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Preface

Mansoor Madani, DMD, MD
Guest Editor

Sleep is defined as the state of natural rest, when there is a reduction in voluntary body movement, temporary blindness, decreased reaction to external stimuli, and loss of consciousness. Sleep is the period of time that the rate of anabolism (the synthesis of cell structure) increases, and the rate of catabolism (the breakdown of cell structure) decreases. A restful night of sleep is necessary and essential for normal body function and survival. Unfortunately, for over a billion people on earth, restful sleep is interrupted by loud snoring and, in many cases, sleep interruption and stoppage of breathing—a condition we all know as obstructive sleep apnea. Those with sleep apnea suffer socially, medically, and financially. Because of its close association with obesity, scientists have noticed a significant increase in the rate of snoring and sleep apnea.

To rectify the snoring problem, hundreds of devices have been invented, many of which are based on unrealistic promises of cure from this annoying condition. When the research of sleep-related disorders began several decades ago, the surgeons of many fields of medicine and dentistry also introduced various procedures, none of which guarantee a cure for sleep apnea. Although cumbersome and, for some patients, hard to tolerate, medical devices such as CPAP (Continuous Positive Airway Pressure) and BIPAP (Bi-level Positive Airway Pressure) are extremely effective and useful.

As surgeons, our primary goal should be focused on patient education and guidance. Unlike many other surgical procedures, the various modalities are not beneficial for all. Weight reduction must be a top priority of recommendation to all overweight or obese patients. To promise a cure or total elimination of symptoms would be an enormous mistake. Making sure that patients, as well as their bed partners, have realistic expectations is the key to success. Collaborations with other colleges and with interested surgeons in other fields will help us to care for our patients with compassion and accuracy. Admitting to patients' lack of response to some surgical or non-surgical ways will open our minds to discover even newer methods and technologies not yet in existence. There will be patients who are disappointed from the surgery results or are non-compliant to use their CPAP, BIPAP, or dental appliances. Only with an open mind and in-depth understanding of the issues at hand can we guide our patients in the right direction.

In this issue, we have compiled information that is crucial to the basic understanding of the socioeconomic and pathophysiologic effects, as well as many surgical and non-surgical methods of diagnosis and treatment of snoring and obstructive sleep apnea. Our hope is that readers choose each procedure carefully and avoid those that are not compatible with their patients' airway anatomy. We explore each section in detail and as thoroughly as possible. We have developed a unique treatment planning chart for snoring and obstructive sleep apnea that guides

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doi:10.1016/j.cxom.2007.06.004

the reader in a systematic way in choosing different options. As for the diagnosis and treatment planning of snoring and sleep apnea, nasopharyngoscopy is explained in a clear and detailed manner. New techniques of home studies researched at the Capital Health System in Trenton, New Jersey, are explained as well. This research is unquestionably going to change the future of sleep medicine. The surgical techniques are explained in a simple way with considerable illustrations, some exclusive to this publication.

Finally, for all professionals who choose to utilize dental appliances, a comprehensive, illustrated chapter is dedicated to this subject. I hope you enjoy reading this issue and enlighten me with your thoughts, personal techniques, and results.

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Dedication

To my wife, Dr. Farideh Madani, whose assistance, support, and encouragement have made years of research and accomplishment possible for me. To my children, Reza and Sheedeh, who are a pure inspiration and have helped me remain true to my profession. To my contributing authors and colleagues whose guidance, enthusiasm, and expertise have made this publication possible. To our extraordinary medical illustrators for their incredible talent in making our concepts more readily understandable and comprehensible. Finally, to our patients and their loved ones who have challenged all of us to find ways to treat the unique conditions of snoring and sleep apnea, which have been ignored for thousands of years.

1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.06.005

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Atlas of the Oral and Maxillofacial Surgery Clinics

Definitions, Abbreviations, and Acronyms of Sleep Apnea

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Understanding the most commonly used definitions, terms, and acronyms in medicine as they relate to sleep-related disorders is a crucial first step for all practitioners interested in caring for patients who suffer from such conditions. We have chosen several important terms, definitions, and acronyms for this article. Many other terms are discussed in each individual article.

Apnea: Literally means ''no breath.'' A cessation, or near cessation, of respiratory airflow that lasts 10 seconds or longer.

Obstructive sleep apnea (OSA): Cessation of breathing during sleep because of a mechanical obstruction, such as a partially collapsed trachea, retropositioning of the tongue in the airway, which blocks airway passage, or a large amount of tissue in the upper airway (Fig. 3). It is a common respiratory sleep disorder characterized by snoring and episodes of breathing cessation or absence of respiratory airflow ($\geq$10 seconds) during sleep despite respiratory effort.

