic profitable.

PEOPLE

The first step is to become a well-trained, knowledgeable laser practitioner. Then one needs a quality, fast, accurate hair removal device. This is followed by a planning and marketing analysis that indicates there is a viable opportunity to generate additional revenue in the local hair removal market. Only then is it time to consider the people who will be delivering the product. The people a physician hires to represent the aesthetic laser service are the next most important critical resource, after the doctor and the product, in delivery of cosmetic laser hair removal. Remember, these are the people who will present, represent, and promote your hair removal product on the phone, in your office, and in the community.

These highly sales oriented positions require outgoing, friendly and persuasive individuals. How does one hire these motivated outgoing types? They are in high demand. Obviously careful interviewing, references, and experience or transferable skills are necessary. Some have even hired human resources consultants to conduct personality profiling and psychometric testing, hoping to uncover the required character traits and sales skills of a successful representative. A brief summary of the recommended or standard recruitment and selection process follows. Even with professional assistance, due diligence, interviewing, and reference checks, a certain amount of luck is required.

The first step in selecting the right person is to determine the skills set necessary for the position. This is done by creating a job description, outlining the abilities and expectations required for the position. In making detailed job descriptions the task of finding the right candidate for the job is easier and is streamlined.

The next step in the search for the right candidate is to recruit in the right way through the right medium. Media to consider:

(1) Newspaper advertisements
(2) Online recruitment
(3) Network contacts
(4) Educational institutes
(5) Career/trade shows

Advertisements should contain the following information:

(1) Job requirements, description of duties
(2) Criteria and qualifications
(3) What we do and who we are
(4) Location for the position
(5) Salary and benefits
(6) Full or part-time
(7) How to apply
(8) Closing date for application submission (applying a timeline gives a sense of importance and immediacy that will motivate a call to action)

The third step in the search for the right candidate is the hiring process: the interviews, testing, reference checks, contract, and probationary period.

In summary the process is as follows:

(1) Job description
(2) Advertise/search for the right candidates
(3) Application
(4) Mini phone interview and screening
(5) Competency based interview or behavioral based interview
(6) Skill tests
(7) Second interview
(8) Reference checks
(9) Job offer and contract
(10) 3 month probation
(11) The employee's post probation interview, and graduation into full employee status

After hiring staff, they must be empowered by teaching them about laser hair removal. This will allow them to sell the procedure. Give them phone scripts for new callers and give them complimentary treatments. They will become the most enthusiastic promoters of the services. They will sell the hair removal product with a tremendous sense of conviction that clients can sense.

Finally, remuneration is critical. Staff sharing in the success always helps. Front desk staff (client service representatives), office managers, and laser technicians should always be paid a healthy base salary, commensurate with expertise and/or experience. One could advocate leaving room for bonus incentives based upon staff's ability to convert contacts to treatments. For the receptionist, it will be the number of calls (leads) to consultations; for the laser nurse it will be converting treatments to re-treatments, and for the office manager, who oversees the whole process, it will be a bonus on the percentage of incremental increase in sales. These monthly bonuses must always be an acceptable percentage of the increasing bottom line. Some form of bonus remuneration will lead to a well-trained, happy, motivated staff.

PLACE

The laser hair removal clinic will need a place for staff and technology. The clinic should always reflect the image of the provider (the physician), and the product. Remember people are paying out of their pockets for a non-insured service, and they will expect a quality outcome that is also delivered in pleasant surroundings. There is competition for their hair removal dollar. That does not mean you must have museum quality paintings hanging on the walls. However, it is important to pay careful attention to the 'look' and 'feel' of the clinic's setting to maximize the positive impact upon your potential hair removal clients.

After providing for a careful, tasteful, image appropriate, and coordinated approach to interior decorating, one must carefully plan all contact points with hair removal clients and create a positive image.

The waiting room

Keep this a private area, with no more than 1 or 2 clients waiting at a time. Clients dislike feeling 'herded' and should not be kept waiting as their time is valuable. When scheduling clients, allow them to have 5–10 minutes before they begin their appointment to experience the atmosphere of the clinic, to sign in, and to absorb the milieu. During this 'absorption phase' they should be exposed (through brochures, videos, posters, prompts, guides, and product displays) to some of the other wonderful cosmetic aspects of the office. This is a very effective form of cross-marketing. It is very important that the person staffing the reception area be familiar with all treatments the clinic offers, and be able to judiciously answer client inquiries.

