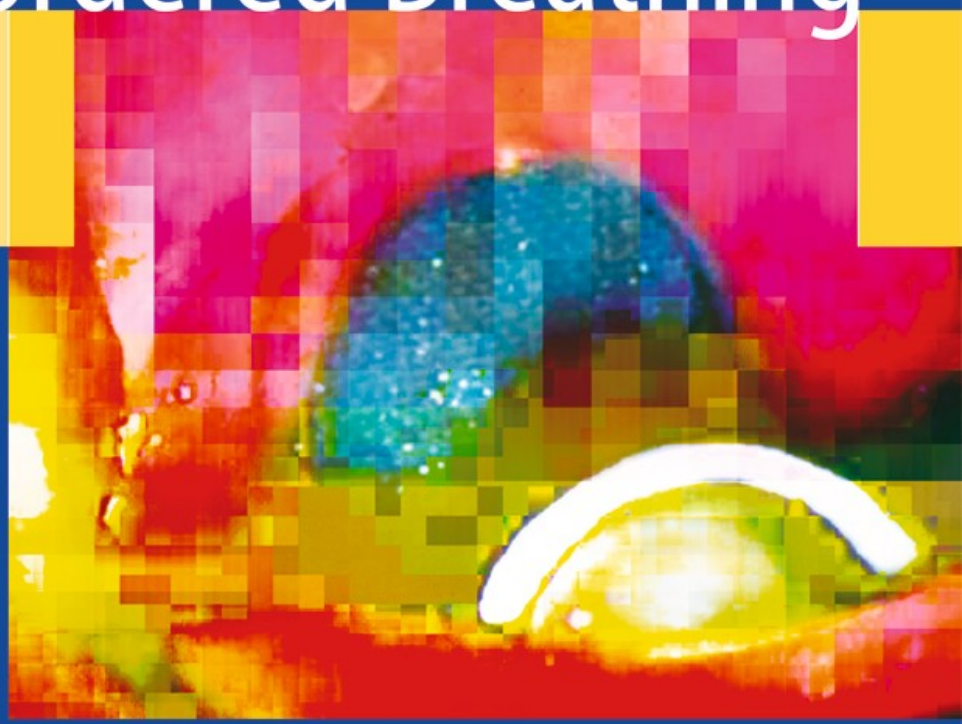
Karl Hörmann
Thomas Verse

Surgery for Sleep Disordered Breathing



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With 92 Figures, Mostly in Colour,
and 32 Tables

Springer

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Preface

Sleep disordered breathing (SDB) is of growing interest. To address the importance to the public health, it has been shown in 1993 that 9% of middle-aged women and 24% of middle-aged men suffer from SDB with consecutive cardiovascular disorders. It is suggested that the prevalence of undiagnosed SDB is much higher. Among these patients the obstructive sleep apnea syndrome (OSAS) plays the most important subgroup with cessations of breathing during sleep (apnea) and symptoms like snoring, daytime sleepiness and hypersomnolence with loss in concentration. Nasal continuous positive airway pressure (nCPAP) ventilation is the gold standard in the treatment of obstructive sleep apnea (OSA). Unfortunately nCPAP ventilation does not exceed long-term compliance rates of much more than 60 percent. To address these patients several alternatives exist. Beyond conservative therapies various surgical concepts become more important.

For more than 15 years now, we give special intent to the field of surgery in sleep medicine. Our sleep laboratory by now encompasses 20 cardiorespiratory polysomnographies each night. Per year we perform almost 1000 surgical procedures for sleep disordered breathing apart from numerous other conservative and apparative treatment modalities.

Referring to the present literature of sleep medicine especially concerning surgical procedures, we tried to summarize the recent knowledge in this field. We want to give general advice as well as specific hints for the surgical treatment of sleep disordered breathing. On the following pages we present standard surgical procedures as well as special concepts concerning sleep surgery. In consideration to our own clinical experience of more than 15 years this book gives advices in indications and contraindications of each surgical procedure and explains the postoperative care. We hope, that this book will become a helpful guidebook for all surgeons with special interest in modern sleep medicine.

Mannheim, February 2005

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Abbreviations

ACP	Antral choanal polyp
AHI	Apnea hypopnea index. Number of apneas and hypopneas that occur per hour of sleep
AI	Apnea index. The number of apneas that occur per hour of sleep
ATE	Adenotonsillectomy
BMI	Body mass index. A measure of weight compared to height, calculated as weight in kilograms divided by height in meters squared (healthy: 18.5–24.9 kg/m²; overweight 25–29.9 kg/m²; obesity >30 kg/m²; morbid obesity >40 kg/m²)
BSSO	Bilateral sagittal split osteotomy
CAPSO	Cautery-assisted palatal stiffening operation
CPAP	Continuous positive airway pressure. Gold standard treatment of obstructive sleep apnea and the upper airway resistance syndrome
CT	Computer tomography
DOG	Distraction osteogenesis
EBM	Evidence-based medicine
ECG	Electrocardiogram
ESS	Epworth Sleepiness Scale. A subjective measurement of sleepiness.
FFT	Fast Fourrier transformation
HS	Hyoid suspension. A surgical procedure for OSA
LAUP	Laser-assisted uvulopalatoplasty. A surgical procedure for simple snoring
LUPP	Laser uvulopalatoplasty. A surgical procedure for simple snoring
MAD	Mandibular advancement device. An oral appliance that moves the lower jaw forward against the upper jaw
MLP	Midline partial glossectomy
MLS	Multi-level surgery
MMA	Maxillomandibular advancement
MO	Mandibular osteotomy with genioglossus advancement
MRI	Magnet resonance imaging
MST	Mucosal strip technique; a surgical procedure for simple snoring
nCPAP	Nasally applied continuous positive airway pressure
NSAID	Non-steroidal anti-inflammatory drugs
ODI	Oxygen desaturation index. Number of oxygen desaturations >4% that occur per hour of sleep
OSA	Obstructive sleep apnea
PAS	Posterior airway space
PSG	Polysomnography. A graphic measurement of sleep and cardiorespiratory parameters
RDI	Respiratory disturbance index. The number of respiratory events that occur per hour of sleep (equivalent to AHI)
RFQ	Radiofrequency. An interstitial thermal ablative technique to reduce hypertrophy of soft tissues and produce scarification
SDB	Sleep-disordered breathing. An inclusive term that denotes all respiratory abnormalities during sleep
SI	Snoring index
STS	Sodium tetradecyl sulfate
TAP	Transpalatal advancement pharyngoplasty; a surgical procedure for OSA
TE	Tonsillectomy
TT	Tonsillotomy
UARS	Upper airway resistance syndrome

UPPP	Uvulopalatopharyngoplasty. A surgical procedure for SDB
VAS	Visual analog scales
VPI	Velopharyngeal incompetence. A dysfunction of the sphincteric closure action of the soft palate

Sleep-Disordered Breathing

1

In our modern competitive society, non-restorative sleep is acquiring an enhanced significance. The international classification of sleep disorders includes 80 different diagnoses of possible causes for non-restful sleep [13]. A subgroup with a comparatively high incidence rate is formed by the so-called sleep-disordered breathing (SDB) disorders. These are further divided into disorders with and without obstruction in the upper airway. SDB disorders without obstruction include primary alveolar hypoventilation (Ondine's curse syndrome), secondary alveolar hypoventilation, and central sleep apnea. These clinical syndromes have neurological causes, and in general resist surgical treatment.

Sleep-disordered breathing disorders with obstruction include primary snoring, upper airway resistance syndrome (UARS) and obstructive sleep apnea (OSA). Currently, these syndromes are regarded as different grades of severity of the same pathophysiological disorder [341]. Snoring is caused by vibrations of soft tissue in constricted segments of the upper airway. By definition, primary snoring is not accompanied by breathing impairment, and entails neither disruption of sleep nor increased daytime sleepiness. Primary snoring may lead to a social problem as a result of the nocturnal breathing sounds, but it is not essentially a disorder of the patient's physical health.

Yet in the case of OSA, an imbalance exists between forces dilating and occluding the pharynx during sleep. The muscle tone supporting the pharyngeal lumen is too low, and the inspiratory suction force, as well as the pressure of the surrounding tissue, which both narrow the pharynx, are too high [412, 386]. This disorder occurs only during sleep as a result of a physiological loss of muscle tone of the pharyngeal muscles in this state. The effects are complete cessation of breathing (apneas) or reduced breathing phases (hypopneas). If sustained long enough, both events trigger an emergency situation for the body. The body reacts with a central arousal, which disturbs the physiological sleep by a release of catecholamines. The latter lead to a strain upon the cardiovascular system via an increase in the tone of the sympathetic system.

In the case of UARS, the muscle tone is still sufficient to keep a partial lumen. The respiratory resistance is thus increased to an extent needing elevated respiratory efforts. After a certain amount of time this breathing impairment is interrupted by the same central nervous activation that is seen when apneas are terminated. The result is an increased occurrence of respiratory arousals without detectable apneas [184].

In contrast to primary snoring, OSA and UARS have an adverse effect on the daytime life quality. Cardinal symptoms of OSA are intermittent snoring (94%), daytime sleepiness (78%) and diminished intellectual performance (58%). Further symptoms are personality changes (48%), impotence in men (48%), morning headaches (36%), and enuresis nocturna (30%) [182].

Obstructive sleep apnea is a widespread disorder affecting up to 10.9% and 6.3% of the male and female populations respectively [237, 584]. OSA is associated with serious adverse consequences for afflicted individuals, such as myocardial infarction [227], stroke [117], hypertension [382], and traffic accidents [508].

In other words, primary snoring is merely an irritating annoyance, whereas OSA and UARS represent diseases with a significant morbidity and mortality. This implies that distinct therapy goals are warranted. Therefore, we consider it vital that a precise diagnosis is established before the initiation of any therapy. The necessary diagnostic work-up includes an anamnesis using standardized questionnaires, a physiological and otolaryngological assessment, and a sleep lab evaluation. For details see the relevant literature [8–10, 13, 143].

General Aspects of Therapy

2

The severity of sleep-disordered breathing (SDB) is crucial in deciding which therapy is most suitable for which patient. The simple snorer is not ill. Therefore, the goal of treatment in the case of primary snoring lies in the reduction of both the duration and the intensity of snoring to a socially acceptable level. In principle, it needs to be kept in mind that: (1) a treatment should not harm the patient, (2) a treatment should be carried out only if the patient has explicitly articulated such a wish, and (3) after any treatment nasal ventilation therapy should remain possible [11]. This last aspect is important because the incidence of obstructive sleep apnea (OSA) increases with age [302]. Especially after aggressive soft palate surgery, many cases have been described in which nasal ventilation therapy was no longer possible due to the development of a nasopharyngeal insufficiency or stenosis [346]. In many places, these cases have seriously impaired the trust in soft palate surgery.

In the case of upper airway resistance syndrome (UARS) and OSA, the goal of treatment is complete elimination of all apneas, hypopneas, desaturations, arousals, snoring and other related symptoms in all body positions and at all sleep stages. Of course, it should also be stressed that in principle a treatment should not harm the patient. But it must be pointed out that in the case of UARS and OSA, a disease with corresponding symptoms is already manifest. Therefore, in order to achieve the therapeutic goal, one will be less reluctant to consider a more invasive therapy with a heightened morbidity and complication rate, a decision that would be indefensible in the case of harmless primary snoring.

In general, the severity of OSA is classified according to the apnea hypopnea index (AHI; the number of apneas plus the number of hypopneas per hour of sleep). Unfortunately, especially in the case of the mild forms of SDB, the AHI is not necessarily correlated to the clinical symptoms of the patients. Furthermore, the AHI is age-dependent. A widespread consensus exists that an AHI ≥ 2 is to be assessed as pathological in children. Newborns should not have any obstructive apneas. No generally accepted consensus exists in adults. In an examination of 385 men with SDB, He et al. [194] demonstrated that the mortality risk rises significantly above an apnea index of 20. In our sleep lab we therefore use the following distinction:

mild OSA	$10 \leq$ AHI < 20
moderate OSA	$20 \leq$ AHI < 40
severe OSA	$40 \leq$ AHI

Below an AHI of 10 it is necessary to make a differential diagnosis between harmless primary snoring and a potentially health-impairing UARS. It should be taken into account that the above values are applicable to 30-year-olds. A 70-year-old patient with a maximum AHI of 15 is not necessarily in need of treatment if he or she does not have any daytime symptoms.

Apart from the AHI, the ailments of the patient play a role. That is, a patient with a UARS and an AHI of significantly below 10, but suffering from intense daytime sleepiness, may already be in need of treatment, whereas an older patient with an AHI of 15 may be fine without treatment. The concomitant diagnoses also need to be taken into account. Since SDB constitutes risk factors for myocar-

dial infarction, arterial hypertension and strokes, patients with a corresponding anamnesis need to be sufficiently treated early on. One should also take special note of traffic accidents in the anamnesis, as these are frequently a result of sleepiness behind the wheel, which again suggests the existence of an SDB.

There are a multitude of treatment options for SDB, which can be classified into conservative, apparative and surgical methods. Conservative methods include weight reduction, optimizing sleeping hygiene, conditioning in respect to the avoidance of certain sleep positions and medicinal treatments.

Obesity constitutes a major risk factor for SDB [56, 481, 454]. Several studies have shown that weight reduction significantly improves OSA in the short run, but the long-term success rate does not exceed 3 % [441].

The maintenance of a certain level of sleeping hygiene (avoidance of alcohol and sedatives, reduction of nicotine and other noxious substances, observance of a regular sleep rhythm, etc.) is part of the standard recommendations in the treatment of SDB. Obviously, no controlled long-term studies exist relating to these measures.

In the case of positional OSA, apneas and hypopneas occur predominantly or solely only in the supine position. In these cases one should always consider the existence of a primarily retrolingual obstruction site. In the supine position, the tongue, in accordance with gravity, falls backward due to the physiological muscle relaxation. As a result of the lower mass, this effect apparently plays a lesser role in the case of the soft palate. Similarly, there are incidents of primary snoring where socially disruptive respiratory noises are manifest only in the supine position. As yet, no long-term results exist concerning conditioning in regards to body position (prevention of supine position). A short-term therapy success of 75 % has been documented in the case of mild and moderate positional OSA by using waistcoats that prevent a supine sleeping position [316]. For the treatment of snoring, the success rate is significantly lower, according to our own experience.

Hein and Magnussen [196] have gathered evaluations of 43 pharmaceuticals, which were tested on patients with SDB. They included alkaloids and analeptics, which also stimulate the pharynx musculature via the respiratory center, tricyclic antidepressants, which reduce the portion of REM sleep, antihypertensives, methylxanthines, oxygen, progesterone analogs, and others. No reports exist of patients with polysomnographic data who have received therapy for more than 18 months. Even for theophylline, a methylxanthine frequently used in Germany, there are no long-term results. Its precise mode of effectiveness is not known, nor is there official approval for its use in adults with SDB. "The present data neither allow a conclusive recommendation of the effective dose, the dose interval, the pharmacokinetics, nor the patient collective" [196].

Apparative treatment options include respiratory treatment with continuous positive airway pressure (CPAP) with its various modifications, oral appliances, and electrostimulation.

The CPAP ventilation therapy described by Sullivan [500], which is for the most part nasally applied, splints the upper airway pneumatically from the nares to the larynx (Fig. 2.1).

Concerning the implementation of CPAP therapy and its diverse modifications, we refer to the specialized literature [109, 113, 139]. With a primary success rate of 98 %, CPAP therapy is, alongside tracheotomy, the most successful therapy modality available. Only these two treatment modalities achieve sufficient cure rates in cases of extreme obesity and severe OSA. Therefore, nasal CPAP therapy is considered to be the gold standard in the treatment of OSA. All other therapies for OSA must be measured against this method. Unfortunately, the long-term acceptance rate of CPAP therapy lies below 70 % [322]. The acceptance rate of CPAP therapy decreases the younger the patient is, and the less his subjective ailments improve with CPAP therapy [236]. As a consequence, many patients with moderate and severe OSA in need of treatment have to be secondarily guided into another therapy. Often surgery is successful in these cases [485].

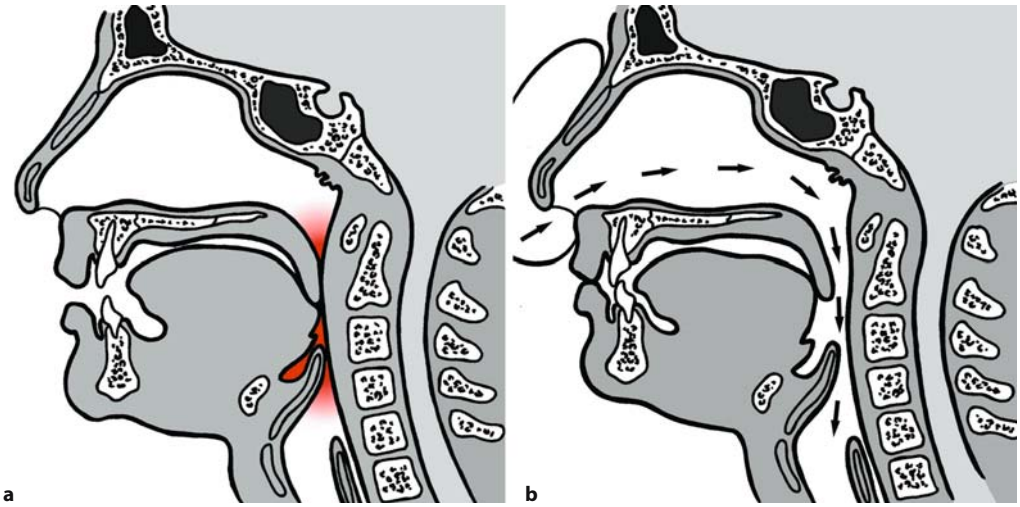


Fig. 2.1a,b. Method of pneumatic stenting of the upper airway with CPAP. **a** airway collapse, **b** stabilization with continuous positive airway pressure

There are three types of oral device: the tongue-retaining device, the mandibular advancement device, and the soft palate lifters possibly combined with tongue extensors. Over the past 5 years, mandibular advancement appliances have had the most success. They have been proven to be the most effective treatment while at the same time entailing the fewest side effects. For mild to moderate OSA, success rates of 50–70 % have been reported [311, 329, 452]. Unfortunately, individual success as well as compliance cannot be predicted with a sufficient degree of accuracy. Subjective compliance of oral devices is found to be 40–80 % [78, 136]. The main side effects are hypersalivation, xerostomia, temporomandibular joint pain and dental discomfort, which can be found in almost 80 % of the patients [373].

Currently, electrostimulation as standard procedure is available only for the transcutaneous or transcutaneous–transmucous application. Initial data from small case series display a short-term subjective success in the treatment of simple snoring but not for OSA [406, 541]. No long-term results are available yet.

Modern concepts regard primary snoring on the one hand and OSA on the other hand as different manifestations of the same pathophysiological disorder (Fig. 2.2) [341]. We agree with this concept and have made it the foundation for our therapeutic decisions.

Two important therapy principles can be inferred from Fig. 2.2. On the one hand, the more severe the SDB, the more aggressive the surgical therapy required, if it is to be effective. Surgical procedures are performed both in the case of primary snoring and at all severity levels of OSA. For the treatment of primary snoring, minimally invasive techniques with a low complication rate should be preferred. In the case of higher level OSA, surgery is only secondarily indicated after an unsuccessful nasal CPAP therapy. For a primary surgical treatment, an AHI of approximately 30 is considered as threshold value [389].

The second therapy principle entails the notion that nowadays SDB is increasingly considered as a disorder of the entire upper airway. For many years, ENT surgeons, by assuming only two sites of obstruction, pursued a concept that from our perspective is too mechanistic. Fujita, for example, classified OSA patients into those with an obstruction solely behind the soft palate (type I), those with an obstruction solely behind the tongue (type 2), and those with an obstruction be-

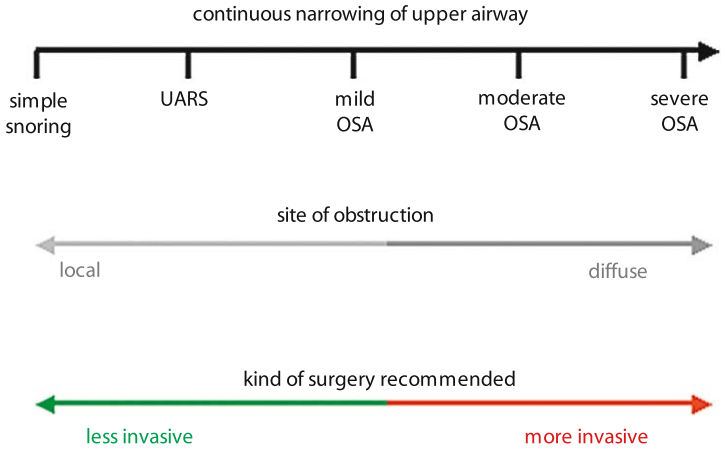


Fig. 2.2. Continuous narrowing of the upper airway. (Modified from Moore [341])

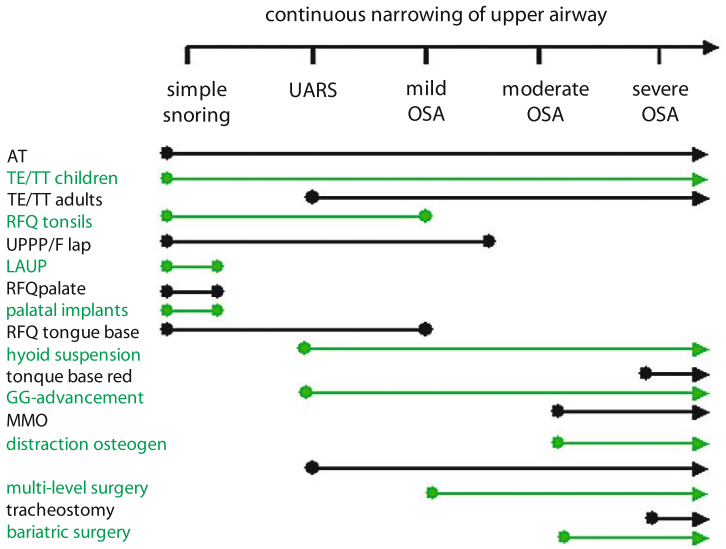


Fig. 2.3. Indications for different surgeries depending on the severity of SDB

hind both soft palate and tongue (type III) [159]. Chapter 3 will discuss more specifically the established techniques of this topodiagnosis. Yet up to now, this topodiagnosis has not been conductive in e.g. raising the success rate of soft palate surgery significantly above 50 %. Therefore, we now assume that this simplified classification into a retropalatal and a retrolingual site of obstruction is applicable only for primary snoring and, to a certain extent, in the case of UARS and mild OSA. Starting with moderate OSA, that is from an AHI of approximately 20, in accordance with our experiences and assessments, there is a need for surgical treatment of both of the two mentioned, potential sites of obstruction along the lines of so-called multi-level surgery. Also in this case, the appropriate combination depends upon the severity and the anatomical disposition (see Chap. 10 on multi-level surgery).

Figure 2.3 illustrates the indications for our preferred surgical techniques, depending on the severity of the SDB. The following chapters will discuss these techniques in detail.

Table 2.1. Levels of evidence of clinical trials [65]

I	Evidence obtained from at least one properly randomized controlled trial
II-1	Evidence obtained from well-designed controlled trials without randomization
II-2	Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one center or research group
II-3	Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin in the 1940s) could also be regarded as this type of evidence
III	Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees

Table 2.2. Levels of evidence [64]

I	Evidence obtained from at least one systematic review based on well-designed, randomized controlled trials
II	Evidence obtained from at least one adequate large, well-designed, randomized controlled trial
III	Evidence obtained from well-designed trials without randomization (cohort or case-control analytic studies)
IV	Evidence obtained from more than one well-designed, non-experimental study
V	Opinions of respected authorities (based on clinical experience, descriptive studies, or reports of expert committees)

Nasal surgery rarely affects the severity of OSA and is of use only in the minority of patients with primary snoring. Nevertheless we see an indication as adjuvant therapy especially to facilitate nasal ventilation therapy. In our opinion, there is no indication for the following procedures: uvulectomy, injection snoreplasty, cautery-assisted palatal stiffening operation, transpalatal advancement pharyngoplasty, and tongue suspension procedures. Based on criteria of evidence-based medicine there is also no indication for the palatal implants, although we have some excellent experience in this field.

In the following chapters, the surgical methods are discussed according to their anatomical position, beginning with the nose and ending with the stomach. Insofar as these surgical techniques are not part and parcel of surgery primers, the techniques favored by the authors and some important techniques of other authors are elucidated.

For each case, we present the results concerning the effectiveness of the particular technique for primary snoring and OSA separately. In isolated cases we discuss the issue separately for children and adults.

In each case we attempt to summarize the relevant data in tables. Each table displays the grading of the particular study according to the principles of evidence-based medicine as recommended by the Canadian Task Force on periodic health examination [65] (Table 2.1).

Depending on the level of the single studies, the level of evidence for each surgical treatment can be determined, as shown in Table 2.2. This level of evidence is stated in the last row of each table in the effectiveness section of each chapter.

Another section in each chapter deals with postoperative care and potential complications. We give pointers towards postoperative supervision and a survey of potential complications of the specific method. Finally, indications and contraindications are specified.

Identifying the Site of Obstruction

3

For a long time, strong emphasis was laid on the importance of the topodiagnosis of the collapse site(s) in the upper airway, especially before choosing an adequate surgical treatment method [463, 465]. An initial classification stems from Fujita, who differentiated the patient pool into three types in accordance with retrovelar, retrolingual, or a combined collapse site [159]. However, CT investigations during sleep have demonstrated that this classification oversimplifies the dynamic processes occurring in the pharynx [231]. Some studies still advocate a rigorous preoperative topodiagnosis [368], but this postulate can no longer be held without reservations because the pharyngeal obstruction site is not determined once and for all. It can change first between wakefulness and sleep, second between the different sleep stages, third postoperatively after upper airway surgery, and fourth depending on a person's age (overview in [127, 540]). Nevertheless, as our colleagues may still request some of these diagnostic procedures, the most important techniques of topodiagnosis will be discussed here censoriously.

3.1 Pressure Measurements

Increased respiratory effort in both children and adults can be recognized with the help of simple esophagus pressure measurements [516]. If these measurements are combined with the registration of the oro-nasal air flow, it is then possible to differentiate between central, mixed, and obstructive respiratory events [521]. Together with the demonstration of frequent arousals in polysomnography, the esophageal pressure probe provides the essential tool in the verification of an upper airway resistance syndrome (UARS) [487].

Initially, single flexible pressure sensors were employed in order to identify a pharyngeal collapse site [221]. As this method turned out to be too time-consuming, multi-pressure sensors with up to six sensors were developed. With these sensors it is also possible to identify several collapse sites. Only one study recommends pressure probes in the selection of patients for laser-assisted uvulopalatopharyngoplasty (LAUP) [477]. Other study groups are more cautious in regards to the predictive value, because postoperative shifts of the collapse site into a different pharynx level, towards both cranial and caudal, have been observed [220, 331, 463, 479].

Several possible reasons have been discussed for the failure of topodiagnosis with pressure measurements in regards to the selection of patients for palatal surgery. On the one hand, pressure probes are incapable of recognizing segments that are already severely constricted but not yet totally collapsed [581]. Suratt et al. [502] observed a shift of the obstruction site during a single apnea phase towards caudal. Furthermore, other authors have registered such a high number of retrolingual obstructions that they recommend the inclusion of the tongue base into the surgery concept along the lines of so-called multi-level surgery [478, 578].

3.2 Flexible Endoscopy

A fiberoptic endoscopy of the upper airway can be administered without difficulty on the awake patient in sitting and supine positions. However, the results do not correlate with those gained in the supine position during sleep [216]. Sleep videoendoscopy is a very sophisticated procedure and has to be restricted to specific indications [43, 392, 428]. Disadvantages of the method include the reduction of the cross-section of the airway by the endoscope, arousal reactions due to the mechanic stimulus, visual obstruction by the phlegm, the simultaneous assessment of only one level of the airway, and the personnel-intense aspects of the procedure [216]. The Müller maneuver consists in the endoscopic observation of the upper airway during intensified inspiratory respiration with closed nose and closed mouth. While older studies considered the Müller maneuver as an identification method for the velar collapse type, and therefore recommended it as a selection criterion for a successful uvulopalatopharyngoplasty (UPPP) [466], nowadays this investigation is no longer regarded to have that value [42, 574].

The flexible endoscopic assessment of the upper airway during pharmacologically induced sleep was first suggested for children [94], and later also for adults [93]. In addition to the disadvantages of an endoscopy during sleep mentioned above, the employment of this procedure is further restricted by the fact that pharmacologically induced sleep cannot simply be equated with natural sleep [96, 308, 404]. Differences in collapse sites according to different sleep phases have already been mentioned. Nonetheless, sleep endoscopy continues to be recommended for preoperative topodiagnosis [202]. But we do not know of any study that was able to demonstrate that the surgical success, regardless of the method, can actually be improved by virtue of such a preoperative diagnosis.

A newer development is the digital analysis of fixated endoscopic images of the soft palate with the help of appropriate software. In an initial study, morphological differences were described in a pool of 121 primary snorers, 79 patients after LAUP, and 51 healthy control subjects [409]. It remains to be seen whether this concept will foster a viable method for the clinical routine.

3.3 Analysis of the Respiratory Sounds During Sleep

In principle, retropalatal and retrolingual collapse sites can be differentiated with the help of a recording of the respiratory sounds during sleep using fast Fourier transfer (FFT) analyses [447]. It was possible to raise the on-target rate of the UPPP from 52.6 % [465] to approximately 75 % [447]. In the USA, such a diagnostic option for the clinical routine exists in the form of the so-called SNAP procedure [547]. The investigator has the possibility to send in an audio cassette with snoring sounds for both an FFT analysis and an acoustic evaluation by an experienced listener. In Europe, the working group of Osman et al. developed the so-called Glan Clwyd snore box, an instrument to differentiate between palatal and non-palatal snoring [368, 371].

3.4 Further Imaging Procedures

Many studies have attempted to establish the collapse site with the help of somnofluoroscopy, radiocephalometry, computer tomography and magnetic resonance imaging. Overall, these imaging procedures are of only limited use in predicting the surgical success of a UPPP [26]. Body mass and apnea hypopnea index (AHI) continue to be decisive parameters.

Radiocephalometry is more successful in determining a retrolingual than a retropalatal collapse site [376, 415]. Accordingly, in the case of therapy failures after UPPP, it is possible to determine a more constricted retrolingual airway and a hyoid bone situated lower in relation to the mandible [416]. Both parameters also influence the success rate of nasal surgery in regards to the AHI in pa-

Table 3.1. Techniques for objective localization of upper airway narrowing

Technique	During sleep	Quantification	Disadvantages	Clinical routine
Pressure measurements in the upper airway	+	+	SE, limited life-span of the expensive probes	+
Flexible nasopharyngoscopy	+	(+)	SE, mom	+
Analysis of the respiratory sounds	+	+	SE	(+)
Cinefluoroscopy	+	+	rad, mom	–
Rapid CT scans	+	+	rad, mom	–
Radiocephalometry	–	+	rad, mom	+
Acoustic reflexions	+	+	SE	(+)
Rapid MRI scans	+	+	Mom (up to 1 hour)	–

SE special expert knowledge necessary, *mom* detects only short periods of sleep, *rad* exposure to radiation.

tients with mild obstructive sleep apnea (OSA) [459]. While radiocephalometry cannot in general be recommended as a routine form of diagnosis, it is certainly of use in patients with malocclusion or suspected retrolingual collapse site, and in patients who need to undergo surgery. An absolute indication is given before a planned maxillomandibular osteotomy [26, 205].

Fluoroscopy, rapid computer tomography and functional magnetic resonance tomography have not become part of the clinical routine, as they are too cost-intensive and cover too short a period of sleep.

A relatively new instrument in this context is acoustic reflectometry. A probe generates a noise signal and measures the reflecting sound using a microphone [126]. As the probe is flexible it already has proven feasibility in sleeping sleep apneics [128]. This so-called flextube reflectometry seems to be a promising tool for routine use.

These procedures remain reserved for specific lines of research [392].

Table 3.1 summarizes the advantages and disadvantages of the diagnostic procedures described above. For our daily routine, we have essentially made the decision that in addition to the otorhinolaryngological evaluation, we only perform an endoscopy in the waking state and sometimes a radiocephalogram. All the other procedures outlined above are available in our center, but require a specific indication.

Nasal Surgery

4

In the ancient world it was known that impaired nasal airflow may lead to sleep-disordered breathing (SDB). Hippocrates (*De morbis,* Liber II, Sect. V) described snoring, enlargement of the lateral nasal walls and a croaky voice as symptoms of nasal polyposis. In 1581, Levinus [280] reported that mouth breathing in the supine position causes restless sleep. In 1892, Cline [79] published a first case study of relief of excessive daytime sleepiness following nasal surgery. In 1898, Wells [558] reported an increase of daytime vigilance in eight of 40 patients after nasal surgery.

Otolaryngologists are often confronted with the expectation that the restoration of the nasal airway will lead to an elimination or reduction of sleep-related breathing disorders. But the relation between nasal airway and SDB is very complex, and at present still not completely understood in every detail. Several excellent review articles summarize the current state of knowledge in regards to the role of the nose in the pathophysiology of SDB [210, 407, 539].

4.1 Effectiveness of Treatment

Currently, there are no scientific data concerning the multitude of nasal oils that are mainly offered over the internet [330]. What has been researched are anti-inflammatory nose drops [254], nasal corticosteroids [55, 91], and nasal dilators (overview in [539]). The objective data are inconsistent. Some series have reported a significant reduction of the respiratory arousals or of the apnea hypopnea index (AHI), but most series did not produce a significant effect. Djupesland et al. [108] even reported a significant increase of the AHI from 9.3 without dilators to 12.2 with dilators in 18 patients with upper airway resistance syndrome (UARS).

The subjective data present a more consistent picture. For the most part, improvements in subjective sleep quality, daytime sleepiness, quality of life and non-apneic snoring are reported (overview in [407, 539]).

4.1.1 Effectiveness for Simple Snoring

There are no long-term results concerning the effectiveness of nasal surgery in the treatment of SDB. Present data are mostly based on non-controlled and non-randomized studies, and do not at least fulfill the grade II-1 criterion of evidence-based medicine. Some working groups provide subjective data regarding the impact of nasal surgery on simple snoring.

Summarizing these inhomogeneous data, which usually lack polygraphic or polysomnographic investigation, a noteworthy reduction or disappearance of snoring is reported in a few studies (Table 4.1).

Furthermore, Illum [228] reported that of the 50 patients who underwent septoplasty and conchal surgery, 58 % were snoring preoperatively and 41.5 % complained of snoring 5 years postoperatively. From these few examples (often cited) and similar publications it is virtually impossible to estimate a percentage success rate of nasal surgery in primary snorers.

Table 4.1. Effect of nasal surgery on snoring.

Author	*n*	Follow-up (months)	Method	Cessation of snoring (%)	Reduction of snoring (%)	EBM grade
Fairbanks 1984 [131]	13	12	Q	53.8	38.5	Retro
Fairbanks 1985 [130]	47	No data	Q		76.6	Retro
Ellis et al. 1992 [120]	126	6–24	Q	31.0	57.1	Retro
Low 1994 [300]	30	4–12	VAS (0–10)	50.0		II-3
Woodhead and Allen 1994 [570]	29	1.5	VAS (0–10)		69.0	II-3
Grymer et al. 1996 [174]	26	3–6	Q	50.0		II-3
Elsherif and Hussein 1998 [123]	96	6–9	Q	50.0	39.6	Retro
Bertrand et al. 2002 [34]	8	12	VAS (1–4)		87.5	II-3
All	**375**	**1.5–24**		**41.9**	**85.3**	**IV**

EBM, evidence-based medicine, *VAS* visual analog scale, *Q* questionnaire, *Retro* retrospective study design.

Nasal surgery may reduce the sound intensity of snoring by 5–10 dB [446]. Nasal surgery improves nasal ventilation, sleep quality and daytime vigilance [146].

4.1.2 Effectiveness for Obstructive Sleep Apnea

Only a few case reports exist on cures of obstructive sleep apnea (OSA) after nasal surgery [114, 195, 473]. On the other hand, in 1977 Simmons and coworkers [471] reported cases with no significant apnea index (AI) reduction despite considerable subjective improvement of nasal breathing and sleep quality.

Until 2002, only ten studies on nasal surgery for OSA have been found that provide data on pre- and postoperative AI or AHI (Table 4.2). Alltogether, 128 patients from eight working groups [20, 63, 101, 155, 434, 458, 459, 527, 532, 533] were included in the studies. The follow-up periods were for the most part short and lasted from 1 month [434] to 50 months [532]. In only one study [434] was there a statistically significant improvement of the severity of OSA after nasal surgery alone. This study included nine sleep apneics. Their AI decreased from 37.8 to 26.7. In four other studies with a total of 30 patients, an increase in the severity of OSA was noticed postoperatively (Table 4.2), which was not statistically significant in all studies. We recorded a noticeable worsening of OSA in two patients with polyposis nasi after paranasal sinus surgery [533]. Despite the reconstitution of nasal breathing, the AHI rose from 14.0 before to 57.7 after surgery. Both patients developed excessive daytime sleepiness and required nasal continuous positive airway pressure (CPAP) therapy. Two similar cases after septorhinoplasty have been reported by Dagan [95].

Lavie et al. [276] reported on 14 patients with OSA who all underwent only septoplasty. OSA severity did not change after surgery, but 12 of their 14 subjects showed improved sleep quality in the polysomnography and reported less daytime fatigue.

We investigated the effect of nasal surgery prospectively in 26 patients with SDB (seven patients with simple snoring, AHI <10, and 19 patients with OSA, AHI >10) [532]. Follow-up investigations were done 12.7 months postoperatively, including a fully attended polysomnography in the sleep lab. The patients (one female, 25 male) had a mean age of 52.5 and a mean body mass index (BMI) of 29.16 kg/m², which remained unchanged at the time of re-examination (29.2 kg/m²).

Table 4.2. Effect of nasal surgery on the severity of obstructive sleep apnea.

Author	*n*	Follow-up	AHI pre	AHI post	*p* value	EBM grade
Rubin et al. 1983 [434]	9	1–6	37.8[a]	26.7[a]	<0.05	II-3
Dayal and Phillipson 1985 [101]	6	4–44	46.8	28.2	n.s.	II-3
Caldarelli et al. 1985 [63]	23	No data	44.2[a]	41.5[a]	n.s.	II-3
Aubert-Tulkens et al. 1989 [20]	2	2–3	47.5[a]	48.5[a]	-	II-3
Sériès et al. 1992 [458]	20	2–3	39.8	36.8	n.s.	II-3
Sériès et al. 1993 [459]	14	2–3	17.8[a]	16[a]	n.s.	II-3
Utley et al. 1997 [527]	4	No data	11.9	27	-	II-3
Verse et al. 1998 [533]	2	3–4	14	57.7	-	Case
Friedman et al. 2000 [155]	22	>1.5	31.6	39.5	n.s.	II-3
Verse et al. 2002 [532]	26	3–50	31.6	28.9	n.s.	II-3
All	**128**	**1–44**	**34.1**	**33.3**		**IV**

[a] Apnea index.
AHI apnea hypopnea index, *n.s.* not statistically significant, *case* case report.

Nasal resistance (active anterior rhinomanometry at 150 Pa) was significantly reduced after surgery (p=0.0089). Daytime sleepiness also decreased. The Epworth Sleepiness Scale (ESS) was ranked 11.9 before surgery and fell to 7.7 after nasal surgery (p=0.0004). The arousal index decreased significantly from 28.9 to 21.7 postoperatively (p=0.0336). However, neither the AHI (31.6 versus 28.9) nor the oxygen desaturation index showed statistically significant improvement after surgery. Despite a reduced nasal resistance, the severity of OSA increased in four patients. Using Sher's criteria [465] (reduction of AHI >50 % and to values <20), only three of 19 patients with OSA (15.8 %) were classified as cured after nasal surgery.

Other studies report cure rates of nasal surgery for OSA between 0 % [20, 533] and 33 % [101]. In the literature, raw data for 76 patients with OSA are provided. Using Sher's criteria, the cure rate of these patients is only 17.5 %.

In summary, patients may be allocated to two groups. With the majority of patients, the normalization of nasal resistance leads to a positive impact on the well-being and the sleep quality, but not on the severity of OSA. Even a worsening of the condition has been described. In a smaller number of patients, an improvement, in some cases even healing, of an existing OSA can be achieved. Reliable criteria to identify responders have not yet been found. Therefore, the prediction of success of a rhinosurgical treatment for an individual with SDB is currently not possible.

4.2 Postoperative Care and Complications

A discussion of the complications and the specific postoperative follow-up treatment after rhinosurgery lies beyond the scope of this book. For this, we refer the reader to the specialized rhinological literature.

Yet in connection with SDB the issue of nasal packing needs to be addressed. In the case of primary snoring and mild OSA, nasal packing usually does not present a problem. However, in the elderly patient with moderate to severe OSA (AHI >30), the AHI may increase if nasal packing is used for epistaxis or after surgery. Even vital complications have been reported [69, 561]. The danger is especially prevalent in the first 6 h postoperatively [30]; therefore, the patient needs to be monitored during this phase. Yet in the opinion of the authors, monitoring in an intensive care unit, even in the case of severe sleep

apnea after multiple surgeries on the upper airway with nasal packings in situ, is necessary only in individual cases. For the specific anesthesiological procedures in the case of sleep apneics, see Chap. 13.

If patients with a preoperatively existent CPAP-obligatory OSA receive nasal packing postoperatively, it is recommended that the continuation of the CPAP ventilation should be done either via a combined mouth–nose mask (full face) or via an oral mouthpiece. Dorn et al. [112] investigated the use of such an oral CPAP application in a pilot study including five patients with severe OSA (mean AHI=54.5) whose noses were packed after nasal surgery. Oral CPAP ventilation proved to be effective and safe.

4.3 Indications and Contraindications

Unfortunately, we do not yet know any factors that can predict success. Low [300] did not find any influence of either preoperative severity of nasal obstruction, preoperative intensity of snoring, preoperative collapsibility of the soft palate, or degree of reduction of nasal obstruction on the postoperative result. In seven of 14 patients with mild OSA, Sériès et al. [459] found that a radiocephalometry revealed narrowing of the airway space behind the tongue (PAS) and an increased distance from the mandible to the hyoid bone. Three months after nasal surgery, a comparison of patients with and without anatomical abnormalities showed that those with normal anatomy experienced a significant improvement in sleep and respiratory parameters (AHI, arousal index). In patients with pathological radiocephalometric findings, however, both indices remained unchanged after surgery. The authors conclude that the presence of craniomandibular abnormalities makes it unlikely that nasal surgery will improve mild obstructive sleep apnea.

Busaba [60] retrospectively compared the safety of performing same-stage nasal and palatopharyngeal surgery (group 1; n=63) with palatopharyngeal surgery at a stage separate from the nasal surgery (group 2; n=28) for the treatment of moderate to severe OSA (mean AHI 36.5 vs 33.5). The two groups were fairly matched according to age, gender, comorbidities, and polysomnographic data. Uvulopalatopharyngoplasty with tonsillectomy was performed in 51% of group 1 and in 68% of group 2. The remaining patients underwent UPPP without tonsillectomy. After nasal surgery the noses were packed bilaterally. The packs were removed the next day before patient discharge. During these 23 supervised hours, the patients were monitored with continuous pulse oximetry. Postoperative complications occurred in three patients (4.8%) in group 1 (pneumonia, tonsil bleed, septal hematoma) and in one patient (3.6%) in group 2 (tonsil bleed). The authors conclude that same-stage nasal and palatopharyngeal surgery for OSA is a safe procedure.

Antila et al. [17] measured the volume of the nasal cavities and nasopharynx of 29 patients using acoustic rhinometry before and after UPPP, employing the laser technique. The static-change-sensitive bed was used for cardiorespiratory monitoring during sleep, but data were not reported. Subjectively, snoring had decreased in 97% of the patients and daytime somnolence had decreased in all cases. There was a tendency of higher postoperative values of midnasal volume in baseline and decongestion recordings, indicating that the conchal area is more patent after the velar operation. Using rhinomanometry, Welinder et al. [557] and Kawano et al. [250] found a significantly lower nasal resistance 3–6 months [250] and 18 months [557] following UPPP.

4.4 Impact of Nasal Surgery on Nasal CPAP Treatment

There are only a few papers reporting on the effect of nasal surgery on the requested CPAP. Apart from several case reports [321, 425, 566], Sériès et al. [458] reported on seven patients who needed nasal operations before they were able to tolerate nasal CPAP treatment.

In a first prospective trial, Friedman et al. [155] performed a septoplasty with partly bilateral reduction of the inferior nasal turbinates in 50 patients with different severities of OSA. All patients were re-examined 6 months after their surgical procedures. The mean BMI remained constant (35.0 kg/m² vs 35.7 kg/m²). Forty-nine patients reported improved nasal breathing, 14 (28 %) snored less, and three (6 %) no longer snored at all after surgery. Daytime activity was increased in 39 apneics (78 %). A sample of 22 patients underwent a second polysomnography. Their AHI increased from 31.6 to 39.5 postoperatively, which was not statistically significant. However, the CPAP required to solve OSA fell from 9.3 mbar to 6.7 mbar. The reduction of CPAP was statistically significant in patients with severe OSA (n=13). The authors conclude that nasal surgery should be included in a comprehensive treatment concept of OSA. Comparable results were reported by Mayer-Brix et al. [320] and by Dorn and colleagues [112]. The latter authors described a reduction of the requested nasal CPAP of 3.2 mbar 6 weeks after nasal surgery.

Biermann [36] retrospectively compared each of 35 severe sleep apneics with and without septoplasty and turbinoplasty. All patients were on nasal CPAP ventilation and a polysomnographic re-examination was performed at least once a year. In the group of patients who underwent a nasal operation, the requested CPAP was 1.5 mbar lower (p<0.01) and the mean duration of daily use was 0.8 hours longer (p<0.01). Apart from that, the author described a negative correlation between CPAP pressure and the duration of its daily use.

All cited reports agree that the requested nasal CPAP can be statistically significantly reduced by nasal surgery. In some cases, nasal surgery improves the patients' compliance regarding a necessary CPAP treatment.

4.5 Conclusion

Non-surgical or operative reduction of nasal resistance significantly improves the well-being, daytime fatigue and sleep quality of the persons concerned; moreover, the number of arousals can be reduced. The number of apneas and hypopneas hardly alters within the group of patients.

Recapitulating the rhinosurgical data of patients with SDB, the authors would like to make the following conclusions. The success rate of only nasal surgery for simple snoring is not available and the success rate for OSA seems to be less than 20 %. The reasons for the low success rates have been articulated by Hoffstein et al. [206]: "Neither the site of obstruction during apneas nor the site of generation of snoring is in the nose." As a consequence, we perform nasal surgery only in patients who complain of nasal obstruction and impaired nasal breathing either during wakefulness or during sleep.

Nevertheless, rhinosurgery occupies a valid position in sleep medicine in those cases where it is necessary to optimize a CPAP therapy, or to make it available to the patient in the first place.

Nasopharyngeal Surgery

5

Cephalometric analysis of patients with obstructive sleep apnea (OSA), simple snorers, and normal controls do not show any significant differences concerning nasal structures [28]. In contrast, Donnelly et al. [110] recently found significantly reduced nasopharyngeal patency and significantly enlarged adenoids in 16 young sleep apneics as compared to 16 age-matched controls. In childhood, adenoidal hypertrophy is a common feature predisposing to sleep-disordered breathing (SDB). Pediatric OSA is equally common in both sexes [359, 555]. Today, there is evidence that the relative adenoid size strongly correlates with the severity of OSA in children [52, 232]. A positive correlation between snoring and adenoid size was described more than 20 years ago [203, 319, 482].

Apart from enlarged adenoids, antral choanal polyps (ACP) may cause snoring or even OSA in children. Only a few cases of children with snoring as a symptom of ACP have been described [76, 268, 367], and only three well-documented cases of pediatric OSA caused by ACP exist in the literature [46, 426, 440]. Crampette et al. [92] reported on two children with snoring suffering from sphenochoanal polyps.

However, in adults, a complete obstruction of the nasopharynx rarely occurs.

5.1 Effectiveness of Treatment

5.1.1 Corticosteroids

Recently, intranasal corticosteroids have been demonstrated to reduce adenoid size, independent of the individual's atopic status [360]. In summary, there seems to be evidence of an improvement in the severity of OSA in children treated with intranasal corticosteroids, but further studies are needed before such therapy can be recommended routinely.

5.1.2 Nasopharyngeal Tubes

In 1981, Afzelius et al. [2] reported two patients with severe OSA cured by self-intubation with a nasopharyngeal tube during sleep. The tubes were fitted individually under fiberoptic visualization with a 3.0–4.0 mm uncuffed latex pediatric endotracheal tube that extended from the nares to a level 5 mm above the epiglottis. No complications were found after 6 months follow-up.