Hypopnea: A disturbance in respiratory airflow that does not meet the defined criteria of apnea but still results in a physiologic consequence, such as an oxygen desaturation and/or an arousal from sleep (Fig. 2). More specific definitions vary widely; for example, a 20% to 50% or more reduction in airflow associated with an arousal and/or a 3% to 4% drop in oxygen saturation. The physiologic consequences of hypopneas are equivalent to those of apneas. It is generally accepted as 50% loss of airflow for 10 or more seconds caused by the lack of thoracic and abdominal effort.

Central sleep apnea: Cessation of breathing (respiratory effort) during sleep as a function of neurologic failure. Simply, the body ''forgets'' to breathe.

Mixed sleep apnea: The combination of central and obstructive sleep apnea in one patient.

Snoring: A noise produced primarily on inspiration during sleep that is caused by vibration of the soft palate and the pillars of the oropharyngeal inlet (Figs. 1 and 4). Snoring implies incomplete obstruction of the upper airway.

Somnolence: Difficulty in maintaining alert wakefulness so that a person falls asleep if not actively aroused. Also called hypovigilance, sleepiness.

Lowest oxyhemoglobin saturation (LSAT): A measure of the lowest level of arterial oxygen in the blood during sleep. Normal oxyhemoglobin saturation is 95% to 98%.

Basic sleep cycle: Progression through orderly succession of sleep states and stages. For the healthy adult, the first cycle begins by going from wakefulness to non–rapid eye movement (NREM) sleep. The first REM period follows the first period of NREM sleep, and the two

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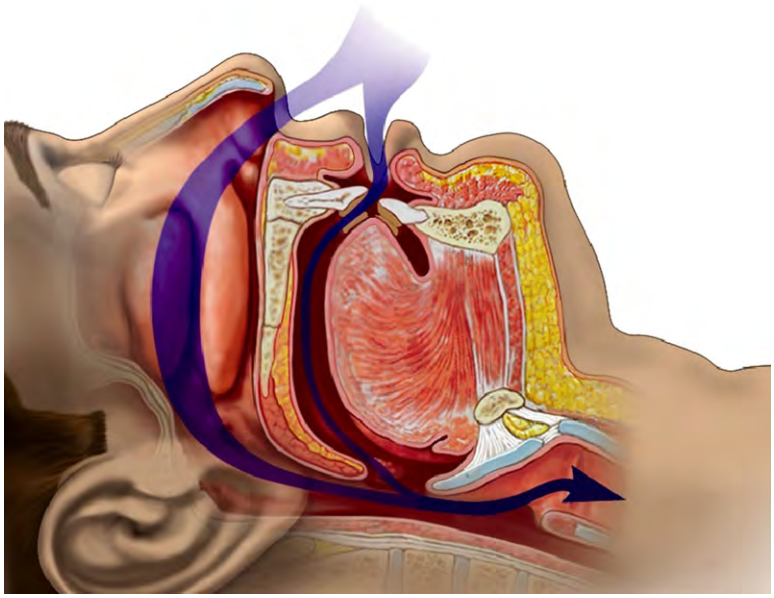

Fig. 1. Normal airway: normal position and size of tongue, hard and soft palate, epiglottis, geniohyoid, and genioglossus muscles, as well as position of the jaws and hyoid bone plus an open nasal passage allows airflow without obstruction through the upper airway. (*Courtsey of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA, all rights reserved; with permission.)

sleep states continue to alternate throughout the night, with an average period of 90 minutes. A night of normal human sleep usually consists of four to six NREM/REM sleep cycles.

NREM (non-REM stages of sleep): Major states of sleep with the exception of REM sleep. It comprises four stages of sleep. **Sleep Stage 1:** A stage of NREM sleep that occurs after