As the clients arrive, greet them by name. Make them feel as though they know you and you know them. Offering a refreshment or snack (examples would include mineral or spring water, tea, coffee, or a light snack) will reinforce the excellence of your client care.

The Treatment Room

A 10′ × 14′ room is ideal. Provide room for changing and reapplication of make-up. Never miss an opportunity to cross-market other cosmetic services during treatments. Posters, videos, and motivated laser nurses can assist laser hair removal clients assess other available aesthetic services.

PRICE

The fees charged for laser hair removal services will vary according to the anatomical zone, type of practice, who delivers the service, laser speed, laser type, and competitive prices (the price-point) in the laser hair removal market.

Price-point in the market is likely to be the most important influence in setting fees. In most markets there will be a fairly narrow range of prices charged for laser hair removal performed on lips, chins, armpits, legs, backs, etc. It is important to find out what other clinics are charging. This is called 'Mystery Shopping'. Have friends or employees call all the competitors, find out what they charge per treatment or groups of treatments, who performs it, what system is used, and how long it takes. Ask for informational mailings. Send mystery shoppers in for consultation and treatment to see what is said and done.

Prices per treatment are likely to range from $50 or more for an upper lip to $600 or more for legs. Single treatments or multiple treatment packages may be sold.

In general, for a new laser hair removal clinic, prices should be at the low-middle range. The best possible service must be provided.

Do not make it difficult for clients to pay. Accept cash, checks, money orders, and credit cards. Also, do not have clients reconcile accounts over a counter in the waiting area. Create a small, private billing office where hair removal clients can settle their accounts in a confidential atmosphere. They will always appreciate this.

Presentation

The presentation of the laser hair removal product will be critical to the success of the clinic's profitability. Presentation links physician, staff, place, price, and even promotion into one harmonious symphony that is known as internal marketing or 'invertising'. Invertising is the summation of all the experiences of the hair removal client, from the time she responds to a promotion to the last time that she comes for a treatment. From the time of the first phone call, every single client contact point should be broken down into all the possible events. Physician and staff must script, practice, and orchestrate in such a manner that the experiences or 'through-put' of the clients, as they flow though the clinic, are positive, and encourage them on to the next phase. The summation of all these small coordinated bursts of activity is the quality performance of a team that can beat the competition.

The standard contact phases that must be orchestrated in the 'through-put' are as follows:

Promotion→Inquiry→Consultation→Treatment→Word of Mouth→Re-treatment→New procedure

The obvious goal is maximizing the client conversion from one phase onto the next. Conversion rates will determine the success and profitability of the clinic. Excellent promotion will generate a large number of leads and consultations. This, through excellent 'invertising' will result in increased treatments. The quality of the product and treatment delivery will maximize word-of-mouth referrals, re-treatments, and conversions to new procedures.

Inquiry (Lead Stage)

Promotion (advertising), although technically the first stage of the process, will be covered later. Making the 'phone ring' is usually the easy part. Anyone can utilize funds for advertisements that lead to a ringing phone. Where most physicians fail is in maximizing the conversion of phone calls to treatments and re-treatments. Unless one prepares for this, a maximum return on advertising or promotional investments will never be achieved.

Each promotional advertising that leads to a call into a hair removal practice is likely to cost between $75 and $250 per call, depending upon the advertisement, the medium, and the market. Each time the phone rings, the clinic will either convert that $75–$250 call into potential revenue or lost money.

For maximum lead conversion, careful telemarketing scripts must be created. These scripts are the exact responses a physician wants the staff to provide during an introductory phone call. It is this interaction that leads to booking consultations. Keep these scripts short, answering common questions, but always playing up the benefits of the laser hair removal product. Staff must be focused on the 'closure to consultation' where 'everything will be explained fully'. The script should focus on the unique and positive selling points of the clinic and hair removal treatments, including competitive prices, and extraordinary service. Avoid giving too much information over the phone. You want prospects to come into the clinic to get more information, at which point you will be able to convert them into clients more successfully. Unfortunately, the risk of providing too much information over the phone will increase, as staff become more knowledgeable. Surprisingly, the increased knowledge only increases the risk of staff saying something inaccurate. This can dissuade prospective leads before they can experience the hair removal center's wonderful 'through-put'.