Nahmias et al. [348] treated 44 patients with OSA with nasopharyngeal tubes. At 4 months follow-up, 44% of the patients still tolerated their tubes. The apnea index (AI) was reduced by 62.3%. Responder rates were given as 36.4%, which is higher than the rhinosurgical success rates. The reason for this high responder rate might be the splinting of the nasopharynx, which is not affected by rhinosurgery.

Masters et al. [315] described the successful use of a modified nasopharyngeal tube to relieve upper airway obstruction in nine infants

with Pierre-Robin sequence, isolated micrognathia, Down's syndrome, and idiopathic generalized hypotension. The well-tolerated tube allows simultaneous use of oxygen prongs. The tube was required for a median of 6 months in children with Pierre-Robin sequence (n=6) and for up to 15 months for the other infants. Apart from three infants who experienced regurgitation of feeds into the nasopharyngeal tubes in the initial period, no other complication occurred.

5.1.3 Surgical Treatment

Khalifa et al. [258] have reported that enlarged adenoids may be associated with ventilatory impairment, which is reversible after adenoidectomy. However, the correlation between adenoid hypertrophy and OSA is not as obvious. Data on the not always sufficient efficacy of isolated adenoidectomy in cases of pediatric OSA have been reported by Nieminen et al. [359] in a controlled, prospective, non-randomized clinical trial. Fifty-eight snoring but otherwise healthy children aged 3–10 years with symptoms suggestive of OSA underwent polysomnography twice, namely before and 6 months after surgery. A second group of 30 non-snoring, healthy children served as controls. Twenty-one children with an obstructive apnea hypopnea index (AHI) greater than 2 underwent adenotonsillectomy. Of the children operated on, 73 % (16/21) had had previous adenoidectomies, which had not resolved the obstructive symptoms, or the symptoms had begun after the adenoidectomy. The epipharynx was checked intraoperatively during the adenotonsillectomy, and none of the children appeared to have substantial re-growth of the adenoidal tissue. In other words, an isolated adenoidectomy does not seem to be as effective as an isolated tonsillectomy nor as a combined adenotonsillectomy for OSA. Nevertheless, isolated adenoidectomy has been shown to improve mental performance in children [372].

In the cited cases of antral choanal polyps, OSA resolved after paranasal sinus surgery. However, this origin of OSA is too rare to recommend paranasal sinus surgery as a standard procedure for OSA.

5.2 Postoperative Care and Complications

This issue will be discussed in context with combined adenotonsillectomies in Sect. 6.1.1. Apart from the evidence stated there, no reports exist of OSA-related problems within the peri- and postoperative period.

For pain control, diclofenac is superior to paracetamol in small children [23]. We also have good first-hand experience with diclofenac.

5.3 Indications and Contraindications

As stated in Chap. 6, Sect. 6.1.1, children with severe OSA show reduced neurocognitive performance, which is reversible after combined adenotonsillectomy [152]. In the treatment of OSA, adenoidectomy alone is not as effective as combined adenotonsillectomy. Therefore, we prefer and recommend the combined procedure if OSA has been diagnosed. This applies also to children younger than 3 years. Because the incidence of postoperative complications is higher after tonsillectomy in this age group, children under 3 years require more intensive postoperative monitoring.

Less is known about children who snore but do not suffer from severe upper airway obstruction. Recently, two controlled studies indicated that, compared to normal controls, children who snored but were otherwise healthy showed reduced neurocognitive and academic performance [39, 525]. We perform an isolated adenoidectomy in our pediatric patients who do not have any other clinical symptoms of SDB apart from regular snoring.

Palatal Surgery

6

6.1 Tonsils

6.1.1 Tonsillectomy and Tonsillotomy

One of the main reasons for obstructive sleep apnea (OSA) in children is tonsillar hypertrophy [177, 260]. It has been demonstrated previously that adenotonsillectomy during childhood cures OSA with high efficiency. However, it is not as clear to what extent tonsillar hypertrophy can also be considered as a cause for OSA in adults, and whether tonsillectomy is effective in these latter cases. The issue will therefore be discussed separately for children and adults.

Furthermore, tonsillotomy [225] and different interstitial thermal ablation techniques [351] have recently been (re)introduced into the field of sleep surgery. These new developments give this issue new topicality. As radiofrequency (RFQ) surgery is a completely different operative technique, it will be discussed separately in Sect. 6.1.2.

6.1.1.1 Children

Effectiveness for Simple Snoring

Surprisingly there are only a few studies focusing on the efficacy of tonsillar surgery for simple snoring. This might be because sleep studies are much more difficult to perform in children than in adults. Many studies do not precisely differentiate between simple snoring and OSA. Another problem consists in the lack of established and validated objective measurement techniques to analyze snoring sounds. Table 6.1 summarizes the data and quality of studies focusing on (adeno)tonsillectomy for simple snoring.

The work by Hultcranz and colleagues [225] deserves special mention; in a randomized study they investigated the efficacy of tonsillotomy compared to tonsillectomy. In both study arms snoring had not reappeared in the majority of children postoperatively after a year. Only two of the children continued snoring after the tonsillotomy, both 6 and 12 months postoperatively. This would seem to point to an advantage of conventional tonsillectomy compared to tonsillotomy, although the difference was not statistically significant. Yet the postoperative morbidity in children who underwent tonsillotomy was significantly lower than in children who received conventional surgery.

In another controlled study, Stradling et al. [488] examined 61 children before and 6 months after adenotonsillectomy, as well as 31 healthy, age-matched children at the beginning of the study and 6 months later. In the group of children who had received surgery, the oxygen saturation and the movement time during sleep, as well as various subjective parameters, were normalized to the level of the untreated, healthy children. An improvement of intellectual performance and – in the case of a pre-existing developmental deficiency – an acceleration of the maturing process were also found [178].

Interesting in this context is the finding of Tzifa and colleagues [522] that tonsillectomy during childhood does not reduce the likelihood of becoming an adult snorer.

Table 6.1. Effectiveness of pediatric tonsillar surgery for simple snoring

Author	*n*	Follow-up (months)	Surgery	Method	No more snoring	EBM grade
Ahlquist et al. 1988 [4]	85	1–12	TE	Q	90.5 %	II-3
Swift 1988 [503]	20	1	ATE	Q	95 %	II-3
Agren et al. 1998 [3]	20	12	ATE	Q	95 %	II-3
Hultcrantz et al. 1999 [225]	41	12	TT (21) vs. TE (20)	Interview	All: 95.1 % 90.5 % vs. 100 %	I
Helling et al. 2002 [198]	99	2–24	Laser-TT	Q	88 %	II-3
All	**265**	**1–24**			**91.0**	**II**

ATE combined adenotonsillectomy, *TE* tonsillectomy, *TT* tonsillotomy, *Q* questionnaires.

Effectiveness for OSA

The number of childhood adenotonsillectomies performed in Europe and the USA has declined over the past two decades. At the same time, the indications for adenotonsillectomy have undergone a transition: while fewer operations have been performed in cases of recurrent inflammation, there has been a percentual increase in adenotonsillectomy performed for relief of obstructive symptoms [173, 432, 433]. The spontaneous resolution of OSA secondary to adenotonsillar hypertrophy within a 1-year observation period has been reported at only 9 % [4].

Therefore, adenotonsillectomy is the most common major surgical procedure performed on children [54, 119, 150, 177, 181, 260, 375, 414]. Those studies providing data on sleep studies as well as pre- as postoperatively are abstracted in Table 6.2.

In a Cochrane evidence-based medicine (EBM) review in 2003 [296], Lim and McKean reviewed 196 references concerning adenotonsillectomy for OSA in children. They did not find one single randomized trial, which means that they could not verify any results. Nevertheless, looking at Table 6.2, there is some evidence, all based on non-controlled studies, that adenotonsillectomy has a positive influence on OSA, at least to a certain degree. All in all we found raw data of 221 children who underwent adenotonsillectomy as an isolated procedure for OSA. The mean apnea hypopnea index (AHI) fell from 17.6 to 4.5 after surgery. Cure rates varied between 78.4 % and 100 % in these studies. Additionally Nandapalan and colleagues reported the disappearance of apneas in 12 otherwise healthy children after adenotonsillectomy [349] and Kudoh and Sanai found that adenotonsillectomy was remarkably effective, even in children with morbid obesity [269].

Apart from the data assembled in Table 6.2, it has been shown that craniofacial deformities are common in children with adenotonsillar hypertrophy, and improve significantly with surgical treatment of the airway obstruction [3]. Görür et al. illustrated that compared with control subjects, adenotonsillary disease with obstructive sleep apnea symptoms led to right and/or left ventricular enlargement and hypertrophy, which resolved after adenotonsillectomy [170]. In addition, adenotonsillectomy was shown to have a long-term effect on quality of life in pediatric patients with sleep-disordered breathing (SDB) [147, 166, 339].

On the other hand, Tasker et al. [506] found some evidence that upper airway narrowing during sleep persisted 12 years after adenotonsillectomy in childhood. Maybe this narrowing is one risk factor for the later development of adult OSA.

In some children, obstructive symptoms recurred years later. One reason contributing to the recurrence of OSA may be adenoidectomy in conjunction with unilateral tonsillec-

Table 6.2. Effect of tonsillectomy on the severity of obstructive sleep apnea in children

Author	*n*	Age (years)	Follow-up (months)	Surgery	AHI pre	AHI post	Success (AHI <5)	EBM grade
Frank et al. 1983 [150]	7		1–1.5	ATE	29.6	3.3	100%	II-3
Zucconi et al. 1993 [587]	14	1–8	2–15	ATE	11.1	3.4	78.6%	II-3
Suen et al. 1995 [498]	26		>1.5	ATE	18.0	4.5	84.6%	II-3
Helfaer et al. 1996 [197]	15	1–12	1st night	ATE	5	2	No data	II-3
Wiet et al. 1997 [565]	31	1–20	No data	ATE	27.7	4.7	No data	II-3
Agren et al. 1998 [3]	20	4–9	12	ATE	3 (ODI)	0 (ODI)	100%	II-3
Shintani et al. 1998 [468]	74	1–9	No data	ATE	24.7	8.2	78.4%	II-3
Bar et al. 1999 [25]	13	1–11	3–12	ATE	7.8	1.0	No data	II-3
Nieminen et al. 2000 [359]	21	2–10	6	ATE	6.9	0.3	100%	II-1
All	**221**	**1–20**	**1–15**	**ATE**	**17.6**	**4.5**	**85.8**	**III**

ATE combined adenotonsillectomy, *ODI* oxygen desaturation index, *AHI* apnea hypopnea index.

tomy. In these cases, the remaining tonsil may undergo hyperplasia, as adenoids may regrow [468]. Guilleminault [180] reported recurrent OSA during the pubertal growth spurt in adolescents who as children had undergone adenotonsillectomy for relief of adenotonsillar hyperplasia and OSA and who had been free of obstructive symptoms over several years. In a follow-up study performed after an average of 7.5 years, Guilleminault found radiocephalometric evidence of anatomic anomalies, particularly behind the tongue (posterior airway space, PAS) and in the mandible, as an explanation for recurrence of OSA [178]. These findings show that children treated successfully with adenotonsillectomy for OSA should continue to be monitored, particularly those in families with a history of bite abnormalities, which reach their full manifestation during puberty.

Postoperative Care and Complications

In general, tonsillectomy seems to be a procedure with low morbidity in the otherwise healthy child [560]. However, there are some reports suggesting that there may be an increased perioperative morbidity in some children after adenotonsillectomy [229, 324, 433]. Strauss et al. [489] propose a decreased respiratory response to carbon dioxide stimulation as a possible cause of the perioperative respiratory problems in these children. A limited resolution of obstructive symptoms following adenotonsillectomy has also been observed in some children with adenotonsillar hyperplasia and OSA who were younger than 3 years and in cases in which certain other disease entities such as Down's syndrome, congenital heart defect, bronchial asthma, craniofacial anomalies, pathological overweight, and cerebral deficiencies have been present [162, 349, 391, 435]. In these cases, postoperative bilevel positive airway

pressure ventilation within the immediate postoperative period has been shown to avoid the risk of reintubation and mechanical ventilation [156]. At least a 24-h period of postoperative monitoring is recommended for these risk group children [324, 431].

Laryngospasm, nasopharyngeal hemorrhage and transient airway obstruction have been described as minor complications after adenotonsillectomy for OSA in children [435].

Indications and Contraindications

Several studies have demonstrated that children who suffer from snoring perform weaker in school than their non-snoring peers [39, 525], and that these deficits can be eliminated with an adenotonsillectomy [152]. A re-evaluation process has therefore begun in relation to when an adenotonsillectomy is indicated. Today, we receive far more referrals for an adenotonsillectomy than several years ago.

Of growing interest here are the recent reports demonstrating that, after a tonsillotomy, children need significantly less pain medication and return significantly faster to normal oral feeding than after a conventional tonsillectomy [225]. The employed techniques (various lasers, coblation, RFQ, cold steel, and others) seem to be secondary factors in relation to the observed lowered postoperative morbidity. It remains to be seen how far tonsillotomy also reduces the risk of postoperative hemorrhage. The current trend points in this direction. Yet at present, tonsillotomy is indicated only in the case of non-inflammatory tonsillar hypertrophy. Chronic tonsillitis is still considered to be a contraindication [198, 483]. Randomized studies are needed to determine the efficacy; the current data are not yet sufficient. The only available study points to a comparable success rate of tonsillotomy measured against conventional tonsillectomy for primary snoring [225].

Based on the available data, we continue to regard adenotonsillectomy as principally indicated for children with primary snoring.

In the treatment of pediatric OSA, tonsillectomy, often in combination with adenotomy, is one of the most successful surgical procedures, despite a lack of sufficiently large randomized studies. The cure rate of adenotonsillectomy as an isolated procedure in children is approximately 85–95%. We consider surgery for cases of verified OSA even if there is no clinical evidence of hypertrophy of tonsils and/or adenoids, as the clinical findings correlate only weakly with the extent of the functional obstruction [4, 50, 275]. Children with OSA suffering from trisomy 21 [309] or sickle-cell anemia [442] also profit from an adenotonsillectomy.

In a retrospective analysis of 400 cases of pediatric OSA, persistent SDB was found in 14.5% after various treatment modalities [176]. Adenotonsillectomy was performed in only 68% of the cases, but showed the best results. Nevertheless, after adenotonsillectomy there also remained some non-responders. In a second prospective survey, the same working group [179] proved that multidisciplinary evaluations of the anatomic abnormalities (i.e., mandibular deficiencies, etc.) before surgery led to better overall treatment results.

In the case of non-inflammatory tonsillar hyperplasia, we perform a tonsillotomy for both indications (primary snoring and OSA), because of the lower postoperative morbidity; the efficacy of this procedure in comparison with conventional tonsillectomy still needs to be verified with the help of randomized, controlled studies.

At present, no reliable data exist for interstitial RFQ surgery of the tonsils in children. According to our current experience, RFQ therapy in children requires general anesthesia. Furthermore, considerable inflammation of the lymphatic tissue may occur postoperatively, which necessitates inpatient supervision. Thus, two of the potential advantages of RFQ therapy are lost. Therefore, we currently cannot generally recommend this procedure for children.

Table 6.3. Effect of tonsillectomy on the severity of obstructive sleep apnea in adults

Author	*n*	Follow-up (months)	AI pre	AI post	AHI pre	AHI post	Success	EBM grade
Orr and Martin 1981 [365]	3	No data	55.5	9.8			100%	II-3
Rubin et al.1983 [434]	5	2–6	50.9	26.6			40%	II-3
Aubert-T. et al.1989 [20]	2	1–15	31.1	18.9			50%	II-3
Moser et al.1987 [347]	4	2–43	20.1	7.5			75%	Retro
Houghton et al. 1997 [217]	5				54.6	3.6	100%	II-3
Verse et al. 2000 [531]	9	3–14			46.6	10.1	88.9%	II-3
All	**28**	**1–43**	**40.3**	**16.4**	**49.5**	**7.8**	**78.6%**	**IV**

AI apnea index, *AHI* apnea hypopnea index, *retro* retrospective.

6.1.1.2 Adults

Effectiveness for Simple Snoring

No sufficient data exist in the literature documenting any positive effect of isolated tonsillectomy on simple snoring in adults. Fairbanks reported one single case of complete resolution of snoring in an adult patient [131]. On the other hand, Tzifa et al. [522] considered whether tonsillectomy could affect snoring, regardless of the patient's age and the indication of surgery. One thousand people took part in their study and filled out questionnaires. The prevalence of snoring was 12.5–48% depending on age. In 19.8% of the cases tonsillectomy had already been performed, usually in childhood. Tonsillectomy did not reduce the likelihood of becoming an adult snorer.

Effectiveness for OSA

As substantial hypertrophy of the palatine tonsils is rare in adults, there are only a few studies available (Table 6.3).

All the studies listed in Table 6.3 furnish raw data. There are a total of 28 complete sets of data of sleep apnea patients who exclusively underwent tonsillectomy. Counting all six studies together, the average number of respiratory events per hour of sleep decreased from 45.2 preoperatively to 13.1 postoperatively. This difference is highly statistically significant ($p<0.0001$). In accordance with the success criteria of Sher [465], this amounts to a healing rate of 78.6% in this selected patient pool.

From these data it can be inferred that a massive tonsillar hyperplasia is rarely seen in adults, but if it exists, tonsillectomy for the treatment of OSA is almost as successful as in childhood.

Postoperative Care and Complications

Tonsillectomy is a standard procedure. The complications and the specific aftercare are sufficiently described in otolaryngological surgery handbooks. Specific aspects in the peri- and postoperative management of patients with SDB will be discussed in Chap. 13.

One particular problem is worth mentioning here. Tonsillectomy patients suffer from substantial pain within the first 10 days after surgery. Therefore sufficient pain treatment is mandatory. In this context, Thorneman and Kervall [515] showed significant advantages of a basic oral pain treatment with paracetamol (750 mg ×6) and diclofenac (50 mg ×3) compared to a regimen in which patients received analgesics only on demand. On the other hand, there was a potentially increased risk of postoperative hemorrhage after tonsillectomy with the use of non-steroidal anti-inflammatory drugs (NSAIDs). Recently Krishna et al. [267] published a meta-analysis concerning this topic. Data from seven

prospective, controlled trials including 1,368 patients were analyzed. There appeared to be no significant increased risk of postoperative bleeding for non-aspirin NSAIDs in this meta-analysis.

Indications and Contraindications

As already mentioned, unfortunately no evidence exists in the literature for the efficiency of tonsillectomy in the treatment of primary snoring. Nevertheless, every otolaryngological surgeon is familiar with individual cases, in which socially disruptive snoring has disappeared after solitary tonsillectomy. However, there is a significant postoperative morbidity. Our own analyses have shown that on average our patients need analgesics for 12 days after a conventional tonsillectomy. The literature reports a risk of postoperative bleeding of up to 6.1% [568]. We have become extremely cautious with the indication of conventional tonsillectomy in the case of primary snoring, as RFQ surgery and tonsillotomy procedures with a lower morbidity rate are available today.

Massive tonsillar hyperplasia is rare in adults. If it does occur, a tonsillectomy (without any additional procedures) will be helpful. From the presented data we always recommend a tonsillectomy in the case of a medium to severe form of OSA. Also in the case of mild OSA we see an indication for a tonsillar procedure, if one site of obstruction on the level of the oropharynx is suspected.

6.1.2 Radiofrequency Surgery of the Tonsils

Radiofrequency techniques use high-frequency current to either cut or coagulate tissue. If used as an interstitial treatment, a electrode is inserted into the soft tissue. By applying RFQ energy, a thermic lesion is created followed by subsequent scarring. As a result, the soft tissue shrinks and stiffens. To differentiate this kind of surgery from cutting RFQ procedures, in the following discussion we will use the term interstitial RFQ.

Within the scope of sleep surgery, interstitial RFQ has been established in the treatment of the inferior turbinates [288, 526], the soft palate [400], and the base of the tongue [398, 399]. Less is known about its use in the treatment of tonsillar hypertrophy.

6.1.2.1 Principle of Interstitial Radiofrequency Surgery

The principle of interstitial RFQ surgery lies in the submucosal application of RFQ energy (low frequency radiowaves). This induces thermic lesions and tissue necroses (Fig. 6.1).

Currently, several systems are available, which are distinguished from each other by the method of energy input they employ. The energy input can either be controlled or uncontrolled. The controlled procedures include somnoplasty (Somnus, Gyrus ENT, Bartlett, USA) and the Celon system (Celon AG Medical Instruments, Teltow, Germany).

The Somnus system has received by far the most evaluations. Radiofrequency is delivered at 465 kHz using a specially constructed needle electrode and monopolar delivery system (Fig. 6.2). A thermo element is integrated into the tip of the electrode, which continuously measures the surrounding tissue temperature. The tissue target temperature is set by the surgeon. The generator then delivers as much energy as is needed to reach and maintain the chosen temperature until the total amount of energy is achieved. While in the case of electrocoagulation, tissue temperatures of above 500° Celsius are reached, with somnoplasty it is possible to generate temperatures significantly below 100° Celsius. The generator is set to the required energy input in Joules (J). The lesion size can be regulated via this energy input.

The Celon system regulates the energy input by means of the tissue resistance. It consists of a bipolar system (Fig. 6.2) with both electrodes in the needle tip, separated by an isolation (Fig. 6.1). A neutral electrode is not necessary. With the help of the applied RFQ energy (300 kHz to 2 MHz), the water is

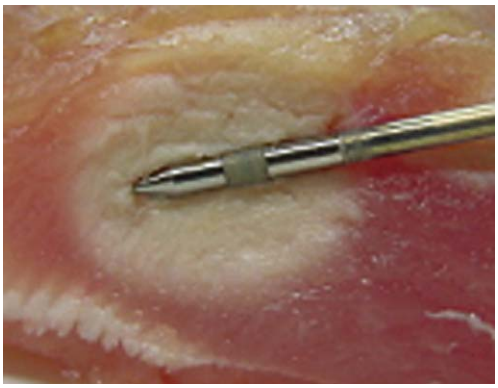


Fig. 6.1. Interstitial application of radiofrequency energy via needle electrode, shown here in turkey hen meat using the Celon system (RFITT, Celon, Teltow, Germany)

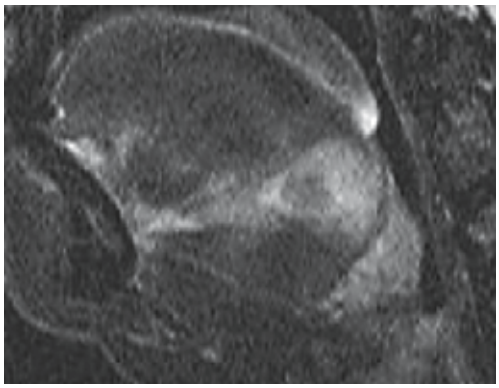


Fig. 6.3. Radiofrequency lesion and perifocal edema in the MRI (TIRM sequence)

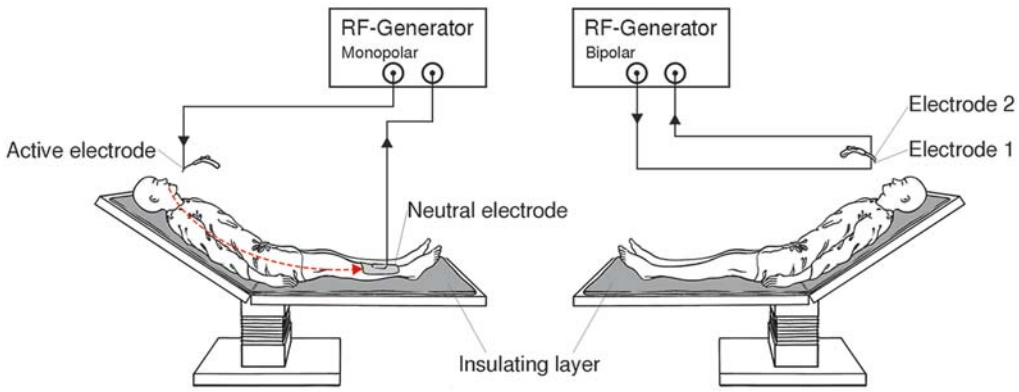


Fig. 6.2. Monopolar (i.e., Somnus) and bipolar (i.e., Celon) systems for interstitial radiofrequency surgery

thrust out of the tissue. As a result, the tissue resistance increases. A high setting of the generated energy level accelerates this process and results in a smaller tissue lesion. This means that lower energy levels need to be set for larger lesions, for instance, on the tonsil or the tongue base, than for smaller lesions on the nasal concha or the soft palate. In vivo this results in tissue necrosis and perifocal edema that can be imaged effectively in the MRI (Fig. 6.3).

Furthermore, a multitude of uncontrolled systems are available for interstitial RFQ surgery, which apply energy for as long as the surgeon wishes. This means that for these systems a certain measure of surgical experience is needed in order to determine the ideal energy input. Popular instances of this type of systems are, for example, the Plasma Coblation System (ENTec, Arthrocare, USA) or the Ellman system (Ellman International, Oceanside, USA). Unfortunately, there are very few studies evaluating the safety

level of these systems; therefore, due to the potential risk, we refrain from employing them.

6.1.2.2 Surgical Technique

Surgery is usually performed under local anesthesia as an outpatient procedure. Surgery is performed in a sitting position. In order to treat potential complications, an intravenous cannula is inserted. The patient is sedated. We prefer midazolam i.v.: if necessary, up to 10 mg are applied. Monitoring by pulse oximetry and an ECG makes sense, but is not usually necessary.

First, a surface disinfection is performed; then local anesthesia is executed. We use prilocaine 2% with suprarenine (1:200,000). According to its size, the tonsil is infiltrated with approximately 5 ml local anesthetic. In our opinion, due to the frequent hypersalivation, the use of a surface anesthetic has not proven to be advantageous.

The technique is similar to that used at other sites. A needle electrode is inserted into the lymphatic tissue of the tonsil. Depending on the size of the tonsil, four to eight lesions are set (Fig. 6.4).

We use two different systems. If somnoplasty is performed (Somnus, Gyrus ENT, Bartlett, USA), a double wand is used to apply two lesions at a time (Fig. 6.5).

We recommend 500 J per lesion. The target temperature is set at 85° Celsius. Other working groups use similar settings [154]. If the bipolar Celon system (Celon AG Medical Instruments, Teltow, Germany) is used, we recommend setting the device at 7 Watts. The results are comparable. However, the Celon system has turned out to be much quicker (seven times as fast as the somnoplasty). Hence, today we predominantly use the Celon system.

Regardless of the system used, the amount of swelling in the initial postoperative period exceeds the initial reduction, which means that tonsil size may be equal to or larger than the preoperative size. Therefore, we do not use the RFQ technique on an outpatient basis

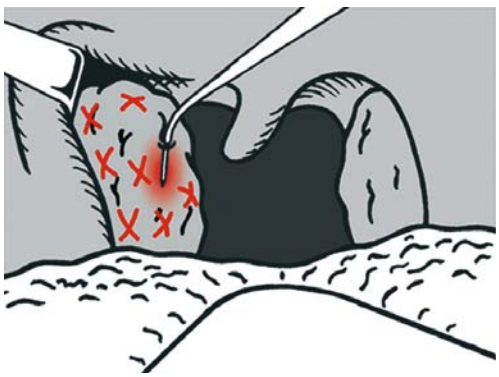


Fig. 6.4. Application pattern for RFQ treatment of the tonsil

Fig. 6.5. **a** Somnus double wand. **b** Application pattern

Fig. 6.6. Radiofrequency of the tonsils. *Right tonsil* Preoperative situation. *Left tonsil* Situation 3 weeks after surgery

in patients with kissing tonsils. Tonsil shrinkage occurs between the first and third week after surgery (Fig. 6.6). A postoperative view at 3 weeks postoperatively is shown in Fig. 6.6.

Like most authors, we perform a single stage procedure, whereas Nelson recommends a second procedure in selected cases [351, 352].

6.1.2.3 Effectiveness for SDB

The calculated reduction of the tonsil size is specified as 51.1 % [154] to 75.0 % [353]. Nelson described improvements in daytime sleepiness (79 %), subjective snoring (81 %) and the Epworth Sleepiness Scale (70 %) 3 months after surgery in 12 patients. These results remained constant after 6 and 12 months in the same population [353]. In children, the same author found an improvement in quality of life variables 1 year after surgery.

Concerning the effectiveness for OSA, there is only one report from Nelson [353]. He performed an interstitial RFQ treatment of the tonsils, combined with an adenoidectomy, in ten children. The AHI decreased from 8.8 to 4.2 (not statistically significant) 1 year after surgery. Additionally, he found improvements in daytime sleepiness and in the obstructive sleep apnea-18 questionnaire score.

Fischer et al. [145] performed multi-level interstitial RFQ therapy of the soft palate, base of tongue and tonsils in 15 sleep apneics. All patients received 16 treatment sites with a total dose of 9,750 J. The AHI decreased significantly from 32.6 to 22.0 after surgery. Using Sher's criteria, 20 % of patients were regarded as cured after the procedure.

6.1.2.4 Postoperative Care and Complications

To prevent infections, we recommend antibiotic prophylaxis for 5 days (i.e., penicillin V). In some cases corticosteroids are needed to reduce postoperative swelling. There is no specific postoperative care. Patients are recommended to consume ice cream, suck ice cubes and cool their necks with moist compresses. Postoperative morbidity has been estimated by Friedman and colleagues [154]. Patients reported pain for up to 2 days after surgery. Pain killers were needed for 1–2 days. On average, patients returned to normal activity after 2.4 days.

Interstitial RFQ surgery of the tonsils is a safe procedure. Intraoperative blood loss ranges from minimal (<20 ml) to none. Neither we nor other working groups have seen any postoperative bleeding or complications after RFQ of the tonsils [154, 351]. Admittedly, the lymphatic tissue tends to develop postoperative edema and the upper airway may be obstructed immediately after surgery. Therefore, overnight observation is recommended in cases of kissing tonsils and in children.

6.1.2.5 Indications and Contraindications

Interstitial RFQ surgery of the tonsils is a minimally invasive procedure with low postoperative morbidity, resulting in a substantial shrinking of tonsillar tissue. In children, the technique competes with different tonsillotomy techniques. Both techniques, interstitial RFQ and tonsillotomy, have to be performed under general anesthesia. Both techniques require overnight observation. Controlled interstitial RFQ surgery is still an expensive technique, as the applicators are single-use

instruments. Therefore, we rarely perform interstitial RFQ surgery in children.

In adults, the procedure can easily be performed under local anesthesia on an outpatient basis. Depending on the underlying anatomy, we usually perform combined procedures on the tonsils, soft palate and base of tongue in patients with simple snoring, upper airway resistance syndrome (UARS) and mild OSA.

Exclusion criteria for interstitial RFQ procedures are asymmetrical tonsillar hypertrophy with suspected lymphoma, a history of peritonsillar abscess, and patients with a clear history of recurrent tonsillar infections [154]. In most cases of moderate or severe OSA, interstitial RFQ is not sufficient.

6.2 Uvulopalatopharyngoplasty

No surgical procedure for the treatment of SDB has received more research attention than uvulopalatopharyngoplasty (UPPP). Since the first UPPP by Ikematsu in 1963, several procedures have been published, which aim at reducing the excessive tissue components of the soft palate without impairing the functions of the soft palate in swallowing and speaking. Several surgical modifications are discussed, and elucidated with perspicuous surgery outlines, in the 1994 symposium proceedings "Snoring and obstructive sleep apnea" [129]. For 12 years we have been using a modification [390] of the technique originally introduced by Fujita in 1981 [157]. From 1986 to 1990 we performed the UPPP without selection criteria – none had been proposed in the literature – and since 1990 we have employed specific selection criteria [390]. Therefore, we are in a good position to judge the long-term effect of this surgical procedure in both groups of patients. The aims of UPPP as a selective measure in the case of obstructive sleep disorders are:

- Significant reduction of the sleep-related respiratory disorder and daytime sleepiness
- No impairment of other functions
- High predictability rate of success
- Very low complication rate
- Option for combination with other therapy modalities
- High long-term acceptance rate by the patient
- High acceptance rate by the sleeping partner

Unfortunately, we have not yet achieved these goals in their entirety because definite selection criteria are not available.

6.2.1 Surgical Technique

In the sitting position, the location of the dimple during the phonation of the vowel "a" and the innervation pattern of the soft palate is determined. A submucous cleft of the soft palate has to be excluded prior to surgery. In the M. palatoglossus (anterior part of the soft palate), muscle spindles can be identified, which play a role in inducing unconstrained swallowing. Therefore, this anterior palatine arch, together with the paired M. uvulae, must be protected when performing UPPP. On the other hand, the M. glossopharyngeus (posterior part of the soft palate) has no muscle spindles; therefore, it can be partially separated without impeding swallowing or the possibility of future nasally applied continuous positive airway pressure (nCPAP) therapy. The best clinical-anatomical studies have been reported by Huang et al. [219] and Boorman and Sommerlad [41].

As with tonsillectomy, the patient lies with reclined head under general anesthesia. An infiltration of the soft palate with vasoconstrictive additive and local anesthetic is not necessary. The uvula tip is grasped and pulled downwards. In this way, the muscle bellies can be distinguished clearly under the mucosa, which means that the excessive mucosa of the uvula can be evaluated adequately. The incision into the mucosa is performed with a semicircular movement in the oral fold of the palatoglossus muscle, approximately 1–2 mm away from the free edge, 1 cm to the uvula base (Fig. 6.7). Then the fibers of the M. palatoglossus are dissected from the tonsil.

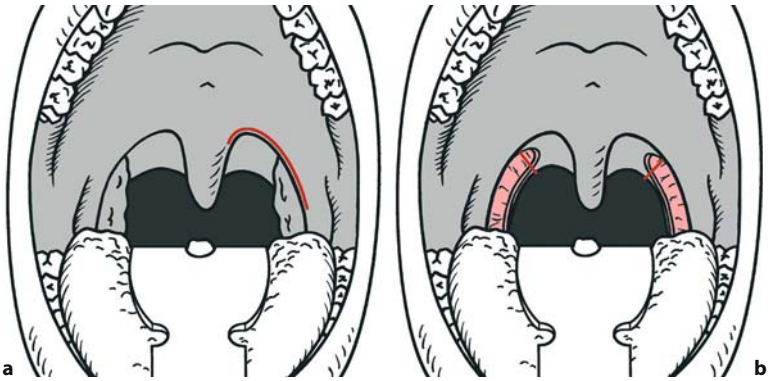


Fig. 6.7. **a** Incision along the caudal edge of the left palatoglossus muscle, with scalpel no. 11. **b** Situation after tonsillectomy with preservation of the posterior pillar

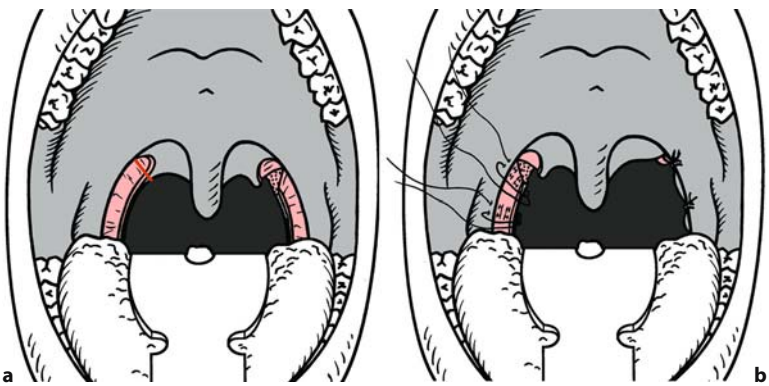


Fig. 6.8. **a** Incision of the posterior tonsillar pillar laterally to the uvula. **b** Suture of both tonsillar pillars with 2-0 absorbable, atraumatic thread

Tonsillectomy follows, in which the posterior tonsillar pillar is initially preserved (Fig. 6.7).

The posterior tonsillar pillar is then partially incised (Fig. 6.8) precisely at the site of maximum tension of the palatopharyngeus muscle, as felt by pulling the posterior pillar forward with a forceps. As a result, the posterior pillar opens up in a "V" shape, which produces a lengthy mucosal edge to be sewed together with the anterior pillar (Fig. 6.8). Now the two pillars can easily be sutured together without tension. This suture combines mucosa and musculature of the anterior pillar (1), of the lateral pharyngeal wall (2), and of the posterior pillar (3) with braided, absorbable, atraumatic thread (e.g., Vicryl 2-0 SH or 2-0 SH1 or Polysorb 2-0 X). We recommend doubling the suture in order to prevent a premature ripping of the suture during swallowing. Usually two sutures per side are sufficient. With these sutures, the posterior tonsillar pillar is moved laterally and anteriorly. This results in a semi-elliptical soft palate (Fig. 6.8), which stiffens as a consequence of the scarring. An identical procedure is performed on the opposite side.

The uvula is pulled downwards towards the mouth, so that the excessive mucosa can be differentiated from the uvula muscle. Only this muscleless part of the uvula is resected (Fig. 6.9).

Finally, redundant mucosa on both sides of the uvula is removed, and the mucosal folds of the anterior and posterior tonsillar pillar as well as the uvula stump are sewed together (Fig. 6.10).

Figure 6.11 shows how the originally more Roman form of the soft palate has turned into

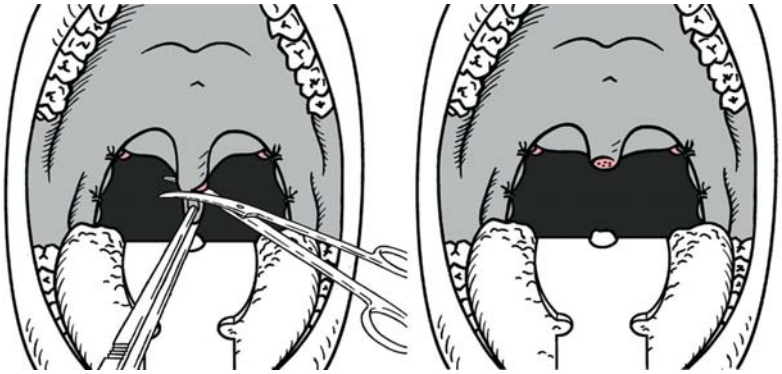


Fig. 6.9. Resection of the redundant mucosa of the uvula

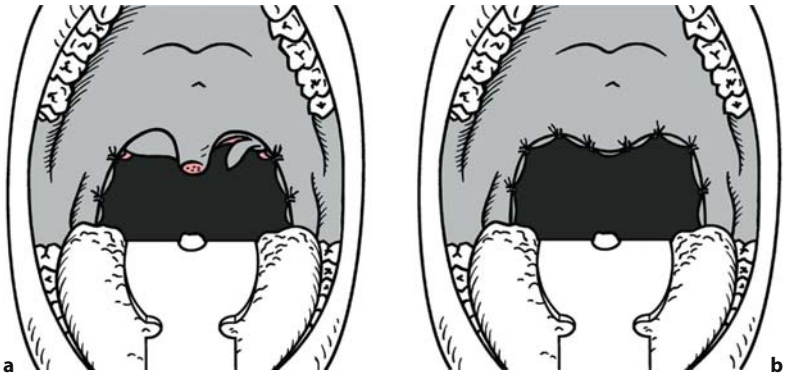


Fig. 6.10. **a** Resection of minimal amounts of excessive mucosa on the left posterior pillar. **b** Final result after adaptive suture

Fig. 6.11. Comparison of the preoperative (patient's right side) and the postoperative (patient's left side) situation

a semi-elliptical one as a result of the lateralization of the posterior tonsillar pillar.

In cases where the UPPP is performed on a patient who has previously undergone tonsillectomy, one usually finds a firm scarring between the remnants of the anterior and posterior tonsillar pillars, which promotes stenosis on the velopharyngeal level, especially towards the uvula. The incision is made where the caudal end of the palatoglossus muscle is assumed to be. Only a small strip of scarred mucosa is excised. Underneath the scars should be unraveled by rending them apart so that the folds of the two tonsillar pillars are well exposed again. Just as in the case of UPPP with tonsillectomy, the posterior pillar is incised at the site of its maximum tension. If the remaining tissue is scarce, small Z-plas-

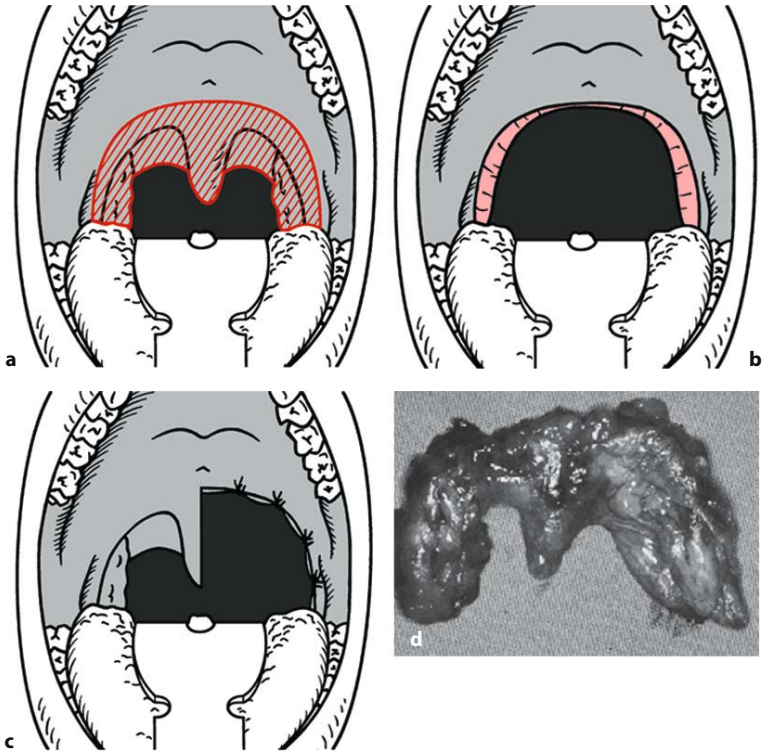


Fig. 6.12. a–c Radical or aggressive UPPP technique according to Simmons et al. [472]. **d** Specimen resected according to Martin et al. [313]

tics will enable more conductive reconstruction conditions for an elliptical new soft palate. Alternatively, in line with current knowledge, in the case of an indication of primary snoring, we either create a uvulopalatal flap or perform laser-assisted uvulopalatoplasty (LAUP). In the case of OSA and UARS, we solely employ a uvula flap modified according to our suggestions (see Sect. 6.4).

According to the above mentioned technique, UPPP has been performed in Ulm and Mannheim on more than 600 patients suffering from primary snoring and obstructive sleep apnea; the careful adaptation of the mucous membrane folds guarantees a controlled healing of the wound. Up to now, no long-term velopharyngeal insufficiency or nasopharyngeal stenosis (as a result of lateralization and forward relocation) has been observed. Follow-up nCPAP therapy was necessary for slightly more than 10% of the patients. In none of the cases was the therapy impaired by an oral air leakage.

When more radical techniques were used (Fig. 6.12), as in the 1980s, permanent velopharyngeal insufficiencies were described in up to 24% of cases [186], and nasopharyngeal stenoses in up to 4% [247]; nCPAP therapy failures occurred as a result of oral leakage [346]. Today, in our opinion, there is no indication for a radical UPPP.

Although a gentle and muscle-preserving UPPP is a treatment with a low complication rate, and therefore presents an attractive therapy for primary snoring and OSA [393], its application is limited due to the lack of predictability of surgical success. For OSA, in patients with velopharyngeal collapse, surgical success is predicted to be slightly over 50% [465].

Table 6.4. Long-term results after UPPP for simple snoring

Author	*n*	Follow-up (years)	No more snoring (%)	Snoring reduced (%)	No change (%)	Snoring worse (%)	EBM grade
Macnab et al. 1992 [305]	118	3–7	55	22	20	3	Retro
Levin and Becker 1994 [279]	69	1.5–7	46	11	43	0	Retro
Chabolle et al. 1998 [72]	39	3–7	44	No data	No data	No data	II-2
Hultcrantz et al. 1999 [224]	30	5–7	8	77	15	0	II-3
Hagert et al. 1999 [187]	254	1–8	18	73	9		Retro
Pasche et al. 2000 [378]	100	4	52	26	22	0	Retro
Hicklin et al. 2000 [204]	201	2–10	19	25	36	19	Retro
Hassid et al. 2002 [193]	57	5	12	68.5	19.5	No data	Retro
All	**57**	**1.5–10**	**29.8**	**43.1**	**29.4**	**8.1**	**IV**

6.2.2 Effectiveness for Simple Snoring

Numerous studies have been published regarding the efficacy of isolated UPPP for primary snoring. Here also the definitions of what constitutes surgical success differ immensely; in the following, we therefore have to restrict ourselves to the compilation of studies with long-term data. In our opinion, only follow-ups of at least 3 years can be regarded as long term. The existing data are summarized in Table 6.4.

Two studies [204, 279] also include short-term results from the identical patient pool: 87% and 76% respectively were classified as responders. This percentage fell in the long-term follow-up to 46% and 45% respectively. Accordingly, Hassid et al. [193] recently described decreasing success rates with increasing follow-up periods.

Combining the values for "snoring reduced" and "no snoring" results in a long-term success rate of 71% for isolated UPPP in the treatment of primary snoring, based on the data of all 868 patients included in Table 6.4. But this figure has to be considered with caution because the diverse evaluation criteria are extremely heterogeneous. Accordingly, the success rates vary in the cited studies between 44% and 91%.

It was possible to corroborate objectively a reduction of the alpha-EEG arousals after UPPP in the case of non-apneic snoring [44]. Janson and colleagues [235] found reductions in daytime sleepiness and fatigue in 155 non-apneic snorers following UPPP.

6.2.2.1 Comparison of Different Soft Palate Surgical Techniques

Chabolle and colleagues [72] also included patients after LAUP in the same follow-up study. The groups were comparable with regards to age, gender, and body mass index (BMI). With 44%, the success rate (complete elimination or satisfactory reduction of snoring) was identical in both groups. But the general satisfaction with the surgery was significantly higher in the UPPP group than in the LAUP group. The reasons remained unclear. On average, in the LAUP group 4.2 treatment sessions (UPPP only one) were necessary, and the rate of unwelcome side effects was slightly higher. Nevertheless, the authors conclude that both procedures are suited for the treatment of primary snoring.

An objective analysis of the respiratory sounds during sleep furnished a similar success rate for UPPP and LAUP, both for short-term (2–11 months) and long-term (29–56 months) follow-up assessment [369, 370].

Table 6.5. Long-term results after UPPP for OSA

Author	*n*	Follow-up short (months)	Follow-up long (years)	Success short (%)	Success long (%)	Criteria of success	EBM grade
Perello-Scherdel et al. 1995 [383]	57/57	6	5 or 10	No data	73.7 (52.6)	AI-Red >50% (AHI <10)	Retro
Lu et al. 1995 [301]	13/13	12	7.3	69.2	30.8	Sher	II-3
Larsson et al. 1994 [274]	50/48	6	3.8	60	50	Sher	II-3
Janson et al. 1997 [234]	25/25	6	4–8	64.0	48.0	Sher	II-3
Hultcrantz et al. 1999 [224]	17/13	3	5–7	82.4	69.2	Sher	II-3
Boot et al. 2000 [42]	58/29	6	3	41	31	ODI-Red >50%	II-3
All	**105[a]/99[a]**	**3–12**	**3–10**	**65.7[a]**	**49.5[a]**		**IV**

[a] Only data of studies using Sher's criteria of success.
AI-Red reduction in apnea index, *ODI-Red* reduction in oxygen desaturation index.

Lysdahl and Haraldson [304] prospectively performed UPPP or laser UPPP (LUPP) in 121 patients. Both techniques achieved significant improvement of subjective parameters such as snoring, awakenings, apneas, daytime sleepiness and sleep spells when driving at short-term follow-up (3 months). UPPP was superior to LUPP for all clinical effect parameters. Five to eight years after surgery, all subjective parameters except sleep spells when driving had worsened, with UPPP again showing better long-term results. Similarly, in the study of Hagert and coworkers [187], the conventional UPPP yielded significantly better results for snoring than LUPP.

6.2.3 Effectiveness for OSA

There are only a few prospective studies covering long-term results of up to 9 years after UPPP. As with the other techniques, the comparability of these data is made problematic due to varying success criteria. Almost unanimously, all authors find a discrepancy between adequate subjective improvement of their symptoms and nearly unchanged objective sleep parameters after UPPP. Therefore, a polygraphic or polysomnographic postoperative evaluation is necessary after 1–3 years.

Every surgeon should study the excellent survey by Sher et al. [465]. The authors used as success criteria an AHI <20 and a reduction of the AHI of at least 50% (or analogously: AI <10 and AI <50%). For the non-selected patient pool this meta-analysis yielded a surgery success rate of 40.7%. In the selected group with clinically suspected obstruction solely on the level of the soft palate, a success rate of 52.3% was found. For the most part, these data are based on short-term results.