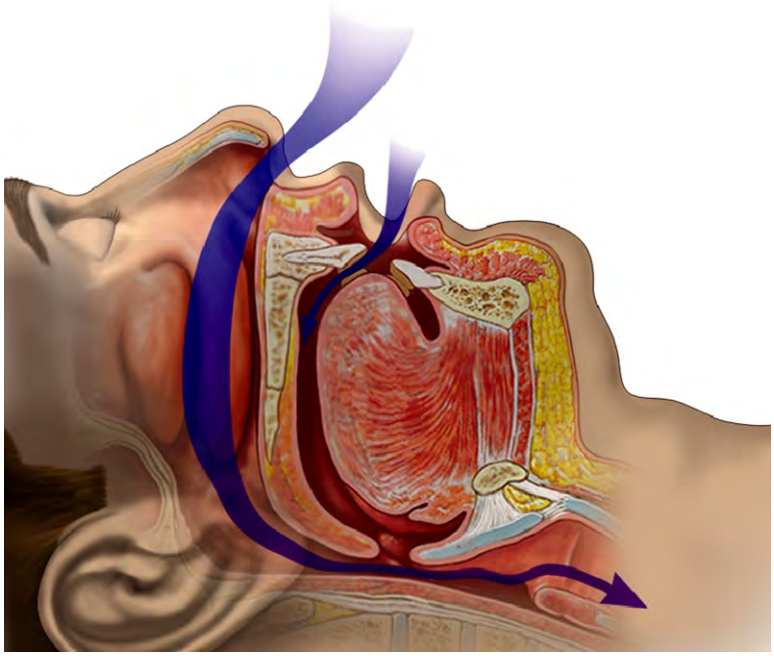

Fig. 2. Hypopnea: enlargement of tongue, elongation of the uvula and soft palate, and partial upper airway obstruction creates a disturbance in respiratory airflow. Although this partial obstruction differs from complete blockage of the airway (apnea), it still results in physiologic consequences, such as oxygen desaturation and/or arousal from sleep and snoring. (*Courtsey of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA, all rights reserved; with permission.)

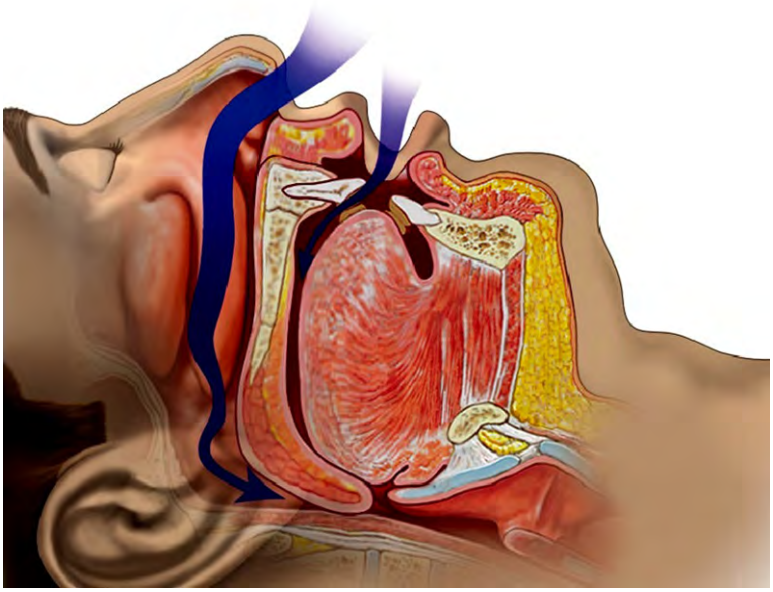

Fig. 3. Obstructive sleep apnea: a combination of several factors causing complete upper airway obstruction leading to cessation of airflow for at least 10 seconds (and more), if repeated more than 5 times per hour then is described as obstructive apnea. The structures blocking the upper airway include: enlarged tongue and retropostioning of tongue base in the pharynx, elongated and edematous uvula, obstructive tonsils and nasal passages, hypertrophic pharyngeal walls, and in general constricted oropharynx. (*Courtsey of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA, all rights reserved; with permission.)

waking. Its criteria consist of a low-voltage electroencephalogram (EEG) with slowing to theta frequencies, alpha activity less than 50%, EEG vertex spikes, and slow rolling eye movements; no sleep spindles, K-complexes, or REMS. Stage 1 normally comprises 4% to 5% of total sleep. **Sleep Stage 2:** A stage of NREM sleep characterized by sleep spindles and K-complexes against a relatively low-voltage, mixed-frequency EEG background; high-voltage delta waves may comprise up to 20% of stage 2 epochs. Stage 2 usually accounts for 45% to 55% of total sleep time. **Sleep Stage 3:** A stage of NREM sleep defined by at least 20% and not more than 50% of the period (30-second epoch) consisting of EEG waves less than 2 Hz and more than 75 uV (high-amplitude delta waves); a ''delta'' sleep stage. With stage 4, it constitutes ''deep NREM sleep.'' Stage 3 usually comprises 4% to 6% of total sleep time. **Sleep Stage 4:** All statements concerning NREM stage 3 apply to stage 4 except that high-voltage, slow EEG waves cover 50% or more of the record. Somnambulism, sleep terrors, and sleep-related enuresis episodes generally start in stage 4 or during arousals from this stage. Deep sleep refers to combined NREM sleep stages 3 and 4 in sleep studies. EEG delta waves (EEG activity with a frequency <4 Hz) also are prevalent or predominant during these two stages of sleep. This period is called ''delta sleep,'' and it appears usually only in the first third of the sleep period. Stage 4 usually takes up 12% to 15% of total sleep time.