The topic of telemarketing can be a book in itself. There are many books and one-day courses on this very topic. Success will be documented by measuring conversion rates. Scripts, price, or presentations may occasionally have to be changed. Once the laser hair clinic is up and running, one should not settle for anything less than a 50% conversion rate of all calls to consultations. In the beginning, the lead conversions are likely to be at 20–25%. Pay close attention to the details of the 10 Ps; individualize the approach to maximize profits. Active leads are the calls that book consultations. Passive leads are the leads that everyone forgets about. These are the callers that did not book a consultation, but may have only requested information. Unfortunately, the clinic has already paid for the passive lead phone calls ($75–250). These callers must become part of a pool the hair removal clinic continues to access. Part of the telemarketing database will gather necessary demographic data. Consider the mailing of a complimentary information package. The information package is sent to active (consultation booked) and passive (information only requested) leads. It describes the procedure of interest, the physician, the facility, and other services offered. Active lead management is simple; these clients are led into the consultation phase. Passive lead management involves a succession of triggered mailings over the first month designed to keep the passive lead (prospective client) interested in the facility. If no consultation is booked after 1 month, the passive lead receives a quarterly newsletter for 2 years. If the passive lead has spent no money in the clinic after 2 years, the prospective client should be dropped from the mailing list.

Clearly this kind of lead management or 'contact management' requires the help of a computer software program. These 'contact managers' are abundant. Goldmine™ and ACT™ are a couple of the popular general business contact management programs. Several programs are adapted to the medical practice, such as Nextech 99™, and Inform and Enhance™. Most recently in the marketplace is SpaMedWare®, developed by SpaMedica® International, a comprehensive practice management software developed and utilized by a medical spa. No one program is perfect, but it should offer contact management, triggered mailouts, full reporting, scheduling, and some limited charting. It is difficult to be efficient without one.

Consultation Phase

The consultation, or treatment, whether offered by a nurse or physician, should be part sales and part informed consent. The positive side of your product, laser hair removal, should always be emphasized first. Once clients know about the procedure, benefits and costs, the informed consent should include alternative treatments, advantages, disadvantages, and risks. The client should have an opportunity to fully read the consent, have any questions answered to their satisfaction, and should then sign each page of the consent document (indicating it was read and understood).

A well executed consultation and consent for hair removal should leave the client excited and hopeful about the potential results, well informed, understanding of the risks, and enthusiastic about going onto treatment.

As mentioned, the laser hair removal consultation is part sales and part informed consent. The informed consent must be implemented fully, accurately, and ethically. This is even more important in those jurisdictions where the cosmetic laser services (including consultation) may be delegated to a nurse or technician. The consultation must be broken down into its sales components. A typical hair removal consultation is scheduled for 1 hour. This includes the waiting room 5 minute cross-marketing absorption phase, 30 minutes for the consultation and consent signing, 10 minutes for a possible test spot and assessment, and finally 15 minutes for client cleanup, makeover, rebooking, account payments, and departure. A staff member who is goal oriented, and has a great smile should assist the client with all phases.

The consultation is broken into the following elements:

(1) **Put on the game face**. The goal at the end of a 30-minute consultation is to pique the client's interest to the point where they will purchase the product on the spot. During these concentrated consultation periods, the delegated

consultation team (usually the receptionist, physician or nurse, and office manager) must 'put on the game face'. Remember much has been spent on (1) the purchase of the lead (promotion); (2) the conversion of that lead into a consultation (telemarketing); and (3) the creation of the right ambiance, atmosphere, marketing literature, and flow through your clinic (presentation). Consultation conversion rates are another stage the clinic will have to live by. It is mandatory that the hair removal clinic projects an organized, confident, well-groomed image.

(2) **Make them your friend**. For the first 10 minutes of every interview, find out about the client. The physician needn't do this. Ask about their families, what they enjoy about their work, etc. Try to make a connection that allows the client to know that you know how interesting they are.

(3) **Find out what they really want**. Ask the client directly what it is they really wish to achieve from hair removal. By clearly getting the client to state their goals, the clinic will better be able to service their needs.

(4) **Reassure the client that you can deliver what they want**. Make sure that laser hair removal can satisfy the specific expectations of the client. The client may have to modify their expectations if they are unrealistic (the usual unrealistic client expectation is 100% permanent hair reduction after 1 or 2 treatments).