Data concerning long-term success are summarized in Table 6.5.

Table 6.5 impressively demonstrates that the effect of UPPP on the severity of OSA decreases over the years. As a consequence of these findings, we and other study groups infer the necessity of a long-term sleep medical control of the patients after UPPP. The employed success criteria are again heterogeneous. If one combines those data from Table 6.5 that use Sher's success criteria [465], this yields a long-term success rate of 49.5% for isolated UPPP including tonsillectomy in the treatment of OSA. Nowadays one can rightly assume a positive long-term effect of

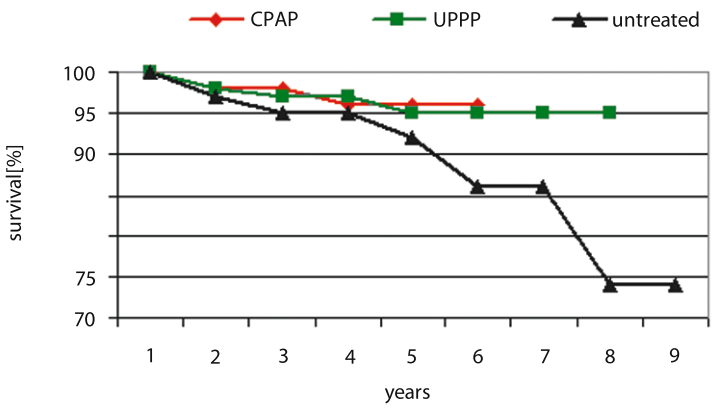


Fig. 6.13. Long-term survival of patients with OSA and different treatments [194, 252]

isolated UPPP, possibly in connection with a tonsillectomy.

In accordance with these results, in a group of 400 patients with SDB who had received UPPP or LUPP, no increase in mortality was found in comparison to a control group comprised of 744 persons [303]. These data may indicate a positive survival effect of UPPP surgery. Keenan et al. [252] contacted their OSA patients treated with either UPPP (n=149) or nCPAP (n=126) over a 6-year period to compare long-term survival rates between these two treatments. There was no difference between the two treatment groups (Fig. 6.13). Furthermore, UPPP for SDB turned out to improve the patients' stimulated long-term driving performance [191] and decreased the number of car accidents within a 5-year period after surgery [190].

For the indication of mild OSA, the efficacy of UPPP with tonsillectomy (n=40) was compared with an oral mandibular advancement device (n=32) in a prospective, randomized study [551]. After 4 years, both groups showed a significant reduction of the AHI; while in the UPPP group the AHI was reduced from 19.9 preoperatively to 14.2 postoperatively, the AHI with oral device was reduced from 17.9 before treatment to 7.2 after treatment. Yet it must be said that in this study the polysomnographic superiority of the oral device is offset by a therapy withdrawal rate of 38 %.

6.2.4 Postoperative Care and Complications

Uvulopalatopharyngoplasty is the most common operation performed for OSA. The anatomic and physiologic abnormalities associated with OSA pose independent risks of complications in the intra- and perioperative periods [98, 312]. Postoperative edema and respiratory depression enhance the risk of reintubation or emergent tracheotomy within the first few hours after surgery [86, 238]. The incidence of lethal complications is given as 0.2–0.03 % [66, 257]. Serious cardiorespiratory complications other than death occur in 1.5 % of the cases [257].

Intraoperatively we administer an intravenous single shot antibiotic with 2 g cefazolin. Apart from this, antibiotics are only used in the case of relevant inflammatory complications. The severe pain occurring in almost all of the patients in the first postoperative days is treated with diclofenac suppositories, and later with tablets. Here we make use of the additional antiphlogistic effect, although the administration of further, more potent analgesics often becomes necessary. We used to prefer metamizol and tramadol. Recently, we have had good experiences with the modern Cox-2- synthesis blockers (e.g., rofecoxib). At any rate basic pain treatments with fixed analgesic applications are superior as compared to a regimen in which patients

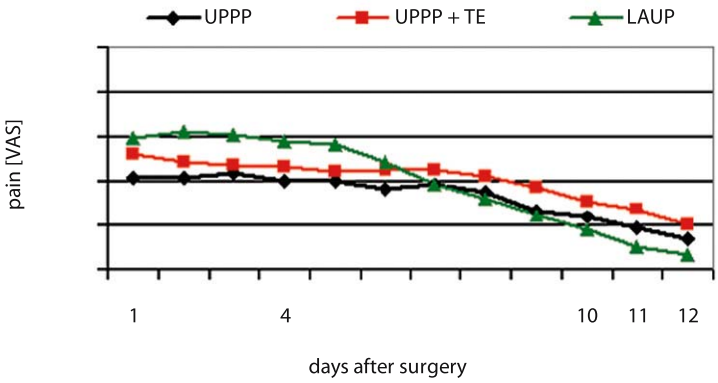


Fig. 6.14. Pain after UPPP, UPPP + tonsillectomy (*TE*), and LAUP. *x-axis* days postoperative. *y-axis* pain sensation on a visual analog scale (*VAS*) with the endpoints 0 = no pain, and 10 = unbearable pain

receive analgesics only on demand [515]. Apart from aspirin there is no significant increased risk of postoperative bleeding for non-aspirin NSAIDs, as recently published in a meta-analysis [267].

In any case, the postoperative pain sensation of patients is so varied that individual pain management is called for. Appropriate postoperative controls are necessary.

During the first postoperative day, the patients are fed via infusion, and take in tea and ice cream, as in the case of a tonsillectomy. From the second day, they receive a special tonsillectomy diet. The threads are removed between the 10th and 13th postoperative day. The inpatient time varies between 2 and 5 days, depending on the ability to eat and the extent of pain. Postoperative intensive care supervision is not usually necessary after isolated UPPP [58, 334].

Most patients are able to swallow liquids on the first postoperative day, albeit under pain. For approximately a third of the patients, the pain continues to be rather severe until the fifth day (Fig. 6.14); for another third, the pain is comparable to regular tonsillectomy, while the remaining patients receiving surgery experience virtually no pain on the fifth day. In the context of follow-ups 6 months after UPPP, so far no patient has complained about pain during food intake.

On the whole, postoperative pain after UPPP and LAUP is comparable in respect to duration, intensity, and consumption of pain killers [518, 559]. Radiofrequency surgery on the soft palate is much less painful [429, 493, 518].

Obviously, the new movement pattern of the operated velum during swallowing needs to be trained from scratch; some patients have described this with interesting observations: a journalist and passionate beer drinker reported a completely new sensation in the velum, which was induced by the froth of the beer. Strongly carbonated beverages may cause gas bubbles to rise into the nasopharynx. Forty per cent of our patients complained of an increased mucous production in the pharynx more than 4 years after a technique involving removal of the oral mucosa of the whole uvula and sewing the tip of the uvula muscle into the median soft palate in the long term. Our more recent technique, described in Fig. 6.10, does not lead to an increased mucous production in the pharynx. Clinically, a dry pharynx is often found. Some patients also experience mildly distorted sensations in the area of the soft palate, but no pain.

As with any tonsillectomy, postoperative bleeding during the healing phase is a possibility. However, as a result of a careful velum suture, this has become a rare occurrence (0.7%) in our own patient pool. Despite double suture, on the fourth to fifth day the suture often breaks in the descending suture area; yet it remains intact in the horizontal part, which is crucial for the stabilizing scarring. In previous years, we often administered

antibiotics (e.g., amoxicillin) over a period of 5–7 days; we repeatedly observed a stomatitis aphthosa in these cases. This has become a very rare occurrence since we have begun applying the antibiotic only perioperatively. Also, the fetid mouth odor setting in with the third postoperative day, which is so typical for tonsillectomy without mucous membrane, is usually absent in our patients.

The dreaded velar insufficiency with rhinolalia aperta and/or entrance of food into the nose during swallowing (Fig. 6.15) has been observed only when the musculature of the anterior palatine arch is partially resected, which we could see in patients after velar surgery alio loco coming for revision surgery.

In none of our patients who have undergone surgery using the above procedure has a velopharyngeal insufficiency been observed. Another reason for velopharyngeal insufficiency is a too short and too firm soft palate. Such patients can be distinguished preoperatively by virtue of the fact that water flows into their nose during the so-called "Finkelstein test" [142]. Patients are asked to drink water with their heads protruded from under a running faucet. In the case of velum sufficiency, no water enters the nose. We use this test pre- and postoperatively in order to document the velar sufficiency of the patient undergoing surgery. Specific problems can be caused by patients with an operated cleft palate who additionally suffer from an obstructive respiratory sleeping disorder.

Because OSA cannot be cured by surgery in every case and SDB can reoccur even after a temporary postoperative normalization, soft palate surgery must always be performed in such a way that CPAP therapy remains an option at all times. But if the palate musculature is partially resected during UPPP, nasal overpressure respiratory therapy with the help of nasal CPAP can become very difficult, because in this case the air escapes through the mouth. Mortimore et al. [346] discovered

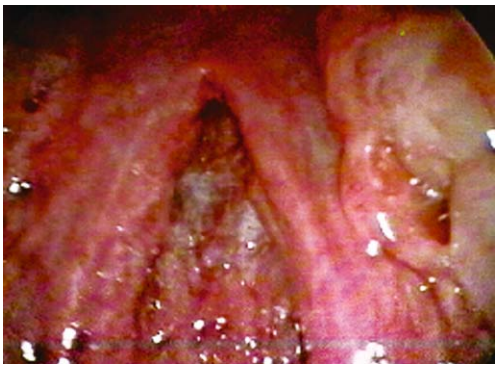


Fig. 6.15. Velopharyngeal incompetence after aggressive UPPP

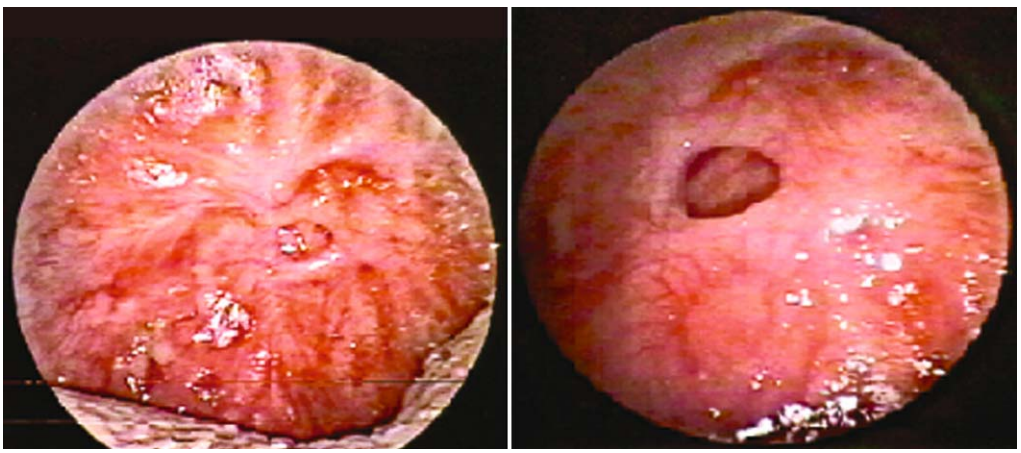


Fig. 6.16. Two cases of nasopharyngeal stenosis after aggressive UPPP

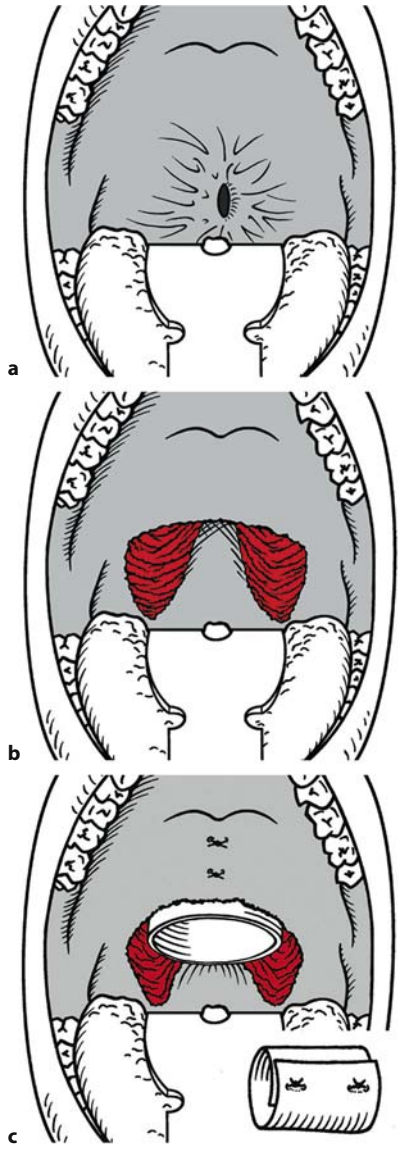


Fig. 6.17 a–c. Treatment of nasopharyngeal stenosis after UPPP. **a** stenosis, **b** situation after opening, **c** situation after insertion of placeholder made of silicon foil (see small picture in **c**)

that after a UPPP with partial resection of the velum musculature, no mask pressure higher than 13 cm water column can be applied nasally through the CPAP mask without creating an air leakage through the mouth. In the case of patients with an intact velum, and also after application of the UPPP technique described here, no air escapes through the mouth, not even in the case of nasal CPAP pressures of 20-cm water column.

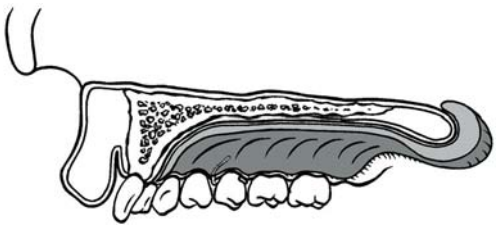


Fig. 6.18. Customized palate obturator with nasopharyngeal extension

Equally dreaded is nasopharyngeal stenosis (Fig. 6.16). The following are considered as risk factors for the development of a nasopharyngeal stenosis: aggressive surgical technique, extension of surgery to the lateral pharyngeal walls, and postoperative wound infection.

The surgical treatment of nasopharyngeal stenosis after UPPP is difficult, and unfortunately does not yield positive results in all cases. Often several surgical procedures and intermittent insertion of nasopharyngeal obturators are necessary [163, 264, 265]. We prefer to open the stenosis with scissors as laser surgery may lead to deep thermic lesions and uncontrolled scarring. It is important to insert a placeholder in the wound to avoid recurrence of the stenosis. We create such a placeholder out of 1 mm thick silicon foil, as shown in Fig. 6.17. This has proven to be effective, easy to handle and cost-effective.

Other authors use other kinds of custom-made nasal obturators (Fig. 6.18) [163]. Nowadays, we regard the appearance of a nasopharyngeal stenosis less as an inevitable complication, but as the result of an inadequate surgical technique.

Katsantonis [248] has classified the late-term complications after UPPP in descending frequency as follows:

- Pharyngeal dryness and hardening
- Postnasal secretion
- Dysphagia
- Incapability of initiating swallowing

- Prolonged angina
- Taste disorders
- Speech disorders
- Numbness of tongue
- Permanent velopharyngeal incompetence (VPI)
- Nasopharyngeal stenosis

A permanent rhinolalia aperta has not been observed in connection with the muscle-preserving technique described above. However, we have observed this sign of a velar insufficiency in the case of patients who received too radical surgery alio loco (resection of palate musculature). Several patients who had received a tonsillectomy with UPPP reported a positive change in timbre and resonance of their voice. Patients with speech professions (French teacher; radio announcer for Italian and French) and two professional musicians (wind players) experienced no difficulties in resuming their jobs after a 3- to 4-week interval. Nevertheless, the indication should be made with special restraint for this patient group [53].

6.2.5 Indications and Contraindications

Foremost, UPPP can eliminate the snoring sound of the so-called "velum snorer". But it is not that easy to recognize the velum snorer with certainty. Clinically, the velum snorer displays characteristic anatomical traits of his or her soft palate, such as a long and/or wide uvula with lateral mucous membrane folds, a salient posterior palatine arch (webbing) (Fig. 6.19), a short distance between soft palate and pharyngeal posterior wall, and formation of craniocaudal mucosal folds in the mesopharyngeal posterior wall. The velum snorer is especially distinguished by a snoring sound characterized by a base frequency of 25–50 Hz and a multitude of overtones, which results in a regular and harmonic sound pattern [445]. The UPPP has no effect in the case of a "tongue base snorer," whose night-time respiratory sounds are characterized by loud, hard, metallic, non-

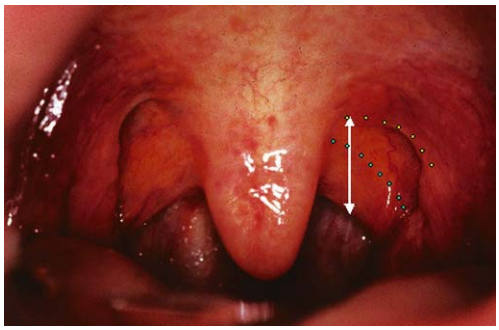


Fig. 6.19. Soft palate. *Yellow dots* caudal edge of M. palatoglossus. *Green dots* caudal edge of M. palatopharyngeus. *White line* so-called webbing = distance of the free edge of the posterior palatine arch to the caudal edge of the M. palatopharyngeus

harmonic snoring with frequency amplitudes between 1,100 and 1,700 Hz.

The literature provides only a few prospective studies for OSA, which suggest the following selection or exclusion criteria for UPPP:

- In general, obesity is a negative selection criterion. The limit for an isolated UPPP appears to lie at a BMI between 28 and 30 kg/m².
- A high AHI or oxygen desaturation index (ODI) is a negative selection criterion for isolated UPPP. The absolute value is disputed; it seems to lie between 20 and 30 per hour. Above an AHI of 25 we pursue a multi-level surgery concept.
- Large tonsils that are removed with UPPP are a positive selection criterion. If still existing, we always remove tonsils in the context of a UPPP for OSA.
- Contradictory data are produced when radiocephalometric data are used for the selection of patients. A retrognathia or a micrognathia are negative selection criteria. In these cases the obstruction often lies behind the tongue.
- A positive Müller maneuver (provoking of a collapse during inspiration against the artificially closed airway) in the context of nasopharyngeal videoendoscopy has no predictive values; therefore, we do not employ it.

An analysis of the literature yields the following exclusion criteria for an isolated UPPP, which in principle we had already formulated in 1990 based on our own results [536]:

- Chronic heart and/or lung diseases
- Neurological/psychiatric illnesses in need of treatment
- High anesthesia risk
- Obesity; BMI >30 kg/m²
- Chronic alcoholism
- Soporific drug abuse
- Severity of OSA; AHI >25
- Severe bite misalignment
- Narrow pharyngeal airway behind tongue
- Large distance between lower edge of mandibula to the hyoid
- Certain craniofacial deformities
- Too short soft palate

If indicated, we perform UPPP and tonsillectomy combined with rhinosurgery in the majority of patients. In these cases, the patient is forced to breathe through the mouth during the nasal packing (1–2 days). This leads to a heightened postoperative morbidity; but this is justifiable in the majority of cases. These patients need to be supervised in the recovery room immediately postoperatively (i.e., during the first 3–6 h after surgery). Supervision in an intensive care unit is usually not necessary [334]. Yet the issue of heightened postoperative morbidity should be discussed with the patient preoperatively, since in principle it is possible to perform nasal surgery and UPPP separately.

We no longer perform isolated soft palate surgery if the AHI is above 25. The experience of diminishing success rates with increased initial AHI has shown that in these cases the complete airway is affected by the disease. We therefore prefer a multi-level surgery concept for moderate and severe OSA, in which UPPP or uvula flap with tonsillectomy plays a central role (Chap. 10).

In children, UPPP is indicated only in exceptional cases, as for example neurologically impaired children, or those with craniofacial deformities or Down's syndrome [1, 226, 255, 261, 490]. We have only limited but positive experience in individual cases of M. Down and Pierre-Robin sequence.

6.3 Uvulopalatal Flap

Uvulopalatopharyngoplasty is a relatively time-consuming surgical procedure, even if the surgeon has sufficient experience and practice. This fact has contributed to the interest generated by a modification, the uvulopalatal flap, developed at Stanford [396]. Today we use a modification of the original technique with lateral extension to the tonsil bed, which is a simple and fast method that does not sacrifice the advantages of UPPP [213].

6.3.1 Surgical Technique

The preparations for surgery are identical to those described for UPPP. Surgery is performed under general anesthesia. The patient lies with reclined head, as in the case of tonsillectomy. In patients with OSA, the first step is always a gentle tonsillectomy (Fig. 6.20). In patients who have already undergone tonsillectomy there is no need for time-consuming opening of the scarring between the anterior and posterior palatine arch as with the UPPP technique. Incisions into the soft palate are then made bilaterally on both sides of the uvula, as shown in Fig. 6.20.

At this point, the classic UPPP technique is left behind. The tip of the uvula is grasped with surgical tweezers and excessive mucous membrane is resected (Fig. 6.21).

The now exposed muscle tip of the uvula is then folded towards cranial using the surgical tweezers. The opening of the velopharyngeal flap is assessed, and the necessary extent of the uvulopalatal flap determined (Fig. 6.22). Powell et al. recommend marking the correct position of the uvulopalatal flap on the anterior side of the soft palate with tincture [396]. As a next step, in the marked area the mucosa of the anterior palatine arch and the underlying salivary glands are removed, with careful preservation of the muscles (Fig. 6.22). Removal of the complete soft tissue above the musculature is crucial as only this can prevent the uvulopalatal

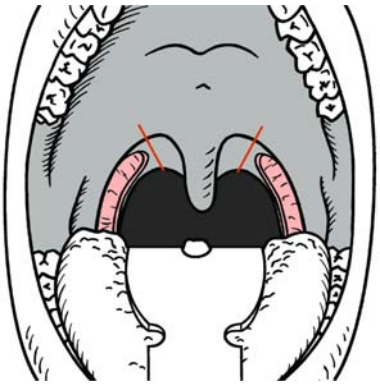


Fig. 6.20. Situation after gentle removal of tonsils. Bilateral incisions into the soft palate on both sides of the uvula

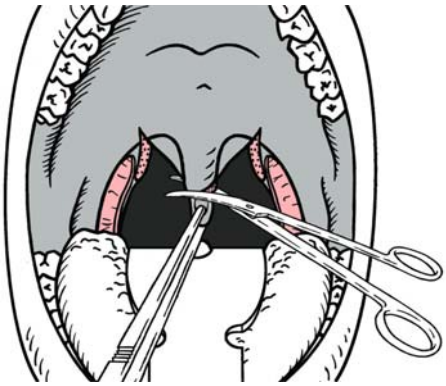
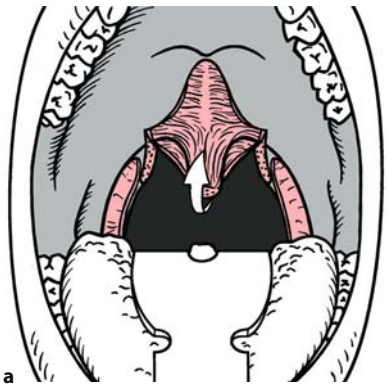


Fig. 6.21. Shortening of the uvula



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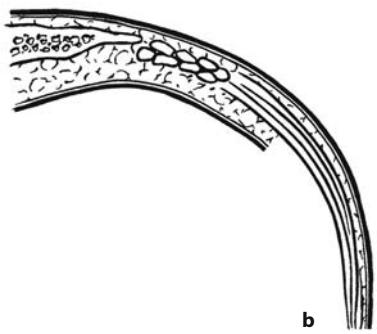
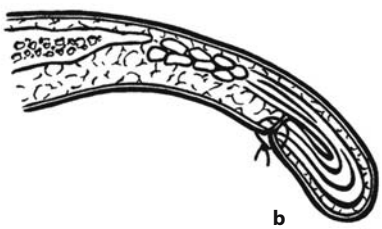


b

Fig. 6.22. **a** Identifying the correct size of the flap by rotating the uvula upwards. Removal of mucosa and salivary glands in the estimated area. **b** Lateral aspect of the soft palate

a



b

Fig. 6.23 a,b. Postoperative situation. **a** Frontal aspect. **b** Soft palate, lateral aspect

flap from becoming too thick. A too thick uvulopalatal flap may lead to dysphagia, articulation impediments, and obstructed breathing.

Now, the uvula is loosely folded into the defect and worked in with atraumatic, resorbable suture material. We recommend a double suture with a thread thickness of 2.0 or 3.0, depending on the dimension of the soft palate. As a rule, five sutures are sufficient. This results in an uvulopalatal flap, the thickness of which is in accordance with the level of the surrounding soft palate (Fig. 6.23). Finally, lateralization of the posterior palatine arch is achieved by sewing together the two palatine arches, comparable to the technique employed for UPPP (Fig. 6.23).

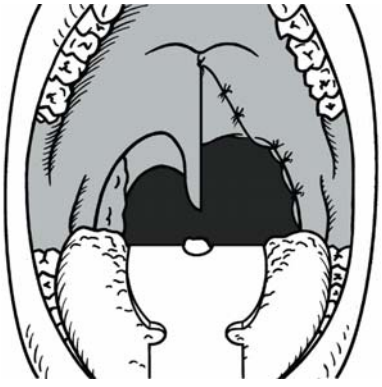


Fig. 6.24. Comparison of preoperative (*left side*) and postoperative (*right side*) situation

The lateralization is achieved by deep intra-muscular sutures (2.0 resorbable thread, atraumatic needle), which are run through the posterior palatine arch (M. palatopharyngeus), through the base of the tonsil bed, and through the anterior palatine arch (M. palatoglossus). We always execute a double suture of the palatine arch; in our experience, a double suture significantly delays tearing of these sutures. The aim of the lateralization is to prevent a potential transverse folding of the pharyngeal posterior wall. Figure 6.24 compares the pre- and postoperative situations.

Figure 6.25 shows the intraoral finding before and 6 weeks after successful uvulopalatal flap including tonsillectomy in a patient with OSA.

6.3.2 Effectiveness for SDB

Only limited data have been published concerning the efficiency of the uvulopalatal flap for the treatment of sleep-related breathing disorders. Only one publication addresses the therapy of primary snoring [357]: 65 patients received an uvulopalatal flap as a sole surgical procedure. The follow-up evaluation occurred after 14 months on average. Both a subjective and objective reduction of the snoring sounds could be demonstrated. For both parameters the differences were statistically significant. Additionally, a polysomnography was performed both pre- and postop-

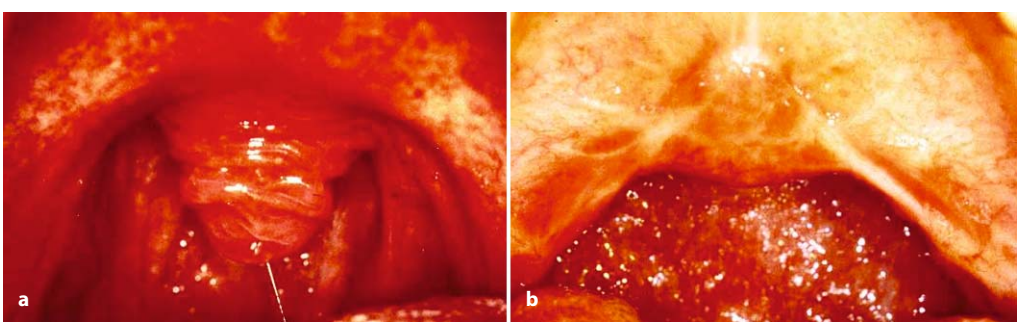


Fig. 6.25 a,b. Uvulopalatal flap. **a** Preoperative finding. **b** Situation 6 weeks postoperatively

Table 6.6. Effectiveness of uvulopalatal flap for OSA

Author	*N*	Follow-up (months)	AHI pre	AHI post	Success (%)	EBM grade
Hörmann et al. 2001 [213]	30	1.5	19.2	8.2	46.7	II-3
Li et al. 2004 [282]	55	6	43.6	12.1	80	Retro
All	**85**	**1.5–6**	**35.0**	**10.7**	**52.1**	**IV**

eratively. The respiratory disturbance index (RDI) remained unchanged (3.2±1.2 vs. 3.0±1.8).

More data exist concerning the efficacy of the uvulopalatal flap for the treatment of OSA. In an initial publication, 80 patients were diagnosed prospectively (EBM II-2) [396]: 59 of them received an uvulopalatal flap; the remaining 21 underwent a conventional UPPP. The results in regard to the polysomnographic and subjective findings were comparable in both groups. However, in 84% of the cases additional surgery on the hypopharynx was performed in the same session; therefore, this study does not allow for inferences regarding the isolated effect of the uvulopalatal flap.

An initial evaluation of 30 patients in our facilities, who received an isolated uvulopalatal flap according to the technique described above without accompanying further surgeries, resulted in a statistically significant reduction of the mean AHI from 19.2 to 8.2 6 weeks postoperatively [213]. Further significant improvements were found in the objectively determined snoring index (SI, 45.3 vs. 21.0) and in the minimal oxygen saturation (79.2% vs. 87.5%). It was possible to classify 46.7% of the patients as responders according to Sher's criteria.

Better results have been reported recently by Li et al. [282], who use a technique comparable to our own [283]. In a retrospective evaluation of 55 patients after uvulopalatal flap with tonsillectomy, these authors achieved a success rate of 80%. The AHI in this series was reduced significantly from 43.6 preoperatively to 12.1 6 months postoperatively. These authors also report a significant improvement of the SI and the minimal oxygen saturation. Furthermore, a significant improvement of daytime sleepiness and of quality of life was observed in seven of eight rubrics of the SF-36.

The amount of data (Table 6.6) from only two studies on the uvulopalatal flap is extremely limited compared to the data available for the UPPP. But since the surgical techniques are very similar in their principles, we feel justified in assuming that the weak data situation is sufficient to posit a comparable efficacy of the uvulopalatal flap with the UPPP in the treatment of OSA. Our extensive surgical experience with this technique, especially in the context of the Mannheim concept of multi-level surgery of OSA, further supports us in this assumption.

6.3.3 Postoperative Care and Complications

The immediate healing phase after uvulopalatal flap proceeds in the same way as after conventional UPPP and after the additionally performed tonsillectomy. Therefore, we implement the same postoperative management as after UPPP, and refer the reader to our discussion in Sect. 6.2.

Three of the four studies already mentioned also furnish information concerning the potential complications after uvulopalatal flap. Neither our study group nor the Stanford group has observed the dreaded velopharyngeal incompetence. Neruntarat described transient nasal regurgitation in two of his patients (4%) [357]. In the Finkelstein test [142], a flow of liquid into the nose

was demonstrated endoscopically in three of our 30 patients, without it becoming clinically relevant. In the longer term, a nasopharyngeal reflux could not be demonstrated. These data are comparable with those of a gentle UPPP, and they corroborate the assumption by Finkelstein that the proof of a subclinical nasopharyngeal reflux in the first weeks after soft palate surgery depends on the intensity with which the surgeon hunts it out.

Nasopharyngeal stenosis, as has been described after other, especially aggressive soft palate techniques, has not been observed after uvulopalatal flap. We are convinced that the scarring and shrinking tendency is lower after uvulopalatal flap than after UPPP, because the sutures do not have to be laid into the free soft palate ridge.

In the first weeks postoperatively, irritations and foreign body sensations are to be expected. This is due to the principle of the surgery, which transports mucous membrane segments that originally have been in the posterior side of the velum to the anterior side. As a result, some patients initially experience an irritation in the nasopharynx when it comes into contact with the flap. These sensations disappear after several weeks. Apparently, a sensory innervation pattern in this area adapts itself to the changed anatomy.

Permanent foreign body sensations develop, especially in cases where not only an incision of the posterior palatine arch is performed, but a cut is also performed in the anterior palatine arch. This is necessary in rare cases, in order to achieve a sufficient opening of the velopharyngeal segment; but this should always be performed as cautiously as possible, in order not to endanger the sensory innervation of the flap and the uvula, which pulls from laterocranial towards mediocaudal. If one abides by this principle, such permanent foreign body sensations, which severely burden the patient, can be reliably avoided.

Our own investigations concerning language and articulation have not brought to light any disturbances in this respect.

As a further complication, a hematoma in the area of the uvula tip with secondary inflammation, which led to a revision of the flap, and a suture insufficiency with partial flap insufficiency, has been described [396]. We also have observed suture insufficiencies with partial or complete dislodgement of the flap from its bed. These suture insufficiencies can be reliably avoided with the help of an adequate suture technique with deep-reaching double sutures and atraumatic suture material. In order to prevent unnecessary postoperative wound pain, it must be ensured that the knots are tightly bound, but that the tissue is not squashed. A slack adaptation of the wound edges is aimed at. Some surgeons consider the use of knot slides to be very helpful in this context.

Originally, the uvulopalatal flap was regarded as a potentially reversible surgical technique. We want to challenge this evaluation; we do not consider the uvulopalatal flap as reversible in principle. Our experience has shown that the scarrings after completed healing of the wound cannot easily be opened up again.

6.3.4 Indications and Contraindications

The uvulopalatal flap is a comparatively modern procedure. We see the indication for the most part in the area of OSA and UARS. For primary snoring, techniques such as RFQ surgery, soft tissue implants and laser-based procedures can be used on an outpatient basis and under local anesthesia. Given the comparable efficacy and the lower costs involved, these procedures are to be preferred.

Uvulopalatopharyngoplasty and uvulopalatal flap are similar in regards to their basic principle and their effects upon the upper airways; therefore, we assume the same indications for both surgical techniques, when they are employed in a muscle-preserving manner. For the isolated soft palate surgery (uvulopalatal flap with tonsillectomy) these areas are UARS as well as moderate to moderately severe OSA. In combination with surgery on the hypopharyngeal segment, we also use the uvulopalatal flap for severe OSA.

On the whole, we see few advantages for the uvulopalatal flap, especially if a tonsillectomy has been performed prior to surgery; but ultimately every surgeon will have to choose for himself the technique with which he achieves better surgical results.

6.4 Laser-Assisted Uvulopalatoplasty

Since 1981, UPPP has gained acceptance as routine therapy in the surgical treatment of SDB [157]. As an essential modification of the conventional UPPP technique, a laser-assisted velum surgery was developed, which was introduced by Carenfelt [67] in 1986, and which he called "laser uvulopalatoplasty" (LUPP). While Carenfelt performed the LUPP under general anesthesia and with sutures similar to those used with the UPPP, at the end of the 1980s, Kamami [243] introduced a further modification, which was carried out under local anesthesia in several sessions on an outpatient basis. This modification was called "laser-assisted uvulopalatoplasty" (LAUP); it has spread rapidly in Europe and since 1992 has also become increasingly popular in the USA [84].

Up to March 2004, more than 100 articles on LAUP have been published world-wide; however, only some of these articles are clinically relevant. Therefore, the present outline intends to structure the literature on the basis of clinical criteria in order to highlight the significance of LAUP/LUPP for everyday routine work. In particular, the indications for LAUP/LUPP, their surgical prospects of success and the complications associated with the procedures will be illuminated.

6.4.1 Surgical Techniques

We found 24 different descriptions of laser surgical techniques of the soft palate explaining in detail which anatomical structures of the soft palate are involved in the surgery. Most of these publications are illustrated with explanatory drawings or photographs. Although the variability of the techniques described is very high, three basic techniques can be identified.

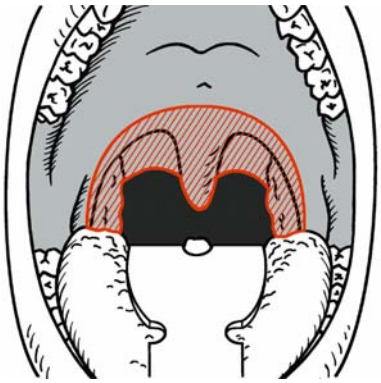


Fig. 6.26. Scheme of LUPP according to Wennmo et al. [559]

The oldest technique, applied by Carenfelt in 1986 [67], is the LUPP, which some working groups [67, 559] reported to be more gentle to muscles, while others regarded it as being substantially more radical [140, 266]. The procedure performed with the LUPP is similar to that carried out with the UPPP, which means the preparation also extends to the pharyngeal walls, and partly to the tonsils (Fig. 6.26). The Carenfelt and Haraldsson working group uses suture techniques for the adaptation of the posterior tonsillar pillar to the tonsillar pillar in order to prevent uncontrolled scarring.

Most authors apply the LAUP technique introduced by Kamami [243]. The uvula is partly or totally removed. Then, two paramedian full-thickness, through-and-through trenches are made over the soft palate, on either side of the uvula, to a height of 1–2 cm. With few exceptions, the LAUP is performed under local anesthesia in an outpatient setting. There are two procedures: the gentler one, which is performed in several (up to five) sessions (Fig. 6.27) and the radical "one-stage" technique (Fig. 6.28).

The most recent modification is described in detail by two working groups [343, 480]. This technique differentiates itself from oth-

Fig. 6.27. Scheme of LAUP in multiple stages modified after Kamami [244]

ers by removing only the mucosa but not the muscles in the area of the anterior palatine arch (M. palatoglossus). The uvula and the posterior palatine arch are treated as in the case of LAUP and LUPP (Fig. 6.29). Morar et al. [343] call this modification the "mucosal strip technique" (MST). Other authors do not address the uvula and call their technique "palatal stiffening" [554].

A combination of both the LAUP and the MST is recommended by Remacle et al. [411]. These authors perform three steps. First they vaporize the palatal mucosa (Fig. 6.30 a) similar to the MST technique. Secondly the palatal arches are trimmed very cautiously, completely protecting the anterior pillar (Fig. 6.30 b). Finally the uvula is either cut or vaporized (Fig. 6.30 c). We do not have our own experience with this technique, but it seems reasonable because it is a very careful technique, not disturbing the palatine arches, and it combines two established techniques.

In most cases the CO_2 laser is used, sometimes the Nd:YAG [554] or the KTP laser [242]. No comparative information pointing to differences between various laser types has been found in the literature. However, Ducic et al. [115] were able to show in an animal test performed in six dogs that the CO_2 laser caused deeper thermal tissue damage and more intensive scarring than the conventional UPPP technique using bipolar coagulation.

According to our experience we see the most advantages in a cautiously performed modified Kamami technique [537]. We strongly advise against radical incisions into

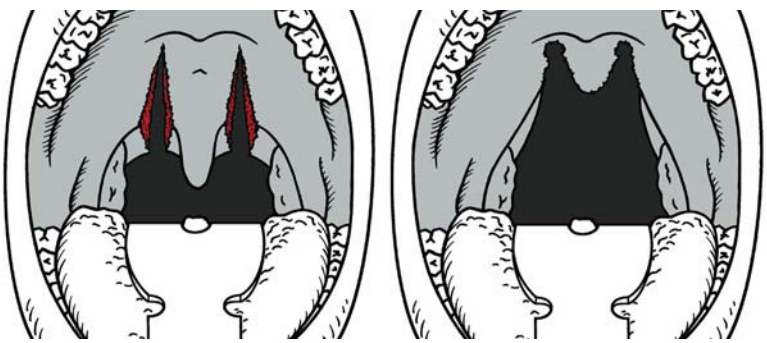


Fig. 6.28. Scheme of "one-stage" LAUP modified after Kamami [244]

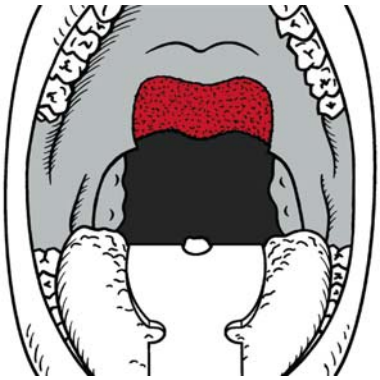


Fig. 6.29. Scheme of MST. Coagulation of the palatine mucosa here combined with a shortening of the uvula according to Skatvedt [480]

the palatopharyngeal and the palatoglossal muscles. As we know from our extensive experience with UPPP surgery, there is no rationale for an aggressive surgical technique. The surgical outcome will not improve after a more radical procedure, but the incidence of severe complications will increase. We do not believe that there are no or only few complications after procedures like the one-stage LAUP (Fig. 6.27), as reported by Kamami [244].

Based on our experiences we developed a modification of the multiple-stage Kamami technique. We operate on the sitting awake patient. In general, there is no need for sedation. We perform a local anesthesia using 5–6 ml prilocaine (2%) with adrenaline (0.01%). Topical anesthesia is not advantageous because it often causes hypersalivation, forcing the patient to swallow frequently. When we started to do LAUP surgery we used the CO_2 laser (8 Watts, continuous wave, superpulse mode) in the majority of cases. It is important to use a backstop protecting the posterior pharyngeal wall from the laser beam. The KTP laser is comfortable to use in contact mode. Today, we predominately use mono- or bipolar high frequency cutting instruments mostly in argon atmosphere, the latter to reduce thermal penetration into the tissue. There is little smoke formation. The staff do not need to use glasses to protect

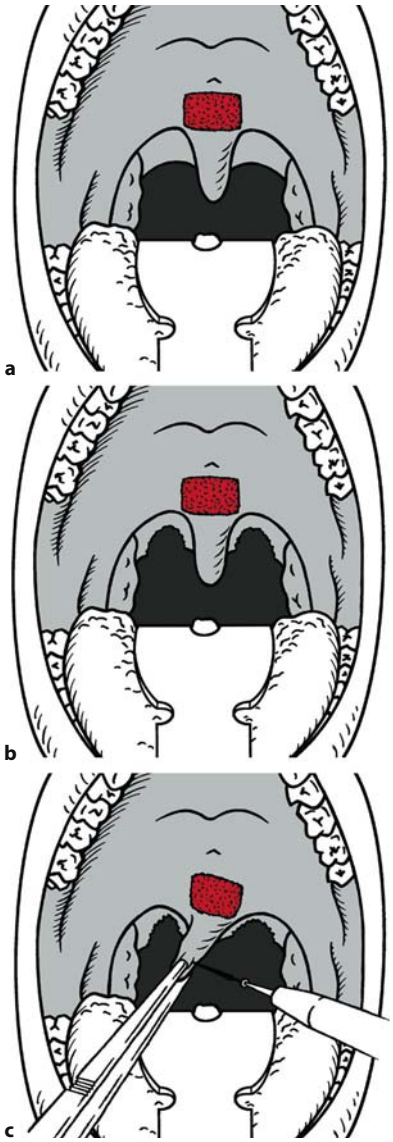


Fig. 6.30 a–c. Scheme of combined LAUP with MST according to Remacle et al. [411]. **a** Coagulation of the palatal mucosa. **b** Resection of posterior pillars. **c** Shortening of the uvula

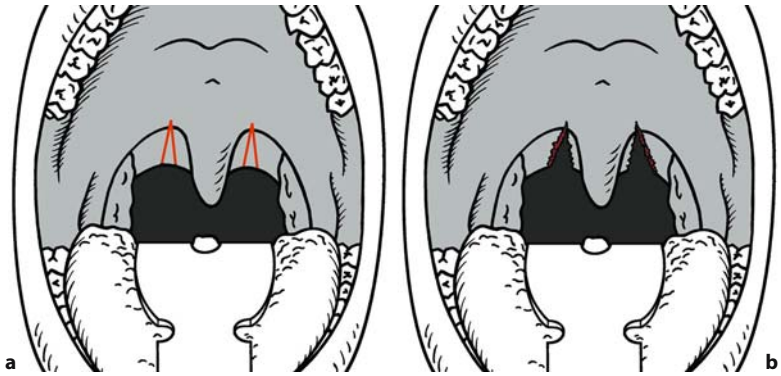


Fig. 6.31. **a** Palatal incision lines. **b** Incisions done

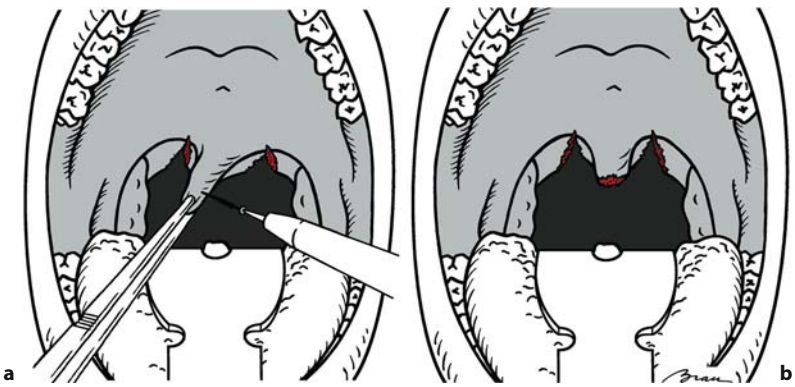


Fig. 6.32. **a** Uvula pulled downwards with forceps. **b** Uvula shortened

their eyes from the laser beam. To sum up, we do not see any need for lasers for this kind of surgery. In our experience, the choice of the surgical tool is much less important than the choice of the appropriate surgical technique.

While the tongue is held down with a blade, an inverse V-shaped incision is made bilaterally to the uvula only cutting about 5 mm into the anterior pillar of the soft palate (Fig. 6.31).

If bleeding occurs it has to be coagulated carefully. To complete the procedure the tip of the uvula is pulled downwards with a forceps. Thereby the uvula muscle becomes apparent. The redundant mucosa is taken away, preserving muscular tissue (Fig. 6.32).

Figure 6.33 shows peri- and postoperative photographs of our technique taken under general anesthesia during one of our surgical courses.

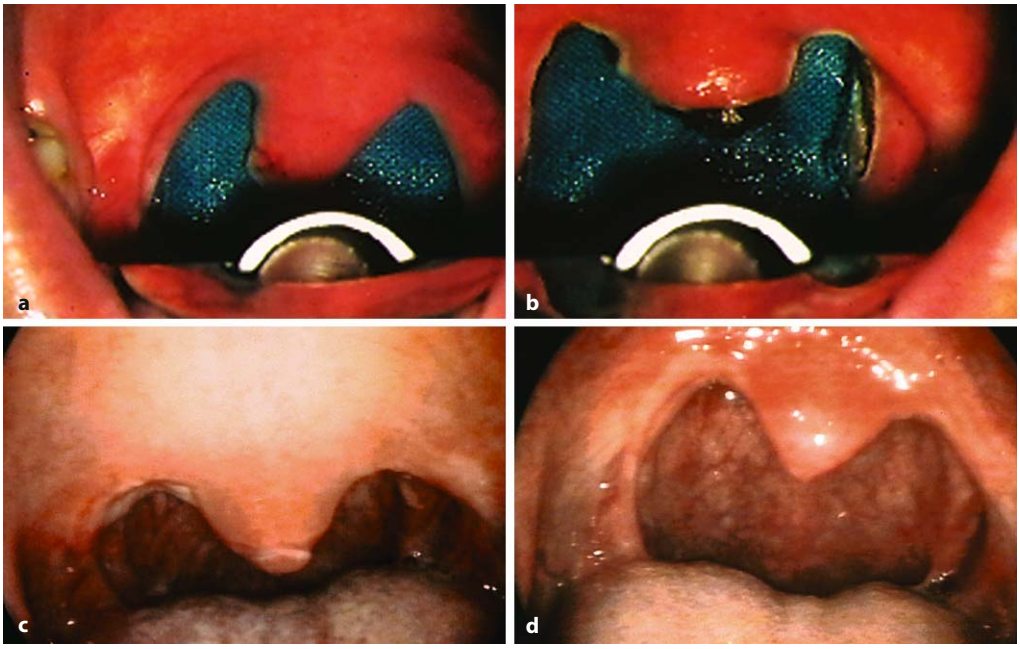


Fig. 6.33. a–d Mannheim/Ulm technique of LAUP. **a** preoperatively, **b** immediately postoperatively, **c** 6 days postoperatively, **d** 3 months postoperatively

6.4.2 Effectiveness for Simple Snoring

There are no generally accepted techniques to quantify snoring. In the literature either visual analog scales (VAS), usually filled out by the patients' bed partner, or so-called snoring indices (SI) based on different algorithms analyzing the recorded snoring sounds during sleep studies are used to describe the effectiveness of LAUP for simple snoring. Others use simple questionnaires with items like "Do you still snore?" to verify treatment success.

Relevant data from prospective studies using VAS to evaluate the subjective improvement of LAUP for simple snoring are given in Table 6.7. Extremely varying definitions of success complicate the interpretation of the results.