REM: The fifth stage of sleep, in which brain activity is extensive, brain metabolism is increased, and vivid hallucinatory imagery or dreaming occurs. It is a state of sleep that recurs cyclically several times during a normal period of sleep, and it is characterized by increased neuronal activity of the forebrain and midbrain, depressed muscle tone, and—especially in humans—dreaming, REM, and vascular congestion of the sex organs. Also called ''paradoxical sleep,'' because in the face of this intense excitation of the central nervous system and presence of spontaneous REM, resting muscle activity is suppressed. The EEG is a low-voltage, fast-frequency, non-alpha record. REM usually comprises 20% to 25% of total sleep time.

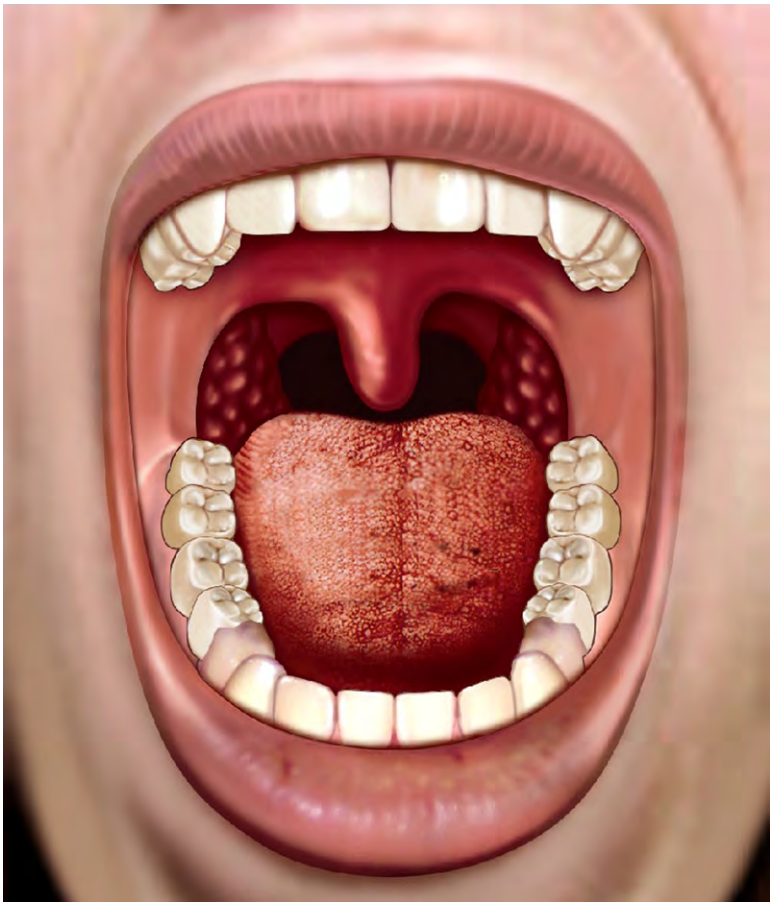

Fig. 4. Surgical treatment always begins in a comprehensive evaluation of the oral and nasal cavity. The size and position of tongue, tonsils, soft palate, uvula, and the jaws, as well as the pharyngeal opening, are of crucial assessment in this view. (*Courtsey of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA, all rights reserved; with permission.)

Polysomnograph/Polysomnogram: Biomedical instrument for measuring multiple physiologic variables of sleep.

Polysomnography (PSG) (sleep study): A mechanical recording of a person's sleep using many criteria, such as the amount of oxygen in bloodstream, pulse, brain waves, and eye movement, among others. Polysomnography continuously and simultaneously records physiologic variables during sleep (Fig. 5).

Full-night polysomnography: Uninterrupted overnight sleep studies compared to split-night studies, during which time patients are awakened to try using continuous positive airway pressure (CPAP) for the second half of their sleep (Fig. 6).

Electroencephalogram (EEG): Recording of electrical potentials from the brain through the scalp and the changes in these potentials. The EEG is one of the three basic variables (along with the electro-oculogram and electromyogram) used to score sleep stages and waking. Surface electrodes are used to record sleep in humans and record potential differences between brain regions and a neutral reference point or between brain regions.