(5) **Assume the sale**. Carefully word all discussions with the client to include the assumption of purchase of the product. 'Mrs X when you are undergoing your laser hair removal your will find …'. Assuming the sale reinforces the urge/impulse of the client to purchase the product. This will translate into a client undergoing treatment.

(6) **Prevent 'buyer's remorse' (future pacing).** The client's mind must be put at ease over the expense of their purchase. This is required to prevent the inevitable remorse experienced by many consumers after a sizable purchase. Clients should be told of the direct benefits of the treatment. As an example, one might ask Mrs X. 'do you have any upcoming social events where the sheer nylons you can purchase after laser hair removal, will look great?' Or, 'The vacation you have planned will be so much more enjoyable without having to shave your legs or underarms'.

(7) **The closer**. The 'closer' should always be someone other than the physician, usually the office manager. This removes the doctor or nurse from discussing finances and keeps them squarely in the role of aesthetic health service delivery. The closer is often an individual with sales experience who will be able to convert a higher percentage of consultations to treatments. The closer will also discuss payment terms and options.

Similar to the lead conversion rate, the percentage of consultations leading to laser hair removal treatment should be no less than 50%. In practices with a high percentage of word-of-mouth referrals (clients who come from other happy clients), the closure rate can approach 80–90%. These successful practices are servicing ‘buyers’. ‘Buyers’ are those clients who call and come knowing they will have treatment. This type of ‘buyers’ practice is the ideal practice profile, but is usually achieved by purchasing enough shoppers (through promotion) and converting a high percentage of them to happy clients. With attention to the 10 P’s of cosmetic medical marketing, one can achieve this type of practice much sooner. Such a clinic’s ‘through-put’ and service will be superior to its competitors.

For the new laser hair removal clinic, where an exclusive ‘buyers practice’ does not exist, most clients are simply ‘shoppers’. These are clients who were purchased through promotion. ‘Shopper practices’ need to work very hard with lead and consultation conversion to achieve maximum profitability. Most shoppers’ practices that attend to service and the 10 Ps should convert at least 50% of consultations to treatment.

Treatment

Like the other stages of contact and conversions, careful consideration must be given to what occurs during the treatment. First and foremost is the obvious — treatments must be safe and effective. If the laser hair removal act is delegated to a laser nurse or technician, ensure that they have been well trained. They must know all clinical parameters necessary to safely, autonomously, and effectively deliver the treatment. Create a written ‘Delegatable Laser Hair Removal Protocol Document’ that clearly outlines the training, continuing education, treatment parameter, and adverse outcome protocol. This document should be kept on file in the clinic, be posted in the laser rooms, and constantly reviewed and updated. Only when safety and efficacy are addressed can one focus on presentation, comfort, and promotion. Have the laser treatment room nicely decorated, clean, well ventilated, and cooled. Have a comfortable clinic gown, room, slippers, towel(s), and treatment bed. Educate the laser nurse(s), and/or technicians on the other procedures, services, and products provided by the cosmetic clinic. Give them the cross-marketing scripts, skills, and bonus remuneration to allow and motivate them into selling the available services. Ensure that posters, wall-prompts, brochures, and continuously running videos on the other clinic services and products are placed, exposed, or provided to hair removal clients during treatment. Finally, have a private clinic space for the client to undress, re-apply make-up, and freshen-up after treatment before leaving the clinic.

Word of mouth, re-treatment, and new procedure

With a well delivered laser hair removal product, the majority (over 80%) of clients should return for their mandatory second treatment and over 60–70% should come back 2–8 times for re-treatments over several years. Re-treatment conversion is not only built on the excellent experiences at earlier contact phases, but also depends heavily on the comfortable delivery of the product and its success. Remember: if the client expects 'some' degree of permanent hair reduction and ongoing, intermittent laser hair maintenance at affordable prices, most clients will be happy repeat customers. A successful hair removal clinic should keep growing; the client base should keep expanding. They will choose other new procedures as well.

One happy hair removal client can generate an average of 4 word-of-mouth referrals (and the clinic only paid for the first lead). Send paying hair removal clients birthday notices and holiday greetings acknowledging your appreciation for the business, and perhaps a time-limited discount coupon that can be applied towards clinic services, for each known referral they send.

Actively solicit word-of-mouth referrals with mailings to clients, and gifts or bonuses (in the form of treatments) if they refer a client.

Conversion is the key to a successful practice. Attention to the 10 Ps will maximize the ability to measure, improve, and control conversion.