Table 6.7. Effectiveness of LAUP for simple snoring

Author	*N*	Follow-up (months)	VAS	Success rate (%)	Def. of success	Laser	EBM grade
LUPP							
Carenfelt 1991 [67]	60 (36)	3–4	1–4	85 (89)	Red >1	CO_2	II-1
Wennmo et al. 1992 [559]	10	2–36	1–3	80	VAS 1	CO_2	II-3
Albu et al. 1998 [5]	90	No data	0–10	80	VAS <4	Nd:YAG	II-3
All LUPP	**160**	**2–36**		**83.4**			**III**
MST							
Ellis 1994 [122]	14	3 (15 –18)	1–10	87.5 (66)	VAS <4	Nd:YAG	II-3
Morar et al. 1995 [343]	25	6	1–100	24 (68)	Red >90% (Red 25%)	CO_2	II-3
Shehab and Robin 1997 [462]	24 (27)	3–52	1–10	79.2 (81.5)	Red >2	CO_2	II-1
All MST	**85**	**3–18**		**76.8 (60.4)**			**III**
LAUP							
Walker et al. 1995 [548]	105	1.5	0–100	60	Red >70%	CO_2	II-3
Hanada et al. 1996 [188]	35	1	1–10	51.4	Red >50%	Nd:YAG	II-3
Vukovic and Hutchings 1996 [544]	25	6	0–12	84	VAS 6	CO_2	II-3
Astor et al. 1998 [19]	38	No data	0–7	76.3	VAS <4 and Red >2	CO_2	II-3
Schlieper et al. 2002 [451]	152	12	1–6	88	VAS 3	CO_2	II-3
All LAUP	**355**	**1–12**		**74.6**			**IV**

VAS visual analog scale, *Red* reduction, *LUPP* laser uvulopalatoplasty, *MST* mucosal strip technique, *LAUP* laser-assisted uvulopalatoplasty.

6.4.2.1 Laser Uvulopalatoplasty

Laser uvulopalatoplasty seems to have a positive short-term impact if used in simple snorers. Long-term results are reported by Lysdahl and Haraldson [304]. The authors prospectively performed LUPP in 60 patients. A control group of 61 snorers received a conventionally performed UPPP. Both techniques showed significant improvement of subjective parameters such as snoring, awakenings, apneas, daytime sleepiness, and sleep spells driving at short-term follow-up (3 months). UPPP was superior to LUPP in all mentioned effect parameters. Five to eight years after surgery all subjective parameters except sleep spells driving had worsened over time, with UPPP again showing better long-term results.

6.4.2.2 Mucosal Strip Technique

The MST also shows satisfying short-term results. Again, patients' satisfaction decreases over time [122]. The only controlled trial showed comparable effectiveness of MST and conventional UPPP [462]. One fact in this trial is remarkable: there was no positive impact of an additionally performed tonsillectomy on the snoring outcome. Uppal et al. [524] compared MST and a punctate diathermy

both combined with uvulectomy in a single-blinded randomized controlled trial (n=62). Results in regard to the subjective reduction of snoring were comparable, with significantly more postoperative pain in the MST group.

6.4.2.3 Laser-Assisted Uvulopalatoplasty

Although every working group uses its own criteria of success, there is evidence that LAUP is effective in the treatment of simple snoring. Looking through the literature there are much more studies on the effectiveness of LAUP on simple snoring using other measurement tools than VAS. We recently summarized this information [537]. LAUP results in an at least short-term reduction of socially disturbing snoring. Some long-term subjective recurrence of snoring does occur [356, 461].

Similar to the findings in patients suffering from OSA, Berger et al. [32] describe a decrease of subjective snoring improvement after LAUP for simple snoring over time in a group of 14 patients. Subjective improvement was stated in 79% 1 month after surgery and decreased to 57% after 10.1 months. Increase of subjective snoring occurred in one patient after 1 month but in three patients after 10 months. Three of those patients (21%), who initially were all simple snorers, developed mild OSA as a result of laser treatment. Similar findings of a decrease of success rates over time are reported by Kyrmizakis et al. [272].

On the other hand, Osman et al. performed objective analysis of snoring sounds using their Gal Clxyd snore box [371]. Twenty-two patients underwent a single-stage LAUP with the KTP laser; another 16 patients received UPPP. At short-term follow-up (2–11 months), subjective snoring improvement was reported in 83% of LAUP patients and in 89% of the UPPP group. The objectively measured SI decreased statistically significant in both groups [370]. Twenty-four patients (12 LAUP and 12 UPPP) out of the same pool of patients were re-evaluated 29–56 months after surgery. The SI was still statistically significant lower than before treatment. There was no statistical difference between short- and long-term follow-up in the SI [369]. There was still no difference between the UPPP and the LAUP patients.

Walker et al. [547] performed objective measurements of snoring sounds using the SNAP system in a series of 27 patients undergoing LAUP. The SI decreased with every new treatment session. The mean frequency of the snoring sounds increased, while the loudness of the low-frequent part of the sound spectrum, which is thought to have its origin in the soft palate level, decreased. A decrease of the relative loudness of snoring sounds below 180 Hz correlates well with the patients' subjective satisfaction.

6.4.3 Effectiveness for OSA

In 2000 we conducted a meta-analysis on the efficacy of laser surgery to the soft palate for OSA [538]. At the time, we did not find any long-term results. Short-term results were given in only eight publications with a total of 232 patients providing pre- and postoperative polysomnographic information. The AHI decreased, but not statistically significant, from 29.1 to 23.4 after LAUP. The authors used diverse criteria of success, a fact that complicates sufficient comparison of the results. Mickelson and Ahuja [333], for example, show a variation in the surgery success rate between 33% and 67% in the same patients merely by applying different criteria. This fact has already been criticized by the American Sleep Disorders Association [12] and by Hoffstein [208].

Today more substantial information exists. Therefore, we always use the criteria recommended by Sher et al. [465] (AHI reduction of at least 50% and AHI reduction to values below 20) to compare the literature results. Table 6.8 summarizes those studies presenting success rates according to Sher.

In earlier publications, Mickelson and the working group of Walker et al. reported their results with LAUP in patients with OSA [336, 548, 550]. Since the investigation periods are identical, only the more recent publications

Table 6.8. Effectiveness of LAUP for treatment of OSA

Author	*N*	Follow-up (months)	AHI pre	AHI post	AI pre	AI post	Success rate (%)	Sessions	EBM grade
Utley et al. 1997 [527]	12	4	8.9	10.3	2	2.3	33	2.4 (+ TE)	Retro
Mickelson and Ahuja 1999 [333]	36	4	28.1	17.9	14.4	5.8	33.3	2.7	II-3
Walker et al. 1999 [549]	38	3	30.3	22.2	20.1	14.6	44.8	4	Retro
Ryan and Love 2000 [437]	44	>3	29	19	9	5	34.1	One stage	II-3
Seemann et al. 2001 [455]	43	2	No data	−7.4	No data	−4.0	32.2	One stage	II-3
Finkelstein et al. 2002 [141]	26	12.3	29.6	25.0	No data	No data	19.2	1.5	II-3
Ferguson et al. 2003 [135]	21 (24)	8.2	18.6 (16.1)	14.7 (22.7)	No data	No data	19.1 (0.0)	2.4 (awaited)	II-1
Berger et al. 2003 [33]	25 (24)	12.2	25.3 (26.0)	33.1 (18.7)	No data	No data	16.0 (45.8)	One stage (UPPP)	II-1
Kern et al. 2003 [253]	33 (31)	>3	35.6 (52.6)	24.1 (28.5)	No data	No data	42.4 (35.5)	3.2 (+ TE)	Retro
Mean	**321**	**>4.4**	**23.4**	**18.1**	**13.1**	**7.7**	**27.7**		**III**

AHI apnea hypopnea index, *AI* apnea index.

were considered in order to prevent patients being included twice in the evaluation.

Looking at the data of the nine studies listed in Table 6.8, one finds polysomnographic data about 321 patients. The overall success rate is 27.7% using Sher's criteria. Medium-term results (>8 months of follow-up) are substantially worse than short-term results. Table 6.8 strongly corroborates the findings of the working group of Finkelstein et al. [33, 141] that promising short-term results after LAUP deteriorate over time.

The controlled studies [33, 135] imply that LAUP is more effective than doing nothing but much less effective than conventional UPPP for OSA. The study of Kern [253] does not really add much new information, as there is a substantial bias in this trial. Patients undergoing UPPP were more severely affected than those selected for LAUP. Therefore, we cannot agree with the authors' conclusion that LAUP and UPPP show comparable efficiency in the treatment of OSA.

Apart from their objective results stated in Table 6.8, Ryan and Love [437] were able to show that the quality of life significantly improved in all domains and daytime sleepiness decreased after LAUP.

The working group of Finkelstein et al. [33, 141] found out twice that their favorable subjective short-term results of LAUP for OSA deteriorated over time (mean follow-up 12.3 months). Postoperative polysomnography revealed that LAUP might lead to deterioration of existing apneas. The authors conclude that these findings are probably related to velopharyngeal narrowing and progressive fibrosis inflicted by the laser beam as found in human specimens after LAUP [31].

Fifteen working groups have searched for criteria to predict the operation success. The following criteria are stated: lower BMI, lower severity of OSA, site of obstruction in the velopharynx, female gender, velopharyngeal obstruction pattern, lack of loud snoring and apneas, exclusion of cranio-facial malformations, and lower age [537]. A clear trend cannot be recognized, which is mainly explained by the fact that the definitions for success are too divergent.

There is a single study providing polysomnographic data on the efficiency of LUPP [385]. In this study the apnea index of 30 patients decreased from 26 before LUPP to 7 at the 5 months follow up after the operation. The success rate according to Sher's criteria was calculated as 63.3%. It is important to keep in mind that this technique includes the removal of the tonsils. This fact makes the higher success rate understandable. In any case, this technique is very similar to the conventional UPPP technique and should be interpreted in this context.

6.4.4 Postoperative Care and Complications

In a survey about complications that occurred in Sweden with soft palate surgery for SDB [66], three deaths were reported with 9,000 UPPPs and one death with 2,900 LAUPs. The latter patient died from a sepsis on the fourth postoperative day, as perioperative prophylaxis with antibiotics had not been carried out.

Generally any kind of soft palate surgery, in particular radical procedures, bears the danger of a limited acceptance of a later nasal CPAP therapy as a result of oro-nasal airflow leakage [546]. Moreover, in 25 publications further complications with LAUP are mentioned, which are summarized in Table 6.9 together with the frequency, in cases where it was stated. The post-surgical observation period ranged from 48 h [510] to 8 years [187].

Long-term complications are particularly strenuous for the patients. Hardly any data can be found regarding this problem. Petri et al. [385] describe a permanent reflux in the nasopharynx (Fig. 6.34) for three of 30 patients. Grontved et al. [171] report a permanent reflux in the nasopharynx for one of 21 patients. In two of 60 patients, Pinczower et al. [388] described a foreign body sensation (Fig. 6.35) 6 months after surgery. The authors deal with this problem in more detail in their publication. They were able to prove that the para-uvular incisions caused damage to the sensitive supply of the neo-uvula area,

Table 6.9. Complications of laser-assisted surgery on the soft palate according to their frequency

Complication	Incidence (%)
Nasal regurgitation (short-term)	80
Sore throat	46
Scar fibrosis	27
Velopharyngeal incompetence	1.5–26.7
Dysphagia	6–26.6
Foreign body sensation	9–25
Paresthesia	22
Aspiration	21.5
Occurrence of other disturbing breathing sounds	20.5
Voice problems	1.3–20
Irritation of taste	0.7–18
Xerostomia	16
Wound infection	1.5–14
Odynophagia	1.4–12
Vomiting	10
Nasal regurgitation (long-term)	4.8–10
Postoperative bleeding	0.7–10
Hypersalivation	5
Nasopharyngeal stenosis	0.1–3.3

which is medial of the incisions. This in turn causes the sensation of a foreign body, which may sometimes lead to vomiting [262], but which apparently recedes in most cases. Nasopharyngeal stenosis (Fig. 6.36) was reported in 0.1–3.3% of all cases and must be considered as a permanent complication. This complication is difficult to correct. Basic surgical principles are described in Sect. 6.2.

Particularly valuable for the assessment of complications occurring with the LAUP is the comparison with the UPPP when the same author uses both surgical techniques. Such a comparison can be found in five publications. Carenfelt [67] describes a significantly higher rate (p>0.05) of scarred nasopharyngeal stenosis after LUPP when compared with the status after UPPP. Chabolle [72] found fewer cases of velopharyngeal incompetence after

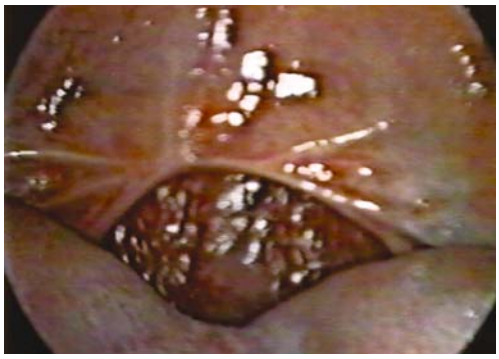


Fig. 6.34. Nasopharyngeal incompetence after LAUP

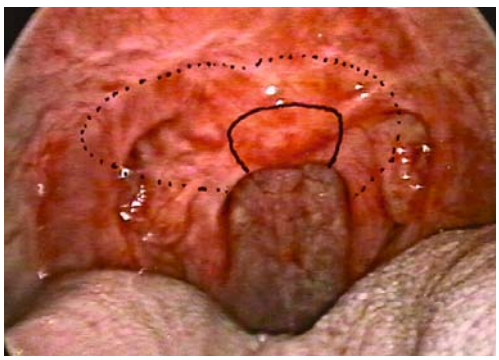


Fig. 6.35. Anesthesia of the soft palate no sensation with needle test) with foreign body sensation after LAUP. *Broken line* oral side. *Drawn line* nasal side

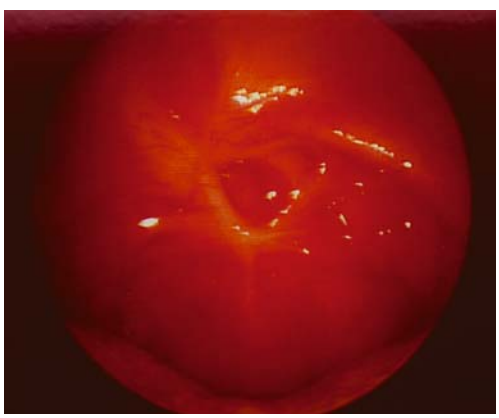


Fig. 6.36. Nasopharyngeal stenosis after LAUP

LAUP (5% vs. 10%) and fewer cases of dysphagia (15% vs. 23%), but more cases of pharyngeal dysphagia (22% vs. 18%), wound infections (10% vs. 5%) and general painfulness (44% vs. 41%).

On the other hand, in a radiocephalometric examination with contrast agent, Finkelstein et al. [140] proved an obstruction of the nasopharynx by LAUP and a dilation of the nasopharynx by UPPP. In an investigation carried out by Shehab et al. [462], the patients reported significantly more pain (p=0.0027) on the seventh day post surgery after LAUP than after UPPP. On the first postoperative day no significant difference was found. For a collective consisting of 110 patients with OSA and 254 simple snorers, Hagert et al. [187] reported postoperative occurrence of other disturbing noises during sleep. Those other noises (smacking, grunting, whistling) were observed in 20.5% after LUPP, but in only 15.1% after UPPP.

6.4.4.1 Pain

Laser surgery of the soft palate is a painful procedure with maximum pain during the third to fifth day after surgery. If done as a multiple-stage procedure, almost 20% of the patients were reported to be unwilling to undergo the next session because of pain [19]. Even 2 years after surgery, some patients stated that they would not undergo a LAUP again because of the painfulness of their procedures.

The mean duration of pain requiring pain killers is cited as being between 5.3 [84] and 15 days [272] after multiple-stage LAUP under local anesthesia. In individual cases pain killers were taken up to 3 weeks postoperatively. Soreness seems to decrease with the number of repeated sessions [19].

In comparison to conventional UPPP, the LAUP procedure turned out to be slightly more painful during the first days after surgery but required pain killers for a shorter period of time [72, 429, 462, 518, 559]. This is in accord with our own experience. In the area of the soft palate, laser surgery is significantly more painful than RFQ treatments [38, 429, 518, 525].

There is little information about specific postoperative pain management after LAUP. We treat our patients successfully with Cox-II antagonists and tramadol. Sometimes oral antibiotics are very helpful to control postoperative pain. Sucralfate was found to alleviate post-LAUP pain in a randomized clinical trial [273]. Sucralfate is known to adhere to proteins that promote healing by forming a protective coating against gastric acid, pepsin, and bile salts. Another future perspective may consist in the use of long-lasting local anesthetics.

6.4.5 Indications and Contraindications

In 2001, the Standards of Practice Committee of the American Academy of Sleep Medicine issued a declaration with six statements regarding laser-assisted surgery of the soft palate [297]:

1. LAUP is not recommended for the treatment of the sleep-related breathing disorders including obstructive sleep apnea (Guideline).
2. LAUP is not recommended as a substitute for UPPP in the treatment of sleep-related breathing disorders including OSA (Guideline).
3. LAUP appears comparable to UPPP in relieving subjective snoring (Guideline).
4. Surgical candidates for LAUP as a treatment for snoring should undergo a preoperative clinical evaluation and a polysomnographic or a cardiorespiratory study to determine if the candidate has a sleep-related breathing disorder including OSA (Standard).
   Since snoring is a primary diagnostic symptom, patients who undergo LAUP should be informed of the need for periodic evaluation for subsequent development of OSA even if the procedure reduces or eliminates snoring (Standard).
5. The need for medications that affect respiration during the perioperative period

should be assessed during the preoperative clinical evaluation (Standard).
6. Patients should be informed of the risks and complications of LAUP (Standard).

We fully agree with this statement and do not perform any laser-assisted surgery of the soft palate in patients with OSA. There are six publications dealing with the upper airway resistance syndrome (UARS). Five of these six groups of authors perform LAUP in patients with UARS. We do not, as it has been documented that LAUP may narrow the nasopharyngeal valve while UPPP has been proven to widen it [33, 140, 437]. For this reason we only perform UPPP or a modified uvula flap, always in combination with a tonsillectomy, if tonsils are still present, in our patients with confirmed UARS, if CPAP therapy is not accepted.

Nevertheless, LAUP seems to be an adequate treatment modality for simple snoring. For this indication LAUP competes with RFQ of the soft palate. While patients with long uvula and redundant mucosa at the posterior pillar (so-called webbing) are good candidates for laser-assisted procedures, RFQ treatment is reserved for candidates with no or minimal redundant mucosa because RFQ does not remove any excessive tissue but stiffens the soft palate by intramuscular scarification.

The following associated conditions are mentioned as contraindications for LAUP: overweight, arterial hypertension, and mental irregularities or lacking co-operation [537]. Being a professional speaker or singer was also seen as a relative contraindication.

The following illnesses are named as local factors: tonsillar hypertrophy, trismus, cranio-facial malformation and cleft palate, macroglossia, prominent plication of the rear oropharyngeal wall, heavy retching, previously existing velopharyngeal incompetence, floppy epiglottis, and neuromuscular diseases of the pharynx. A solely retrolingual site of formation of snoring sounds is naturally also seen as a contraindication.

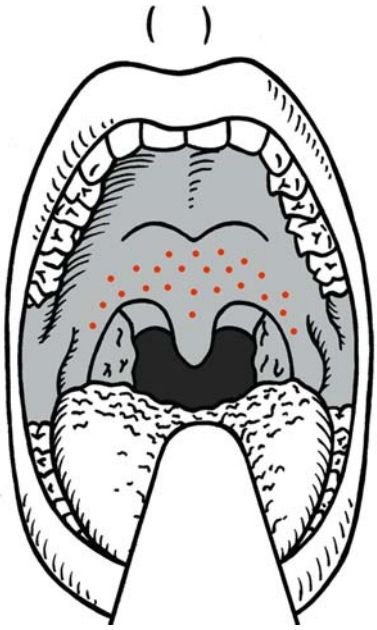


Fig. 6.37. Punctate diathermy of the soft palate according to Whinney et al. [562]

6.5 Radiofrequency Surgery of the Soft Palate

In 1995 Whinney and colleagues suggested a procedure that today can be considered as a precursor of RFQ surgery on the soft palate [562]. The authors performed 10 to 15 punctate penetrations of the mucosa and diathermized the palatal muscles on each puncture to achieve a stiffening of the soft palate, palpable to the surgeon (Fig. 6.37).

Today, RFQ systems have been established that need fewer thermic lesions to achieve a treatment effect. In terms of the soft palate, this interstitial RFQ surgery competes more with the LAUP than with the classical UPPP. The fundamental aspects of RFQ surgery have already been discussed in Sect. 6.1.2 in the context of tonsil treatment. In contrast to tonsillar surgery, however, a plethora of data from clinical studies is available for the soft palate.

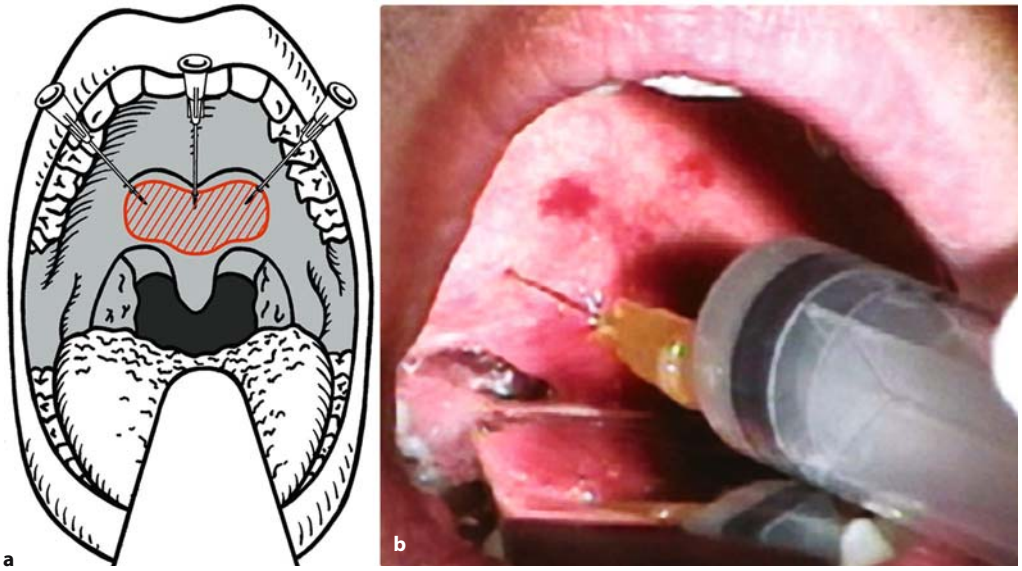


Fig. 6.38 a,b. Local anesthesia. **a** Area of infiltration. **b** Application of local anesthesia

6.5.1 Surgical Technique

Surgery is usually performed under local anesthesia as an outpatient procedure on the sitting patient. In the case of an isolated soft palate treatment, sedation is usually unnecessary. Monitoring by pulse oximetry and an ECG is recommended, but not mandatory.

We perform surgery in the area of the soft palate without mucosal disinfection, using prilocaine 2% with epinephrine (1:200,000) for local anesthesia. Surface anesthetics cause a bothersome hypersalivation; therefore, we never take recourse to this option. In order to achieve an adequate analgesia, the pathway of the sensory innervation needs to be taken into account. The nerve fibers run from lateral towards the uvula. It is important to begin the local anesthesia sufficiently close to the hard palate, because the RFQ applicators need to be inserted approximately 2 cm superior to the expected lesion. As a rule, 5–8 ml local anesthetic are sufficient for the local anesthesia (Fig. 6.38).

It has been proven to be beneficial to lay the needle on the soft palate in order to determine the correct position for the lesion and puncture before penetrating the mucosa with the RFQ applicator. It is crucial to check the position of the active probe in the tissue before applying energy. This can be done either by palpation or by moving the probe back and forth. If the active electrode is situated too superficially, an ulcer develops as a result of the thermic damage, which heals with delay.

Currently, using the Somnus system (Gyrus ENT, Bartlett, USA), we prefer to apply four to six lesions at 85° Celsius target temperature and 400–500 J for the initial treatment. In this respect our concept differs from other concepts, which either favor a single lesion [137, 464] or several lesions with total energy amounts between 1,099 [509] and 2,100 J [519]. As target temperature, either 80 °C or 85 °C are used.

In the case of the Celon system (Celon AG Medical Instruments, Teltow, Germany) we use 10–12 Watts, depending on the thickness of the soft palate, and also apply six lesions (Fig. 6.39). It is efficient to limit the number of punctures of the mucosa by not pulling the needle completely out of the soft palate after the first lesion, but pushing forward again

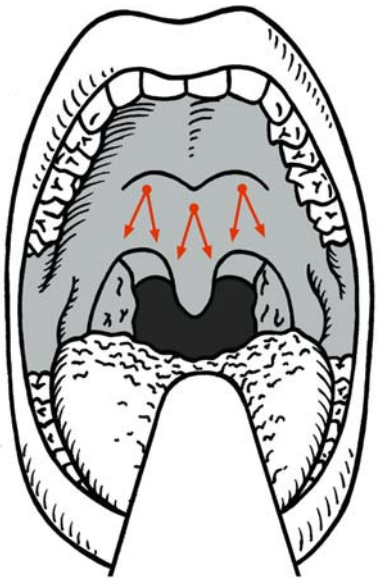


Fig. 6.39. Soft palate procedure: six lesions

with a slightly changed target direction. In this way the bleeding, which is minor anyway, can be minimized even further.

In the case of soft palate therapy, usually two or sometimes three sessions are necessary until a satisfactory reduction of the snoring sound is achieved to a socially acceptable level. The follow-up sessions are basically performed in the same way as the first; but in the case of smaller soft palates we reduce the number of lesions to four.

Other authors proceed more aggressively, and apply up to nine lesions to the soft palate; we have not found an increase in efficacy by applying larger or more frequent lesions. However, developments in this field are awaited.

6.5.2 Effectiveness for Simple Snoring

In 1998, Powell et al. [400] first reported the use of interstitial RFQ surgery for the human soft palate in the treatment of simple snoring. In the following 5 years, various study groups attempted to repeat or modify this study in order to assess the value of the new procedure.

Stuck and colleagues recently summarized the results in a meta-analysis [493]. The survey of the literature generated 22 original articles dealing with interstitial RFQ surgery of the soft palate in the treatment of snoring. Eighteen studies were prospective clinical trials; 15 of these focused on treatment efficacy, three of which included a comparison with other treatment modalities such as intraoral devices, LAUP or UPPP. One study was a medium-term follow up of previously published material.

Nineteen of the 22 studies used temperature-controlled RFQ tissue ablation (somnoplasty). The remaining three studies used the Ellman (monopolar), VidaMed or Coblation (bipolar) system. Between one and four application sites per treatment session were selected.

Obstructive sleep apnea was ruled out with polysomnography in 19 of these studies, with a maximum RDI of 10 or 15 respectively. Furthermore, obese patients were excluded in most of the trials (16 out of 22), although the maximum BMI varied between studies (between 27 and 40 kg/m^2). Follow-up periods were usually 6–8 weeks, but especially retrospective trials had a significantly longer follow up (2–18 months). Treatment efficacy was assessed with the help of VAS or snoring scores filled out by the bed partner in 16 of the 18 studies addressing treatment efficacy. Detailed information is given in Table 6.10.

The studies providing results of subjective snoring (VAS or SI) were summarized in terms of two meta-analyses. In those studies using the VAS, a total of 505 patients were treated. The weighted mean score of these studies was reduced from 8.2 to 3.7. The mean weighted treatment effect was 4.5.

In those studies using the SI, a total of 167 patients were treated. The weighted mean±SD was reduced from 8.1 to 3.3 and the weighted mean treatment effect was 4.8. The changes in mean snoring scores of the studies involved were significant at a level of $p<0.01$.

In three trials, different treatment protocols concerning the number of application sites per treatment session were compared (i.e., three to four versus one) [125, 137, 464].

Table 6.10. Effectiveness of RFQ of the soft palate for simple snoring

Author	*n*	Device	Lesions/ treatment	Method	Follow-up (weeks)	Results snoring pre – post	EBM grade
Powell et al. [400] 1998	22	Somnus		VAS	8–12	8.3–1.9	II-3
Boudewyns and van de Heyning 2000 [45]	45	Somnus		SI	8	7.6–3.6	II-3
Cartwright et al. 2000 [68]	10	Somnus		SI	8	7.5–2.8	II-1
Coleman and Smith 2000 [85]	12	Somnus		VAS	8	8.3–2.1	II-3
Emery and Flexon 2000 [125]	19 24	Somnus	1 3	SI	7	7.8–2.3 8.9–2.5	II-3
Fischer et al. 2000 [144]	4	Somnus		Satisfaction	8	75% satisfaction	II-3
Hukins et al. 2000 [223]	20	Somnus		VAS	8	7.5–4.6	II-3
Li et al. 2000 [289]	22	Somnus		VAS (relapse)	14 months	8.3–1.9	II-3
Taliaferro 2000 [504]	19	Ellman		Satisfaction	3–5	84% satisfaction	II-3
Back et al. 2001 [21]	21	VidaMed		SI	3 (12) months	9–4 (5)	II-3
Ferguson et al. 2001 [137]	16 31	Somnus	1 3–4	VAS	6	8.9–5.5 9.1–5.5	II-3
Sher et al. 2001 [464]	105 57 32	Somnus	1–3 1 3	VAS	8	7.8–3.2 7.5–3.2 7.6–2.7	II-3
Back et al. 2002 [22]	18	Coblation		VAS	3 (9.5) months	6.5–5.0	II-3
Blumen et al. 2002 [38]	15	Somnus		VAS	6–8	8.3–1.7	II-1
Haraldsson et al. 2002 [192]	16	Somnus		SI	No data	8.2–4.1	II-3
Johnson et al. 2002 [239]	60	Somnus		VAS	2–18 months	9.0–3.5	Retro
Terris et al. 2002 [511]	10	Somnus		VAS	16	7.5–3.1	II-1
Trotter et al. 2002 [519]	36	Somnus		VAS	17.5 months	9–7	Retro
Tatla et al. 2003 [507]	10	Celon	6	VAS	16	7.7–4.6	II-3
Said and Strome 2003 [439]	39	Somnus		VAS	14 months	8.8–4.2	Retro
Fang et al. 2003 [132]	32	Somnus	1	SI	4.5 months	7.9–3.6	II-3
All (VAS)	**505**		**1–6**	**VAS**		**8.2–3.7**	**II**
All (SI)	**167**		**1–3**	**SI**		**8.1–3.3**	**II**
All (satisfaction)	**23**			**Satisfaction**		**82.4%**	**II**

VAS visual analog scale, *SI* snoring index.

One study was based on snoring scores [125] and compared a group of 19 patients receiving 698 J (mean value) at the midline as a single treatment with a group of 24 patients receiving three lesions with a mean total of 1,254 J per treatment session. The group receiving multiple lesions (total amount of energy per patient: 2,165 J) showed a slightly more pronounced reduction of mean snoring scores (7.8 to 2.3) compared with the group receiving single lesions (total amount of energy per patient: 2,196 J; 8.9 to 2.5).

The two studies comparing the effects of single versus multiple lesion treatments based on VAS showed comparable effects for these two treatment protocols [137, 464], with a higher total amount of energy delivered per patient for the multiple lesion group (1,676 versus 3,418 J, and 1,898 versus 2,001 J). The main advantage of multiple lesion treatments seems to be the reduced number of treatment sessions necessary (3.3 versus 1.75 [125], 2.38 versus 1.94 [137] and 2.9 versus 1.6 [464] rather than a higher efficacy in respect to the final outcome.

Kania et al. [245] analyzed the influence of energy delivered on snoring outcome in 43 patients. One group received 1,250 J and the other group 1,500 J per treatment at three sites. The 1,500-J delivery led to a better snoring reduction with a significant difference after two treatment sessions.

In two studies with a longer follow up, a relapse over time was seen in 11–41% of the patients [289, 439]. The results for the VAS in this study increased from 2.1 to 5.7 after 14 months. Eight of the nine patients showing a significant relapse were again treated with RFQ surgery. Their mean snoring score could again be reduced from 5.8 to 3.3. Two studies re-evaluated initial success rates (3 months) after 12 and 9.5 months respectively. Mean postoperative SI increased from 4 to 5 in the first study (12 months) [21] and the success rate decreased from 33 to 28% in the second (9.5 months) [22].

Terris et al. [511] compared interstitial RFQ surgery of the soft palate with LAUP in a prospective, randomized manner. LAUP revealed a slight advantage over RFQ but resulted in a greater degree of postoperative discomfort.

Recently we finished a placebo-controlled, prospective trial. Each of 15 primary palatal snorers received either an isolated RFQ surgery of the soft palate or a sham operation. In the latter the applicators were inserted into the soft palate but no energy was delivered. For the whole group of individuals we obtained comparable results to the meta-analysis stated above with a significant reduction in snoring severity (VAS). However, there was no superiority of RFQ surgery compared to the control group. These newest results question the often reproduced significant effect of RFQ of the soft palate on simple palatal snoring. However, these results need to be confirmed.

6.5.3 Effectiveness for OSA

There are only two studies dealing with isolated interstitial RFQ at the soft palate for OSA. Blumen et al. [37] treated 29 patients with an AHI of 10–30 and a BMI of less than 30 kg/m² using the Somnus unit. Three protocols with different total energies per session (1,300 J, 2800 J, and 2100 J) and a maximum target temperature of 85 °C were investigated. The mean number of sessions was between 2 and 2.5 depending on the amount of energy delivered per treatment session, but no more than three. For the entire group the AHI significantly decreased 8.5 months after surgery. The cure rate (defined as an AHI below 10 after surgery) was estimated as 65.5%. Daytime sleepiness as measured with the Epworth Sleepiness Scale improved in 62.1% of the patients.

Brown et al. [57] performed interstitial RFQ at the soft palate in more severely affected patients with an AHI up to 78. Although the reduction in mean AHI was statistically significant in this sample too, no clinically significant differences were found between pre- and post-treatment groups with respect to any other sleep parameters.

Detailed information using Sher's criteria of success is given in Table 6.11.

Table 6.11. Effectiveness of RFQ of the soft palate for treatment of OSA

Author	*N*	Device	Follow-up (months)	AHI pre	AHI post	Success rate (%)	Sessions	EBM grade
Brown et al. 2001 [57]	12	Somnus	1.5	31.2	25.3	16.7	3	II-3
Blumen et al. 2002 [37]	29	Somnus	8.5	19.0	9.8	65.5	2.1	II-3
Mean	**41**	**Somnus**	**6.5**	**22.6**	**14.3**	**51.2**	**2.4**	**IV**

To summarize, there is very little evidence that interstitial RFQ treatment of the soft palate might be effective for mild OSA.

6.5.4 Postoperative Care and Complications

Concerning postoperative complications no serious adverse events were reported, though it should be mentioned that there was a significant variation in the overall complication rates provided, which ranged from 0 % to 50 % [493]. The most frequently reported complication was a mucosal erosion/ulceration. Mucosal blanching was also reported as accompanying the treatment and to be related to the intensity of postoperative pain [21], but was not assessed by us as a complication. In general, the comparison between different studies concerning postoperative complications poses difficulties. To a certain extent, "mucosal erosion" in particular seems to be inevitable at the site of the intrusion of the needle (and is not regarded as a complication). It has to be distinguished from secondary erosions or ulcerations because of the energy delivered. Nevertheless, "mucosal erosion" is often listed as a complication without further description.

Four studies reported moderate complications in terms of severe palatal damage (palatal fistula, uvula loss/sloughing) [45, 125, 137, 380]. One of these studies reported the highest rate of overall postoperative complications with 50 %, all being moderate complications such as major mucosal breakdown and uvula sloughing [380]. In this study, technical parameters and the intraoperative setting were comparable to the other studies using temperature-controlled RFQ surgery. One significant difference was the regular use of oral corticosteroids before and after treatment in every patient. This is the reason why we do not give any corticosteroids routinely. Series with a larger number of patients showed complication rates of about 1–5 % [45, 464, 497].

In those studies where postoperative morbidity was compared with other surgical approaches (UPPP or LAUP), interstitial RFQ surgery was associated with the least amount of postoperative pain [38, 68, 429, 518, 524]. In the study of Troell et al. [518], for example, mean postoperative pain duration was 2.6 days for RFQ surgery compared to 13.8 days for LAUP and 14.3 days for UPPP.

6.5.5 Indications and Contraindications

On the basis of the presented data, we currently see an indication for RFQ surgery of the soft palate only in the case of primary snoring. In the case of mild OSA or UARS, we perform a combined RFQ surgery of tongue base, tonsils and soft palate; if we assume that the obstruction is solely situated on the level of the soft palate, we perform a UPPP or uvula flap with tonsillectomy. In the case of moderate to severe OSA, RFQ therapy is usually not sufficient; we therefore pursue a multilevel surgical concept.

For primary snoring, RFQ surgery of the soft palate competes with LAUP. Nevertheless, we do not think that the two surgical procedures can be arbitrarily substituted for one another; rather, the specific method employed should be indicated depending on the clinical assessment of the soft palate. In the case of pronounced webbing and particularly exces-

sive mucous membrane at the soft palate, LAUP has in our opinion proven to be an adequate procedure. Here an ablative procedure is needed, which removes the redundant mucosa. We believe that the choice of technical device is of secondary importance. In contrast, RFQ surgery is not an ablative procedure. It is effective interstitially through a diminishing and stiffening of the soft palate. As a result of its impressive reduction of postoperative morbidity, RFQ surgery is always our therapy of choice in those cases without excessive mucous membrane. If excessive mucosa exists only at the uvula, we combine RFQ surgery of the soft palate with resection of the redundant mucosa, saving the uvular muscle. However, even careful shortening of the uvula is painful.

Soft palate implants (Sect. 6.6) compete directly with RFQ surgery of the soft palate as the indication and anatomical requirements are identical for both techniques. Soft palate implants also produce only a low postoperative morbidity. Currently there are no comparable data for this technique, however.

6.6 Palatal Implants

Uvulopalatopharyngoplasty and LAUP are standard procedures of simple snoring, uvulopalatopharyngoplasty a treatment for OSA or UARS at the palatal site of obstruction. However, these treatments are invasive, destructive, painful, and to a certain extent irreversible. Furthermore, UPPP requires general anesthesia. Therefore, a new minimally invasive procedure that places cylindrical implants within the soft palate has been introduced recently [318].

The anti-snoring implant consists of polyethylenterephthalat (PET). This material has been used as a vascular endoprosthesis (since 1960), as mesh in stomach surgery (since 1970), and in heart valves (since the end of the 1970s). Three rod-shaped implants are inserted in the soft palate. The implants themselves and the surrounding scarring induce a stiffening of the soft palate, which reduces or eliminates snoring.

6.6.1 Surgical Technique

As in the case of LAUP and interstitial RFQ surgery of the soft palate, this technique is performed on an outpatient basis in the sitting patient. After mucosal disinfection with hexetidine 0.1% and topical anesthesia with lidocaine spray, the palate is infiltrated with approximately 3 ml of prilocaine 2% with epinephrine 1:200,000. If required, sedation is induced (e.g., with midazolam ®, titrated according to effect); but in most cases this is not necessary.

The implants are delivered in a hollow needle (Fig. 6.40). The complete hand piece is a

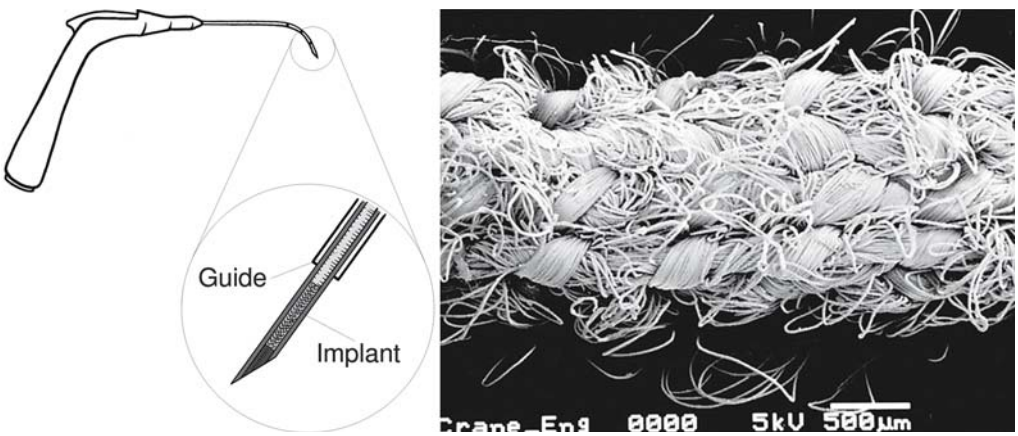
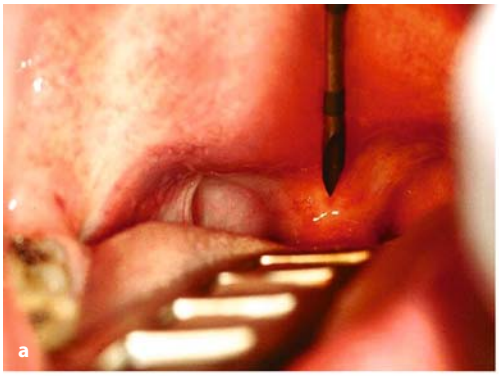


Fig. 6.40. Delivery tool



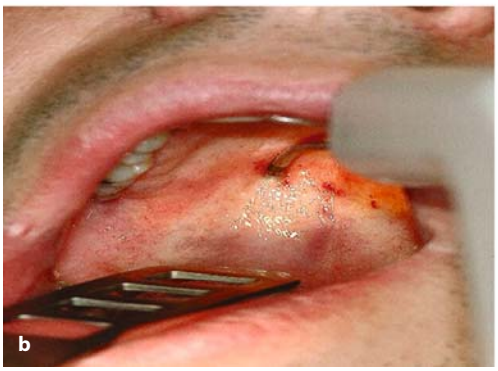
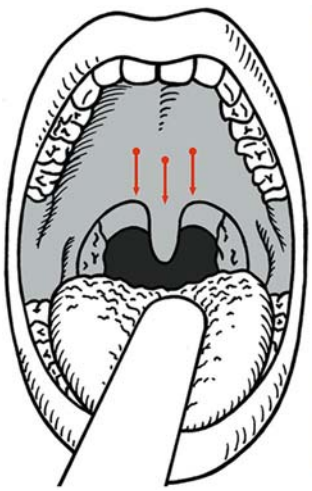


Fig. 6.41. **a** Finding the correct position of the implant by placing the delivery tool onto the soft palate. **b** Insertion of three implants. **c** Position of implants within the soft palate



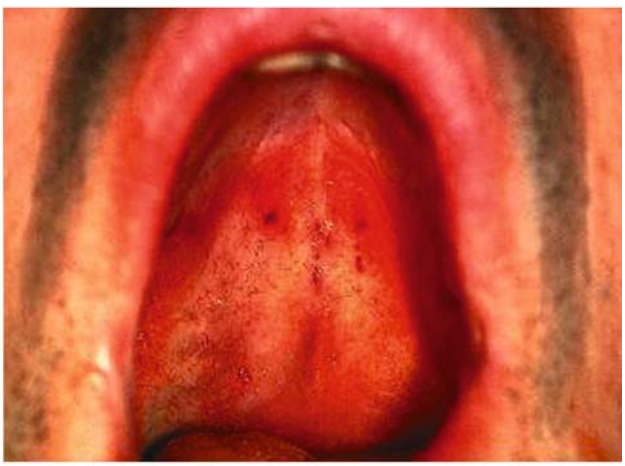


Fig. 6.42. Postoperative situation

disposable instrument. Until now, only one implant has been available per hand piece; therefore, three hand pieces have to be used for one surgery. In the future, the hand pieces will be loaded with three implants in order to reduce costs.

In order to locate the position for the implant, the hollow needle is initially placed on the surface of the soft palate, as in RFQ surgery. The position of the implant is marked on the needle. In this way, the correct position for the punctures is determined (Fig. 6.41). Now the needle is inserted into the soft palate, and the implant pushed forward with the help of a mandrin, pulling the needle back at the same time. The implant is supposed to settle intramuscularly. It is crucial that the implants do not bulge through the mucosa, neither anteriorly nor posteriorly. For each implant the needle is inserted into the soft palate near the junction of hard and soft palate. Once the needle is advanced deeply enough towards the free margin of the soft palate, the implant is deployed. The other two implants are placed parallel to the first one. The correct positioning is verified by palpation and transnasal pharyngoscopy after implantation (Fig. 6.41).

After the surgical procedure the implant can no longer be discerned. In Fig. 6.42 one can still distinguish the punctures, but not the implants themselves.

6.6.2 Effectiveness for Simple Snoring

So far, there has been only one conference paper on this topic [317]. Fifteen non-obese patients (age 41.2±8.6 years; BMI 26.2 ±2.5 kg/m²) with polysomnographically and endoscopically verified velar primary snoring were included in a prospective case study. Snoring was evaluated by the bed partner with a VAS, and was recorded with the SNAP system. Follow up was scheduled 90 days postoperatively. Snoring was reduced subjectively on the VAS from 7.3±1.6 to 2.5±2.1 ($p<0.01$) and objectively in the SNAP analysis from 347±239 to 264±168 snoring events per hour ($p>0.05$). In none of the patients a deterioration was found when the polysomnographic data were compared pre- and postoperatively.

6.6.3 Postoperative Care and Complications

The procedure is performed on an outpatient basis. We give a perioperative antibiotic prophylaxis with 2 g cefazoline intravenously, which we continue orally for 5 days with cefuroxime 2×500 mg per day. Up to now, all implants have been placed without complications.

Only minor discomfort (minor sore throat) was reported in four cases within the first 3 days post-procedure. Pain scores on the VAS were minimal (1.9 at day 2, 0.1 at day 90). Twelve patients were prescribed 500 mg of paracetamol for 1 day as advised by the surgeon. Three separate patients needed this medication for a total of 2, 3, or 4 days, respectively. No patients needed narcotic analgesics or NSAIDs.

No significant speech disturbance was found after the procedure. Two implants partially extruded after 30 days causing mild pain for the patient, but there was no need for analgesics. Additionally, one of the patients with a partial extrusion complained of a foreign body sensation. One implant was removed easily under local anesthesia while the other implant was removed without anesthesia. In both cases the lesions healed without any further clinical sequelae. Despite the partially extruded implants, the snoring of these patients decreased over time. No severe adverse events were observed for any of the 15 patients.

6.6.4 Indications and Contraindications

Up to now, the technique has only been used in simple snorers. Its short-term results are comparable with interstitial RFQ surgery of the soft palate. Soft palate implants directly

compete with this procedure. Longer follow-up intervals are required to show whether one of these two minimally invasive techniques will turn out to be preferable. First results from other research centers are to be expected shortly.

In comparison with the soft palate implants, interstitial RFQ surgery has the advantage that it can be additionally extended to the tongue base, the inferior turbinates, or the tonsils. This is of particular advantage in those cases where the surgeon is not certain whether he or she is dealing with an exclusive palatal snoring.

Currently, studies have been initiated to investigate the efficacy of soft palate implants for mild OSA. We have our doubts, given that no volume-expanding effects in the area of the nasopharyngeal valve are to be expected. But the results remain to be seen.

Candidates for palatal implants differ from those for LAUP. LAUP is an ablative procedure in which the posterior palatine arch and the uvula are shortened. This is not the case for soft palate implants. Therefore, primary snorers with pronounced webbing and a longer uvula should receive a LAUP; on the other hand, in cases where there is no excessive mucosa, soft palate implants or interstitial RFQ surgery are to be preferred because of the significantly lower postoperative morbidity.

6.7 Other Soft Palate Procedures

Apart from the procedures previously described, many surgical techniques for the soft palate have been suggested for the treatment of SDB. Most of these procedures have only been mentioned in a single publication, as for example soft palate surgery with a microdebrider (shaver) [505], and have since been all but forgotten. Illustrating all these techniques or modifications is beyond the scope of this book.

However, a few of these techniques have recently received more attention, or are so fundamentally different in their approach, that we consider it worthwhile to describe them briefly.

6.7.1 Uvulectomy

A search of the literature generated more than 60 hits for this topic. Most of the hits refer to ritual indications and not to SDB. Only one publication recommends uvulectomy as a simple and complication-free method for the treatment of primary snoring [18]. The success rate given is 61%; but it must be said that the majority of the responders requested further treatment for the reduction of their snoring. Uvulectomy is described as a very painful treatment, comparable to a complete UPPP.

Another publication recommends uvulectomy for the therapy of UARS [358], yet offers no success rates. In this context we once again wish to draw attention to the study by Mortimore et al. [346], which demonstrated that, after an isolated uvulectomy, oronasal air leaks occur in the case of CPAP therapy for low respiratory pressures; these can make an effective respiratory treatment impossible. In our opinion, uvulectomy is generally not recommended. It is crucial that the musculature of the soft palate is preserved during surgery. Solely excessive mucosal folds may be resected.

Today there are safer and more effective procedures for the treatment of both OSA and primary snoring.