Electromyogram (EMG): Recording of electrical activity from the muscular system; in sleep recording, synonymous with resting muscle activity or potential. The chin electromyogram, along with EEG and electro-oculogram, is one of the three basic variables used to score sleep stages and waking. Surface electrodes are used to record sleep in humans and measure activity from the submental or masseter muscles. These records reflect the changes in resting muscle activity. During REM sleep, the chin/cheek electromyogram is tonically inhibited.

Electro-oculogram (EOG): Recording of voltage changes that result from shifts in position of the eyeball, which is possible because each globe is a positive (anterior) and negative

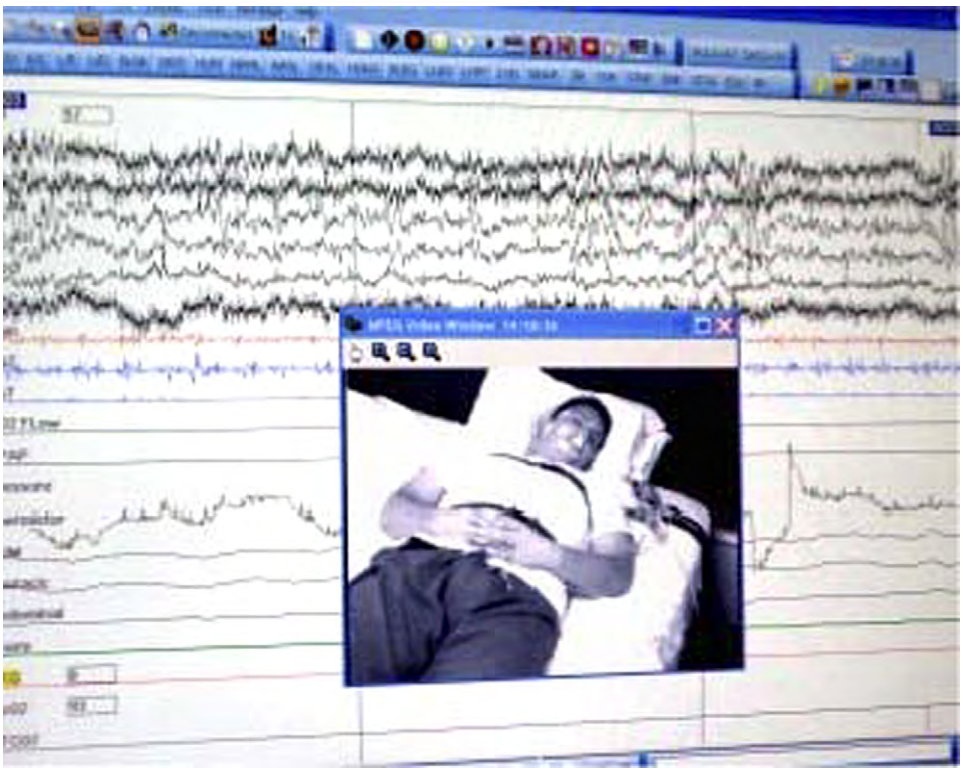

Fig. 5. In an overnight standard polysomnography (sleep apnea study), patients are monitored both visually and electronically. The patient's 24-channel multilevel monitoring and direct visualization using a computer monitor are shown here.

(posterior) dipole. Along with the EEG and the electromyogram, one of the three basic variables used to score sleep stages and waking. Human sleep recordings use surface electrodes placed near the eyes to record the movement of the eyeballs. REM in sleep indicates a certain stage of sleep (usually REM sleep).