Promotion

Thus far, this chapter has focused on the details of the 'through-put' and the internal marketing details. The surest way to waste money is to promote a practice and product before working out the intricate details of its delivery. If one does not take time with the first few Ps, then one is likely to waste tens of thousands of dollars on advertising with unacceptably low conversion rates.

Promotion can be divided into internal and external promotion.

Internal Promotion 'Invertising'
(1) Direct mail – to your existing database
(2) Cross-marketing

External Promotion
(1) Public relations, talks, seminars
(2) Public relations consultant/publicist
(3) Advertising
  (a) Direct mail to targeted zip codes/preferred list
  (b) Internet
  (c) Yellow pages
  (d) Radio
  (e) Television
  (f) Print media, newspapers, magazines
(4) Trade shows

Promotion can be an isolated campaign, usually 6–12 weeks in duration, with one or more media (e.g. radio, newspaper, and direct mail). The advantage of one focused, time-limited promotional campaign is that it saturates the target market for a brief period of time.

Consistent promotion or advertisement placement is often used on a weekly or bimonthly basis to maintain leads using the best performing medium. Advertisements may be strongly 'image oriented' *or* 'call to action', or a combination of 'imaging' *and* 'call to action'. Image advertising is easily recognized as the most common form seen on television and magazines. Image advertisements are often run by large companies with a large advertising budget. These are directed to the creation and implementation of advertisement slicks with an 'image' oriented design. Such an approach allows the consumer to identify with the image; the image becomes brand recognition. Image marketing is not designed for, nor does it require of the consumer any immediate action. Image advertising is intended to put your product at the top of consumers' 'mind share' so that the prospects/clients will always think of the advertiser in a certain product category. An advertisement designed to have the consumer pick up the phone and impulsively/decisively call a number is called 'call to action' advertising.

Cosmetic laser surgery advertisements are often examples of combined 'image' and 'call to action' advertising. Laser aesthetic services are a very visual product and imagery evokes strong emotion and consumer impulses. A laser hair removal advertisement showing before and after images of a model's long smooth legs would be such an example. However, most medical practices cannot afford to place image advertisements with the hope that clients will call for a consultation. Medical practices are not usually large corporations. A medical practice must produce immediate leads and business with its advertising dollars. A medical practice may entice the client with image marketing. This must be followed by a strong 'call to action' such as 'call now for a free consultation' or 'upper lip hair removal at a $99 discount, for the first 100 callers'. In aesthetic medical advertising, combinations of strong imagery, bold print, before and afters, strong call to actions, and the word 'free' usually generate an adequate number of leads with low lead costs.

Lead cost is the amount of investment required to acquire each phone call (lead) assigned to a specific advertisement. The calculation is very easy. It is an automatic component of most contact management reports. It is the cost of the specific advertisement the number of leads attributed to that advertisement. For example, if an advertisement costs $3000 to implement and generates 30 calls over the next 3–4 weeks, the lead cost is $3000 ÷ 30 = $100. As a rule, in laser hair removal where the product price per treatment may average only $500, the lead cost cannot exceed more than $100 per call.

Internal marketing 'Invertising'

Direct mail

For practices with large existing client bases, direct mail is where promotion should begin. Primary practitioners, internists, and dermatologists often have large rosters of long-term repeat clients. These clients already know and trust their physicians. These physicians have brand recognition. The lead conversion rates should approach 80% (converting leads to consultations). The lead costs should be around $20–50/lead. Here, the cost is a simple direct mail campaign to existing clients. The ideal target group is female clients 20–65 years of age. A mass mailing to your existing clients, describing your new laser hair removal services, should cost $2000 for 5000 mailouts. You should generate 40–50 calls (leads) from this simple campaign ($50 lead cost).

This routine can give the physician and staff a trial run of both the presentation and 'through-put' the clinic has developed with the simplest group of clients. This simple example can improve the telemarketing, consultation, and treatment skills on currently existing happy clients. This should always be the first trial before the clinic goes out and buys 'shoppers' through more expensive promotional activities.

Cross-marketing

Provide clients who come to the office with all clinic awareness materials (customized brochures, video exposure, posters) of all available services. Remember to track the cost of these materials, and the percentages of clients who come from these activities. This leads to an assessment of efficacy and possibly alterations.

External marketing

Promotional activities outside the current existing practice.