6.7.2 Palatal Stiffening Operation

Ellis et al. [121] investigated the mechanics of snoring in the laboratory as an aid for devising a more effective operation. These studies have shown that there are several methods by which snoring can be generated, but that palatal flutter is probably the most important factor. The dominant parameters in the generation of flutter of the palate are its length and stiffness. Any removal of tissue to shorten the palate, as in UPPP, inevitably risks impairing its function. Therefore, the authors were the first to choose the stiffening alternative. Using a laser, a central longitudinal strip of mucosa was removed from the surface of the soft palate, which healed by fibrosis, pro-

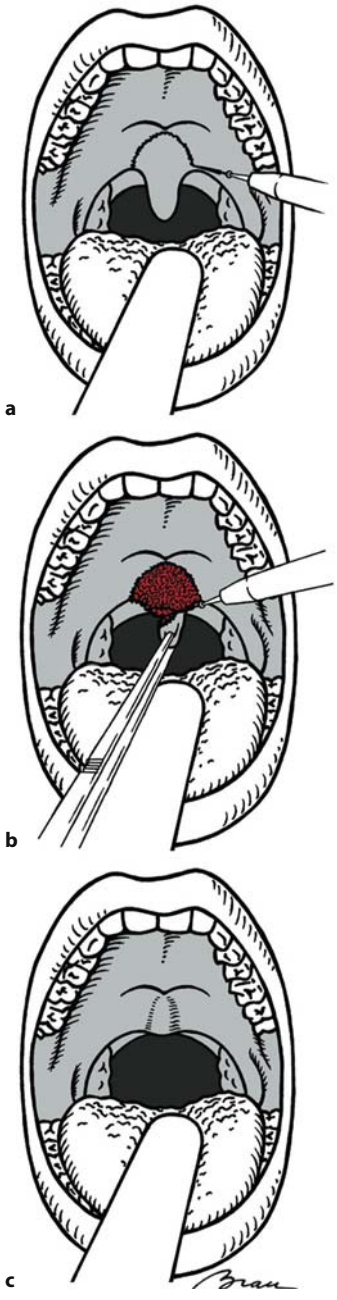


Fig. 6.43 a–c. Cautery-assisted palatal stiffening operation. **a** Incision. **b** Resection of palatal mucosa and shortening of the uvula. **c** Stiffening after secondary wound healing 3 weeks postoperatively

ducing the required stiffening. The early results have been promising. Detailed data concerning laser-assisted palatal stiffening are given in Sect. 6.4.

Other working groups adopted this technique using electrocautery to remove the anterior palatal mucosa in order to achieve palatal stiffening. Mair and Day [306] removed a 2 cm central palatal mucosal flap under local and topical anesthesia. The resection starts 1 cm from the junction of the hard and soft palate, which is gently dissected down to the uvula. Finally, the redundant mucosa of the uvular tip is resected, preserving the uvular muscle (Fig. 6.43).

Throughout the operation the palatal muscles remain intact. By week 2 or 3, the palate is stiffened (Fig. 6.43). Regarding further details about the precise surgical procedure, we refer the reader to the original publication [306].

This technique is recommended for primary snoring as well as for mild forms of OSA [306, 556]. Mair and Day investigated 206 patients who underwent isolated cautery-assisted palatal stiffening operation (CAPSO) for habitual snoring. No sleep studies were performed. Four to six weeks after surgery 190 patients (92%) reported successful reduction or elimination of snoring. Follow-up evaluation 6–36 months postoperatively (mean 12 months) revealed a drop in the success rate to 77% (145 successes in 188 patients).

Wassmuth and colleagues [556] evaluated the effect of CAPSO for OSA. As they are part of the same working group, the surgical technique used was identical to that of Mair and Day. The authors included 25 sleep apneics with a baseline AHI of 25.1±12.9. Three months postoperatively the AHI had statistically significantly decreased to 16.6±15.0. Using Sher's criteria, the success rate was estimated as 48%. Daytime sleepiness as measured with the Epworth Sleepiness Scale improved highly significantly.

Cautery-assisted palatal stiffening operation is designed as an outpatient procedure under local anesthesia. The surgical setting and postoperative care are the same as with LAUP. No sedation is required. No antibiotics or steroids are administered.

No perioperative complications have been reported so far. Postoperative complications include minor bleeding (1%), temporary velopharyngeal incompetence (<1%), prolonged throat pain (4%), and intermittent tiny vesicles at the scar site for up to 2 months after surgery [306]. Hoolsema [211] described subjective complaints in some patients, such as an inability to articulate a rolling "r", increased gag reflex, aspiration, and altered taste sensations at short-term follow-up.

Cautery-assisted palatal stiffening operation is painful. Pain has been rated between 50 and 60 for the first 8 days on a VAS with its endpoints 0 = no pain and 100 = maximum pain [556]. This means CAPSO is as painful as our conventional UPPP technique (see Sect. 6.2).

To sum up, CAPSO shows similar short-term results for simple snoring and for mild OSA as compared to other soft palate procedures. We do not use it for simple snoring as we think there are less invasive procedures available producing less postoperative morbidity. In cases of redundant mucosa we prefer the LAUP, which reshapes the free margin of the palate. In the other cases we prefer either interstitial RFQ surgery or the palatal implants as these techniques are much less painful. For OSA we perform a conventional UPPP or an uvula flap, always combined with a tonsillectomy if tonsils are still present, because for this procedure there are reliable long-term data documenting superior efficiency.

6.7.3 Injection Snoreplasty

Injection snoreplasty was introduced in 2001 to treat palatal snoring [48]. The surgical concept consists of the injection of sclerosing agents into the soft palate. The ensuing scarring causes a stiffening of the soft palate. The authors initially used 3% sodium tetradecyl sulfate (STS) as an effective agent. In Europe, this substance has not been approved for this usage; therefore, there are no European study reports, and for the same reason we do not employ injection snoreplasty. In a recent publication, further agents were assessed in respect to their efficacy [49]. None of the tested substances produced better results than STS. Only 50% ethanol was found to produce equivalent subjective and objective snoring efficacy and equivalent pain and recovery time compared to STS. However, a higher rate of transient palatal fistula was found in the case of ethanol.

The patient is maintained in a sitting position in the surgical chair. The authors perform only topical anesthesia, first using a spray, which is then followed by a local anesthetic gel. The latter is placed on the end of a tongue depressor and placed against the soft palate for up to 10 min. Injected local anesthesia is not thought to be necessary. During the first treatment, 2.0 ml of 1% STS (10 mg/ml Sotradecol, Elkins-Sinn, Cherry Hill, NJ, USA) is injected with a single needle penetration into the midline soft palate. The desired anatomic plane of injection is the submucosal layer of the soft palate. After approximately 2 min, the injected midline palate turns a purple, hemorrhagic color, as the sclerotherapy agent begins to take effect. Over a period of weeks, the mucosa heals, and a midline scar remains. For patients undergoing a second treatment the site of injection is modified (Fig. 6.44). Breitzke and Mair [48] used 3% Sotradecol in most cases for repeated treatment sessions. For more details see [48].

Twenty-seven patients were included in an initial controlled case study. On average, 1.8 sessions were necessary. Six weeks postoperatively, 25 patients (92%) reported a major subjective snoring reduction and were satisfied with the operation [48]. The same patient pool received a further follow-up on average after 19 months [47]. The subjective success rate dropped to 75%. In this second follow-up an objective snoring analysis with the SNAP system was performed. In 71% of the patients an objective improvement of snoring sounds was demonstrated. Subjective and objective results correlated well in this study.

So far, intraoperative complications have not been reported. There is no specific postoperative care. The overall discomfort level created by the procedure was reported to be 3.5 on the VAS with endpoints 0 = no discomfort and 10 = maximum discomfort. To date, four patients have developed a transient, asymptomatic palatal fistula. One had received STS and the other three 50% ethanol.

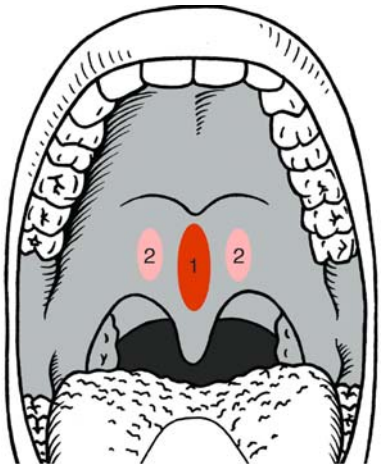


Fig. 6.44. Injection snoreplasty with 3% sodium tetradecyl sulfate. During the first treatment session, the agent is applied in the midline. In the second treatment session, the agent is injected paramedially on both sides

As with palatal tissue breakdown, treatment was entirely supportive without the use of antibiotics or steroids. All four patients healed spontaneously without complications and with good snoring results.

The data are limited in their scope by the fact that they stem from merely one study group, and only encompass a small number of patients. Having said this, the method does appear to produce results in simple snorers that are comparable to other minimally invasive surgeries of the soft palate.

6.7.4 Transpalatal Advancement Pharyngoplasty

Evaluations of pharyngeal properties before and after UPPP, using both computerized tomography and acoustic reflection, have demonstrated increases in oropharyngeal size and decreases in oropharyngeal collapsibility. Larger increases in these characteristics are associated with a successful clinical response to UPPP [463, 583]. However, UPPP failures are associated with smaller volume increases, compliance changes, and subsequently are observed to have a persistent palatal site of obstruction. Woodson and Toohill [577] concluded from these findings that in some patients technical failure may occur, and introduced a new surgical alternative to UPPP, the so-called transpalatal advancement pharyngoplasty (TAP).

The surgical principle consists in not only altering the inferior edge as in a UPPP, but also in advancing the base of the soft palate at the hard palate. This entails a partial resection of the posterior edge of the hard palate. Surgery is performed under general anesthesia. The preparations and the surgical setting are analogous to those of UPPP. To all patients perioperative antibiotics and dexamethasone (10 mg) was administered. In the original publication [577] local infiltration with an adrenal local anesthetic and the superficial insertion of 4% cocaine solvent along the floor of the nose was recommended.

Initially, a conventional UPPP is performed. In the second phase, the advancement of the soft palate (Fig. 6.45) occurs. First a reverse V-shaped mucous membrane soft tissue flap is prepared and the transition from the hard to the soft palate is exposed (Fig. 6.45a). Subsequently, soft and hard palate are separated, exposing the nasopharynx (Fig. 6.45b). Now the posterior edge of the hard palate is partially resected. For the reinsertion of the soft palate, drill holes are placed towards nasally (Fig. 6.45c). Finally, the adaptation of the soft palate to the hard palate and the realignment of the soft tissue flap are performed (Fig. 6.45d). In regards to the exact surgical technique including potential pitfalls we refer the reader to the original publication by Woodson and Toohill [577].

In a first series including six patients with severe OSA, the authors were able to achieve a reduction of the AHI from 52.8 to 12.3 after isolated TAP. Four of these six patients (67%) fulfilled the healing criteria according to Sher. In a second series, six further patients first underwent a UPPP and in second session a TAP [582]. Four patients received solely a TAP in the second session; three of them fulfilled the healing criteria according to Sher (AHI 74.5 preoperatively vs. 29.2 postoperatively). The maximal area behind the soft palate increased by 321% and the retropalatal closing pressure decreased significantly as

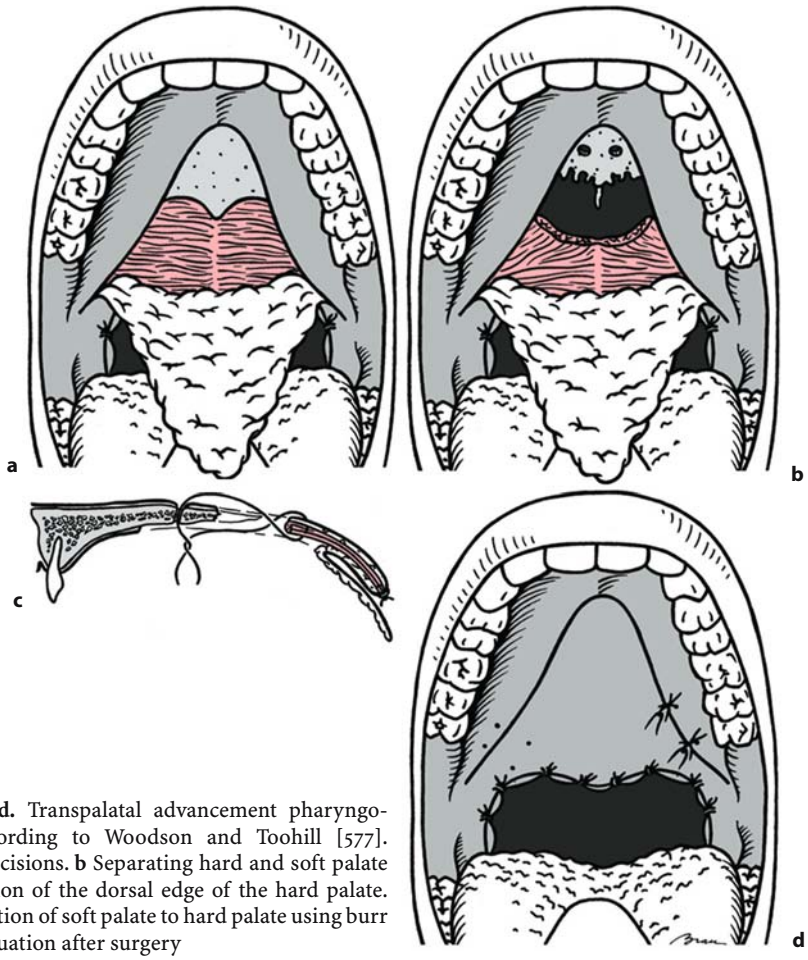


Fig. 6.45a–d. Transpalatal advancement pharyngoplasty according to Woodson and Toohill [577]. **a** Palatal incisions. **b** Separating hard and soft palate and resection of the dorsal edge of the hard palate. **c** Readaptation of soft palate to hard palate using burr holes. **d** Situation after surgery

compared to the situation after UPPP. In his most recent publication concerning the matter, Woodson describes an increase in both the anterioposterior and the lateral dimensions of the retropalatal airway after TAP in seven patients [581].

Postoperative care is similar to that after conventional UPPP. Antibiotic prophylaxis is recommended for 5 days. Additionally, 10 mg dexamethasone is given perioperatively.

As there are only data for a limited number of patients after TAP, it is not possible to determine the frequency of potential complications. In his publications, Woodson reports transient palatal fistulas, mild intermittent oropharyngeal dysphagia, partial flap necrosis and one case of severe otitis media.

The TAP is a treatment modality for OSA, especially for those patients who still show a narrow retropalatal airway after a UPPP. Only very few reports exist documenting TAP used as a primary technique. Woodson has employed the technique for the treatment of more severely affected sleep apneics. No data exist concerning the efficacy for mild OSA, especially in comparison with UPPP for a larger patient pool. The technique is more invasive than the conventional UPPP, and therefore it poses more potential risks. For this reason we have not included TAP in our surgical repertoire, but consider it as a solution for specific individual cases.

Lower Pharyngeal Airway Procedures

7

7.1 Radiofrequency Surgery of the Base of Tongue

The feasibility of interstitial radiofrequency (RFQ) surgery of the tongue base was first investigated in a porcine model [399] using the Somnus unit. The authors found a very mild initial edematous response that promptly tapered off 24 h after surgery. Ten days after interstitial RFQ surgery, a volume reduction was documented at the treatment site. The procedure turned out to be safe and was transferred to the use in patients suffering from obstructive sleep apnea.

7.1.1 Surgical Technique

We prefer performing RFQ therapy of the tongue base under local anesthesia. In the upright position, the patient is comfortably positioned either in the clinical chair or on a surgical bed. As perioperative monitoring we initiate an ECG and a pulse oximetry. In contrast to the application of RFQ therapy at the nasal conchal and the soft palate, sedation is recommended in this case. We administer sedation intravenously with 4- to 10-mg midazolam, by titrating the drug up to the desired level of sedation. Also in contrast to the application of RFQ on the soft palate, we consider perioperative antibiotic prophylaxis as essential after application on the tongue base. We administer 2 g cephazolin intraoperatively and perform a postoperative prophylaxis for 5 days with two times 250 mg cefuroxim per os. In terms of cost efficiency, a different antibiotic management, e.g. with an oral penicillin, can certainly be envisioned. Yet a general omission of an antibiotic prophylaxis is not recommended.

Following a surface disinfection with hexetidine 0.1 %, an infiltration anesthesia is performed. We use 2 % prilocaine with adrenalin additive (1:200,000). We do not perform a surface anesthesia because some patients develop a potentially very discomforting hypersalivation, which can severely impede the patient's cooperation. In total, between 5 and 10 ml local anesthetic are applied.

We employ two different RFQ systems. On the one hand we use the Somnus system (Somnus, Gyrus ENT, Bartlett, USA), and on the other hand the Celon system (Celon AG Medical Instruments, Teltow, Germany). Both are so-called controlled systems (for more information see Sect. 6.1.2).

The Somnus system is a monopolar system that necessitates the attaching of a neutral electrode to the patient. Using the latest Somnus model, the Somnus radiofrequency generator Model S2, we were able to demonstrate with the help of in vitro and in vivo studies employing MRI that a setting of 600 J with a target temperature of 85 °C creates optimal lesions [491, 492]. Therefore, we have substantial evidence to recommend this setting. Today, we administer between 8 and 16 lesions per session, depending on the size of the tongue base. For this a special needle device is used (Fig. 7.1). As in tonsillar surgery, double wands help to save operating time.

Given the high number of lesions, it is virtually impossible to maintain a fixed application pattern. Yet one should attempt to avoid placing the application needle twice on the same location. But if this does occur, the monitor of the generator (Fig. 7.2) will indi-

Fig. 7.1. Somnus needle device for use at the base of the tongue

Fig. 7.3. Celon radiofrequency generator with foot switch

cate that the radiofrequency energy is being transmitted only very slowly into the tissue. In these cases, pulling back the applicator and renewing the puncture is recommended.

When using the Celon system, we set the generator to an output of 6–7 W (Fig. 7.3). The lower the output is set, the larger the lesions in the tissue will become.

It is much more difficult to penetrate the tongue surface than the surface of the soft palate. Therefore, together with Celon, we

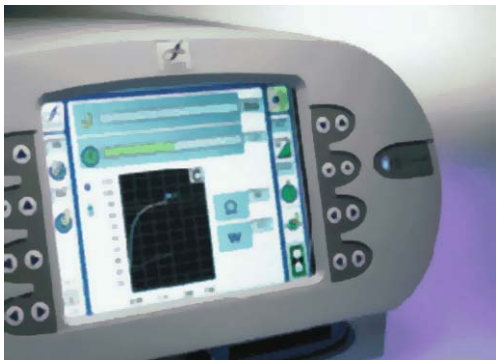


Fig. 7.2. Somnus radiofrequency generator Model S2

have developed a special faceted tongue base applicator, the so-called Celon Pro Sleep Plus (Fig. 7.4). The applicator is covered in a synthetic coat. Only the tip of the probe with the active electrode is exposed. The coat prevents the applicator from being inserted too far into the tissue. This reliably protects deeper-lying structures, as for example the neurovascular bundle of the tongue. Substantial additional force would be needed to push the probe beyond the coat into the tongue. A radiofrequency energy application accidentally going too deep is made all but impossible.

This is a bipolar system; therefore, a neutral electrode does not have to be attached to the patient. The surgical procedure is identical to that with the Somnus system (Fig. 7.5). Also in this case, 8–16 lesions are placed, depending on the size of the tongue base.

The bipolar technique allows for a more rapid energy transmission into the tissue. We have calculated the time difference solely for the energy application to consist in a factor of 7. Everything else, for example, preparation, setting up the apparatus, local anesthesia, and follow-up care, takes up an identical amount of time.

In our patients, we have been able to reduce the average number of therapy sessions required to 1.8 because of the intensification of the therapy with 8–16 lesions. A further optimization through an additional increase of the number or size of the lesions is currently probably not to be expected.

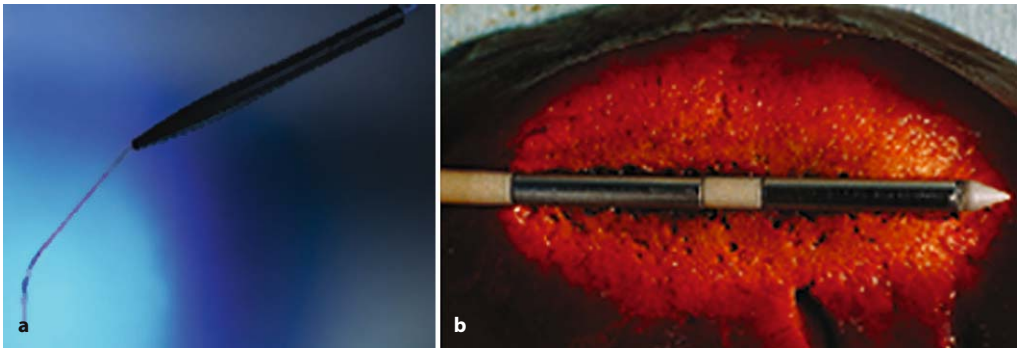


Fig. 7.4. **a** Faceted Pro Sleep Plus radiofrequency probe with coat. **b** Detailed view of the active electrodes

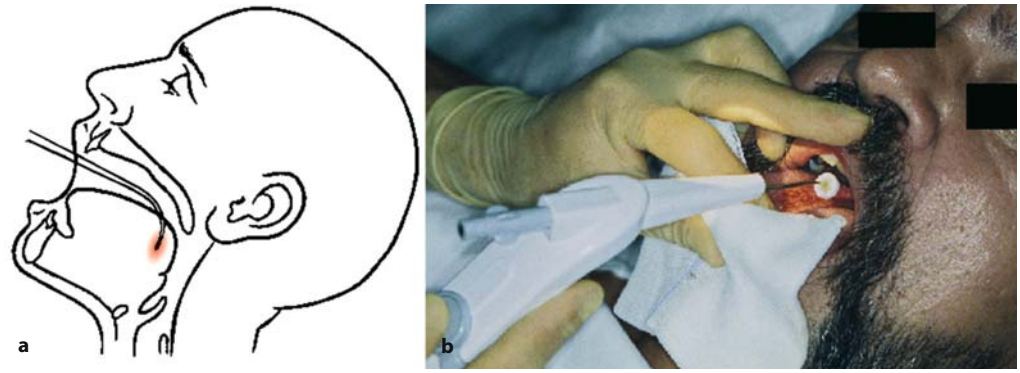


Fig. 7.5. **a** Outline of the RFQ of the tongue base. **b** Intraoperative situation

7.1.2 Effectiveness for Simple Snoring

Up to now, there have been no studies investigating the effect of isolated interstitial RFQ surgery of the tongue base for simple snoring. According to our own experience in more than 500 interventions, RFQ of the tongue base is effective in the treatment of simple snoring if the patient is suffering from non-palatal snoring. Snoring improved subjectively after isolated tongue base RFQ in patients with obstructive sleep apnea (OSA) [496]. As the combined treatment of soft palate and tongue base does not induce a higher rate of postoperative morbidity or complications than isolated tongue base procedures, nowadays we prefer the combined procedures.

7.1.3 Effectiveness for OSA

In 2001 the use of RFQ at the base of tongue was still regarded as not thoroughly enough assessed [314], but today sufficient data exist concerning its efficiency in OSA (Table 7.1).

Comparison of the cited studies is facilitated by the fact that all study groups worked with the same system. The total energy amounts applied vary from 7,915 J [286, 398] to 13,394 J [575]; yet no clear correlation between applied total energy amount and surgery result can be deduced.

Table 7.1. Efficiency of RFQ of the base of tongue for OSA

Author	*n*	Device	Follow-up (months)	Sessions/ total energy/	AHI pre	AHI post	Success rate (%)	EBM grade
Powell et al. 1999[a] [398]	15	Somnus	4	5.5/1,543 J/1	47.0	20.7	46.7	II-3
Woodson et al. 2001 [575]	56 77	Somnus CPAP	1.5	5.4/ 2,720 J/3.1	40.5	32.8	20	II-1
Stuck et al. 2002 [496]	18	Somnus	1	3.4/2,800 J/4	32.1	24.9	33	II-3
Li et al. 2002[b] [286]	16	Somnus	28	5.5/1,543 J/1	39.5	28.7	No data	II-3
Riley et al. 2003 [424]	19	Somnus	3	4.6/1,741 J/3	35.1	15.1	63.2	II-3
All[c]	**108**	**Somnus**	**2.0**		**39.1**	**26.7**	**33.5**	**III**

[a] Only patients with OSA (AHI > 10) included.
[b] Update of Powell 1999 study.
[c] Without data of Li et al. 2002 and without the 77 patients of Woodson et al. 2001.
EBM evidence-based medicine, *AHI* apnea hypopnea index.

An analysis of the success rates given in Table 7.1 produces the following result: for a total of 108 patients (excluding the study of Li et al. [286], as the patient pool is partly identical to that of Powell et al. [398] and excluding the 77 CPAP patients of Woodson et al. [575]), a surgical short-term success rate employing Sher's criteria of 33.5 % for RFQ of the tongue base was achieved for (on average) moderate OSA. This seems to indicate that the efficacy of this technique is almost equal to the invasive tongue base resections (Sect. 7.3). But in our opinion the data from Table 7.1 need to be interpreted cautiously because the study design of the RFQ studies is very different. In all the other procedures, a sleep lab evaluation is performed before and after the therapy. But in the case of the RFQ treatments, therapy continues until the polysomnography produces a satisfactory result. This is the issue at stake: the polysomnography exhibits a high night-to-night variability, which in this case becomes evident in a positive manner only for the surgery result [328, 332]. In other words, we doubt that the presented results would be corroborated by a therapy design delineated from the start by a defined number of sessions, lesions, and a defined amount of energy input.

The best results are described by Riley and colleagues [424]. This study is distinguished from the others by the fact that besides two lesions at the tongue base it also applies a lesion on the anterior part of the tongue. Possibly this procedure contains a potential for an improvement of the objective results of RFQ on the tongue base.

We are also of the basic opinion that RFQ therapy of the tongue base has been proven to have an effect in the treatment of OSA; but in terms of objective results it cannot compete primarily with the standard continuous positive airway pressure (CPAP) therapy. Yet the subjective results are absolutely equivalent with regard to daytime condition and quality of life [575].

A careful reading of the raw data in the cited studies indicates that mainly mild forms of OSA are suitable for therapy with RFQ at the tongue base.

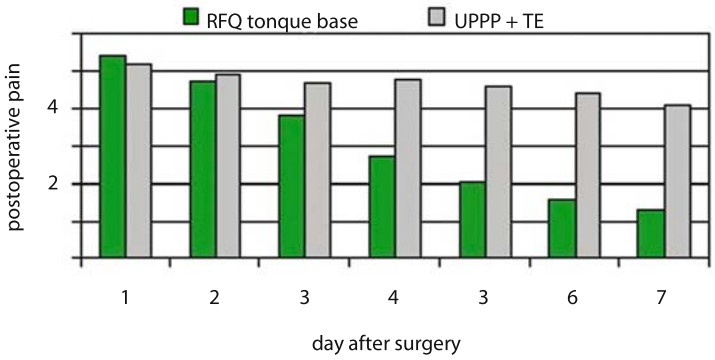


Fig. 7.6. Mean postoperative pain scores over 1 week after RFQ of the tongue base. *UPPP* uvulopalatopharyngoplasty, *TE* tonsillectomy

7.1.4 Postoperative Care and Complications

When we started our RFQ treatments at the base of the tongue, all patients were kept overnight for clinical monitoring after every treatment session. Over the last 100 treatments we have observed virtually no complications; therefore, this requirement can no longer be upheld as a general rule. Yet it is necessary to observe the patients until the sedation has sufficiently worn off. Because of its short half-life we solely use midazolam. As with any surgery at the head performed under local anesthesia, the patient is not capable of driving postoperatively. Therefore it must be ensured that the patient is picked up. If these provisos are observed, in our experience nothing is to be said against performing RFQ at the tongue base on an outpatient basis.

The patient requires a perioperative antibiotic prophylaxis [494]. We administer 2 g cephazolin intraoperatively and 2×250 mg cefuroxim per os for 5 days postoperatively. Corticosteroid administration is not routinely necessary.

In contrast to the application at the soft palate, postoperative pain is to be expected. In the case of our own patient pool, we have analyzed the level of pain with the help of visual analog scales with the endpoints 0 = no pain and 10 = maximal pain [495]. The results, compared with the pain level after combined uvulopalatopharyngoplasty (UPPP) with tonsillectomy, are given in Fig. 7.6.

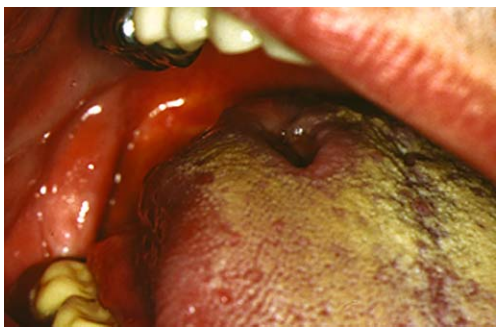


Fig. 7.7. Ulceration at the base of the tongue after RFQ treatment

The patients require analgesics for approximately 4–5 days. We have achieved good results with retarded diclofenac (3×100 mg), if necessary in combination with retarded tramadol (2×200 mg). Pain level and response to analgesic medication vary considerably between individuals, so individualized pain management with corresponding controls is necessary.

Currently, study data exist only for the Somnus system. Apart from vasovagal reaction, no intraoperative complications have been reported so far.

The postoperative complication rate is widely divergent, namely between 41% [380] and 0% [424]. But with its complication rate

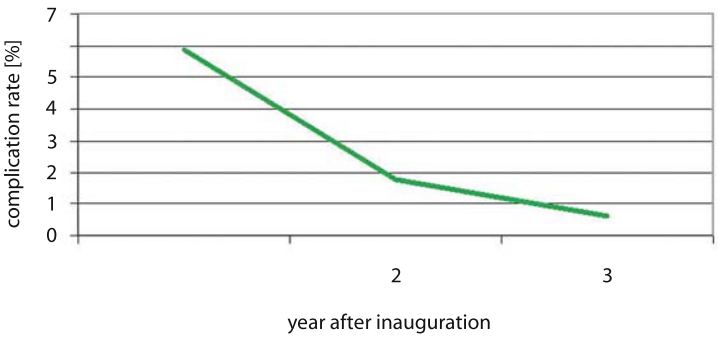


Fig. 7.8. Complication rate of RFQ depending on the surgical skill

of 41%, the study by Pazos and Mair is an exception. All other studies report complication rates of below 2%. We believe the most probable explanation for these divergent results lies in the perioperative management. In contrast to our own procedure, Pazos and Mair recommend the general use of corticosteroids, whereas antibiotics were administered only in the case of inflammatory complications. The prophylactic administration of corticosteroids may predispose to inflammatory complications. We therefore advise against their use.

The most severe complication is an abscess of the tongue base, which has been reported by four study groups [380, 398, 497, 575]. We have taken our own case as an incentive always to perform intra- and postoperative antibiotic prophylaxis. Since then, 4 years have passed, and we have not encountered a further abscess in over 1,000 treatments. A much more frequent complication is the occurrence of ulcerations at the tongue base (Fig. 7.7). They usually develop as a result of a too superficial positioning of the active electrode below the mucosa; in rare cases they are caused by a leak in the protective electrode sheath caused by excessive flexing of the electrode during treatment. These lesions at the tongue base cause a prolonged odynophagia of up to 3 weeks. Other complications are rare and consist in infection, edema, tongue pain well beyond 1 week, neuralgia up to 3 months and thrush.

For our own patient pool we have analyzed the complications of a total of 711 treatments of 477 patients with the Somnus system and the Celon system in 2002. Overall, the complication rate was 2.4%, with a slight advantage for the Somnus system. At the tongue base, one abscess, five ulcers, and seven prolonged odynophagias for maximally 3 weeks were registered. It is interesting to note that the complications diminish with an increase of treatment experience (Fig. 7.8) [497].

Apparently, a surgical learning effect exists. Today we have reached complication rates of below 1%. By observing the recommended perioperative management, RFQ surgery at the tongue base has established itself as a safe procedure with a low postoperative morbidity.

7.1.5 Indications and Contraindications

With RFQ, for the first time a minimally invasive and effective procedure for the tongue base is at our disposal. The postoperative morbidity and complication rate are strikingly low. Therefore we regard RFQ at the tongue base as a very significant broadening of the surgical therapy spectrum. Accordingly high is the number of operations performed in our center.

With regards to primary snoring, currently no data exist in the literature. Nevertheless, as a result of our extensive clinical experience, we have also employed RFQ at the tongue base for the treatment of primary snoring. But the problem here lies in the difficulty in identifying the tongue base snorer preoperatively, as there is no reliable clinical

diagnosis technique. Furthermore, pure tongue base snorers are relatively rare. Recently we were able to demonstrate that neither postoperative morbidity nor complication rate increases if the soft palate is treated in the same session. We therefore primarily perform a combined tongue base and soft palate treatment in the case of primary snoring. Because the tongue applicators are also suitable for the soft palate, not many further costs ensue. Objective evaluations are still to be performed, but we have reason to assume that with the combined procedure we can both improve the outcome and reduce the number of necessary sessions.

From the data presented in Table 7.1 we infer an indication for RFQ at the tongue base for mild OSA and upper airway resistance syndrome (UARS). A precise apnea hypopnea index (AHI) threshold cannot be given. We consider a primary indication up to an AHI of 30. In the case of more severe OSA, RFQ at the tongue base is additionally an essential element of our multi-level surgery concept (see Chap. 10).

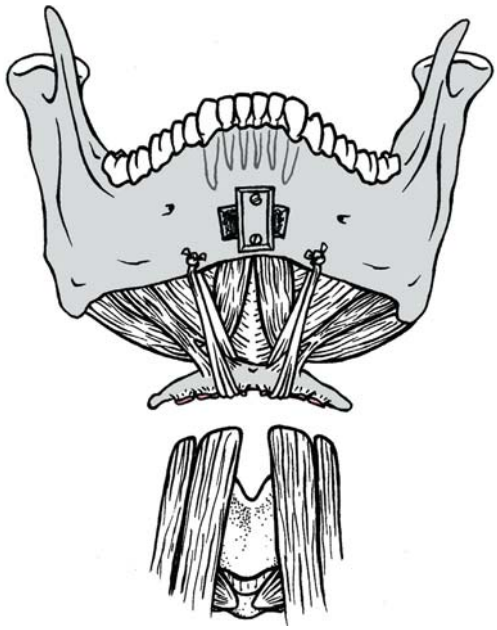


Fig. 7.9. Original technique of hyoid suspension with homologous fascia lata according to Riley et al. [419], here combined with genioglossus advancement

7.2 Hyoid Suspension

Over the past 20 years gentle surgical procedures have been developed for the retropalatal obstruction site, but only very few techniques have been established for the removal of hypopharyngeal constriction. Long-term results are all but missing [391]. Furthermore, because of their invasive nature and their peri- and postoperative morbidity, many of these procedures need to be critically evaluated.

Prevention of the collapse of the tongue musculature, which relaxes during sleep, towards dorsal into the upper airway with the help of a suspension of the hyoid bone is not a new idea. At the beginning of the 1980s a widening of the upper airway after hyoid suspension was demonstrated, first for the animal model [379, 528], and later for humans [251]. Initially, fixation of the hyoid on the chin was attempted. In the meantime, several authors have favored the suspension at the thyroid cartilage.

7.2.1 Original Surgical Technique (1986)

Based on the finding from radiocephalometric studies that in sleep apneics the hyoid is positioned lower than in healthy subjects, in 1986 a new therapy concept was presented for the treatment of hypopharyngeal constriction: the inferior sagittal osteotomy of the mandible with hyoid myotomy-suspension [419]. Here the hyoid was supposed to be moved upwards and towards frontal. This was achieved on the one hand with the help of a medial osteotomy at the chin with advancement of the origin of the M. genioglossus (see Chap. 8, Sect. 8.1) and on the other hand with the help of a suspension of the hyoid at the chin with homologous fascia lata strands after myotomy of the intrahyoidal musculature (Fig. 7.9).

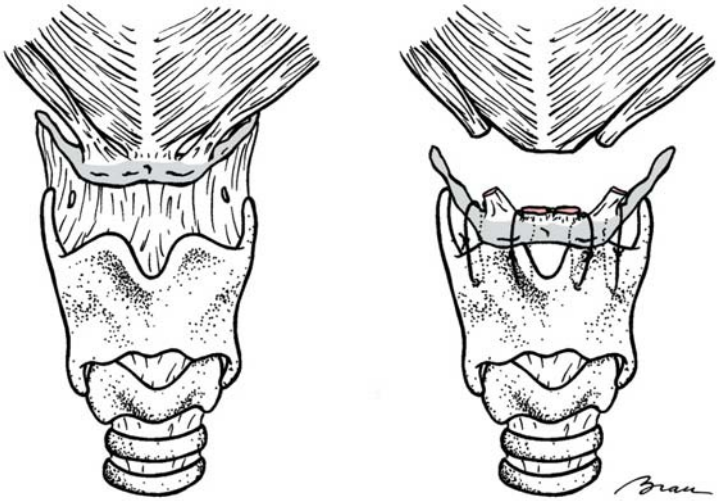


Fig. 7.10. Modified hyoid suspension according to Riley et al. [421]

7.2.2 First Modification (1994)

Although this procedure has been shown to be effective in improving OSA, it involves extensive surgical dissection of the submental region as well as the requirement for fascia lata harvest [291]. Other authors use other material instead of the homologous fascia lata, as for example non-resorbable suture material or special anchor systems [100, 263, 405, 443, 453]. In the meantime, the Stanford group has modified its technique in reaction to the drawbacks mentioned. In this modification, originally presented by Riley and colleagues [421], the hyoid is no longer fixated on the mandible but on the upper edge of the thyroid cartilage. The resulting movement of the tongue base towards anterior and caudal increases and stiffens the upper airway. Access is achieved via a 3–4 cm wide horizontal skin incision along the relaxed skin tension lines on the level of the hyoid. A portion of the body of the hyoid is isolated in the midline. The inferior body of the hyoid bone is dissected clean. The stylohyoid ligaments are sectioned from the lesser cornu, but the remaining suprahyoid musculature is left intact. A subcutaneous vertical incision is made to allow exposure of the thyroid notch and superior thyroid lamina. Ticron no. 1 sutures (Davis & Geck, American Cyanamid Co., Danbury, USA) are placed through the superior portion of the thyroid cartilage and around the hyoid bone as illustrated (Fig. 7.10).

7.2.3 Ongoing Modification by Hörmann

In the meantime, we have further modified this method [212, 214]. To be less invasive and more effective, we do not perform a cutting of the ligamenta stylohyoidea and a myotomy of the supra- and infrahyoidal musculature. For this procedure we prefer intubation anesthesia for the hyoid suspension. The procedure can basically also be performed under local anesthesia [355]. But in these cases we then recommend an intravenous sedation with e.g., midazolam. The patients receive an intraoperative single-shot antibiosis with 2 g cefazolin.

The patient is then placed on the operating table with slightly reclined head. Initially it may be helpful to mark the position of the hyoid and the upper edge of the larynx. For cosmetic reasons, the skin incision is performed above the hyoid bone along the relaxed skin tension lines (Fig. 7.11).

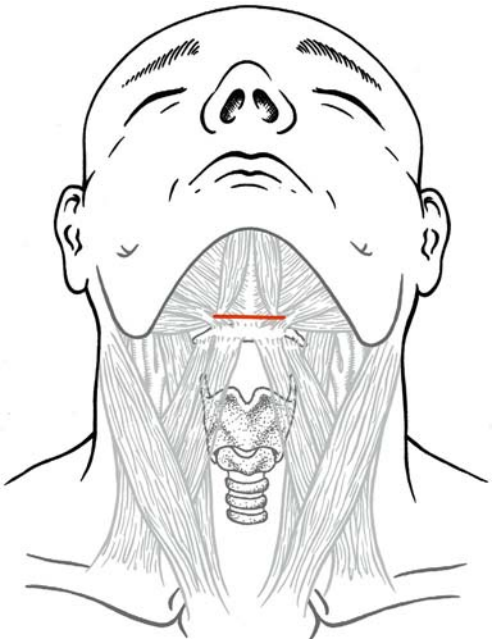


Fig. 7.11. Hörmann's technique of hyoid suspension. Dermal incision

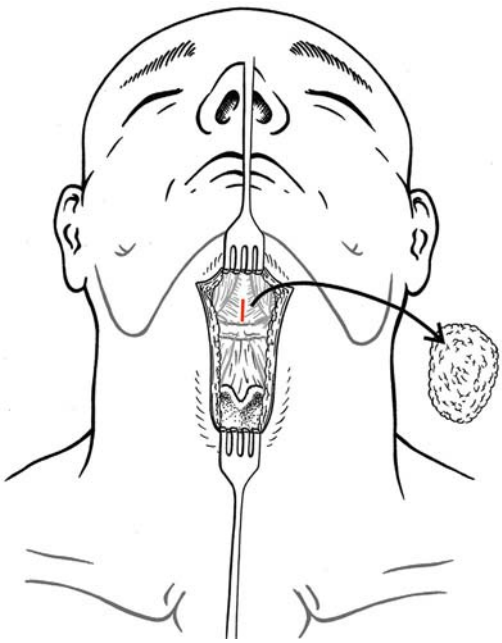


Fig. 7.12. Hörmann's technique of hyoid suspension. Exposure of the hyoid bone and thyroid cartilage. Resection of redundant fat

One proceeds through the submental fat up to the mouth floor musculature. Without damaging it, the muscles are sectioned down to the hyoid; then the thyroid cartilage is exposed. It is useful if the assistant or nurse pushes the larynx towards cranial with two fingers. For esthetic reasons it is now important that a sufficient amount of fat tissue is resected (Fig. 7.12). Failure to do so will, as a result of the advancement of the hyoid, create an unattractive supralaryngeal wrinkle as a turkeylike appearance.

In contrast to the originally described method, our new modification needs only one triangular suture, which passes on both sides paramedial transcartilageal through the thyroid cartilage and medial around the hyoid. For the suture a monofilamentous grade 3 steel wire (Ethicon, Hamburg, Germany) is used. For this, first the suprahyoidal musculature is vertically separated precisely in median, until a Langenbeck retractor can be applied (Fig. 7.12, *red line*). The fascia in the midline between each sternohyoid muscle is incised with electrocautery until the plane of the thyroid cartilage is reached. The blood supply to the thyroid cartilage is provided by the blood vessels of the perichondrium. Unnecessary elevation of the perichondrium should, therefore, be avoided to reduce the risk of necrosis. The muscles on both sides are retracted to expose the lateral parts of the thyroid cartilage. Now, starting at caudal, a sharp needle is pierced in through the cartilage without drilling. The steel wire is fixed at the end of the needle, which is pierced out on the contralateral side of the thyroid cartilage from behind (Fig. 7.13 a). Then the hyoid body is encircled with the wire ligature until the tip of the needle appears on the Langenbeck retractor (Fig. 7.13 b). To prevent accidentally opening up the pharynx tube by the suture, the assistant elevates the hyoid with a Joseph retractor. To prevent tearing of the suture, the distance to the free upper edge of the thyroid cartilage should be at least 5 mm. Especially

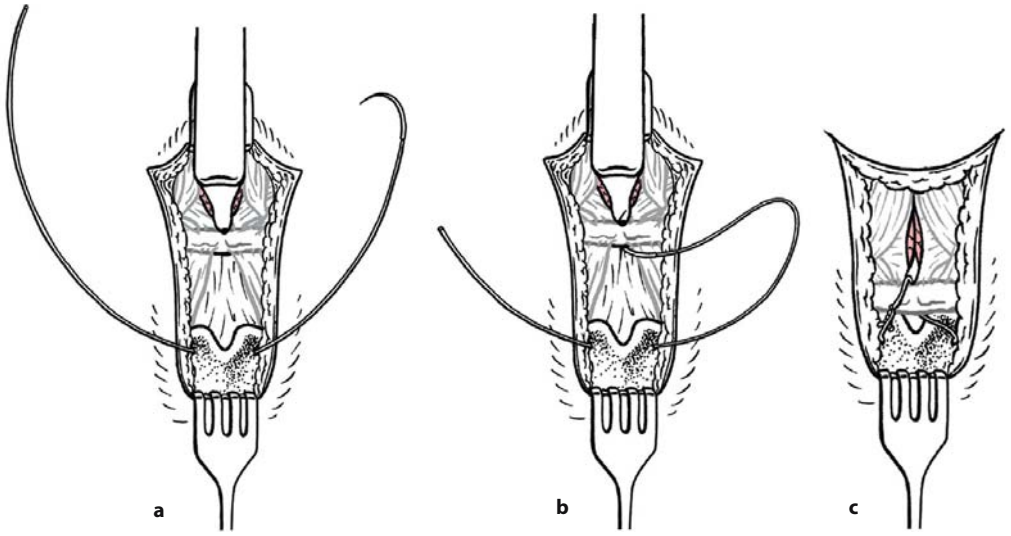


Fig. 7.13 a–c. Hörmann's technique of hyoid suspension. **a** transfixing the thyroid cartilage with the steel wire suspension. **b** undermining the hyoid bone. **c** completion of suspension

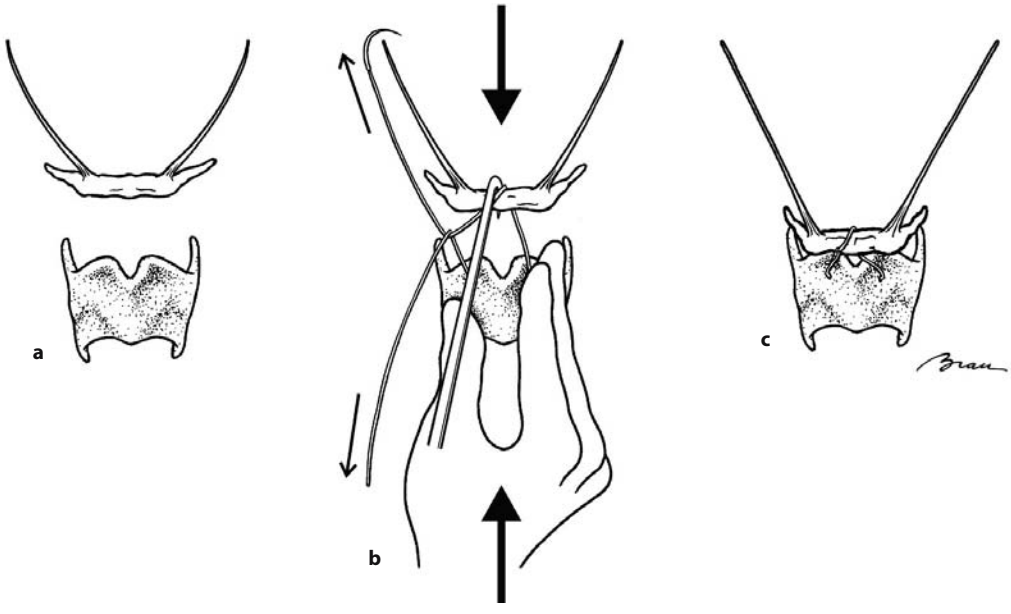


Fig. 7.14 a–c. Hörmann's technique of hyoid suspension. **a** preoperative situation. **b** hyoid suspension without myotomy and without cutting of the ligamenta stylohoidea. **c** situation after surgery

Table 7.2. Effectiveness of isolated hyoid suspension for OSA

Author	*n*	Follow-up (months)	AHI pre	AHI post	Success rate (%)	EBM grade
Riley et al. 1994 [421]	15	3–6	46.9	21.3	53.3	II-3

in men, ossifications of the thyroid cartilage may complicate the piercing of the cartilage with the ligature, or in individual cases even make it impossible. A surgical drill system as, for example, used in ear surgery is of help here.

Now the actual suspension takes place (Fig. 7.13 c). One more time the hyoid is undergirded with the Joseph retractor. With one hand the assistant pulls the hyoid with this retractor towards anterior and caudal, while pushing the larynx with the other hand towards cranial. The surgeon now fixates the hyoid in this position on the larynx with the ligature by intertwining the two wire ends. To achieve an optimal result, it is important not to make a kink in the wire ligature, as otherwise it cannot be tightened. Finally the wire ends are twisted inwards to prevent a painful piercing of the skin. For 2 days a Redon drainage with suction is applied.

This modification, which makes a myotomy and a cutting of the ligamenta stylohyoideum dispensible, both shortens the surgery time, and reduces the surgery area. With this modification we achieve a reduction of the invasiveness of the procedure (Fig. 7.14).

7.2.4 Effectiveness for Sleep-Disordered Breathing

Hyoid suspension is a surgical technique, which up to now has been suggested only for the treatment of OSA. Currently, no published data exist in regards to its usefulness for primary snoring. At our department, 26 patients with primary snoring or UARS were treated at least with the hyoid suspension between January and May 2004. Twenty-five of them (96 %) reported a significant reduction in their snoring after operation.

Also in regards to the efficacy in the therapy of OSA, data for isolated hyoid suspension are rare because the hyoid suspension is almost always performed together with a mandibular osteotomy with genioglossus advancement. The only existing data are presented in Table 7.2.