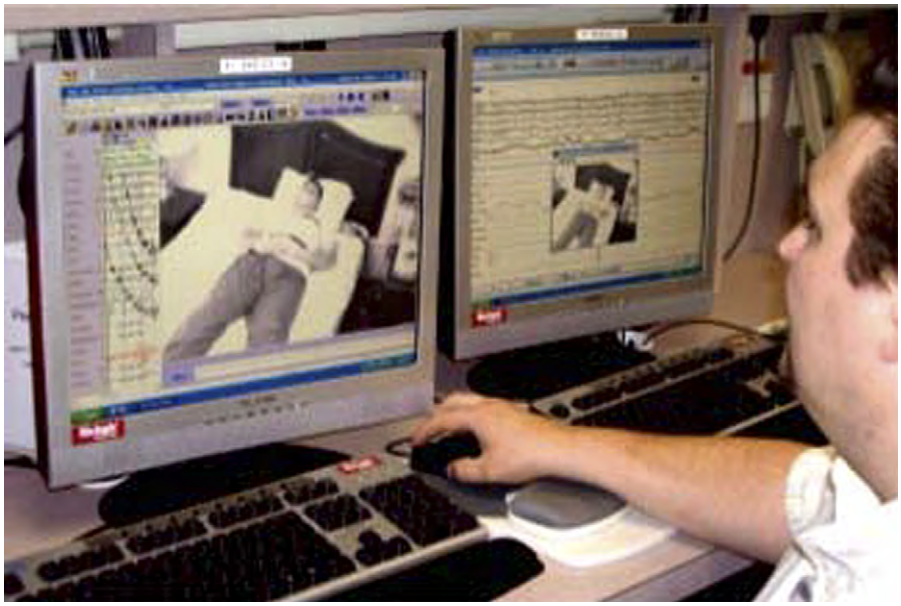

Fig. 6. Polysomnography requires an overnight technician trained in monitoring patients to asses each individual and, in some cases, score the results. The more modern devices will perform complete scoring automatically.

Electrocardiogram: A graphic measurement of cardiac myoneural electrical activity.

Pulse oximetry (OX): A noninvasive measurement of the estimated level of arterial oxygenation in circulating blood SaO_2 (saturation of oxygen) A measure of blood oxygenation.

Home sleep monitoring: Sleep studies performed at home are gradually modernized and used as an alternative to polysomnography (Fig. 7). Some of the devices have been approved by the US Food and Drug Administration for screening and diagnosis of sleep apnea.

CPAP (NCPAP, nCPAP): A device that is used to alleviate symptoms of sleep apnea by providing a continuous, stable, predetermined volume of air to a nasal mask that the patient wears while asleep (Fig. 8). This continuous pressure keeps the airway from collapsing, as it does during obstructive sleep apnea. The pressure of CPAP is expressed in centimeters of water (cm H_2O). The positive pressure can range from 5 to 20 cm H_2O. Different patients require different pressures. The value is determined in a CPAP titration study.

BIPAP (bilevel positive airway pressure): Bilevel pressure device used to treat sleep apnea. The ''bi'' refers to two pressures: a lower pressure for exhalation and a higher pressure for inhalation. Bilevel machines are more expensive than a standard CPAP, but some patients tolerate it better because they can exhale comfortably against the constant inhalation pressure. The BIPAP can be set to drop the level at specific intervals or on demand.

Auto-PAP (APAP, automatic titrating [autotitrating] positive airway pressure): Also used to treat obstructive sleep apnea by positive airway pressure in which air pressure levels are automatically adjusted according to the patient's breath-to-breath requirements.

Periodic limb movement syndrome (PLMS): Characterized by leg movements or jerks that typically occur every 20 to 40 seconds during sleep. Periodic limb movement disorder causes sleep to be disrupted. These movements are typically reported by the bed partner. They fragment sleep and leave the person with excessive daytime sleepiness. This condition is related to restless leg syndrome.

Restless leg syndrome (RLS): A disorder of wakefulness in which leg movement may impede sleep onset. This feeling is difficult to describe and commonly is referred to as a crawling, tingling, or prickling sensation.

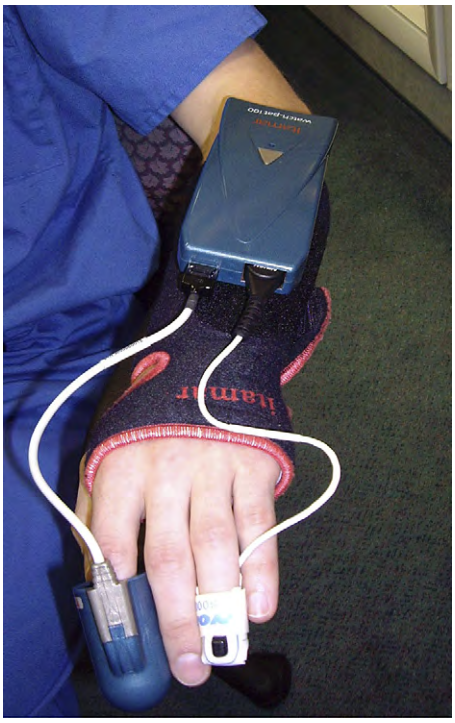

Fig. 7. Home sleep monitoring: one of the latest technology to asses, monitor, and diagnose sleep apnea. It eliminates overnight stay in a lab or hospital. It is a wrist-worn device that allows patient to be tested at the convenience of their home. The PAT 100 device comes with a memory card that, once connected to a computer, will score and create a report within minutes.