Public relations

Make an effort to speak at various medical societies, women's groups, and home shows that match the target market. Given the expense of a physician's time, the lead cost of these activities will be very high. However, this is a good way to generate awareness during the start-up phase of a hair removal clinic.

Public Relations Consultant

If laser activities and services are the only offered services, then the lead costs of $200–500 for a consultant will be too expensive. However, a good Public Relations Consultant (PRC) can be indispensable to a large, multi-service practice over the long run, especially if other cosmetic surgical procedures are offered. A good PRC will generate awareness and media stories about the physician, the clinic, and its services. It doesn't take long to become known as a laser aesthetic expert.

Internet

One-time start-up costs of $1000–6000 and maintenance of $500/year are quite expensive. Initial lead costs, due to the one-time start-up expense, may prohibit this; but lead costs decrease with time (due to the one-time only expense). A web site also serves as an information center somewhat akin to the Yellow Pages for the digital set. Today, much of the target market (women 20–65) use the Internet. As the number of Internet users increases, there will be a decrease in use of traditional directory services such as Yellow Pages, so it is wise to get online. However, do not expect that a web site will keep the hair removal clinic busy in the beginning.

Radio

Aggressive 30 and 60 second laser hair removal spots on the radio usually cannot be achieved with lead costs of less than $150. Such costs usually make this medium too expensive. In addition, advertising for such services is better received by clients in a visual format. Radio spots may not be the right medium for newcomers to this market space.

TV

Lead costs of $175–250 are again too expensive for hair removal (remember, the average treatment cost is $500). This medium is better left for advertisers who have an established business and want to maintain their market position as leaders and develop/protect a strong brand awareness.

Direct mail

Such lists are purchased from a variety of companies. These are like direct cold calls with lead costs of $200 or more for laser hair removal alone. Success rates are not high. Direct mail works best when you cultivate your own lists called 'house lists'. House lists are best, because most people on this list have not only given you permission to contact them, but came to you to say 'yes, I want you to send me information'.

Yellow Pages

Traditionally, Yellow Pages advertisements have been indispensable. They generated leads themselves – as well as supported leads generated from other promotional activities. When measured by themselves, Yellow Page hair removal lead costs of $150–200 can be expected. However, because leads generated from other promotional media such as newspapers, radio, etc., often look for the clinic Yellow Pages number, their supportive, and integrated value cannot be ignored. However, in recent years with the increase in the usage of the Internet, most paper directories have become obsolete. Most prospects in your target market will do a search on Google, your cities, directory, etc. However, you do still have some portion of your target market who have not moved toward the digital age, so a smaller scale advertisement will still be appropriate and relevant. Do not purchase full page, 4 color advertisements in multiple telephone books! Unless the laser hair clinic has other, more expensive cosmetic services to offer, it is pointless to incur the fees of up to $10,000/month in Yellow Pages advertisements.

Magazines

Line rates are more expensive than similar rates in newspapers. However advertisements are ‘sexier’ and shelf life is longer. Conversely, the market reach is usually smaller with magazine advertisements. In general, lead costs of $150 can be achieved with magazine-generated laser hair removal advertisements. Having a ‘call to action’, such as a limited time offering, will also increase the response rate, thereby decreasing the lead cost, and increasing your ROI.

Newspapers

As a general rule, the newspaper generates the lowest lead costs for laser hair removal. If there is more than one daily newspaper in the target area, research which newspaper reaches the greatest percentage of your target market (women 20–65 and making over $30,000). A large launch advertisement with a subsequent weekly presence preceding and during peak hair removal times (fall, winter, spring) should result in lead costs between $75 and $125. These advertisements should be a combination of image advertising, with a little story about the product, and a strong ‘call to action’.

Use these lead cost numbers as a guide. Utilize the advertisement departments of newspapers and magazines, or employ the services of an advertising agency ($2000–3000 per advertisement). Try different media, but above all measure! If an advertisement does not work, and enough calls are not generated, lead costs will be too high (that is, anything above $150). By measuring lead costs, promotions can be adjusted. If the advertisement does not work, than the wrong medium may have been chosen (try another), or the message may be poorly designed (change it). Do not be satisfied until lead costs are $125/lead or lower.