The success rate of the 15 patients for isolated hyoid suspension with a severe OSA is slightly above 50 % according to Sher's criteria. But the data are not yet sufficient to verify scientifically the efficacy of isolated hyoid suspension in the treatment of OSA. Further controlled studies are needed. Nevertheless, the data correspond with our own clinical experience in the therapy of OSA. Furthermore, hyoid suspension, in the modification suggested by Hörmann, has established itself as an essential and effective therapy element in the context of our multi-level concept [215, 530].

7.2.5 Postoperative Care and Complications

We perform hyoid suspension on an inpatient basis. Apart from the perioperative single-shot antibiosis, antibiotics are indicated only if inflammatory complications develop. The Redon drainage is removed after 2 days, depending on the circumstances. In the majority of cases (64 % in our own patient pool) a passage dysphagia of up to 4 weeks is to be expected. The postoperative diet should take this factor into account.

In order to protect the upper airway in severe OSA, several authors recommend a routine nasal CPAP respiration during the postoperative phase after hyoid suspension [295]. We always employ CPAP respiration in those cases where the patient already was using

such an apparatus preoperatively. In cases where a patient has not previously used an apparatus, the observation in the first hours postoperatively in the recovery room is sufficient for us to decide whether CPAP therapy is indicated or not prior to the relocation to a normal care unit. If CPAP therapy is necessary, a pressure of 10 cm H_2O is used. Intensive observation is usually not necessary after hyoid suspension. Concerning postoperative management after surgical procedures at the upper airway for severe OSA, compare also Chap. 13.

Neruntarat recently described self-limited aspiration as a complication after hyoid suspension within the first 3 weeks after surgery [355]. In our own patient pool we have observed hematomas, seromas, disturbances of the wound-healing process, as well as temporary articulation distortions. A relatively frequent complication is the hematoma. Ever since we started maintaining the Redon for at least 2 days under suction, the incidence of hematomas requiring treatment has decreased. In one of our cases the wire ligature was torn out of the larynx cartilage. A surgical revision with removal of the ligature became necessary. No other severe complications have been reported.

7.2.6 Indications and Contraindications

Hyoid suspension is an invasive surgical method with potential complications. For the tongue base, a minimally invasive alternative exists in the form of RFQ surgery. We therefore see no primary indication for the hyoid suspension for primary snoring except in cases where the snoring problem takes a central place or an alternative operation did not succeed.

In the case of mild OSA with a suspected retrolingual collapse site, hyoid suspension competes with RFQ therapy at the tongue base. Because of its significantly lower invasiveness and postoperative morbidity, we primarily choose the RFQ, and offer hyoid suspension as a secondary therapy concept after failed RFQ surgery. But for mild OSA and appropriate bite status, the treatment with oral appliances is a viable alternative. These bite plates achieve a comparable cure rate and have a long-term acceptance rate of approximately 50 %.

Also, OSA purely related to supine position reacts well to a hyoid suspension, as this form of OSA is virtually always caused by a falling back of the tongue during sleep. Correspondingly, here again bite plates are an alternative option.

In the case of moderate OSA, the cure rate both of RFQ therapy and of the bite plates decreases. For this indication, hyoid suspension is superior to RFQ. Therefore we consider moderate OSA (AHI 20–40) as a primary indication for the hyoid suspension. If the obstruction site is suspected to lie solely in the retrolingual segment, an isolated hyoid suspension presents itself as an option; as described above, this can certainly be performed under local anesthesia.

For more severe forms of OSA (AHI>40), we increasingly assume that the complete airway is affected. For severe OSA, respiratory therapy is to be preferred in general. But if surgery becomes necessary in cases of therapy failure or non-compliance, an isolated hyoid suspension is often not sufficient. In the case of severe OSA we therefore pursue primarily a multi-level concept, which combines procedures at the soft palate and at the tongue base (see Chap. 10).

7.3 Tongue Base Reduction

In the mid-1990s, before a minimally invasive surgical procedure at the tongue base was available for the first time in the form of RFQ, several surgical concepts existed for the volume reduction of the tongue via an open resection. In those cases where surgery was performed on the tongue base, a temporary tracheotomy often became necessary in order to secure the upper airway. A further problem was posited by painful swallowing impairments, which often lasted 3 or more weeks. As a result, these surgical techniques were always

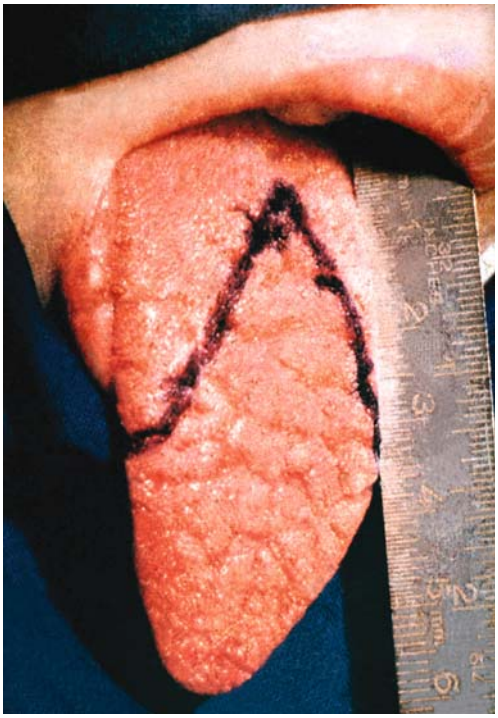


Fig. 7.15. Partial tongue resection in a patient with Down's syndrome

reserved for the severe cases of OSA, which could not be treated with respiratory therapy. Still today, individual cases exist where such an invasive procedure can be indicated; therefore we will describe the essential techniques.

A second group of patients, for which a partial tongue resection in the context of sleep-disordered breathing (SDB) may be indicated, are those with a macroglossia, e.g. in the case of Down's syndrome. For this second group, only individual case studies are found in the literature; therefore, it is not possible to describe numerically the connection between OSA as a result of macroglossia and surgical therapies. Fig. 7.15 shows one of our own cases, with intended resection borders. As a result of the surgery of macroglossia in children with different malformation syndromes, several techniques for partial tongue resection in the anterior and medial tongue third are available [97, 241, 344].

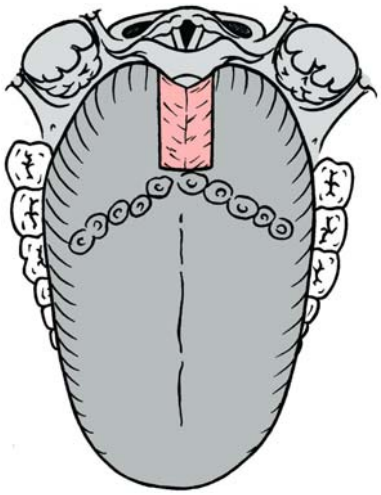


Fig. 7.16. Midline resection of the tongue base

7.3.1 Surgical Technique

In principle, two different basic techniques can be made out, which distinguish themselves by the surgical approach. The first description of a transoral tongue base resection in the medial area stems from Djupesland's group [106, 107]. In the USA, a laser surgery modification with partial epiglottis resection has been developed [158].

Both techniques are performed under general anesthesia in the operating theatre. Before treating the tongue base, a tracheotomy is performed and anesthesia is administered through a laser-safe endotracheal tube. The tongue base is either exposed by use of a Davis mouth gag or a small adult or child No. 3 tongue blade. The smaller blade allows prolapsing of the tongue base into the field [572]. A rigid laser laryngoscope can be used as an alternative. A midline portion, approximately 2–2.5 cm in width, beginning posterior to the circumvallatae papillae and extending towards the vallecula approximately 4–5 cm in length is deeply excised using a CO_2 or a KTP laser (Fig. 7.16). We prefer the CO_2 laser (20 Watts in a continuous wave or superpulse mode). Care is taken to stay in the midline. Bleedings are coagulated with electrocautery.

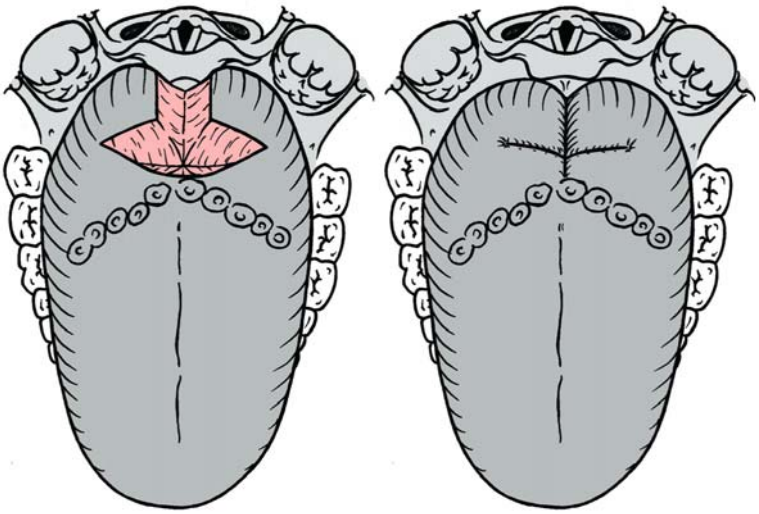


Fig. 7.17. Lingualplasty: additional lateral wedge resection according to Woodson [572]

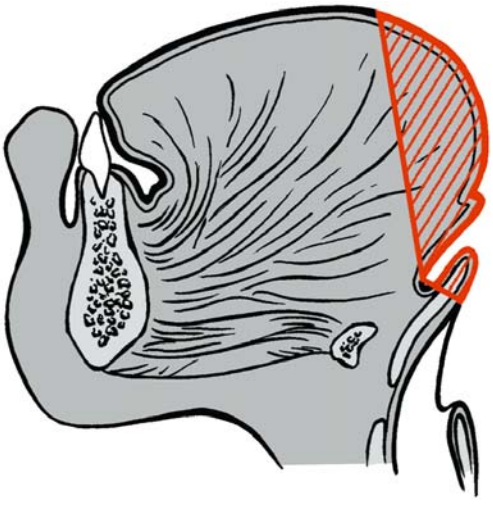


Fig. 7.18. Additional resection of the majority of the free portion of the epiglottis

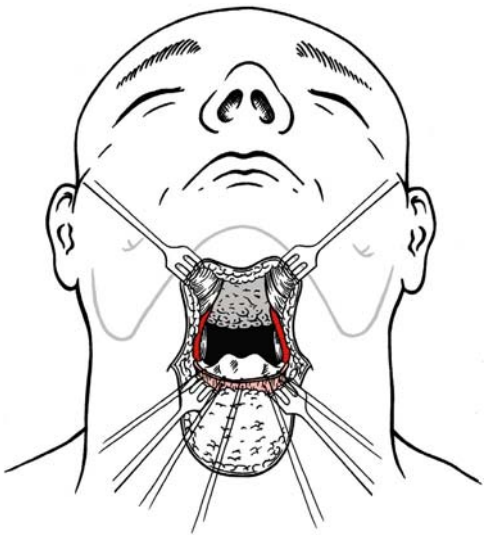


Fig. 7.19. Transcollar tongue base resection according to Chabolle et al. [73]

Woodson and Fujita [572] recommend performing a so-called lingualplasty. Beginning at the anterior corner of excision, an additional centimeter-long wedge of lateral tongue is excised in order to create a defect (Fig. 7.17). It is important that the wedge resection laterally is superficial to ensure preservation of neuromuscular structures.

After removal of the midline tongue, additional lingual tonsils and redundant tissue of the epiglottis are removed via a laser laryngoscope. Finally, the defect is sutured using 2-0 absorbable sutures (i.e., Vicryl, Ethicon). This advances the tongue base (Fig. 7.17). Some authors [335] always resect the majority of the free portion of the epiglottis, others only do

Table 7.3. Efficiency of tongue base reduction for OSA

Author	*n*	Add. proc.	Follow-up (months)	AHI pre	AHI post	Success (%)	EBM grade
Fujita et al. 1991 [158]	12	No	5–15	56.3	37	41.7	Retro
Djupesland et al. 1992 [107]	20	UPPP	8.7	54	31	35	II-3
Woodson and Fujita 1992 [572]	14	No	1.5	50.2	8.6	78.6	II-3
Mickelson and Rosenthal 1997 [335]	12	No	2.4	73.3	46.6	25	II-3
Chabolle et al. 1999 [73]	10	UPPP	3	70	27	80	Retro
All	**68**			**59.4**	**29.6**	**50.0**	**IV**

Add. proc. additional procedures, *retro* retrospective.

so in the case of an omega-shaped epiglottis [572] (Fig. 7.18).

In contrast to the described transoral tongue base reductions, Chabolle and colleagues [73] perform transcollar resections in severe sleep apneics. Again this technique is performed under general anesthesia with the patients intubated transnasally. A skin incision is made in a neck fold parallel to the lower border of the mandible, between the hyoid bone and the mandible. The lower border of the submandibulary glands, the anterior belly of the digastric muscles, the mylohyoid muscle, and the geniohyoid muscles are exposed and sectioned. After identification of the neurovascular bundle, the tongue base is exposed, and the pharynx is entered through the valleculae. Then the authors perform a resection of the tongue base that extends laterally to the lingual-tonsillary folds and anteriorly to the circumvallatae papillae (Fig. 7.19).

The procedure is usually combined with a hyoid suspension. The pharynx is finally closed with 1-0 non-absorbable or absorbable sutures, and the skin is sutured in two layers.

There are a few patients with normal-sized tongue and normal skeletal properties, whose retrolingual airway is solely constricted due to lingual tonsil hypertrophy. This is especially the case in patients who received a tonsillectomy in childhood because of a compensatory increase of lymphatic tissue in Waldeyer's ring. In these cases, a leveling of the lingual tonsil with the CO_2 laser (continuous wave or superpulse mode; 8 Watts) via a laser laryngoscope suggests itself as an adequate procedure. We perform about one or two such procedures per year. In our experience, since the tongue musculature is not damaged, in almost all cases a tracheotomy is not necessary. But in the case of a very prominent finding, one can proceed bilaterally, first leveling one side, then the other.

7.3.2 Effectiveness for OSA

As the partial resection of the tongue is an invasive surgical method with in some cases obligatory temporary tracheotomy, it is not surprising that the literature exclusively provides data for the treatment of severe OSA. These data are compiled in Table 7.3.

It is notable that the results range between 25 % and 80 % success rate (Sher's criteria). Altogether, data for only 68 patients are available; 22 of these data sets stem from retrospective analyses. The data situation can therefore be regarded as provisional, and only allows for a cautious inference. It appears that some patients with severe OSA due to a hypopharyngeal collapse do indeed profit from a partial tongue resection, especially if clinically only a macroglossia is manifest [335]. The extent to which less severely affected sleep apneics achieve better results with regards to the clinical success rate can only be speculated.

Dündar and colleagues have presented a case study of an OSA caused by a massive enlargement of the lingual tonsil [116]. They removed the superfluous lymphatic tissue with a CO_2 laser. The apnea index was 45.5 preoperatively and could be reduced to 2.5, 2 months postoperatively.

7.3.3 Postoperative Care and Complications

Because of the potential inflammation and postoperative bleeding, partial tongue resections require special postoperative observation and in most cases a tracheotomy. We observe our patients during the first postoperative night in an intensive care unit.

As a result of the acute pain in swallowing, effective analgesic management is necessary. Usually it is not sufficient to administer peripherally effective substances. As the patients are also incapable of swallowing tablets, we administer alternatively tramadol and metronidazol drops as base therapy. As the subjective pain is very different interindividually, however, an individual solution is warranted.

A gastric probe is placed intraoperatively. As soon as the patient is able to swallow, we switch to a porridge-based diet. Only very rarely is nourishment via the stomach probe necessary for more than 3 days.

Up to now, no severe complications have been reported after transoral tongue resections, with the vast majority of patients receiving a tracheotomy to secure the upper airway within the first postoperative days. Woodson and Fujita report about one case of subcutaneous emphysema related to tracheotomy. Using the transcollar approach, Chabolle and colleagues [73] described five early and three late abscesses (50 %) in their series of patients, all requiring surgical intervention.

Minor bleeding (8–25 %), prolonged odynophagia for up to 3 weeks (5–8 %), tongue edema (5 %), and short-term changes in taste sensation (8–56 %) were reported as minor complications [106, 158, 335, 572]. According to our experience in this field, patients develop prolonged odynophagia even more frequently.

In the case of an isolated resection of the lingual tonsil, neither we nor the literature has reported any severe postoperative bleeding or inflammation. Usually, a tracheotomy is not necessary. But we do observe the patients during the first postoperative night in the intensive care unit. The symptomatic pain configuration is relatively less salient. Furthermore, we have as yet not observed any permanent other complications, such as long-term changes in taste sensation.

7.3.4 Indications and Contraindications

Because of the described invasiveness and postoperative morbidity of partial tongue base resection, this surgical procedure is reserved for severe cases of OSA that cannot be sufficiently treated with nasal respiration therapy. In principle, we do not perform a partial tongue base resection in cases where the patient has not previously received respiration therapy. As most cases call for a tracheotomy, this procedure has been increasingly relegated to the background in our center. This is due to the fact that with hyoid suspension, RFQ surgery, and mandibular procedures in the case of skeletal anomalies, we have less morbidizing alternatives at our disposal, which show at least a comparable efficacy.

Therefore we consider an indication for partial tongue base resection only as ultima ratio when conservative and surgical therapy options have been exhausted, and when a tracheotomy must be avoided under all circumstances.

The situation is different in regards to the mere leveling of the lingual tonsil. This procedure is less painful, and needs no tracheotomy. For mild OSA, this procedure competes somewhat with RFQ therapy at the tongue base; due to the latter's superiority in respect to postoperative morbidity, the former should be used only in the case of a massive enlargement of the lingual tonsil or for moderate to severe OSA.

7.4 Tongue Suspension

In the absence of other anatomical abnormalities, such as skeletal malformations or tongue base tumors, snoring can be caused by a falling back of the tongue during sleep. During the daytime, this phenomenon is prevented by the voluntary motor system. In 1992, based on this observation, a glossopexy was suggested in which the tongue base is fixated at the chin with the help of a tissue sling in order to prevent a collapse towards posterior as a result of the physiological muscle relaxation during sleep [134].

7.4.1 Surgical Technique

In the original technique, a glossopexy is combined with a resection of the tongue base [134]. For glossopexy the authors use homologous fascia lata. The fascia lata is applied as a sling in the body of the tongue; the ends are passed through two holes in the mandible and sutured to each other after maximal anterior suspension of the tongue (Fig. 7.20).

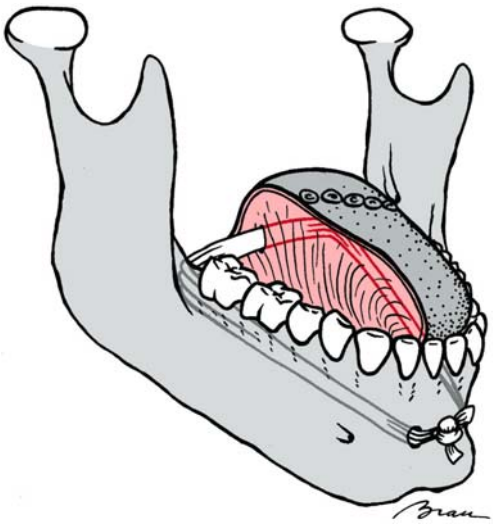


Fig. 7.20. Original technique of glossopexy with fascia lata modified after Faye-Lund et al. [134]

This technique has not become established because of the considerable amount of preparation and the necessity of producing fascia lata. Yet this method has gained renewed currency with the introduction of the Repose system (Influ-ENT, USA), characterized as minimally invasive [104]. It is comprised of a surgical kit that includes, apart from surgical instruments, a non-resorbable suspension suture, which is passed through the tongue base and then fixated with the help of a screw at the inner side of the chin. In contrast to RFQ therapy of the tongue base, the Repose system requires general anesthesia; we therefore consider it to be minimally invasive only to a certain degree.

The technique proceeds along the following lines [571]. First the included inserter is placed in the midline floor of the mouth posterior to the orifice of Wharton`s duct. The screw is placed firmly against the mandible, perpendicular to the lingual cortex, and is then inserted. A suture passer is passed through the stab wound, and a doubled-looped suture is passed through the tongue lateral to the midline into the hypopharynx. The point of insertion is approximately 1 cm from midline and 1 cm below the foramen cecum. A single strand of the suspension suture is then passed opposite the double loop with the suture passer. A curved Mayo needle is used to pass the suspension suture across the base of the tongue. The suspension suture is then passed into the looped suture strand and pulled anterior, finishing all three passes. Finally the suture is tied; care is taken to avoid cutting the suture on the incisor teeth (Fig. 7.21). Tightness of the suspension is determined by assessing with the fingers the tightness at the tongue base where an indentation can be felt.

The Repose technique can also be easily combined with other surgical techniques. Thomas et al. [514] report good results of a combination with an UPPP in the context of multi-level surgery. Fibbi and colleagues [138] combine the Repose tongue sling with a genioglossus advancement in the case of clinically relevant tongue base constriction.

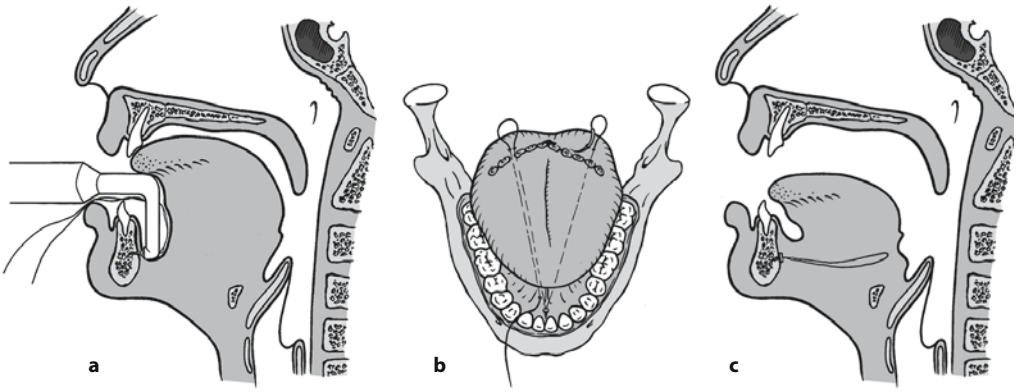


Fig. 7.21 a–c. Tongue suspension suture with the Repose system. **a** Insertion of bone screw with Repose kit. **b** run of sutures through the tongue. **c** Situation after surgery

7.4.2 Effectiveness for Simple Snoring

Until now, the technique has been employed in the treatment of both OSA and simple snoring. Data for primary snoring stem from two multi-center studies [571, 580], which apparently to some extent contain the same patient data; therefore, we will only discuss the more recent study, which includes a larger number of individuals.

Woodson [580] treated 14 primary snorers with the Repose system. The AHI was 9.2 postoperatively, and rose non-significantly to 15.6, 2 months after surgery. The other respiratory polysomnography parameters also showed no significant changes. Subjective outcome measures included Epworth Sleepiness Scale (ESS), Functional Outcomes of Sleep (FOSQ), the quality-of-life questionnaire MO-SF36, and a ten-point visual analog and behavior-based scale of snoring and sleepiness. Two months after surgery there were statistically significant improvements in all parameters except in respect to the visual analog scale for sleepiness.

According to this study, the Repose system is successful in the therapy of snoring in the case of clinically attested tongue base constriction. As further studies, and especially comparisons, e.g., with RFQ surgery at the tongue base, are not available, it is currently possible only to speak of a preliminary trend or informed opinion.

7.4.3 Effectiveness for OSA

More study data are available for OSA; they are summarized in Table 7.4. The studies by Woodson partially comprise identical patient data; therefore, only the more recent publication was used for the calculation of the mean values.

The mean values for pre- and postoperative AHI as well as for the surgical success rate after Sher given in Table 7.4 are almost identical to those after isolated RFQ therapy at the tongue base (Sect. 7.1). Both techniques are used for the same indication, namely clinically evident obstruction at the tongue base level, and apparently both techniques are comparable in regards to their efficacy.

Thomas et al. [514] have compared the Repose tongue sling and the genioglossus advancement respectively with an UPPP in a randomized controlled study; they found slight advantages for the Repose procedure (57 % success rate with Repose vs. 50 % with genioglossus advancement). The subjective results in regards to daytime sleepiness and snoring were comparable.

Table 7.4. Efficiency of tongue suspension for OSA

Author	*n*	Follow-up (months)	AHI pre	AHI post	Success rate (%)	EBM grade
Woodson et al. 2000[a] [571]	9	2	33.2	17.9	33.3	II-3
DeRowe et al. 2000 [104]	14	2	32.6	16.2	28.6	II-3
Woodson et al. 2001[a] [580]	14	2	35.4	24.5	28.6	II-3
Sorrenti et al. 2003 [484]	15	4–6	44.5	24.2	40	Retro
All[a]	**52**	**2–6**	**37.7**	**21.7**	**32.6**	**IV**

[a] Since these studies in part rely on the same patient data, only the more recent study has been used in the calculation of the mean values.

7.4.4 Postoperative Care and Complications

It is generally recommended to treat the patients perioperatively with broad-spectrum antibiosis. In our center we use 2 g cephazolin as a single shot and steroids (dexamethasone 2×10 mg and prednisolone 40–60 mg for 3–5 days after surgery); non-steroidal anti-inflammatory medication is administered by some authors [571]. Initially, swallowing disorders need to be taken into account; but in only a marginal number of cases do they call for a special diet. After a maximum of 3 days all patients were again able to swallow in a normal manner [138].

On a visual analog scale with the end points 0 = no pain and 10 = maximal pain, the postoperative pain is given as 7.6 on the first postoperative day, and as 1.7 on the 14th day after surgery [571]. From our own experience we are able to report that in the case of one patient the suspension had to be removed because of persisting pain. Woodson and colleagues did not encounter such cases in their series [580]. Fibbi and colleagues [138] report the case of a prolonged odynophagia lasting for 3 weeks.

Postoperative complications include delayed floor-of-mouth sialadenitis (17.4%), dehydration requiring intravenous rehydration several days after surgery (4.3%), and delayed gastrointestinal bleeding requiring hospitalization (4.3%) [571, 580]. All complications resolved without sequelae. During the first weeks, temporary swallowing and speech impediments are regularly reported.

In our own patient pool we had two cases in which the suspension suture spontaneously tore apart. The following night snoring and apneas recurred. Furthermore, we have the impression that the thread slowly cuts towards anterior through the tongue. This does not cause severe annoyance, but may over time lead to a reduction of the therapy effect.

7.4.5 Indications and Contraindications

Basically, the Repose tongue base suspension is potentially helpful in the therapy of airway obstruction at the tongue base. For OSA, the results are comparable with RFQ therapy at the tongue base. Apart from the costs, we believe there are two fundamental drawbacks to this method; therefore, we currently no longer use this technique.

On the one hand, general anesthesia is necessary in order to place the suspension suture. We therefore do not agree with the estimation of the provider, who characterizes the procedure as minimally invasive. In our opinion, it should be possible to perform a minimally invasive surgical procedure for the therapy of SDB on an outpatient basis and under local anesthesia. Here RFQ has clear advantages. The second, to our mind even more important aspect is the fact that it is very difficult to achieve the correct tightness.

The aim of the suspension suture is to prevent airway collapse during sleep without impeding the function of the tongue during the day, especially in respect to speaking and swallowing. This technique consists in a tight-rope walk between sufficient effectiveness in regards to the severity of the SDB on the one hand, and on the other hand the unhindered functioning of the tongue musculature during the day. The concrete disadvantage of the method lies in the lack of a postoperative option to readjust the tightness. For this readjusting a second general anesthesia is necessary.

If the system were to be developed further so that a readjustment were possible under local anesthesia, the Repose suspension suture could certainly enrich the current therapy spectrum. In its present version we see no indication for the Repose technique in our center.

Maxillofacial Surgeries

8

8.1 Genioglossus Advancement

In 1986, inferior sagittal osteotomy of the mandible was used for the first time in the treatment of obstructive sleep apnea (OSA) by the Stanford research group [419]. They used this technique in combination with a hyoid suspension (Sect. 7.2) in patients with severe OSA. Since then the so-called mandibular osteotomy with genioglossus advancement (MO) has become part of several surgical protocols. Interestingly, the technique has until now only been used in combination with other techniques and not as an isolated procedure for treating OSA.

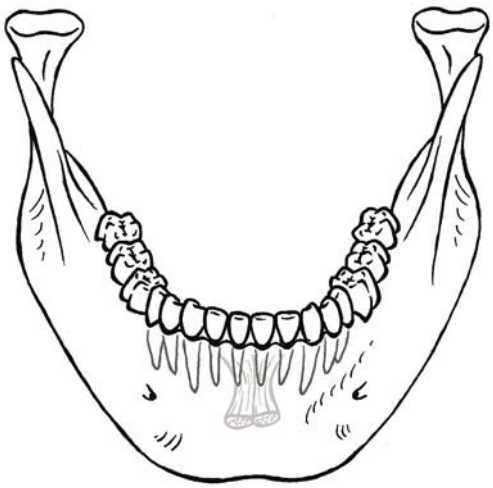


Fig. 8.1. Origin of the genioglossus muscle at the genial tubercle on the inner cortex of the mandible

8.1.1 Surgical Technique

The genioglossus muscle has its origin at the oral side of the mandible. The surgical principle consists in mobilizing the whole area of this muscle insertion by incorporating the genial tubercle on the inner cortex via an osteotomy of the chin, and then moving it towards anterior (Fig. 8.1). In this new position the bone segment is fixated osteosynthetically, either with a 24-gauge stainless steel wire or a screw. External cortex and cancellous bone are removed in order to prevent a cosmetically disagreeable protrusion of the chin.

The surgical approach is completely intraoral. The mucosal incision is made approximately 10–15 mm below the mucogingival junction and a subperiostal flap is developed to expose the symphysis. Exposure and identification of the mental nerves are unnecessary. In order to reduce the extent of the dissection, entailing a reduction of potential complications, Riley et al. have twice revised their technique of inferior sagittal osteotomy. Figure 8.2 shows the most recent technique [292], which we have adopted in our center. Miller et al. [337] recently recommended the use of the Genial Bone Advancement Trephine system (Stryker Leibinger Corp., Kalamazoo, USA) and reported good results.

A rectangular osteotomy encompassing the estimated location of the genial tubercle/genioglossus muscle complex is performed under copious irrigation. The superior horizontal bone is cut approximately 5 mm below the root apices to prevent incisor root injury and the inferior horizontal bone is cut approximately 10 mm above the inferior border (Fig. 8.2). Occasionally, the superior horizontal bone cut has to be made 1–2 mm above

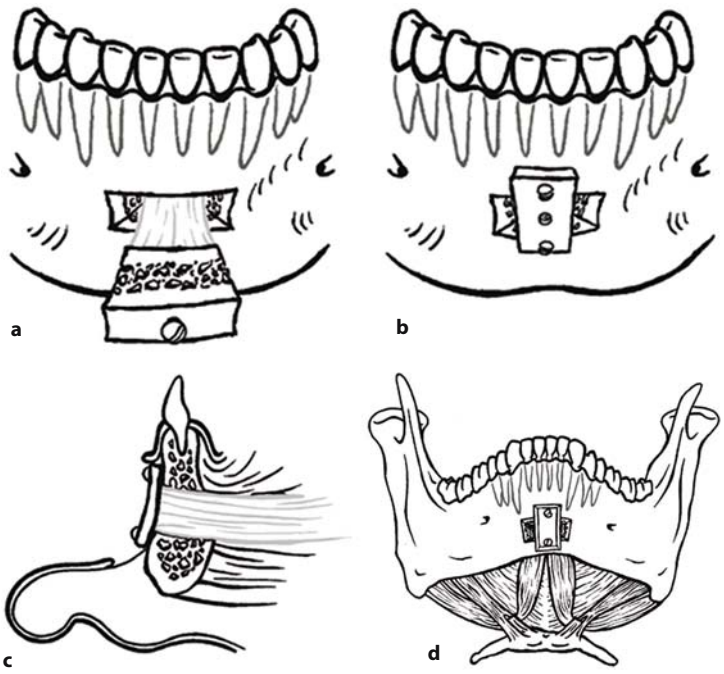


Fig. 8.2 a–d. Inferior sagittal osteotomy of the mandible. **a** Bony segment pulled forward after rectangular osteotomy. **b–d** Postoperative situation

the incisor root apices because of the vertical position of the genial tubercle/genioglossus muscle complex [338]. Due to the elongated canine tooth roots that are often present, the vertical bone cuts are made just medial to the canine roots to avoid root injury. Before completing the osteotomy, a titanium screw is placed in the outer cortex to control and manipulate the bone flap. The amount of advancement depends on the thickness of the mandible. The bone flap is advanced and rotated about 30–45°, just sufficient to create bone overlap for a fixation screw.

Li et al. [294] control bleeding with electrocautery and a hemostatic agent such as Gelfoam (Pharmacia and Upjohn Co, Kalamazoo, MI, USA). Bone wax is not recommended due to extrusion problems. These authors do not use surgical drains. In their hands the procedure is routinely completed within 30–40 minutes.

In treating the hypopharyngeal site of obstruction, most authors combine the MO with a hyoid suspension [354, 405, 421]. Fibbi and colleagues [138] recommend the combination of MO with a tongue suspension suture (Repose) (Sect. 7.4). Furthermore, the MO is part of some multi-level surgery protocols as discussed in Chap. 10.

8.1.2 Effectiveness for OSA

The MO is a therapy for OSA, but not for primary snoring. As mentioned above, we have not been able to find any studies using polysomnographies when investigating the effectiveness of MO as an isolated procedure. Therefore, we have decided to summarize in Table 8.1 only the current data of studies performing combined procedures for tongue base obstruction.

With one exception, these are all retrospective data; in addition, they are all short-term data, so an efficiency verification according to the principles of evidence-based medicine (EBM) is not yet available. Yet the patient data currently available from 80 individuals suggest that the procedure is efficient.

Table 8.1. Effectiveness of MO for OSA

Author	*n*	Adjunctive procedure	Follow-up (months)	AHI pre	AHI post	Success rate (%)	EBM grade
Riley et al. 1986 [419]	6	Hyoid susp.	3	73.6	21.0	80.0	Retro
Riley et al. 1989 [418]	55	Hyoid susp., UPPP (*n*=42)	3	58.0	23.2	67.3	Retro
Riley et al. 1994 [421]	15	Hyoid susp.	3	44.7	12.8	53.3	II-3
Fibbi et al. 2002 [138]	4	Repose	6	22	No data	75.0	Retro
All	**80**		**3–6**	**54.9**	**20.0**	**66.0**	**V**

Retro retrospective.

In this context, the study by Neruntarat [354], who compares short- and long-term results, is of interest. All patients had received an uvulopalatal flap, a hyoid suspension and an MO in the framework of a multi-level surgery concept. In his retrospective analysis of 46 patients, a therapy success (Sher's criteria) of 78.3 % after 6 months and of 65.2 % after on average 39 months was found. Obviously this points to a decrease of the therapy effect over time. Unfortunately, it cannot be deduced which partial effect can be ascribed to the MO.

8.1.3 Postoperative Care and Complications

The MO is performed under general anesthesia on an inpatient basis. In cases where no further procedures involving the upper airway have been performed, a hospital stay of about 2 or 3 days is sufficient. We administer an intraoperative single-shot antibiosis with e.g. 1×2 g cephazoline. The administration of corticoids is not necessary.

As MO is used in severe OSA, some authors generally protect the upper airway with the routine use of nasal continuous positive airway pressure (CPAP) during the postoperative phase. We observe our patients in the recovery room for some hours and apply CPAP only in cases that show repeated apneas. If a CPAP therapy is necessary, a pressure of 10 cm H_2O is used. Observation in an intensive care unit is usually not necessary after MO.

As a minor complication, wound dehiscence has been observed intraorally. It usually heals spontaneously without sequela. Furthermore, transient numbness of the lower lip and lower central incisors for several weeks [337], dysphagia for up to 1 week, and self-limiting aspiration have been reported [354]. In general, tooth root injuries, mental nerve injuries, and mandibular fracture have been reported only very rarely as potential complications [292]. In our own group of patients, one subject developed a severe wound infection several days after surgery, requiring surgical intervention. Similar cases have been reported by other authors as well [281, 418]. Speech problems or dysphagia have neither been reported nor have they been seen in our own patients.

8.1.4 Indications and Contraindications

Like hyoid suspension, MO is an invasive surgical method with potential complications. Radiofrequency (RFQ) surgery exists for the tongue base, as a minimally invasive alternative. We therefore see no primary indication for the MO in patients with primary snoring, upper airway resistance syndrome, and mild OSA.

In the case of moderate and severe sleep apnea with tongue base obstruction, the MO is a surgical treatment option. In our center we have completely ceased to perform this technique. We had better experiences with

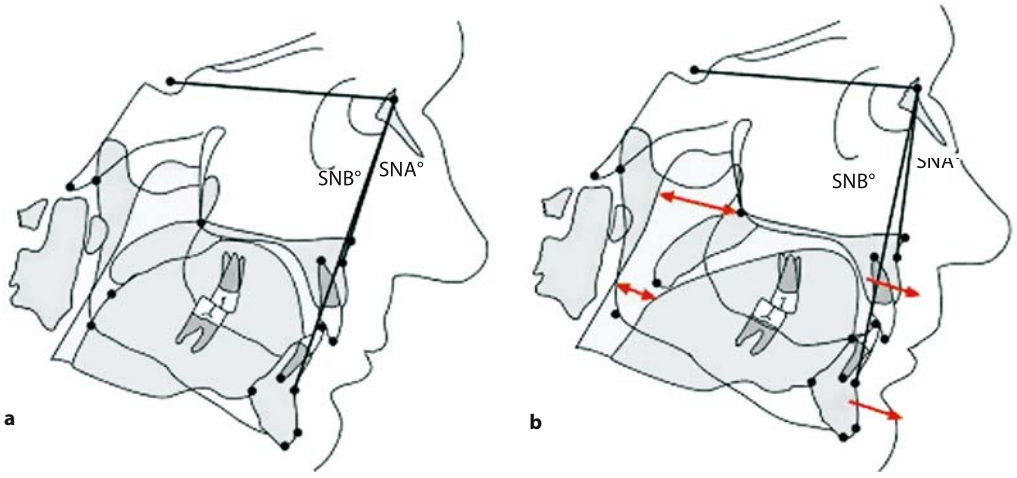


Fig. 8.3. **a** Preoperative situation. Retropositioned maxilla and mandible with narrow pharyngeal airway space. **b** After MMA the widened pharynx, an anteriorly positioned tongue and soft palate can be seen. The angles SNA° and SNB° determine the sagittal increase in space

hyoid suspension. The latter can be performed more rapidly (15 vs 35 min), is the only procedure that can be performed under local anesthesia, uses less osteosynthesis material, and is at least in our hands less prone to complications. Nevertheless, in the hands of an experienced surgeon, MO may be a viable alternative in the treatment of moderate to severe OSA.

8.2 Maxillomandibular Advancement

Maxillofacial surgery for the correction of malposition of the upper and lower jaw was first suggested by Kuo et al. [271] as an alternative to tracheotomy in the treatment of OSA. Today, maxillomandibular advancement (MMA) can be seen as the most successful surgical procedure after tracheotomy. On the other side, it must be said that it is an invasive surgical technique with corresponding morbidity and complication rates. Therefore, it is used as primary therapy in patients with relevant deformities of the face and the skull in most instances. For sleep apneics without a jaw anomaly, the Stanford two-phase concept has become the standard treatment. In phase 1 it offers a multi-level surgery of the soft palate and tongue base, and if necessary of the nose in accordance with Chap. 10; only in the case of therapy failure does it offer MMA as a secondary procedure.

The rationale of MMA is the simultaneous expansion of the naso-, oro-, and hypopharyngeal airways as soft palate, tongue, and lateral pharyngeal walls are advanced or stretched (Fig. 8.3).

8.2.1 Surgical Technique

Although MMA is a routine procedure in maxillofacial surgery, it is technically demanding and performed by a team of surgeons in a hospital environment under general anesthesia [401].

8.2.1.1 Surgery on the Upper Jaw

In order to advance the upper jaw it has to be freed from the upper parts of the midface and the cranial base, moved forwards (and if necessary simultaneously up- or downwards),

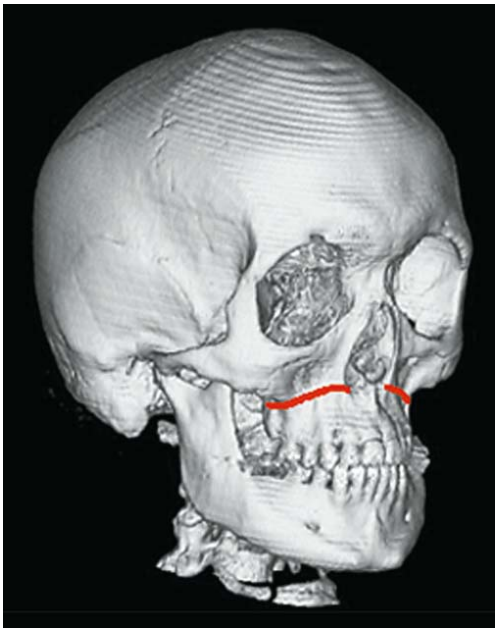


Fig. 8.4. Le Fort I osteotomy (*red line*). The nasal septum and the pterygomaxillary junction are detached with a chisel, the paranasal and zygomatic buttresses are cut with a reciprocating saw

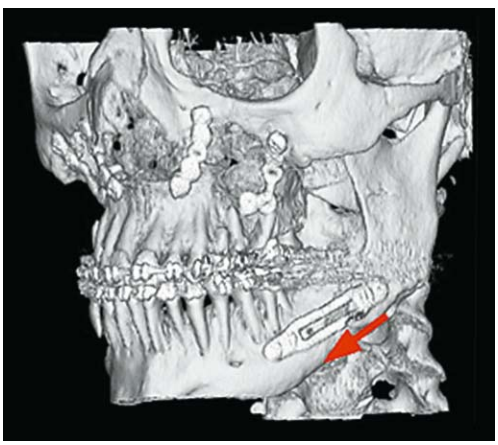


Fig. 8.5. Osteosynthesis technique using titanium miniplates in orthognathic surgery. Maxillary advancement in the Le Fort I level stabilized by four miniplates on the paranasal and zygomatic buttresses. Simultaneous mandibular advancement (*red arrow*) utilizing adjustable split-fix miniplates (all Synthes, Paoli, PA, USA)

and stabilized in the new position. The usual method consists in a transverse osteotomy of the maxilla (so-called Le Fort I osteotomy) [361]. The osteotomy lines (Fig. 8.4) more or less resemble the fracture lines analogous to the Le Fort I fracture.

While in the 1970s and 1980s, wire osteosyntheses, zygomatico-maxillary suspensions, and intermaxillary fixation (for approximately 6 weeks) were used, now miniplate osteosynthesis has become the standard procedure to hold the maxilla in its new position until bony union has occurred (Fig. 8.5). The extent of the maxillary advancement is determined individually depending on the amount judged necessary for relief of OSA, the new position of the mandible and the nutrition status during operation, as excessive soft tissue stretching in the soft palate region may compromise vascularity. In most studies 10 mm are suggested, as some relapse (backward movement of the maxilla) has to be expected.

In case of stabilization with miniplates, intermaxillary fixation is not necessary in most instances; this is especially of relevance in the immediate postoperative phase in OSA patients. Furthermore, the amount of relapse will be minimized when using miniplates.

8.2.1.2 Surgery on the Lower Jaw

In principle, the advancement of the lower jaw can be performed almost anywhere in the mandible, ranging from an osteotomy in the mandibular body to the ascending ramus [397, 417]. The most common method is the bilateral sagittal split osteotomy (BSSO) according to Obwegeser Dal-Pont with lateral corticotomy anterior to the mandibular angle [417] (Fig. 8.6).

In this procedure, the lingual bone separation proceeds horizontally between lingula and incisura semilunaris. The osteotomy line on the buccal side proceeds vertically from the molar region to the inferior border. The sagittal split is then performed using a chisel (Fig. 8.6). It is crucial to take care that the inferior alveolar nerve re-

mains lingually of the chisel in order to prevent lesions. After aligning the mandible to a correct occlusion, osteosynthesis is performed. Here wire sutures, or preferably position screws or miniplates can be used (Fig. 8.6).

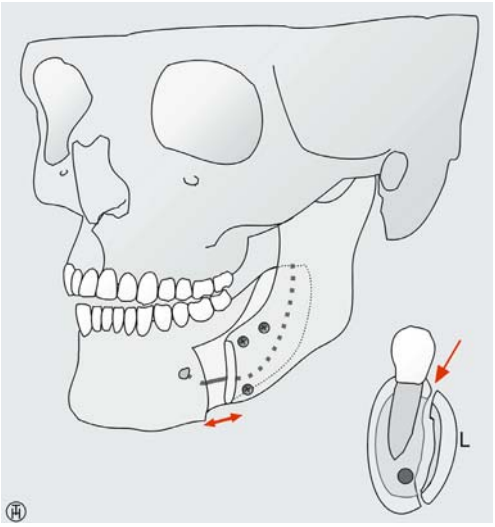


Fig. 8.6. Sagittal osteotomy of the mandible with lateral corticotomy anterior to the mandibular angle according to Obwegeser [361]. *L* lateral

In all cases of MMA surgery, some skeletal relapse has to be accepted. Factors determining the amount of relapse include osteosynthesis technique and the amount of advancement. In the maxilla and mandible 10–30 % can be reckoned with. Thus in a 10 mm advancement a net forward movement of 7–9 mm will persist, which is judged sufficient for OSA relief.

8.2.2 Effectiveness of Maxillomandibular Advancement for OSA

Maxillomandibular advancement can be considered the most successful surgical procedure for the treatment of OSA after tracheotomy with respect to treatment outcome. Several controlled studies have demonstrated a comparable reduction of the apnea hypopnea index (AHI) after MMA compared with CPAP therapy [205, 402, 420] (Table 8.2). Furthermore, an equivalent optimization of the sleep architecture compared with CPAP has been reported after MMA [87].

The successful results seem to be maintained for long follow-up periods. The Stanford studies report a short-term success rate

Table 8.2. Maxillomandibular advancement for OSA.

Author	*n*	Adjunctive procedure	Follow-up (months)	AHI pre	AHI post	Success rate (%)	EBM grade
Waite et al. 1989 [545]	23	UPPP, MO, MLP	1.5	62.8	15.2	65.2	II-3
Riley et al. 1990 [420]	30	HS	6	72.0	8.8	96.7	II-I
Hochban et al. 1997 [205]	38		2	44.4	2.5	97.4	II-I
Prinsell 1999 [402]	50		5.2	59.2	4.7	100	II-I
Li et al. 2000 [287]	40		50.7	69.6	8.9	90	II-3
Bettega et al. 2000 [35]	20		6	59.3	11.1	75	II-3
Goh et al. 2003 [165]	11		7.7	70.7	11.4	81.8	II-3
Dattilo and Drooger 2004 [99]	15		1.5	76.2	12.6	86.7	II-3
All	**227**		**12.4**	**62.3**	**8.1**	**89.9**	**III**

HS hyoid suspension, *MO* mandibular osteotomy with genioglossus advancement, *MLP* midline partial glossectomy.

of 97% after 6 months [420], and a success rate of 90% after 51 months [287].

Furthermore, Li and co-workers [284] were able to show by way of radiocephalometry and nasopharyngoscopic examinations that pharyngeal depth increased by 48% of the amount of the maxillary advancement and that pharyngeal length increased by 53% of the maxillary advancement in five patients after MMA.

8.2.3 Postoperative Care and Complications

For patients suffering from severe OSA, it is recommended to start nasal CPAP at least 1 month before surgery to stabilize the cardiovascular system and reduce upper airway edema [35].

After surgery, extubation should be performed by the operating room staff with the patient fully awake. MMA patients require careful monitoring, including continuous pulse oximetry, in an intensive care environment [401]. Minor desaturations do not call for CPAP therapy; yet frequent desaturations or apneas require CPAP ventilation therapy. When feasible, non-opioid drugs are used for postoperative analgesia (see Chap. 13).

Nutritional counselling is recommended, emphasizing clear liquids during the first week, followed by a soft diet for 2 months. Today, most authors do not favor prolonged intermaxillary fixation and use modern titanium plate systems for osteosynthesis. The usual hospital stay for MMA is between 2 days [401, 420] and 1 week [35]. On average, patients return to their normal activities after 2–4 weeks. Patients should be asked to continue nasal CPAP until a follow-up polysomnography has confirmed the surgical success. Nasal decongestants should be administered for the first postoperative week as maxillary osteotomies lead to tearing of the nasal mucosa and edema with impaired nasal respiration.