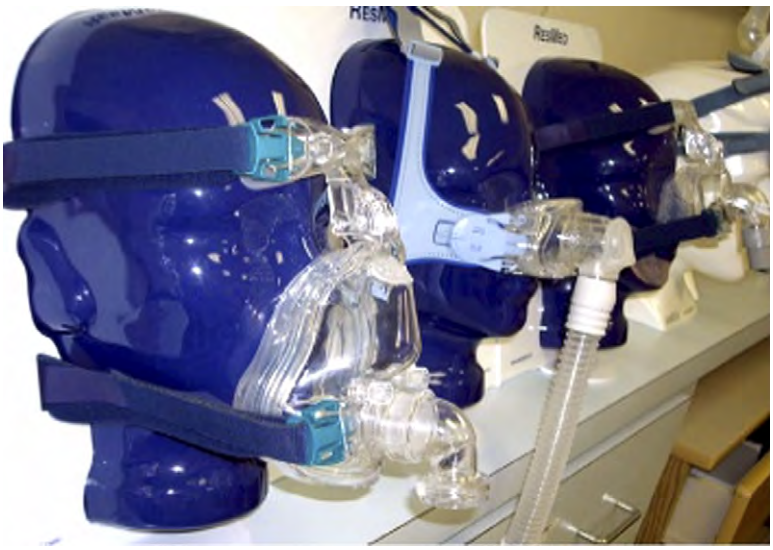

Fig. 8. There are various designs of CPAP (Continuous Positive Airway Pressure), although considered "the gold standard" for treatment of obstructive sleep apnea, CPAP has poor patient compliance and acceptance because it is considered cumbersome and, in some cases, intrusive.

Upper airway resistance syndrome (UARS): Excessive daytime sleepiness (with or without other consequences of sleep fragmentation) caused by repetitive sleep arousals related to airway-resistive breathing disturbances, with respiratory disturbance index less than five per hour and in the absence of oxygen desaturations less than 90%. Snoring is generally (but not necessarily) present. Presumptively, "nonapneic snoring" with excessive daytime sleepiness.

Velopharyngeal incompetency or insufficiency (VPI): A dysfunction of the sphincteric closure action of the soft palate that allows regurgitation of fluid into the nose during swallowing and air escape into the nose during speech (open rhinolalia or "cleft palate speech"). This condition has been reported to be associated with excess tissue removal of soft palate during traditional uvulopalatopharyngoplasty.

Indexes of importance to sleep apnea

As a general rule, knowing various indexes is one of the most important tools of communication among interdisciplinary teams that manage patients with sleep-related disorders. We briefly describe a few important indices.

Apnea Index (AI): The number of apneic episodes that occur per hour during sleep. A measure of the severity of sleep apnea.

Hypopnea Index (HI): Mean number of hypopneic episodes per hour of sleep.

Apnea-Hypopnea Index (AHI): The number of apneic plus hypopneic episodes that occur per hour during sleep; 5 to 20 = mild, 21 to 50 = moderate, more than 51 = severe.

Body Mass Index (BMI): A measure of weight compared with height, calculated as weight in kilograms divided by height in meters squared. Some researchers believe that chances of heart attack and stroke increases ninefold for patients with morbid obesity. The categories for body mass index are as follows:

Healthy (desirable): 18.5–24.9 kg/m2
Overweight: 25–29.9
Obesity: ≥ 30
Morbid obesity: ≥ 35

Oxygen Desaturation Index: The number of oxygen desaturations less than 90% that occur per hour of sleep.

Respiratory Arousal Index: The number of breathing-related sleep arousals or respiratory event arousals (alterations of sleep stages) per hour of sleep. This is the best measure correlated to excessive daytime sleepiness.

Respiratory Disturbance Index (RDI): Also called the apnea-hypopnea index (AHI), it is the mean number of respiratory disturbances per hour of sleep. The respiratory disturbance index is a calculation of the total number of apneas and hypopneas divided by number of hours of sleep.

Epworth Sleepiness Scale (ESS): Index of sleep propensity during the day as perceived by patients and derived from the answers to eight questions. This subjective score ranges from 0 to 24 and is not considered a reliable score.

Flattening Index: Number indicating the amount of airflow limitation caused by partial closure of the upper airway; 0.3 indicates an open airway, 0.15 is mildly obstructed, 0.1 is severely limited airflow, and 0.0 reflects a totally closed airway. Flattening index is used to identify the condition known as upper airway resistance syndrome and is continuously recorded in diagnostic sleep studies and CPAP titrations.

PLMD Arousal Index: Number of sleep-related periodic leg movements per hour of sleep that are associated with an EEG arousal.

Multiple sleep latency tests (MSLT): Measurements of the time required for sleep onset, which indicate a person's tendency to fall asleep.