Trade shows

Local convention or trade shows for aesthetic enhancements geared to consumers are good places to showcase your clinic. First, the attendees of these conventions or trade shows are interested in what you have to offer, and are doing research. This is where you can impress them. You can secure booths as small as 10′ × 10′ which is a minimal investment to put you in front of your prime target market. Create a 'buzz' around your booth, hold demonstrations, contests, and provide something of value to take away with them. This could be in the form of a pen with your branding on it; however, a coupon with a significant value is a great way to measure your investment. A coupon or voucher creates a 'call to action' and you are providing a perceived value. A pen is a great writing tool, but it is not a true incentive to call your center over your competitor. A voucher or coupon has monetary value and thus, if the prospect is interested in your service, they will 'cash in' their coupon to receive the greatest value for the service they are going to invest in. This is a great way to track and measure the lead cost of this effort.

PRECISION AND PREDICTABILITY

Conversion rates will determine clinic success and profitability. Implementing the 10 Ps will help maximize conversions. Measurements of conversions must always be made. Measurements lead to adjustments, re-engineering, and alterations of the process at each contact stage. Remember:

Advertisement → Lead → Consultations → Treatment → Re-treatment → Word-of-mouth

By measuring, one knows the precise conversion rates for each stage. Any time the conversion rate falls below optimum standards, adjustments become mandatory. If the clinic is already converting at 50%, do not accept this. Strive for 75 or 90%.

Measure conversions weekly. Staff bonuses should be based on optimal rates. By conducting weekly staff meetings where conversion rates are discussed, sudden drops in otherwise optimal rates will often reveal a cause. There might be an inadvertent change in protocol, or a staff interpersonal and/or family crisis. Measurement will be the key to micromanagement of a successful laser hair removal practice. Measurement will give one the power to control practice flow and profitability.

The following, then, are the measurements that must be tracked.

(1) Referral source cost (advertising cost)
(2) Lead cost = cost of advertisement ÷ number of leads (calls)
    — keep less than $125, aim for $75
    — measures success of the advertisement (promotion)
(3) Lead conversion rate = number of leads ÷ number of consultations
    — percentage of leads converted to consultations

- — measures telemarketing success
- — keep over 50%, aim for >75%

(4) Consultation conversion rate = number of treatments ÷ number of consultations
- — measures success of consultation phase
- — keep over 50%, aim for 75%

(5) Re-treatment conversion = number of re-treatments ÷ number of treatments
- — percentage of clients who come back for re-treatments
- — measures success of the treatment phase
- — keep over 75% between hair removal treatments 1 and 2, and 50% thereafter

(6) Word of mouth referral rate = number of word of mouth referrals ÷ number of treatments
- — percentage of clients who refer other clients
- — aim for 25%

(7) Return on investment = revenue in sales from an advertisement ÷ dollars spent on the advertisement
- — ROI for each advertising dollar
- — minimal acceptable ROI should be 3:1, that is $3 in revenue for each dollar of advertising
- — aim for 10–15:1, with re-treatment and word of mouth referrals augmenting the profitability from the initial lead costs

PROFITABILITY AND PLEASURE

By using the 10 Ps as a template to construct a laser hair removal practice, happy clients will follow. These clients, in turn, generate word of mouth referrals, which makes for a profitable program. With this profitability, and self-determination, comes pleasure. It is this pleasure that leads to enjoyment. A laser hair removal practice can be lucrative, stimulating, and pleasurable.

INDEX

Page numbers in *italic* denote figures, tables or boxes

LASER HAIR REMOVAL

Second Edition

David J Goldberg MD JD

Clinical Professor of Dermatology, Mount Sinai School of Medicine, and Skin Laser and Surgery Specialists of New York and New Jersey, New York, NY, USA

The author of the best-selling text on *Laser Hair Removal* (2000) now returns to the subject. The topic has moved on immensely in the period between editions. During this time, there have been technological innovations with lasers themselves – and this text notes the implications of these – but the most important developments have been in the nuanced approach now adopted in practice by cosmetic physicians. The avoidance of complications, problematic skin, and practical pearls have all assumed a much higher importance. Accordingly these topics now have increased material devoted specifically to them in this text. No practitioner of laser hair removal can afford to be without this improved clinical resource.

REVIEWS OF THE FIRST EDITION

'An invaluable tool for all those working in laser area medicine'

Journal of Applied Cosmetology

'This is a well-produced volume written by an acknowledged expert in the field. The colour photographs are excellent.'

Journal of Cosmetic Dermatology

Published in association with the *Journal of Cosmetic and Laser Therapy*

informa
healthcare

www.informahealthcare.com

9 780415 414128