Temporomandibular joint dysfunction is a potential complication after maxillomandibular surgery. Kerstens et al. [256] reported that 11.5% of the 480 patients who underwent surgery for dentofacial deformity developed temporomandibular joint symptoms after surgery. Similar data were given by White and Dilwick [563] (7.9%). However, temporomandibular joint problems can often be found in patients suffering from dentofacial deformities and the vast majority of the patients presenting with preoperative temporomandibular joint symptoms reported improvement after surgery [291]. Here two patient groups have to be distinguished: first, patients with normal occlusion who undergo MMA for OSA treatment only; and second, patients with marked maxillary/mandibular retrusion where MMA is intended for relief of OSA and to improve the occlusal relationship.

Further complications are temporary mild to moderate hypopharyngeal edema (20%) and hypopharyngeal hematoma (5.7%), partly obstructing the airway [293]. In large maxillary advancements, patients frequently develop velopharyngeal incompetence of a temporary nature. Predominantly velopharyngeal incompetence is a phonetic deficit without liquid regurgitation. But there are also singular prolonged cases of velopharyngeal incompetence with regurgitation up to a maximum of 12 months [294].

Hypesthesia of the lower lip is a typical complication of BSSO (anesthesia <1%; hypesthesia <5%) [35, 420]. A high percentage of resolution within the first months after surgery is reported. Recovery of full mandibular function (maximum mouth opening; bite force) will take some time and will not be gained in all instances. Occlusion disturbances are a further frequent complication in up to 50% of the cases, requiring minor occlusal equilibration by way of orthodontics or prosthodontics [545].

Rare complications include local infection, perforation of the palate, and maxillary pseudarthrosis [35]. Furthermore, severe complications such as tooth loss, facial nerve paralysis, osteomyelitis, damage of the inferior alveolar nerve, and amaurosis have been reported.

The incidence rate for complications increases with higher patient age, especially after 45 years [35, 545].

Furthermore, the esthetic effects of MMA should be pointed out. These should especially be taken into consideration if the patient presents no jaw malpositions preoperatively, but is solely receiving surgery for the treatment of OSA. As a consequence, Goh and Lim [165] have recently suggested a modified procedure, which includes partial resections of the upper and lower jaw in order to counteract the esthetically disagreeable advancement of the jaws. It is debatable in how far these additional osteotomies can be justified with respect to a purely esthetic indication, as complication rates should be expected to be significantly higher.

8.2.4 Indications and Contraindications

In addition to the sleep lab diagnosis, radiocephalometry is necessary in order to determine the indication and amount of MMA. In general, the parameters given in Fig. 8.7 are analyzed. If the SNA angle [angle measurement from sella (S) to nasion (N) to subspinale (A)] is at least 82°, and the SNB angle [angle measurement from sella (S) to nasion (N) to supramentale (B)] is at least 80°, a maxillomandibular deficiency can be ruled out.

While in the case of a maxillomandibular deficiency, MMA may already be used as a primary therapy of OSA, the indication is more difficult in the case of a regularly shaped facial skull. Most authors, including ourselves, see the indication for surgery only in those cases in which respiratory therapy has either been abandoned or refused, or is not possible. In principle, an obstruction in both the retropalatal and the retrolingual segment is demanded as a precondition for the MMA. A posterior airway space (PAS) <11 mm is generally considered as a positive selection criterion for MMA. Hochban et al. [205] determine the PAS at the level of the mandibular plane, whereas Prinsell [401] suggests measuring the PAS at its narrowest place instead of at strictly defined anatomical landmarks.

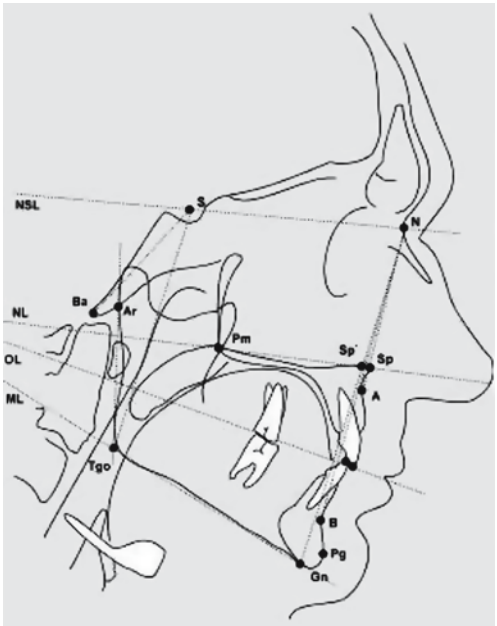


Fig. 8.7. Basic radiocephalometric landmarks for sagittal and vertical maxillomandibular relationships. *S* sella, *N* nasion, *Ba* basion, *A* subspinale, *B* supramentale, *Pg* pogonion, *Gn* gnathion, *Tgo* tangent point gonion, *Pm* pterygomaxillare, *Ar* articulare, *Sp* anterior nasal spine, *NSL* nasion-sella line, *NL* nasal line, *OL* occlusal line, *ML* mandibular line. Special OSA parameters are not included

It is also being debated whether, after the failure of a respiratory therapy, less morbidizing and aggressive surgical procedures should be performed initially, or whether MMA should be considered primarily in the case of normal maxillofacial dimensions, too. The opinions on this are quite varied. Hochban et al. posit the indication very generously. One argument is that soft palate surgery prior to MMA may increase the chance of postoperative velopharyngeal incompetence. Most other study groups [35, 99, 420], in accordance with the Stanford two-phase model, posit the MMA indication only secondarily, namely after failed uvulopalatopharyngoplasty (UPPP) with

tonsillectomy as well as hyoid suspension and RFQ of the tongue. Other groups [545] perform MMA in the first place and combine the operation with pharyngeal surgery. We believe that in each study group an interdisciplinary dialogue should take place between the otorhinolaryngologist and the maxillofacial surgeon in order to determine a constructive therapy concept.

8.3 Distraction Osteogenesis

Since its introduction into maxillofacial surgery by McCarthy et al. in 1992 [323], distraction osteogenesis (DOG) has become an accepted procedure in the treatment of severe maxillomandibular deficiency in syndromic and non-syndromic patients. As a grossly retropositioned mandible or midface causes a narrow pharyngeal airway, OSA is often found in these cases. Thus DOG will be the procedure of choice where conventional MMA cannot be performed or is expected to lead to unstable results. This is especially true for neonates and young children, in whom MMA is rarely performed [29].

In DOG, an osteotomy of the mandible or midface without advancement is followed by a short latency period of 4 days. Then the two or more bony segments are slowly moved apart (in most instances at 1 mm/day) using some kind of distraction device. Thus the unmineralized tissue filling the osteotomy gap is slowly stretched until – after cessation of distraction – it will turn into bone during the 4–10 week consolidation period. The device is then removed and orthodontic appliances are used to act against relapse and help to achieve proper occlusion.

8.3.1 Mandibular Distraction Osteogenesis

The first devices designed for mandibular distraction were extraoral distractors, which are fixed to the bone by percutaneous pins. Initially, unidirectional devices prevailed (i.e., distraction in only one direction); now most companies offer multidirectional distractors, which allow correction of the distraction vector during treatment (Fig. 8.8).

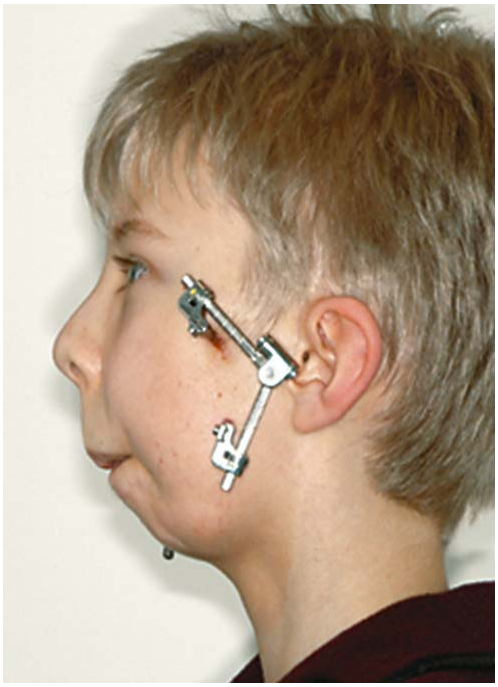


Fig. 8.8. Thirteen-year-old boy suffering from mandibular hypoplasia and retrusion caused by trauma in infancy. Severe pharyngeal narrowing and OSA. Distraction of the mandible with multidirectional distractors on both sides (Multiguide, Stryker-Leibinger Co, Kalamazoo, MI, USA)

Extraoral devices are mainly used in syndromic neonates and infants, where placement of internal distractors is difficult (e.g., Pierre-Robin sequence, Nager syndrome, Stickler syndrome, velocardiofacial syndrome, Pfeiffer syndrome, Treacher-Collins syndrome).

In less complicated cases, intraoral unidirectional distractors might be used (Fig. 8.9). These are inconspicuous and avoid facial scars. Most companies offer internal distractors with a 15–25 mm distraction range; thus for larger advancements extraoral devices are still preferred.

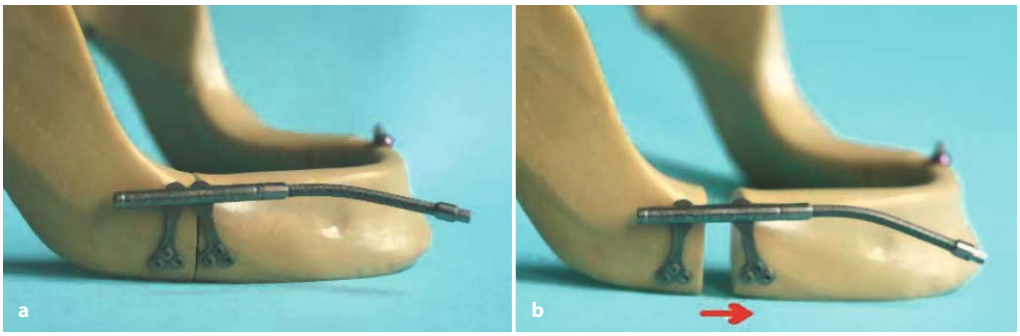


Fig. 8.9. Internal mandibular distractor: **a** during activation (here maximum 15 mm). The flexible activation rod lies in the buccal sulcus (Zurich mandibular distractor, Martin Co., Tuttlingen, Germany). Note the transverse osteotomy in contrast to the sagittal split in MMA. Fixation of the device is achieved with 1.5 mm diameter monocortical microscrews **b** situation after osteotomy and device placement.

8.3.1.1 Surgical Technique

Distraction osteogenesis is a technically complicated procedure performed under general anesthesia after nasotracheal intubation in a clinical setting (in adults, local anesthesia is possible but rarely used). Perioperative antibiotics are preferable.

In neonates and children a lateral corticotomy in the area of the mandibular angle or ascending ramus is performed via an intraoral buccal sulcus incision. The upper and inferior borders are cut with burs or reciprocating saws. The pins are then fixed bicortically via stab incisions and a greenstick full fracture is done with a chisel. Finally, the distractor is attached to the pins and the mobility of the segments is tested by distractor activation.

Regarding internal devices, the operation starts with a buccal sulcus incision and the distractors are temporarily fixed with micro- or miniscrews. The osteotomy line is marked, the distractor removed and a full osteotomy performed. The distractors are reattached and the mobility of the segments is tested by turning the distractor. Finally, the intraoral incision is closed. Fixation of the device can be performed via transbuccal stab incisions or preferably with a contra-angle handpiece and screwdriver.

In contrast to the sagittal split osteotomy in MMA, the osteotomy is at right angles to the outer cortical border. Care has to be taken not to cut the inferior alveolar nerve during the outer corticotomy or to place bicortical pins through the nerve canal. To prohibit violation of tooth buds or roots, preoperative radiologic diagnostic investigations are necessary. In syndromic patients, CT scans are obtained in most instances to obtain an understanding of the individual pathology. Reformatting and volume rendering software allow examination of all important structures and visualization of the upper airways. In non-syndromic adult cases, OPT and lateral cephalogram are sufficient in most instances.

8.3.2 Maxillary-Midfacial Distraction Osteogenesis

Maxillary-midfacial DOG includes advancements at the Le Fort I to Le Fort III levels. Internal and external devices are both available. All procedures are performed under general anesthesia in a hospital environment. Several syndromes are associated with sleep-related breathing disorders because of the pharyngeal narrowing caused by midfacial retrusion. These include Crouzon's disease, Apert syndrome, Weber-Christian disease, achondrodysplasia and to some extent cleft lip and palate. In cases of severe preoperative airway obstruction, temporary tracheotomy has to be considered.

8.3.2.1 Surgical Technique

At the Le Fort I level, surgery is similar to MMA. The only differences are that the osteotomized bone is not advanced and that distractors instead of plates are inserted. When designing the osteotomy, it should be kept in mind that there must be enough bone cranially to fix the distractor. Furthermore, distractor placement on both sides should be parallel and aligned to the planned distraction vector. Mistakes will lead to unwanted movements with potentially unacceptable results. At the Le Fort III level, access is gained via a bicoronal incision. The lateral orbital rim, the nose, and the zygoma are freed from above. Pterygomaxillary disjunction is done via an intraoral incision or through the bicoronal incision. Most internal Le Fort III distractors are fixed in the transition from zygomatic arch to the zygoma (Fig. 8.10) and the activation rods leave through the bicoronal cut. Alternatively to internal devices, extraoral halo-borne distractors may be used. The major advantages are that there is no need for parallel alignment of the distractors and the

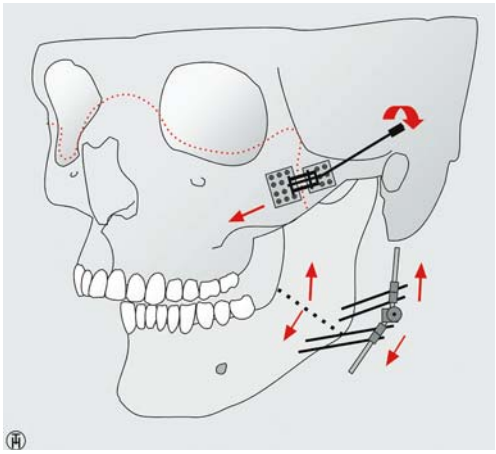


Fig. 8.10. Mandibular DOG using an external device (cf. Fig. 8.8). *Dotted black line* represents the typical osteotomy line in the mandibular angle area (the bone cut may be placed almost anywhere). In the midface a Le Fort III advancement by way of an internal distractor is shown (*red dotted line*). The activation rod passes through the skin in the region of the bicoronal incision necessary for the osteotomy. *Red arrows* symbolize distractor activation and segment movement

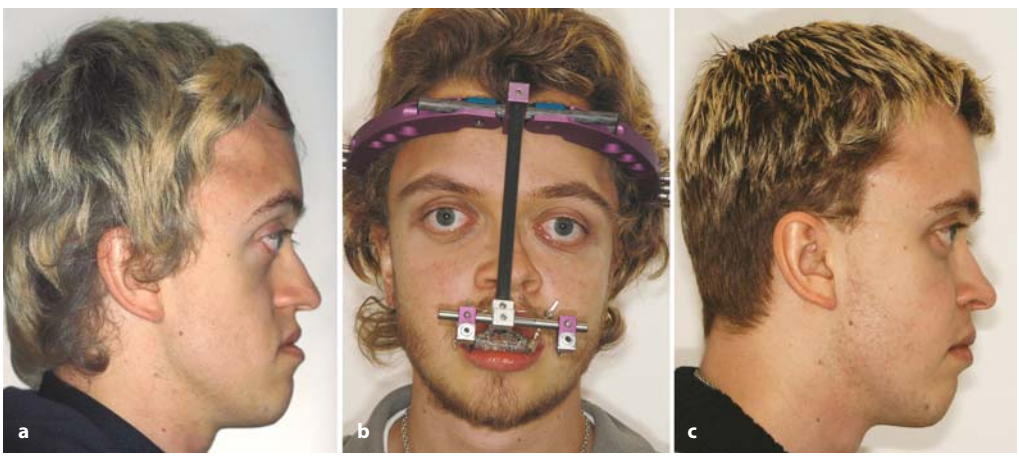


Fig. 8.11 a–c. Midfacial distraction in a case of Crouzon`s disease. External halo-borne distractor (RED, Martin Co. Tuttlingen, Germany) used to advance the midface after a quadrangular osteotomy (i.e., Le Fort III minus the nasal part). **a** Preoperative situation. **b** During distractor activation. **c** Six months after removal of the device (16 mm advancement). The connection of the midface to the extraoral distractors can be achieved via orthodontic splints or miniplate retention systems

Table 8.3. Mandibular DOG for OSA in infants and children

Author	*n*	Age	Diagnoses	Distraction length (mm)	Success
Moore et al. 1994 [342]	1	6 years	TC-S		Decannulation
Williams et al. 1999 [567]	4	∅ 2.7 years	TC-S, Nager	15–27	Decannulation in 3/4
Schierle et al. 2000 [449]	3	7–15 months	Nager, Down	15–20	Decannulation in 2/3
Morovic and Monasterio 2000 [345]	7	1–18 months	PR-S, TC-S	10–25	Decannulation, "reduced" AHI
Sidman et al. 2001 [470]	11	2 weeks–5.5 years	PR-S, Down, Nager	10–22	Decannulation, relief of OSA in 10 patients
Denny et al. 2001 [102]	5	6–26 days	PR-S	∅ 12.4	Decannulation, no OSA
Villani et al. 2002 [543]	2	2/3 months	PR-S	15/20	Decannulation
Ortiz-Monasterio et al. 2002 [366]	15	∅ 3 years	PR-S		AHI 28 → 0
Perlyn et al. 2002 [384]	4	15–64 months	Nager, TC-S	8–25	Decannulation
Izadi et al. 2003 [230]	15	∅ 8.5 days	PR-S, TC-S, Stickler, Nager	12–15	14/15 avoidance of tracheotomy
All	**67**				**64/67**

TC-S Treacher-Collins syndrome, *PR-S* Pierre-Robin sequence, *Nager* Nager syndrome, *Stickler* Stickler syndrome, *Down* Down syndrome.
Exact pre- and post-treatment sleep lab data are missing, as are follow-up reports with respect to OSA.
Decannulation decannulation and closure of tracheotomy was successful.

osteotomy cuts can be freely designed, as no bone for distractor anchorage is needed superior to the bone cut. Furthermore the distraction vector can be changed during treatment (Fig. 8.11). The only drawback is its rather clumsy appearance, being extraoral. Internal distractors are removed after a consolidation period of 6–12 weeks, external devices after 3–8 weeks.

8.3.3 Efficiency of Distraction Osteogenesis for OSA

Most publications on DOG in OSA patients include only small numbers or are case reports. Concerning neonates or children, exact polysomnographic pre- and postoperative data are not given in the majority of reports. However, avoiding or ending tracheotomy is the major treatment objective in this patient group and DOG is the most effective procedure. Only in cases of central apnea decannulation could not be achieved (Table 8.3).

As can be seen in Tables 8.3–8.5, most studies deal with syndromic patients, such as those with ankylosis of the temporomandibular joint, which can be considered as most difficult to treat surgically. Looking at the three-dimensional pharyngeal airway changes induced by DOG, major improvement in OSA should be expected when treating these malformations. Figures 8.12 and 8.13 demonstrate a typical OSA case.

No data regarding the long-term outcome are yet available. As DOG leads to stable skeletal results, a similar outcome in adults as in MMA has to be expected. In syndromic children, there is only limited skeletal relapse, too. As the affected midface shows no or only little growth after DOG, a midfacial retrusion (and possibly OSA) will reappear. Further surgery on the midface is therefore a part of the treatment scheme.

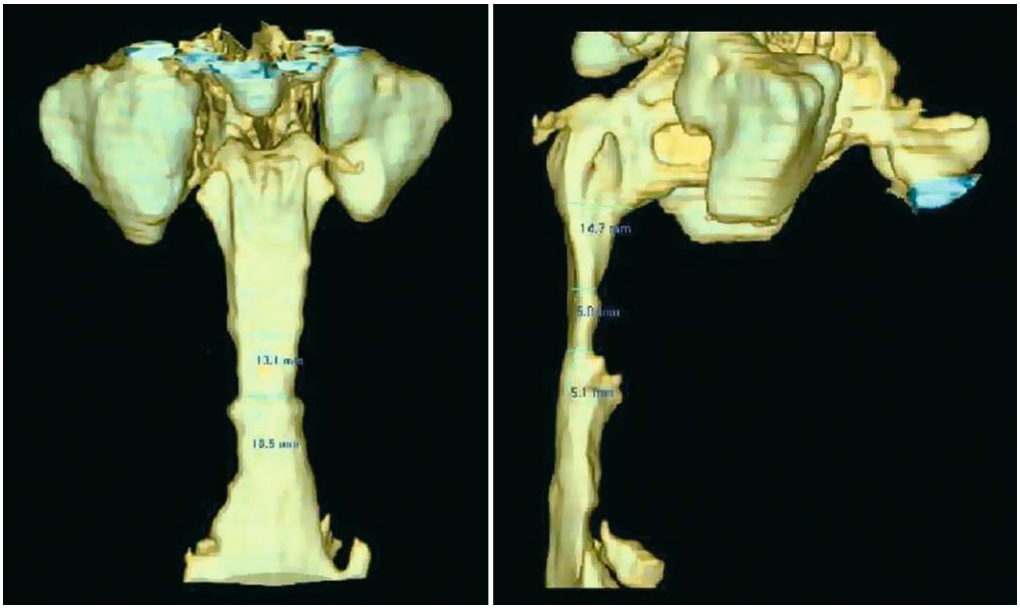


Fig. 8.12. CT-based volume rendering of the pharyngeal airways in a 53-year-old non-syndromic male OSA patient. Preoperative situation displaying narrowing in the retrovelar pharynx (software: Vworks, Cybermed, Korea)

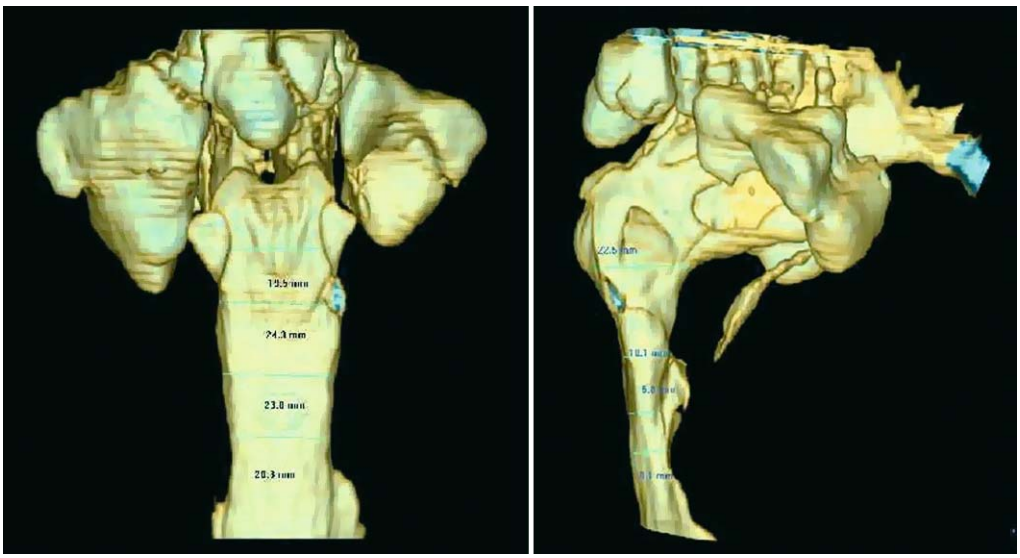


Fig. 8.13. Same patient as in Fig. 8.12. Postoperative situation after 16 mm advancement in the Le Fort I level. Significant sagittal and also transversal widening of the naso- and oropharynx. AHI reduction from 39 to 9 in a 2-year follow-up polysomnography

Table 8.4. Mandibular DOG for OSA in adults

Author	*n*	Age (years)	Diagnoses	Distraction length (mm)	Success
Karakasis et al. 2001 [246]	1	48	TMJ ankylosis	20	RDI: 52.8 → 10.7
Paoli et al. 2001 [374]	1	44	OSA	12	AHI: 87.9 → 23.3[a]
Li et al. 2002 [285]	5	26–68	1/5 hemifacial microsomia	5.5–12.5 (∅ 8.1)	RDI: 49.3 → 6.6
Wang et al. 2003 [553]	28	3–60 (∅ 21.2)	21/28 TMJ ankylosis	9–30 (∅ 8.1)	23/28 cured, 5/28 improved AHI: 58 → 3.2
Harada et al. 2003 [189]	1	31	OSA	15	AI: 29.9 → 4.1
Woodson et al. 2003 [573]	1	48	OSA	37	RDI: 38 → 2
All	**37**			**9.5**	

TMJ ankylosis ankylosis of the temporo-mandibular joint, *RDI* respiratory disturbance index.
Follow-up data are only on behalf of the skeletal stability.
[a] After DOG, a maxillary advancement was performed, final AHI: 6.6.

Table 8.5. Maxillary-midfacial DOG for OSA.

Author	*n*	Age (years)	Diagnoses	DOG level	Distraction length (mm)	Success	Follow-up
Cohen 1999 [83]	4	0.7–10	Apert, cleido-cranial dys.	LF-III; mono-bloc LF-I	17–25	Improve-ment of OSA	
Cedars et al. 1999 [71]	7	4–13	Crouzon, Apert	LF-III	16–27	3/7 initial cure of OSA, recurrence in 2; 1/7 partial improvement, 1/2 decannulated	0 –2.5 years
Meling et al. 2000 [327]	2	4–5	Pfeiffer, Crouzon	LF-III	23–25	Improvement of OSA, tracheotomy avoided	
Uemura et al. 2001 [523]	1	2.5	Crouzon	LF-III	16	AI: 16.4 → 2.6	12 months
Satoh et al. 2002 [444]	1	13	Hajdu-Cheny-s.	LF-III	20	Improvement	
Elwood et al. 2003 [124]	2	3–6	Achondro-dysplasia	LF-I	25	Decannulation	18 months
All	**17**				**16–25**		

LF Le Fort.

A fascinating option during DOG is to perform multiple sleep studies during the advancement of the upper or lower jaw. Thus the efficacy and the average length needed to treat OSA can be analyzed [374, 573]. This could help to define the advancements that are needed to treat OSA effectively and investigate the relation of morphologic changes and OSA.

8.3.4 Complications and Postoperative Care

Most potential problems of MMA may be encountered in DOG (cf. Sect. 8.2). Beside these, DOG has further intricacies, which will be listed below. First of all, DOG is a technically demanding procedure (more difficult than MMA), where surgery and the postoperative period are equally important. Device malposition or improper vector planning may lead to therapy failure, and a high learning curve has been stated [340]. Thus the overall complication rate will be higher than in MMA. Some orthodontic therapy will be needed in most cases to achieve proper occlusion. One of the problems is to decide when to remove the device. The bony regenerate should be still "ductile" to end up in satisfactory occlusion by way of intermaxillary elastics but strong enough to prevent relapse. This is an important issue as perfect occlusion will not be achieved by DOG alone in most cases (in contrast to MMA). Compared to MMA, a higher percentage of open bite will be seen.

A major issue is the cost of DOG, as distractors belong to the most expensive hardware. Thus financing therapy can be difficult. Relapse does not seem to be a major problem in most reports, thus a stable skeletal situation can be expected. Unwanted esthetic effects play no major role as all patients treated by DOG will suffer from extreme maxillomandibular malformations; thus DOG will lead to a normalized facial appearance (Fig. 8.11).

8.3.5 Indications and Contraindications

Indications for DOG are given by the underlying skeletal malformation to be treated. DOG solely for the cure of OSA will be an exception in patients with severe mandibular retrusion where conventional mandibular advancement bears the risk of an unstable skeletal situation. Thus the majority of patients will suffer from syndromic diseases, cleft lip and palate, and post-traumatic deformities.

Ancillary soft tissue operations such as RFQ therapy can be debated where maximum advancement cannot be achieved or in cases of tonsillar hyperplasia and macroglossia. As the airways are extremely constricted in syndromic patients, isolated soft tissue therapy will not be the procedure of first choice. Avoiding or ending tracheotomy will be the major aim in children and close cooperation between craniofacial surgeon, maxillofacial surgeon, ENT surgeon, neurosurgeon and pediatrician will be necessary.

Laryngeal Obstructive Sleep Apnea

9

The most frequent sites of obstruction are situated behind the soft palate and/or behind the tongue. Nevertheless, the larynx may contribute to the genesis of OSA. As early as 1981, Olsen and colleagues [362] described a case of obstructive sleep apnea (OSA) caused by a laryngeal cyst. Removal of the cyst yielded the disappearance of apneas. Since then several case reports and small case series have been published; but it is still not possible to determine the concrete incidence of laryngeal OSA. Basically there are two forms of laryngeal OSA: the pediatric and the adult form. In the following discussion, they will be considered separately.

9.1 Pediatric Laryngeal OSA

During childhood, malformations, complex malformation syndromes, tumors or laryngomalacia may be considered as possible causes of a laryngeal OSA. In newborns, a further aspect can make matters worse: the immaturity of the respiratory control is often responsible for repetitive apneas and periodic breathing in early postnatal life. Consequences of this unstable breathing on blood gases and heart rate can lead to severe cerebral hypoxia and be life threatening, especially in preterm infants [111, 476, 486].

Malformations that lead to a laryngeal OSA have been documented in various case studies. Ruff et al. [436] describe the case of a previously healthy 13-year-old boy who developed OSA and bilateral vocal cord dysfunction secondary to type I Chiari malformation. He subsequently underwent a tracheostomy, a posterior fossa craniectomy, and C1-laminectomy. Four months after surgery he returned to school but still continued to require his tracheostomy. Two other case reports [40, 413] document that a congenital aplasia of the epiglottis may result in laryngeal OSA. Both children developed daytime sleepiness as a result of their OSA. One child underwent tracheostomy after she had developed heart failure. She was decannulated at the age of 7. Recently Chan et al. [74] presented an unusual case of a child with adenoid hypertrophy and occult supraglottic lymphatic malformation that manifested as laryngeal OSA.

Up to now, neurofibromas [470] and laryngeal papillomatosis [233] have been described as causes of OSA during childhood. We ourselves have recently treated a childhood OSA resulting from a hemangioma of the larynx of a 4-year-old. The therapy consists in a resection or treatment of the tumors. Depending on tumor entity, size, and location, a temporary or permanent tracheotomy may become inevitable.

Laryngomalacia, or congenital laryngeal stridor, is a relatively benign, self-limiting condition first described in 1843 [27]. It seems to be the most common laryngeal congenital anomaly of all [209, 585]. It plays a significant role in the pathogenesis of laryngeal OSA in the case of the newborn, and especially for the preterm infant. In order to diagnose this dysfunction, a fiberoptic laryngoscopy is essential. McSwiney [325] described three anatomic abnormalities that cause laryngomalacia. (1) The epiglottis may be long and curled upon itself (the so-called omega-shaped epiglottis), and it prolapses posteriorly on inspiration; (2) the aryepiglottic folds may be short; and (3) the arytenoids may be

more bulky than normal and prolapse forward on inspiration. Additionally a mild subglottic edema may be present [585].

In mild cases, attentive observation is still the method of choice. Improvement always occurs before 12–18 months of age, and the outcome of these patients is invariably good [325]. In more severe cases, either a tracheotomy or laryngeal surgery may become necessary.

9.1.1 Surgical Techniques

Three principal types of surgery for laryngeal OSA can be distinguished. These are employed depending on the individual anatomic situation of each child.

The first technique to be described consists in a partial resection of the epiglottis. Zalzal et al. [585] first described a case series of ten patients who underwent epiglottoplasty. This procedure addresses both the epiglottis and the mucosa of the aryepiglottic folds and the arytenoids. The epiglottis is grasped with cup forceps, and scissors are then used to trim the lateral edges of the epiglottis and the aryepiglottic folds. The mucosa of the arytenoids and corniculate cartilages is trimmed in a similar fashion. The author described the bleeding as minimal. Perioperative antibiotics are recommended.

Golz et al. [168] perform partial laser epiglottidectomy both in infants and adults if the epiglottis is found to be unusually long and flaccid. This technique solely addresses the epiglottis. As we do, the authors use a Kleinsasser laryngoscope, a Riecker-Kleinsasser chest support, and the CO_2 laser (continuous wave or superpulsed mode, 6–10 Watts). The extent of the resection was individualized for each patient in this series according to the anatomic abnormality causing the obstruction. The authors perform a U-shaped excision leaving the lateral sides of the aryepiglottic folds intact.

The second principal technique is called supraglottoplasty. Its characteristic consists in the resection of supraglottal mucosa. Senders and Navarrete [457] differentiate between four types of laser-assisted supraglottoplasty depending on the individual laryngeal finding (Figs. 9.1–9.4). They use the CO_2 laser adapted to a microscope micromanipulator (100–200 ms pulse sequences; 5–8 Watts). The authors excise either the supraarytenoidal mucosa (arytenoidoplasty; Fig. 9.1), the mucosa of the aryepiglottic folds (aryepiglottoplasty; Fig. 9.2), the posterior edges of the epiglottis (epiglottoplasty; Fig. 9.3), or the lingual mucosal surface of the epiglottis (epiglottopexy; Fig. 9.4). Depending on the anatomical situation, every combination of the four techniques can be performed.

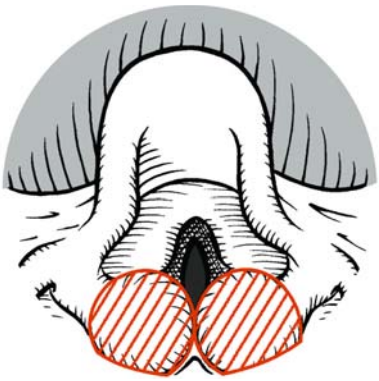


Fig. 9.1. Arytenoidoplasty according to Senders and Navarrete [457]. Coagulation of redundant mucosa of the arytenoids with a defocused laser beam

The amount of redundant mucosa that should be resected is most suitably identified using the "suction test" [395]. Instead of the CO_2 laser, laryngeal microinstruments can be used. We prefer the CO_2 laser because of its additional hemostatic effect. For relatively minor cases we have found that it is advantageous to vaporize the mucosa with a defocused laser beam, instead of excising it.

A third technique deals with the problem of the shortened aryepiglottal fold. Here the problem is not the redundant mucosa, which prolapses into the glottis during inspiration, but rather a too short distance between arytenoid and epiglottis root. We and other study groups [298, 456] treat these cases with a

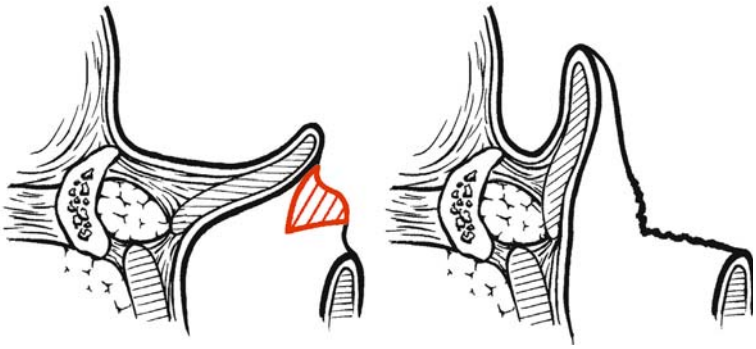


Fig. 9.2. Aryepiglottoplasty according to Senders and Navarrete [457]. Opening of a too short aryepiglottic fold

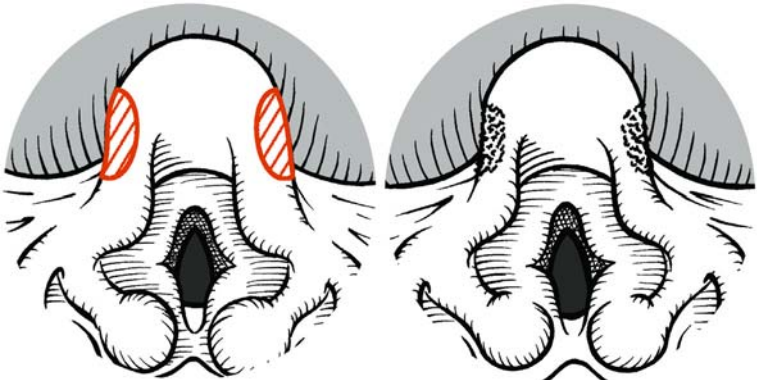


Fig. 9.3. Epiglottoplasty according to Senders and Navarrete [457]. Reduction of the too big epiglottis

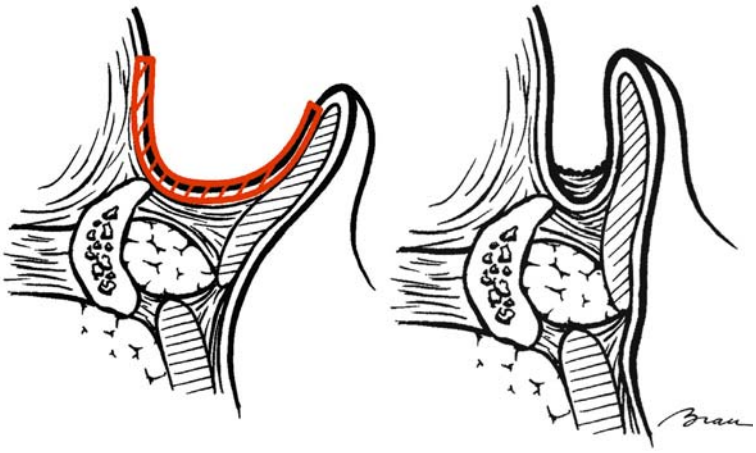


Fig. 9.4. Epiglottopexy according to Senders and Navarrete [457]. Scarring approximates the epiglottis to the base of the tongue

Table 9.1. Effectiveness of surgery for severe laryngomalacia in children

Author	*n*	Procedure	Follow-up	Success rate (%)	Definition of success	EBM grade
Golz et al. 2001 [168]	12	Partial laser epigottidectomy	14–52 months	100	Subsiding of stridor	Retro
Senders and Navarrete 2001 [457]	23	Laser supra-glottoplasty	No data	78	Immediate relief of symptoms	Retro
				82.6	Avoidance of tracheotomy	Retro
Toynton et al. 2001 [517]	91	Aryepiglotto-plasty	1 month	54.9	Relief of stridor	Retro
				94.5	Improvement of stridor	
Reddy et al. 2001 [410]	106	Supraglotto-plasty	No data	95.7	Relief of symptoms	Retro
Denoyelle et al. 2003 [103]	136	Laser supra-glottoplasty	3 days to 60 months	79	Relief of symptoms	Retro
All	**368**			**81.62**		**IV**

Retro retrospective.

V-formed, 3–4 mm deep incision into both of the aryepiglottic folds. Even intraoperatively the laryngeal entrance in the anterio-posterior dimension becomes visibly wider. For this procedure we also prefer the CO_2 laser (continuous wave or superpulsed mode; 6–8 Watts).

In principle, according to the individual anatomical situation, combinations of the three basic techniques are also possible. Toynton and colleagues [517] combined an incision of the arytenoid fold with a removal of redundant supraglottal mucosa.

9.1.2 Effectiveness for Sleep-Disordered Breathing

Unfortunately, there are no studies presenting clean sleep lab data before and after larynx surgery. On the other hand, there are many therapy studies that use as primary variables the daytime symptoms of laryngomalacia. Table 9.1 summarizes the results of several recent studies.

It is difficult to compare the studies in Table 9.1, as they deal with different techniques, employ different success criteria, and in part treat very different kinds of patients. From a few of the studies [103, 457] it can be deduced that patients who have not been successfully treated with larynx surgery, are those who display significantly more frequently complex or additional malformations.

Because these are solely retrospective studies, it needs to be mentioned that an evidence proof according to Cochrane criteria has not yet been established. Nevertheless, we do feel justified to infer a tendency to the effect that a high percentage of children with a severe laryngomalacia can be spared a tracheotomy with the help of an individually adapted larynx procedure.

9.1.3 Postoperative Care and Complications

Despite the high success rate, in 11.6 % of the cases an initial deterioration of the stridor and in 4.7 % the necessity of a reintubation or tracheotomy (1.2 %) must be anticipated. These risks further increase in those cases

that do not present an isolated laryngomalacia, but complex malformations [457]. In any case, the children should be observed in an accordingly furnished intensive care unit during the first postoperative night. In cases where the parents or other supervising persons are present, monitoring of the respiration may be sufficient. In any case, this procedure should be performed on an inpatient basis.

Most authors [103, 457] routinely use corticoid therapy (beclomethasone, 125 µg/kg) within the first 3–5 days postoperatively, as we do in our center. In contrast to other recommendations, we do not routinely use anti-inflammatory drugs or antibiotics.

Overall, the complication rate of the described surgical procedures is quite low, and does not vary significantly between the various techniques. The overall complication rate is given as between 5.8 % [517] and 7.4 % [103]. There is no difference concerning the complication rate in patients with isolated laryngomalacia compared to those having additional congenital anomalies [103].

As minor complications, aspiration of early feeds (7.0 %), granulomas (1.5 %) that had to be removed under general anesthesia, significant edema (1.5 %), minor intraoperative hemorrhage (1.2 %), and a posterior fibrous web between the arytenoids (0.7 %), which required division with microscissors or laser, have been described.

Major complications were seen in up to 3.7 % of the patients. These consisted in recurrence of disease, need for tracheotomy, supraglottic stenosis, fibrous intralaryngeal webs, and one case of non-airway-related perioperative death [103, 517].

9.1.4 Indications and Contraindications

The diagnosis of the laryngeal OSA is performed with the help of an endoscopic examination. In the case of tumors and complex malformations, the therapy depends on the primary disease. Laryngomalacia is a disease of the perinatal phase, and is especially salient in the case of preterm infants. In minor cases, waiting is the therapy of choice. A close cooperation with the child's pediatrician is necessary.

In severe cases, an endoscopy needs to be employed in order to determine whether a shortening of the epiglottis, a removal of redundant supraglottal mucosa, an incision of the aryepiglottic fold, or a combination of the three procedures is indicated. In the case of a correct indication, in over 80 % of cases the children can be spared a tracheotomy or a decannulation becomes possible. We do not consider a minimum age restriction to be in effect for these procedures.

The alternative to a surgical procedure consists in a non-invasive respiration therapy [133].

9.2 Adult Laryngeal OSA

In contrast to children, laryngomalacia plays only a minor role in adults. The only exception to this is the so-called "floppy epiglottis." The floppy epiglottis is a relatively rare anatomic finding in adults. Nevertheless, Catalfumo and colleagues [70] found this condition in 12 of 104 patients who failed an UPPP procedure. We relatively frequently observe a floppy epiglottis in older male patients [535]. One explanation for this may be the fact that apart from the pinna of the ear the epiglottis is the only organ of the head and neck consisting exclusively of elastic cartilage. Pellnitz [381] has shown a significant increase in the length, breadth, and weight of the epiglottis in males, while females show reductions for the same parameters. Histological study of 500 epiglottal specimens obtained at autopsy shows that size increases in the male epiglottis is due to secondary intercellular deposits of byproducts of the metabolism. There were sex-specific differences in the perichondrium. Pellnitz postulated specific hormonal influences in connection with these findings, since the growth of the larynx is considered a secondary sexual characteristic. Nevertheless, a floppy epiglottis has also been described in younger men and, rarely, in women [15, 569].

In contrast to pediatric laryngeal OSA, the removal of redundant supraglottic mucosa is not a treatment option for adults. The condition also rarely occurs in adults, probably as a result of repeated exposure to subatmospheric pressure [403]. Nasal CPAP ventilation is the treatment of choice in these cases.

Tumors as cause of a laryngeal OSA are much more frequently a possibility in the case of adults than for children. Specifically, the following tumor entities have been reported as inducing OSA: squamous cell carcinomas of the oral vestibule [569], the epiglottis [168], the glottis [430], and superior laryngeal nerve schwannoma [552]. Additionally, laryngeal OSA has been observed after irradiation therapy [77, 200] and after reconstructive laryngectomy for glottic carcinoma [430].

Acquired laryngomalacia has furthermore been described as a consequence of laryngeal trauma [569], sarcoidosis [161, 460], Hunter's syndrome [364], acromegalia [16],and mast cell pharyngitis [61].

A far larger group is made up of neurological diseases. Especially the Shy-Drager syndrome [164, 249], and vocal cord paralysis (due to other reasons) [16, 207, 564] are to be considered. An OSA can also occur after closure of a tracheostoma, even if no OSA existed prior to the tracheotomy. Especially in the elderly, laryngeal pathologies may facilitate the development of OSA after surgery. Therefore, postoperative reevaluation is recommended for all elderly patients with laryngeal abnormalities after operative closure of the tracheostomy [534].

9.2.1 Surgical Techniques

The surgical techniques are basically the same as those used in children. First, an exact diagnosis is necessary which ideally is obtained via endoscopy. In the case of tumors or more complex disorders the therapy is determined by the primary disease.

If a floppy epiglottis is manifest, the partial resection via a laser laryngoscope and the shortening of the glosso-epiglottic ligament are indicated [168, 535]. In contrast to the situation in children, difficulties may arise in the cutting of the cartilage. We therefore employ the CO_2 laser in continuous wave mode and set it at an input rate of 10 to 12 Watt. In individual cases the additional use of relevant microinstruments can be of advantage. Furthermore, the use of curved rotating microdissection monopolar scissors as used in laparoscopic surgery has been recommended [363]. We ourselves have not had any experience with these instruments. In both cases the major part of the free epiglottis is resected (Fig. 9.5).

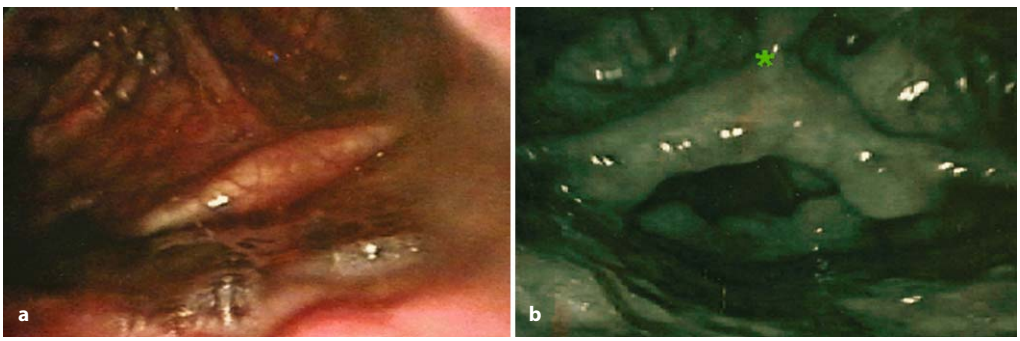


Fig. 9.5 a,b. Laser partial epiglottectomy. **a** Preoperative situation with complete occlusion of the larynx. **b** Situation after surgery with larynx wide open. *Shortened glosso-epiglottic ligament

9.2.2 Effectiveness for Sleep-Disordered Breathing

With one exception, the literature only offers case studies dealing with this topic. It is therefore not possible to determine the efficacy of the presented surgical procedures in relation to the OSA. Golz and colleagues [168] retrospectively reported on a series of 27 patients after partial laser resection of the epiglottis. Preoperatively the mean apnea hypopnea index (AHI) was at 45±14.6. Follow-up polysomnographies were performed at least 1 year after surgery. The AHI decreased to 14±5.1. A statistically significant decrease was achieved in 21 patients (77.8 %). Unfortunately, no raw data are presented. Therefore it is not possible to calculate the success rate using Sher's criteria.

In summary, the described surgery of the larynx appears to achieve successful results in a carefully selected patient pool. But for the evidence according to Cochrane criteria, grade V must be assumed.

9.2.3 Postoperative Care and Complications

The patients undergo extubation immediately postoperatively. A follow-up respiratory treatment or tracheotomy is not necessary. We recommend the perioperative administration of 500 mg dexamethasone intravenously. In contrast to children, an observation in an intensive care unit is not necessary if the option of either an extended (several hours) postoperative observation in the waking room or cardiopulmonary monitoring is available. In our center a perioperative antibiotics prophylaxis with 2 g cephazolin is performed. Since usually no major dysphagic problems arise, no special postoperative diet is necessary. The analgetic regimen depends on the individual case.

In contrast to children, as far as we know, postoperative supralaryngeal stenoses have not been described in adults. From the few case studies no major complications can be inferred. From our own experience we can report mild dysphagia, which regularly occurs especially during the swallowing of fluids in the first week postoperatively; but parenteral nutrition did not become necessary in any of these cases.

9.2.4 Indications and Contraindications

Also for adults a precise endoscopic diagnosis is the precondition for a therapy. We always perform a fiberoptic endoscopy in the flat position. In individual cases, an additional sleep endoscopy under sedation or, even better, during natural sleep, can be helpful [201].

In the case of a floppy epiglottis, a respiration therapy is frequently not possible because the continuous positive airway pressure presses the epiglottis onto the larynx entrance, comparable to a lid on a pot [535]. In these cases, no alternative to surgery exists. From tumor surgery we know that, in contrast to a partial resection of the tongue base, a partial resection of the epiglottis frequently does not produce any significant dysphagia. Therefore, the partial resection of the epiglottis with the CO_2 laser is overall not very stressful for the patient; as a result we quite generously posit the indication for surgery. Yet it must be said that a floppy epiglottis is in our experience a rare occurrence. We perform a partial resection of the epiglottis only about twice per year. Of the more than 700 patients a year who undergo surgery in our center for sleep medical indication, these cases make up merely 0.3 %.

In less severe cases, it is possible that a hyoid suspension or a genioglossus advancement is sufficient to move or suspend the epiglottis far enough towards anterior so that a larynx occlusion no longer occurs. The decisive criterion here is not the size of the epiglottis but its stiffness. The laxer the epiglottis, the more one should consider a partial resection. But if the epiglottis is shifted towards dorsal due to an enlarged tongue

base, we are of the opinion that the hyoid suspension, if necessary in combination with a radiofrequency therapy of the tongue base, should be preferred.

For all other disorders of the larynx, the therapy depends on the primary disease. But vocal cord palsies – even bilateral paralysis – can be very favorably treated with a respiration therapy [564, 586].

Multi-Level Surgery

10

A multi-level procedure for the surgical therapy of obstructive sleep apnea (OSA) was presented for the first time in 1989 by Waite and colleagues [545]. The authors combined nasal surgery with an uvulopalatopharyngoplasty (UPPP), tongue surgery, a genioglossus advancement, and a maxillomandibular advancement osteotomy (MMO). Basically, the classification of the upper airway into different levels of obstruction stems from Fujita [160], who distinguished between retropalatal, retrolingual, and combined retropalatal and retrolingual obstruction. On the basis of this distinction, Riley et al. [422] defined the term and concept of multi-level surgery.

In the meantime, the first studies have been published concerning virtually every possible combination of soft palate and tongue base procedures. To give some structure to these data, we will distinguish in the following between minimally invasive concepts for mild OSA and more invasive concepts for moderate and severe OSA.

Multi-level surgery is also performed on children with severe OSA on the basis of various primary illnesses in order to avoid an otherwise necessary tracheotomy. These concepts are discussed in a separate section.

10.1 Surgical Concepts

10.1.1 Effectiveness of Minimally Invasive Multi-Level Surgery for Mild to Moderate OSA

Of the procedures employed, only the isolated radiofrequency (RFQ) therapy can be regarded as a minimally invasive technique. A prerequisite for inclusion of the data into Table 10.1 is the application at least at the soft palate and tongue base, as well as the presentation of raw data for the calculation of the various parameters (Table 10.1).

The data in the table are still very sparse. Yet we believe that it is possible to deduce two trends. On the one hand, the combined treatment of tongue base plus soft palate does not appear to improve significantly the results of an isolated tongue base treatment in respect to the apnea hypopnea index (AHI). In our clinical experience, the advantages of a combined treatment lie more in an additional effect upon the respiratory noises during sleep. We have recently been able to demonstrate [496] that the postoperative morbidity and complication rate after combined treatment and after isolated tongue base treatment are identical. Moreover, as the tongue base probes can also be used without difficulty at the soft palate, no significant further costs are created by an expansion of the therapy to the soft palate. As snoring is frequently more of a burden to the patients than the health impediment caused by the often mild OSA, we almost exclusively perform combined treatments, even if the obstruction is assumed to be located solely at the tongue base.

Yet the relatively low success rate of the study by Fischer et al. [145] (RFQ at the soft palate, tongue base and tonsils) is difficult to interpret adequately, as for other surgical procedures an unambiguously positive effect of tonsil reduction on the severity of the OSA has been demonstrated. The authors themselves use somewhat different success criteria and describe a success rate of 33 %. According to our experience (Sect. 6.1.2) and that of other authors [351], RFQ surgery at the lymphatic tonsil tissue produces a pronounced vol-

Table 10.1. Combined RFQ surgery for OSA

Author	*n*	Application sites	Device	Follow-up (months)	Sessions, total energy, lesions	AHI pre	AHI post	Success rate (%)	EBM grade
Stuck et al. 2002 [496]	18	SP, TB	Somnus	2	3, 4300 J, 7	25.3	16.7	38	II-3
Fischer et al. 2003 [145]	15	SP, TB, Tons	Somnus	4.8	1, 7750 J, 12	32.6	22	20	II-3
All	**33**		**Somnus**	**3.3**		**28.6**	**19.1**	**30.3**	**IV**

AHI apnea hypopnea index, *SP* soft palate, *TB* tongue base, *Tons* tonsils.

ume effect; therefore we would have assumed a stronger effect on the AHI. Further studies will be needed to clarify this issue.

We see a second trend in the limitation of RFQ surgery to cases of mild OSA with an AHI of maximally 20. This trend is corroborated by the results of the only placebo-controlled study on this topic. Woodson et al. [576] treated 30 patients respectively with continuous positive airway pressure (CPAP), combined RFQ at soft palate and tongue base, or a sham operation. Unfortunately, the authors did not provide any raw data; therefore this study could not be included in Table 10.1. As expected, CPAP respiration was found to be superior to RFQ surgery, and RFQ in turn superior to the sham operation. Yet in regards to the subjective results, which were measured with various validated test instruments for the assessment of life quality, no differences were found in the comparison of CPAP with RFQ surgery.

10.1.2 Effectiveness of Multi-Level Surgery for Moderate to Severe OSA

On the level of the soft palate, invasive therapy concepts include either an UPPP or an uvulopalatal flap. Different procedures have been recommended for the treatment of hypopharyngeal obstruction. Table 10.2 summarizes the existent data. In the case of a relevant clinical diagnosis, several authors additionally perform nasal surgery. Recently, we were able to demonstrate that additional nasal surgery does not have a positive effect on the severity of the OSA [529, 530]. This result is in line with the information we gathered in Chap. 4 in regards to isolated nasal surgery in the case of OSA. For the sake of a lucid presentation, we have therefore omitted references concerning additive rhinosurgical procedures from Table 10.2.

Altogether, data of 827 patients from retrospective studies and from prospective case control series exist. For the present study situation, this results in grade IV evidence according to the criteria of the Canadian task force on periodic health examination. The success rate according to Sher et al. [465] is almost 54 %. With the exception of the study by Nelson [350], the studies dealt with on average severe forms of OSA. We are of the opinion that a sufficient amount of data exist to validate the efficacy of multi-level surgery in the case of severe OSA.

Difficulties arise in attempting to evaluate the divergent concepts against each other. For the area of the soft palate, all study groups either perform the conventional UPPP or more rarely the uvulaflap, always including tonsillectomy. We consider these techniques to be comparable. Therefore the concepts differ from one another in respect to the therapy of the hypopharyngeal constriction of the upper airway. Two study groups [107, 118] recommend in somewhat dated publications a partial resection of the tongue base. With 32 %

Table 10.2. Multi-level surgery for OSA

Author	*n*	Technique level 1	Technique level 2	Follow-up (months)	AHI pre	AHI post	Success rate (%)	EBM grade
Djupesland et al. 1992 [107]	19	UPPP	MLP	8.7	54	31	31.6	II-3
Riley et al. 1993 [422]	223	UPPP	GA HS	9	48.3	9.5	60.1	Retro
Johnson and Chinn 1994 [240]	9	UPPP	GA	39	58.7	14.5	77.8	II-3
Ramirez and Loube 1996 [405]	12	UPPP	GA HS	6	49	23	41.7	II-3
Elasfour et al. 1998 [118]	18	UPPP	MLP	3–21	65.0	29.2	44.4	II-3
Lee et al. 1999 [278]	33	UPPP	GA	4–6	55.2	21.7	66.7	Retro
Bettega et al. 2000 [35]	44	UPPP	GA HS	6	45.2	42.8	22.7	II-3
Hsu et al. 2001 [218]	13	UPPP	GA HS	12.6	52.8	15.6	76.9	Retro
Hendler et al. 2001 [199]	33	UPPP	GA	6	60.2	28.8	45.5	Retro
Nelson 2001 [350]	10	UPPP	RFQ	2	29.5	18.8	50.0	II-3
Vilaseca et al. 2002 [542]	20	UPPP	GA HS	6	60.5	44.6	35.0	II-3
Neruntarat 2003 [355]	32	Flap	HS	8.1	44.5	15.2	78.0	Retro
Neruntarat 2003 [354]	46	Flap	GA HS	39.4	47.9	18.6	65.2	Retro
Friedman et al. 2003 [153]	143	UPPP	RFQ	No data	43.9	28.1	41.0	Retro
Miller et al. 2004 [337]	24	UPPP	GA	4.7	52.9	15.9	66.7	Retro
Dattilo et al. 2004 [99]	37	UPPP	GA HS	1.5	38.7	16.2	70.3	II-3
Verse et al. 2004 [530]	45	Flap	RFQ, HS	4.7	38.3	20.6	51.1	II-3
Hörmann et al. 2004 [215]	66	Flap	RFQ, HS	3.4	38.9	19.3	57.6	II-3
All	**827**			**1–39**	**47.1**	**20.6**	**53.9**	**IV**

HS hyoid suspension, *GA* mandibular osteotomy with genioglossus advancement, *MLP* midline partial glossectomy, *RFQ* radiofrequency of tongue base, *Retro* retrospective.

and 44% respectively the success rates lie below average. Furthermore, as shown in Sect. 7.3, partial tongue base resection is a procedure with a relatively high postoperative morbidity and complication rate. We therefore regard this procedure to be historical.

Two further concepts [153, 350] solely employ the minimally invasive RFQ surgery at the tongue base. The retrospective analysis of Friedman et al. [153] achieves a relatively low success rate of 41%. Yet of interest in this study is the fact that a control group of patients, who had received only an UPPP, per-

Table 10.3. Staged concepts of multi-level surgery for OSA

Author	*n* stage 1	Non-resp. stage 1	*n* stage 2 (MMO)	Resp. stage 2 (MMO)	AHI pre stage 1	AHI post stage 2	EBM grade
Riley et al. 1993 [422]	223	89 (40%)	24	23 (97%)	75.1	8.4	Retro
Lee et al. 1999 [278]	33	11 (33.3%)	3	3 (100%)	74	5	II-3
Bettega et al. 2000 [35]	44	34 (77.3%)	20	15 (75%)	59.3	11.1	II-1
Li et al. 2000 [291]			19	18 (94.7)	63.6	8.1	II-3
Hendler et al. 2001 [199]	33	18 (54.5%)	7	4 (57.1%)	90.1	16.5	Retro
All	**333**	**152 (45.6%)**	**73**	**63 (86.3%)**	**69.2**	**9.7**	**III**

MMO bimaxillary advancement.

formed significantly worse. Nelson [350] presents an average success rate of 50%, but treated patients with less severe OSA. The mean AHI in his series was 29.5, compared to the mean value of all studies, which was 47.1. Undoubtedly, of all the tongue base procedures presented here, the RFQ has the lowest postoperative morbidity and complication rate. But we infer from the data a tendency indicating that solely a RFQ at the tongue base, combined with the UPPP, is not in itself sufficient for properly treating a severe OSA with surgical means.

For the therapy of hypopharyngeal constriction, most studies employ either mandibular osteotomy with genioglossus advancement or hyoid suspension, or both. Currently, the data do not provide information as to which combination is superior. It presumably depends more on with which technique the surgeon achieves the best results.

Initially, we followed the Stanford [422] concept. However, after mandibular osteotomy with genioglossus advancement, several complications occurred in our patient pool, such as infections of the oral floor with abscess formation and loosening of the osteosynthesis; therefore, we have searched for alternatives with fewer complications. We believe that we have found the solution in a combination of RFQ and hyoid suspension [530, 215]. In the context of this concept, tonsillectomy and hyoid suspension have shown themselves to be the most effective elements of our multi-level concept.

With the exception of the study by Johnson and Chinn [240], who present long-term data over a postoperative span of 3 years, Table 10.2 only includes short-term data. Therefore, a long-term evaluation of on average 51 months coming out of Stanford [423] of 40 patients with primary surgical success has received special attention. After more than 4 years, 90% (36/40) still enjoyed treatment success. Four patients had again developed an OSA. In this group the AHI was 83.3 preoperatively, 10.5 6 months postoperatively, and 43 after 4 years. But it should be mentioned that in the meantime these patients had experienced a significant weight increase (body mass index [BMI] 28.7 kg/m² preoperatively; 28.0 kg/m² after short-term follow-up; 30.6 kg/m² after long-term follow-up).

Similar results have been described recently by Shibata et al. [467]. Additionally to the improvement of the AHI, these authors were able to demonstrate a postoperative normalization of the arterial hypertonus for 31 patients.

Obviously, the best success rates are found for staged concepts, which provide as a second, additional surgical stage a bimaxillary advancement in the case of the non-responders. This dividing up into two phases also goes back to the Stanford study group [422] and has gained acceptance in many places. The available data are presented in Table 10.3.

As presented in Sect. 8.2, in the context of multi-level surgery the MMO is also an eminently successful treatment in regards to the

severity level of the OSA. This is apparently also the case for morbidly obese patients. In a series of 23 obese sleep apneics with a mean BMI of 45 kg/m², the Stanford two-phase concept achieved a success rate of 82.6 %. In this series, the mean AHI fell from 83 preoperatively to 10.6 6 months postoperatively. But it should be mentioned that the patients had also reduced their weight. The average BMI was 43 kg/m² postoperatively. The authors conclude from their data that counseling in regards to weight reduction and avoidance of weight gain will improve treatment outcomes.

It is striking that only a relatively small number of patients have actually chosen an MMO, as can be seen in two series [278, 422]: in both of the studies only 27 % of the candidates chose the MMO option. The reason for this remained unanswered in the studies. Apparently, due to the potential risks involved, MMO is not a surgical option for the majority of sleep apneics.

10.2 Postoperative Care and Complications

Multi-level surgery for OSA is an inpatient treatment. With the exception of isolated RFQ treatments, it should not be performed on an outpatient basis. As a rule, the duration of the hospitalization is 5 days. Because the patients are for the most part severe sleep apneics, special perioperative measures are necessary; these are described in Chap. 13.

Even in the case of severe sleep apneics, postoperative observation in an intensive care unit is not required if an observation option exists for the first postoperative hours in the recovery room. If events here are without complication, the patient can be brought into a normal care unit. If the patient has already received a CPAP respiration device preoperatively, he or she should be encouraged to continue using it postoperatively for several days, until the postoperative inflammations have reliably subsided. If the patient does not possess a CPAP device, we apply one. A pressure of 10 cm H_2O is usually sufficient.

Our patients receive postoperative antibiotics prophylaxis for 5 days. Intraoperatively we administer 2 g cephazolin once, and postoperatively we administer 2×250 mg cefuroxim per os for 5 days. In principle, the use of more cost-efficient broadband antibiotics is also possible. We do not consider routine administration of corticosteroids necessary.

The most painful part of the multi-level surgery is comprised by the soft palate procedures and the tonsillectomy. In order to keep the pain as low as possible postoperatively, it is important to take care that intraoperatively the sutures at the soft palate are knotted tightly, but that the soft tissue is not squeezed. A loose adaptation of the wound edges should be attempted, as postoperatively in some cases a significant edema is to be expected. Even after adequate surgery, the period of pain requiring analgetics lasts an average of 12 days in our experience. Because the pain varies strongly interindividually, however, an individualized pain treatment plan with relevant controls is needed. Due to their long half-life and the absence of hemostatic side effects, we recommend as base medication the new Cox-II blockers refecoxib or celecoxib. Persistent pain despite adequate analgesics may indicate the beginning of a wound infection. In these cases an antibiosis, e.g., with amoxicillin, can quickly alleviate the condition.

Apart from pain, the possibility of serious dysphagia must be taken into account. In the first 3 days, some patients need to receive parenteral nutrition. In some cases a one-time administration of corticosteroids (e.g., 250–500 mg methylprednisolone) is sufficient. In virtually all cases, oral nutrition can be resumed after 3 days, even without the administration of cortisone. After tonsillectomy we prescribe the usual diet.

The complications after multi-level surgery consist on the one hand in the sum of the complications of the individual procedures. These have already been discussed in the relevant chapters. On the other hand, it is of course conceivable that the effects of several simultaneous surgical treatments at the upper aerodigestive tract are amplified. In this

context Altman and colleagues [6] were able to demonstrate abnormal objective swallowing in 9 of 15 patients 18 months after multi-level surgery for OSA. Six of 15 demonstrated normal objective swallowing. Of these, five reported subjective change. This study is in accordance with the results stemming from our multi-level therapy protocol. Almost all of our patients initially suffer from dysphagia, which in some cases persists for up to 3 weeks. Up to now, in the context of our concept we have not observed a continued dysphagia with impediment of food intake lasting over several months.

10.3 Indications and Contraindications

Minimally invasive multi-level surgery in the form of an isolated RFQ therapy is not yet sufficiently validated scientifically. Yet in analogy to the results concerning the isolated use at the soft palate and at the tongue base we are of the opinion that we can posit a legitimate indication both for primary snoring as well as for mild forms of OSA. It remains to be seen by how far the additional treatment of the tonsils, as suggested by Fischer et al. [145], will broaden the indication. Yet currently we assume that above an AHI of 20, more invasive techniques achieve better success rates.

For moderate and severe OSA, a variety of combinations has been described. At the soft palate, UPPP with tonsillectomy is the preferred procedure. For no other surgical procedure does a comparable amount of data exist. Some study groups, including ours, like using the uvulaflap (Sect. 6.3). Since the techniques are so similar, it is ultimately up to the surgeon with which technique he or she feels most comfortable.

In our opinion, partial resections of the tongue base are obsolete as routine procedures. They often require a temporary tracheotomy, and should be restricted to special cases. This leaves mandibular osteotomy with genioglossus advancement, hyoid suspension and RFQ for the therapy of a hypopharyngeal constriction. As described above, we feel justified to infer from the data in Table 10.3 that an isolated RFQ at the tongue base in combination with the UPPP plus tonsillectomy is not sufficient for the treatment of severe OSA. Therefore, the soft palate procedure should be combined with a hyoid suspension and/or a genioglossus advancement. Which combination is ultimately the most successful cannot as yet be inferred from the available data. The largest Stanford series [422] uses both techniques in combination. This protocol with a success rate of 60 % after Sher [465] is currently regarded as the standard procedure.

In our daily practice we have replaced the genioglossus advancement with RFQ therapy, and we perform an uvulaflap with tonsillectomy, a hyoid suspension and RFQ therapy of the tongue base. With the help of this newly devised protocol we have been able to reduce significantly the postoperative morbidity and complication rate. With the Mannheimer multi-level surgery concept, we achieve a success rate of 57.6 % after Sher [465]; this result situates us above the average level of the cited studies. We believe that with this less morbidizing therapy concept, we are acting in the interest of our patients, even if combinations with mandibular osteotomy and genioglossus advancement may furnish somewhat higher success rates.

In the case of those patients who, even after a multi-level surgery, continue to suffer from an OSA in need of respiratory treatment, yet continue not to tolerate the respiration therapy, it should be tested whether a maxillomandibular advancement osteotomy is an option.

Finally we want to point out another recommendation. Terris [512] concludes that many sleep apneics also suffer from cosmetic impairments such as microgenia, turkey gobbler deformity or nasal deformities. He suggests treating these disorders together with the surgical treatment of the sleep apnea, as frequently the same surgical entrances are used.

To sum up, there is at least some evidence that multi-level surgery is effective in patients with moderate and severe OSA and in pa-

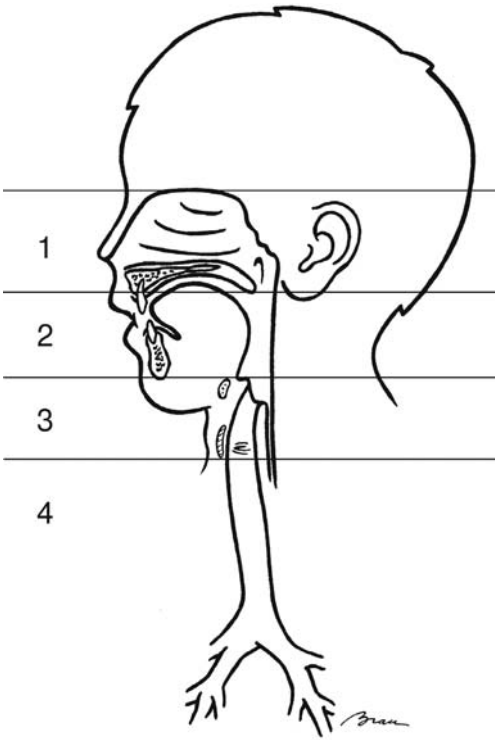


Fig. 10.1. Functional and anatomic airway zones in infants and children according to Burstein et al. [59]. *1* nares to velum, *2* lips to hypopharynx, *3* epiglottis to trachea, *4* subglottis to bronchii

tients with morbid obesity [290]. Of course, nasal ventilation therapy remains the gold standard treatment in these cases. However, as a secondary treatment after failure or definitive interruption of the ventilation therapy, surgery offers the chance of substantial improvement of the OSA for many patients.

10.4 Multi-Level Surgery in Children

The study group of Cohen and Burstein reports good success for surgical multi-level treatment in the case of children with neurological disorders [80] and children with other disorders such as Down's syndrome, hemifacial microsomia, Pierre-Robin sequence, and various craniofacial disorders [81]. In these series, the authors were able to spare respectively 83 % and 90 % of the children who had undergone surgery from having a previously recommended tracheotomy. Tonsillectomy, adenoidectomy, turbinectomy and/or septoplasty, tongue hyoid advancement, UPPP, conventional mandibular advancement, distraction osteogenesis of the mandible, and tongue reduction were combined with each other. But the authors do not mandate a rigid therapy concept. Rather, the specific combination of single operations is determined by the individual clinical diagnosis, which is classified into four levels (Fig. 10.1) [59].

In any case, multi-level surgery in children is a multi-disciplinary task requiring excellent interdisciplinary cooperation. In our opinion pediatric multi-level surgery should be reserved to a few specialized centers.

Tracheotomy

11

Tracheotomy was the first effective treatment for patients with severe obstructive sleep apnea (OSA) [270, 438, 474], and even today it remains the method of last resort. A tracheotomy is indicated much more often in children, as some malformations can be corrected only after a period of waiting for the best point in time to perform surgery.

11.1 Surgical Technique

Tracheotomy is a standard technique performed by every general, ENT, or maxillofacial surgeon. We always perform a complete mucocutaneously anastomized tracheostomy to avoid granulation and difficulties when changing the tubes. However, patients who require a tracheotomy for OSA often are morbidly overweight. Standard-sized tracheostomy tubes often are too short because of increased submental or anterior cervical girth. The surgeon has two options to overcome the problem: modify the tracheostomy tube or recontour the neck to accommodate a standard tube. As the patients are supposed to be able to handle the tracheostomy tube on their own, we prefer the latter approach. Gross and coworkers [172] described their surgical technique and retrospectively estimated their complication rate after 23 months as 43 %, including wound infections, neck abscess, and hemorrhage.

Today an increasing number of percutaneous dilating tracheotomies are performed, especially in intensive care units. It is a promising tool for patients who require their tracheotomies for short-term periods [90, 326]. Two groups of patients require tracheotomies as a treatment for OSA. In the first group, tracheotomies are performed to protect the upper airway during the immediate postoperative period after invasive procedures within the upper airway. Most surgeons perform conventional surgical tracheostomies in these patients, as they are already in the operating theater. This is what we also recommend and do. The other group of patients needs their tracheostomies for long-term periods. Here we see a clear advantage for the conventional surgical approach.

11.2 Effectiveness for OSA

Partinen et al. [377] studied the survival rates of 198 patients with OSA, of whom 71 were treated with tracheotomy, while the rest were managed conservatively with weight reduction. Over a follow-up period of 5 years, there were 14 deaths, all of them in the group undergoing conservative therapy.

Ledereich et al. [277] compared 30 patients with permanent tracheostomies with 71 patients who had received other therapies (temporary tracheotomy, uvulopalatopharyngoplasty [UPPP], tonsillectomy, nasal operations or conservative treatment with medications stimulating respiration). Patients were observed for 5 years. Excessive daytime sleepiness was reported by only 24 % of those in the tracheostomy group but by 59 % of those who had undergone other treatments. Apnea phases were recorded in 3 % of the tracheotomized patients and in 35 % of the other patients. Snoring was reported by 13 % of patients with tracheostomy but by 58 % of the comparison group.

Table 11.1. Effect of tracheotomy on the severity of obstructive sleep apnea

Author	*N*	Follow-up (months)	Age (years)	AHI pre	AHI post	Success rate (%)	Definition of success	EBM grade
Guilleminault et al. 1981 [181]	50	9–72 (mean 32)	12–66	No data	No data	100	AI <5	Retro
Haapaniemi et al. 2001 [185]	7	30–108	41–64	56.3% (O_2 min)	82.9% (O_2 min)	100	No data	Retro
Kim et al. 1998 [259]	23	No data	22–77	58.2 (37.2)	19.8 (26.0)	73.9	AHI <20	II-3
Thatcher and Maisel 2003 [513]	79	3–240	25–70	81	No data	100	No data	Retro
All	**159**	**3–240**	**12–77**			**96.2**		**IV**

AHI apnea hypopnea index, *Retro* retrospective.

Studies providing polysomnographic data are summarized in Table 11.1. Although there are no randomized controlled studies, tracheotomy can be regarded as a very effective treatment modality for OSA.

In a study by Kim and coworkers [259], all patients classified as non-responders after tracheotomy showed evidence of cardiopulmonary decompensation as defined by an initial $PaCO_2$ greater than 45 mmHg prior to surgery.

Cohen et al. compared 13 pediatric tracheostomy patients with 50 children who had undergone other kinds of sleep apnea surgery. Clinical success was achieved in 100% after tracheostomy and in 59% of the sleep apnea surgery group [82]. However, the tracheotomized children showed impaired quality of life for 95% of the items investigated.

Thatcher and Maisel [513] observed a decannulation in 16 out of 79 patients 2 months to 13 years after tracheotomy for OSA: five patients chose continuous positive airway pressure (CPAP) ventilation, three grew intolerant of their tracheostomies, three underwent successful UPPP, two experienced significant weight loss and three with unknown diagnosis of decannulation.

11.3 Postoperative Care and Complications

Guilleminault et al. [181] followed 50 tracheotomized OSA patients over a period of on average 32 months (range: 9 months to 6 years). Following tracheotomy, all patients exhibited an apnea index below 5, but all experienced persistent central respiratory events during the first postoperative year. Kim et al. [259] report that in patients with cardiopulmonary decompensation, tracheotomy led to improvement but not elimination of OSA in seven of 13 patients studied. One reason cited was the increased incidence of central respiratory events, while another related to the occlusion of the tracheostomy by chin and neck adipose tissue. A similar case with occurrence of severe central sleep apnea 4 years after initially successful tracheotomy for OSA was reported by Fletcher [148].

Conway et al. [89] followed 11 patients over 90 months and reported three categories of complications: granulation, stenoses and psychosocial problems. Less complications were seen with the cervical skin flap technique, wherefore the authors favor this technique. Thatcher and Maisel [513] recorded 14 deaths within a 20-year period after tracheotomy in 79 patients. Average age at time of death was 62 years. Five deaths were cardiopulmonary, four were from cancer, two were from postoperative

Table 11.2. Comparison of the possible indications for a temporary or permanent tracheotomy

Temporary tracheotomy	Permanent tracheotomy
For the postoperative securing of the airways after:	As ultima ratio for:
Laryngeal surgery	Therapy failures with CPAP or BIPAP masks in the case of excessive obesity
Tongue base surgery	Surgically not curable pharyngeal obstruction
Surgery on upper and lower jaw	Patients who cannot receive intubation
	Or for children with:
	Congenital malformations, which cannot be surgically corrected, or can be surgically corrected only after puberty

complications of unrelated surgeries, and one from aspiration. Tracheostomy-related mortality included one postoperative myocardial infarction and one tracheal-innominate fistula.

Obstructive sleep apnea may also recur following closure of a tracheostoma [534]. This occurs not only in patients who have undergone tracheotomy for the treatment of OSA, but also in those who have undergone tracheotomy for completely unrelated reasons. Primarily responsible are laryngeal changes in advancing age, which promote the development of OSA following closure of a tracheostoma. Elderly adults with pathologic changes in the larynx should be followed postoperatively in order to recognize the possible recurrence of OSA following closure of their tracheostomas. Five similar cases were reported by Kim et al. [259]. Likewise, polysomnography with occluded tracheostomy is recommended before surgical closure in children [520].

11.4 Indications and Contraindications

Basically, it is necessary to differentiate between a temporary and a permanent tracheotomy (Table 11.2). While we occasionally still employ the former in the context of other invasive procedures on the upper airway in order to secure the airway during the postoperative phase, we have not performed a permanent tracheotomy in adults for the past 3 years.

The situation in children is different. Especially for children with congenital malformations, a permanent tracheostomy may become necessary [7]. For example, in the case of laryngomalacia after successful tracheotomy, one can wait for the stabilization of the laryngeal skeleton and relevant growth [7, 457]. But also prematurity, cardiovascular malformations, and neurological and congenital/chromosomal abnormalities predispose a higher risk to require tracheotomy. Some malformations can be corrected surgically. Quite a few of these cases initially require a tracheotomy to gain time to await the optimal occasion to perform the necessary surgery. The following inherent dysfunctions are known to predispose to OSA, sometimes requiring a tracheotomy in children: Shy-Drager syndrome [249], Crouzon syndrome [475], congenital laryngeal anomalies (laryngomalacia, subglottic stenosis, glottic web, vocal cord paralysis, laryngeal stenosis, subglottic hemangioma) [7], congenital tracheal abnormalities (tracheomalacia, anterior compression, tracheal stenosis, tracheo-oesophageal fistula) [7], cerebral palsy [310], CHARGE association [427], Chiari type I malformation [436], achondroplasia [167], Canavan disease [149], and Duchenne muscular dystrophy [307].

Although tracheotomy is still the gold standard of care in these patients with malformations, we always have to keep in mind that this procedure causes a great deal of postoperative morbidity for both patient and family [82]. A variety of newer treatment modalities, such as distraction osteogenesis of the mandible and midface, or multi-level surgery today offer sufficient alternatives in specific cases [81].

Bariatric Surgery

12

Weight loss associated with almost complete resolution of sleep apnea was observed by Schwartz et al. [454] in those patients with obstructive sleep apnea (OSA) in whom the upper airway critical pressure fell below minus 4 cm H_2O. They concluded that weight loss was associated with a reduction in upper airway collapsibility and that resolution of sleep apnea depends on the absolute value to which the upper airway critical pressure falls. Unfortunately, only a few patients with sleep-related breathing disorders succeed in maintaining their weight reduction. Guilleminault [183] reports that only 3% of patients with OSA who experienced a significant improvement in their sleep apnea symptoms as a result of weight loss maintained their weight after 5 years; many patients, in fact, regained their weight and even exceeded their baseline weight.

In a series of 216 overweight patients with OSA, resolution of OSA by means of weight loss alone was successful in 11.1% of patients (n=24) [441]. Patients were re-examined after an average of 94.3±27.4 months. While 13 patients had maintained their weight, 11 had regained lost weight. Furthermore, six of the 13 patients (46%) who had maintained their weight had redeveloped clinically manifest OSA (apnea hypopnea index 40.5±24.1). On the other hand, nine of 11 patients (82%) who had regained lost weight exhibited manifest OSA. Thus, after 3 years, only 3% of patients showed relief of OSA. The authors point out a significant intraindividual variability and recommend periodic follow-up of these patients as a reinforcement for weight maintenance and for early detection of the reappearance of OSA.

On the other hand, Guilleminault [183] also reports promising 5-year results in morbidly obese females who had undergone gastric surgery.

Prior to 1999, bariatric surgery was largely performed using an open technique. The number of procedures done in the USA was relatively stable: between 10,000 and 15,000 per year. The numbers increased to 75,000 in 2002. Much of the increase in the number of procedures performed reflects the sudden explosion during this time of the use of a laparoscopic approach for the performance of bariatric surgery [450]. Two operative approaches are commonly performed – the vertical banded gastroplasty and Roux-en-Y gastric bypass [24, 88]. By limiting the storage capacity of the stomach to 30–50 cm^3 and reducing the pouch-emptying rate by creating a 10 mm diameter anastomotic gastrointestinal stoma, these two gastric restrictive surgeries significantly reduce the total volume and rate at which food can be consumed. The gastric bypass further limits caloric intake by inducing a dumping syndrome whenever sugar is consumed [51]. In general, mean weight loss is greater after gastric bypass than after vertical banded gastroplasty.

12.1 Effectiveness for OSA

In general, reliable and substantial weight loss can be accomplished by gastric bypass surgery with accompanying major reductions in associated co-morbidities [105]. The currently still limited polysomnographic data on the effect of gastric surgery for OSA are listed in Table 12.1.

Table 12.1 Effect of gastric surgery on the severity of obstructive sleep apnea.

Author	*n*	Surgery	Follow-up (months)	BMI pre	BMI post	AHI pre	AHI post	*p* value	EBM grade
Charuzi et al. 1985 [75]	13	Gastric bypass	6	222.5 %	150 %	88.8	8.0	<0.0005	II-3
Sugerman et al. 1992 [499]	40	Gastric bypass or VBG or HG	69.6 ±28.8	56	40	64	26	0.0001	Retro
Scheuller and Wieder 2001 [448]	15	Gastric bypass or VBG	12–144	160 kg	105 kg	96.9	11.3	<0.0001	II-3
Guardiano et al. 2003 [175]	8	Gastric bypass	28±20	49	34	55	14	=0.01	II-3
Rasheid et al. 2003 [408]	11	Gastric bypass	3–21	62	40	56	23	<0.05	II-3
All	**87**		**3–144**	**56.2**[a]	**39.2**[a]	**71.5**	**19.3**		**IV**

[a] Only studies presenting BMI data.
AHI apnea hypopnea index, *VBG* vertical banded gastroplasty, *HG* horizontal gastroplasty.

In addition to the data presented in Table 12.1, we found a case report of successful normalization of severe OSA and morbid obesity after vertical silastic ring gastroplasty [501]. Three months after surgery the patient stopped nasal continuous positive airway pressure (CPAP) ventilation during his 2-week holiday without reoccurrence of daytime fatigue.

On the other hand, it has to be mentioned that in the long run there are cases of recurrence of sleep apnea without concomitant weight increase, as described in 14 cases 7.5 years after successful weight reduction surgery [387]. Comparable results have been seen after dietary weight loss as well [441]. Nevertheless, these patients might gain access to upper airway surgery, as being severely overweight is one of the negative predictors for successful sleep apnea surgery in general.

12.2 Postoperative Care and Complications

The incidence of obstructive sleep-disordered breathing has been shown to be almost 90 % in severely obese patients [151]. Therefore we strongly recommend putting these patients onto CPAP ventilation before surgery. Empiric CPAP at 10 cm H_2O can be considered for those patients who cannot complete a polysomnography. The patient should continue to use the CPAP device until broad weight reduction has been achieved. Especially during the immediate postoperative period, the CPAP device may be needed to protect the upper airway until sedative and muscle-relaxing drugs have been metabolized [222].

Many surgeons now perform these procedures using a laparoscopic approach, thus minimizing hospital stay and time of recovery. Complications after bariatric surgery can be divided into intraoperative, perioperative, and late complications. Iatrogenic splenectomies have been reported as an intraoperative complication after open gastric bypass operations. Podnos and colleagues [394] re-

cently analyzed the complications after 3,464 cases of gastric bypass operations, published in 17 papers, for morbid obesity. Within the perioperative period they calculated the following incidences of complications (open gastric bypass vs laparoscopic gastric bypass; *p* value): anastomotic leaks (1.7 vs 2.1 %, 0.31), bowel obstruction (not reported vs 1.7 %), gastrointestinal tract hemorrhage (0.6 vs 1.9 %; 0.008), pulmonary embolus (0.8 vs 0.4 %; 0.09), wound infection (6.6 vs 3.0 %; <0.001), pneumonia (0.3 vs 0.1 %; 0.24), and death (0.9 vs 0.2 %; 0.001). Bowel obstruction (2.1 vs 3.2 %; 0.02), incisional hernia (8.6 vs 0.5 %; <0.001), and stomal stenosis (0.7 vs 4.7 %; <0.001) were identified as late complications. In other words, endoscopic procedures reduce the risk of morbidity (especially hernias and wound infections) and mortality as compared to the open approach. A detailed report on potential complications of surgery for obesity is given by Byrne [62].

Recently some preoperative factors predicting complicated postoperative management after endosopic Roux-en-Y gastric bypass operations have been identified: body mass index (BMI) >50 kg/m², forced expiratory volume (FEV_1) <80 %, previous abdominal surgeries, and abnormal ECG [169].

12.3 Indications and Contraindications

Gastric surgery is reserved for morbidly obese patients (BMI >35 kg/m²) with obstructive sleep apnea or any other serious medical condition. Primarily we put morbidly overweight patients on nasal CPAP or BiPAP ventilation. In non-responders and patients who cannot accept ventilation therapy, even multilevel surgery shows reduced success rates with increasing overweight. For these patients gastric surgery seems to offer a noteworthy alternative, in particular as untreated OSA may cause continued morbidity especially in the extremely obese patient.

If surgery is considered, the patient should be evaluated by a multidisciplinary team that incorporates medical, nutritional, and psychological care [299].

Anesthesiologic Airway Management

13

13.1 Implications in Patients with OSA

Obstructive sleep apnea (OSA) is, by definition, a problem of the upper airway. Its presence indicates an increased likelihood of difficult intubation and airway maintenance under anesthesia. Three different groups of patients undergoing general anesthesia can be defined that require different strategies for managing the airway: patients who have been diagnosed for OSA, patients with symptoms suggestive for sleep apnea, and patients who lack signs of the syndrome or in whom such features are missed preoperatively. Surgical procedures can be OSA related or for any other diagnosis with varying invasiveness. The common goal in all patients will be to avoid inadequate ventilation and oxygenation resulting in hypoxemia or hypercarbia and any associated hemodynamic changes (e.g., tachycardia, arrhythmia, and hypertension) leading to increased morbidity and mortality. Death, brain injury, cardiopulmonary arrest, airway trauma and damage to teeth are among the adverse events associated with difficult airway management.

Widespread guidelines for management of the difficult airway were introduced by the American Society of Anesthesiologists (ASA) in 1992 and have been published in revised form in 2002 [14]. A difficult airway is defined as the clinical situation in which a conventionally trained anesthetist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both. The purpose of the ASA guidelines is to reduce the likelihood of adverse outcomes.

The first step in managing the difficult airway is to identify any patient at risk in the preoperative period. Evidence on prediction of difficult airways is inconclusive, but any patient with a diagnosed OSA or a suspicion based on clinical signs such as obesity, limited mouth opening or a large tongue should be treated as a patient with a difficult airway until proven otherwise. The description of a difficult airway in previous anesthesia records or in an anesthesia pass issued by an anesthetist offers clinically suggestive evidence that difficulties may reoccur. Whenever possible, an airway history should be obtained prior to the initiation of anesthetic care in all patients. Focused medical history, physical examination and review of medical records may improve the detection of a difficult airway in patients with OSA, therefore enabling the anesthetist to prepare the patient and the anesthesia team for the occurrence of airway difficulties. In some patients, additional evaluation may be indicated to judge further the likelihood of the anticipated airway difficulty.

It is widely accepted that preparatory measures will help to minimize the risk in patients presenting with a difficult airway. In a known or suspected difficult airway, the patient should be informed of the special risks and procedures for management of the difficult airway. An additional experienced anesthetist and specialized equipment for difficult airway management should be available, and a strategy or algorithm for establishing a secure airway should be defined. Pre-oxygenation should be performed for 3 or more minutes and supplemental oxygen should be administered whenever possible during the

process of establishing a secure airway and also after extubation.

There are several basic management choices when faced with a suspected or known difficult airway: awake intubation versus induction of general anesthesia followed by intubation attempts, the preservation versus the ablation of spontaneous ventilation, non-invasive versus invasive techniques for the initial approach to intubation.

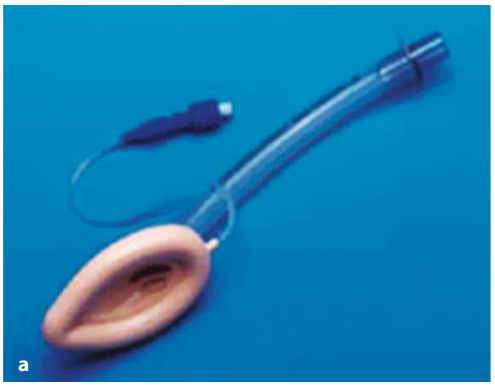
13.2 Strategies for Intubation in Patients with a Known or Suspected Difficult Airway

One important strategy in patients with a known or suspected difficult airway may be the avoidance of the necessity for invasive airway management. Whenever feasible, local anesthesia infiltration or regional blockades should be preferred in these patients.

Awake intubation may be attempted in patients with OSA with a fiberoptic bronchoscope after application of local anesthetics. Once the glottis has been successfully identified, the tracheal tube can be advanced and general anesthesia can be inducted. If the procedure fails due to lack of patient cooperation, or difficulties in identifying the glottic aperture caused by anatomical aberrations or massive secretion, the case may be canceled, the feasibility of local or regional anesthesia may be considered, or the decision for invasive airway access may be made. The latter might be considered as first choice in some patients with the options of surgical or percutaneous tracheostomy and surgical or needle cricothyrotomy with the option of jet ventilation.

When general anesthesia is induced in patients with a known or suspected difficult airway, tracheal intubation will still be successful in a number of patients without problems, especially when performed by an experienced anesthetist. If the initial intubation

Fig. 13.1. McCoy blade with option of leverage of the epiglottis



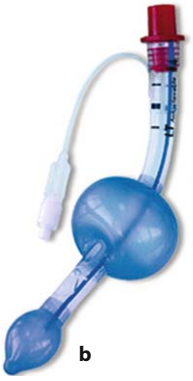


Fig. 13.2. **a** Laryngeal mask airway. **b** Laryngeal tube

attempt fails, an additional anesthetist should be called if not already present, and the option of awakening the patient and returning to spontaneous ventilation should be considered based on the urgency of the surgical procedure. The possibility of face mask ventilation is the key issue for all further proceedings: when face mask ventilation and oxygenation of the patient are possible, repeated attempts at tracheal intubation can be tried, with modified techniques where necessary. Alternative approaches may be the use of a fiberoptic bronchoscope, the use of special laryngoscope blades such as the McCoy blade with the option of additional leverage of the epiglottis (Fig. 13.1), or the use of an intubation stylet. The McCoy blade allows a major problem in many OSA patients, the big tongue, to be overcome. In many patients, correct positioning of the head will further aid in achieving the goal of tracheal intubation. Pressure on the cricoid cartilage by an assistant, ideally backward, upward and towards the right ("BURP" – backward, upward, rightward pressure) may also facilitate identification of the glottis. Any "blind" intubation attempts without visualization of the glottis should be avoided, as they may lead to trauma and swelling interfering with further management of the airway.

Whenever face mask ventilation is difficult or impossible in a patient after induction of general anesthesia and a failed intubation attempt, supraglottic airway devices such as the laryngeal mask airway (Fig. 13.2 a) or the laryngeal tube (Fig. 13.2 b) should be inserted to ensure oxygenation of the patient while reconsidering intubation strategies. One approach can be to attempt fiberoptic intubation via the supraglottic device, directly or with a tube exchange catheter, after preoxygenation of the patient.

Fiberoptic intubation may be facilitated by using the intubating laryngeal mask airway (Fig. 13.3), which provides a curved steel shaft guiding the fiberscope towards the glottis. Another option is to reconsider the necessity of tracheal intubation versus the possibility of maintaining the airway with a supraglottic airway device for the surgical procedure planned.

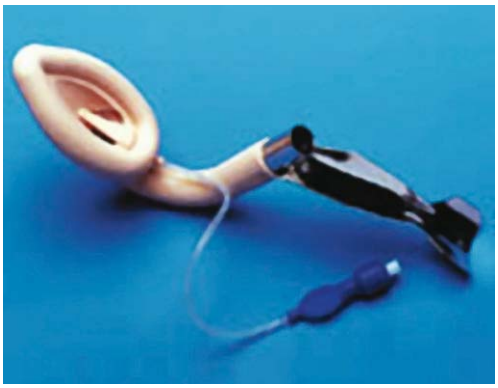


Fig. 13.3. Intubating laryngeal mask airway

Fig. 13.4. **a** ProSeal laryngeal mask airway. **b** Laryngeal tube suction

Newer alternatives to tracheal intubation and face mask ventilation such as the ProSeal laryngeal mask airway (Fig. 13.4a) or the laryngeal tube suction (Fig. 13.4b) provide an additional lumen allowing placement of a gastric tube and suctioning and should be preferred over the standard devices in obese patients, as the airway seal achieved is better, too.

13.3 Life-Threatening Situations

In any situation requiring urgent airway maintenance, the presence of a preformulated strategy to ensure oxygenation and achieve tracheal intubation is absolutely mandatory.

The anesthetist may be faced with two different scenarios: a patient presenting with severe obstruction, cyanosis and/or hypoxemia who requires urgent intubation and cannot be ventilated with a face mask or cannot be intubated (or a combination of both). In other patients, general anesthesia may be inducted and the team is surprised by difficulties maintaining the airway in a patient who lacks signs of a difficult airway or in whom such features were missed preoperatively.

The emergency airway should be basically the same as above, but the choice of the options and strategies should be narrowed down to the techniques the anesthetist is most acquainted with. In any patient requiring urgent oxygenation, supraglottic airway devices should be inserted early even when face mask ventilation is possible, as the airway seal with these devices is superior and the rate of gastric insufflation is therefore lower. Fiberoptic intubation via these devices or the use of a newer supraglottic alternative providing access to the alimentary tract for suctioning should be considered. However, if the problem is caused by airway obstruction on the glottic level, this strategy fails and options of surgical or percutaneons tracheostomy and surgical or needle cricothyrotomy with the option of jet ventilation must be considered early, especially when oxygenation is difficult or not possible. Close cooperation with the ENT specialist is mandatory, not only in these critical incidents, but in the pre- and perioperative management of patients with OSA.

13.4 Extubating the Difficult Airway

After successful management of a difficult airway, several considerations should guide the decisions for the postoperative phase. The surgical procedure, the condition of the patient, as well as any documented or suspected trauma to the upper airway caused by manipulations during the process of securing the airway will influence the anesthetist's strategy for extubating the patient with a difficult airway. While removal of the tracheal tube will not be a problem, reinsertion in case of any airway obstruction will not be easier than during the first attempt.

Immediately after a patient with a difficult airway has been successfully intubated, the equipment for airway management must be rechecked and completed as necessary to allow adequate reaction on any peri- and postoperative airway problems. The use of steroids to reduce mucosal swelling of glottis and upper airway induced by manipulation during repeated intubation attempts is recommended.

In general, patients with a known difficult airway must be awake and communicative for extubation and airway reflexes must have returned. Spontaneous ventilation must be sufficient, allowing an adequate tidal volume and oxygenation. After profound suctioning of the pharynx to remove secretions, the cuff of the tracheal tube should be deflated and the tube should be closed to test whether swelling may cause airway obstruction after removal of the tube. If no breath sounds are noticed around the tracheal tube, there is a high risk of complete airway obstruction and the patient should be taken to an intensive care unit for prolonged weaning. If the swelling persists, tracheostomy must be considered. In all patients in whom breath sounds around the tube can be heard, extubation may be attempted with the complete equipment and personnel for difficult intubation present.

13.5 Postoperative Care

Patients with OSA often show respiratory depression and repetitive apneas even after successful surgery in the postoperative phase. Respiratory disorders can be induced by post-traumatic swelling of the upper airways leading to a mechanical obstruction. Postoperative edema formation can be prevented by infusion of steroids during the operation. Another aspect of postoperative respiratory problems is the respiratory depression induced by perioperatively administered opioids. There are many reports demonstrating the coincidence of postoperative apneas and the use of opioids, but the correction of upper airway abnormalities is very painful and leads to the obligatory use of opioids in combination with a non-opioid analgesic. Furthermore the use of clonidine seems to be helpful because of the co-analgesic effect of the substance and the reduction of blood pressure. Elevated blood pressure levels often can be seen after surgery, leading to a higher risk of postoperative bleeding.

To avoid postoperative respiratory complications and episodes of high blood pressure, it seems necessary to monitor these patients for at least 2 hours. An admission to the intensive care unit can be prevented by an interdisciplinary cooperation in the recovery area.

13.6 Documentation

The presence and nature of airway difficulties should be documented in the patient´s file. In addition, an anesthesia pass should be issued describing the problem and the strategy that led to successful management. The patient or a responsible person should be informed and instructed to carry the pass at all times and show it whenever surgical procedures are planned to facilitate future medical care.

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