Neck circumference: Not truly an index of apnea but clearly an important measure of estimated upper airway obstructions. As a general rule, neck size of more than 16.5 inches may correlate with obstructive sleep apnea in male patients. In women this correlation may be much lower neck size.

Retrognathic jaw position: Not an index but an orthodontically relevant measuring ratio that correlates with retropositioning of the jaw and the tongue base, which creates upper airway obstruction.

Procedures terminology

Various surgical procedures and hundreds of devices and inventions are designed to correct, reduce, or even eliminate snoring and sleep apnea. No claim has ever been proved to effectively eliminate the problem of obstructive sleep apnea completely, however. The reason is simply the multisite factors of apnea and inability of a single procedure or device to address them all. We briefly describe a few procedure terms:

Mandibulomaxillary advancement: A surgical procedure to advance either one or both jaws forward in addition to positioning the chin forward. The effectiveness of this procedure in corrected selected patients is equal to CPAP.

The illustration in Fig. 9A depicts an open bite deformity with retrognathic mandible and maxillary vertical excess. Note narrow airway in the retropharynx area. By performing maxillary impaction and advancement genioplasty and mandibular forward expansion, not only is the obstructed airway corrected but also the patient's functional and cosmetic enhancement are appreciated (Fig. 9B).

Genioglossus advancement (GGA): Advancement genioplasty to include genioglossus muscle to reposition the tongue in a forward position for treatment of obstructive sleep apnea.

Hyoid advancement: A surgical procedure to advance the hyoid bone and open the airway passage to improve obstructive sleep apnea.

Oral appliance therapy: A dental device designed to advance the position of the tongue and lower jaw forward to improve breathing and reduce snoring sound in patients with obstructive sleep apnea or various other disorders. Unfortunately, a patient's long-term compliance is an important issue when the appliance is given to most patients.

Radiofrequency ablation or radioablation: A thermal ablative treatment method to reduce hypertrophy of soft tissues (Fig. 10A–C). It also has been termed "somnoplasty and coblation" based on the makers of the devices. Long-term success of these procedures in most

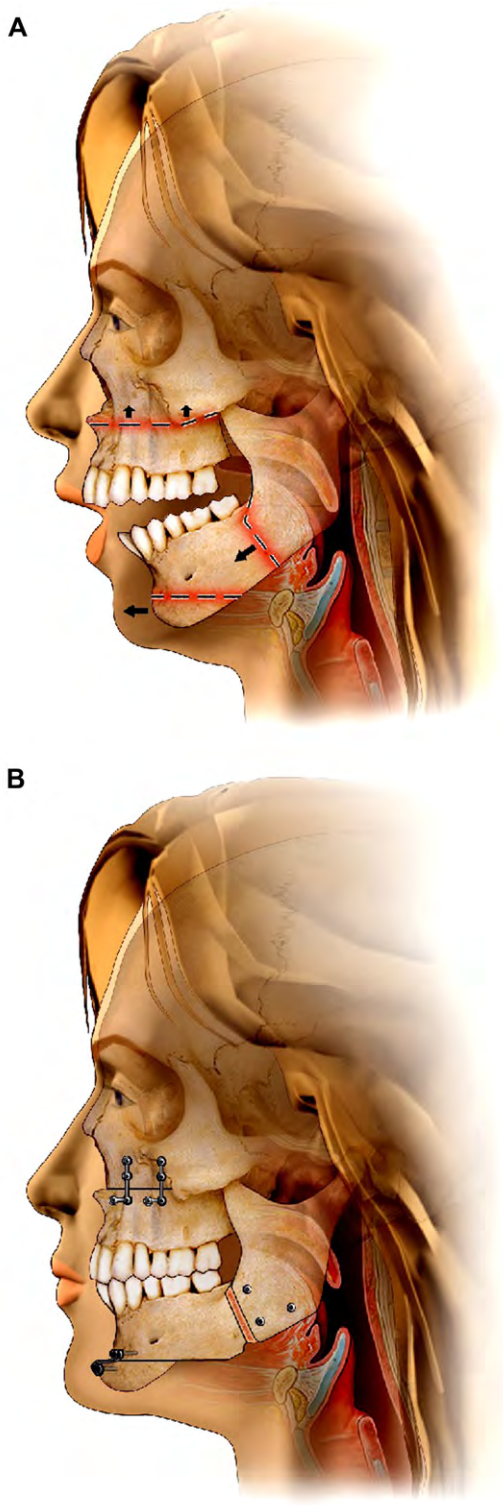

Fig. 9. (*A*) Mandibular micrognathism or bimaxillary retrognathism and a receded chin create a narrowing of the pharyngeal airway. Typically, patients have a retropostioning hyoid bone and very narrow airway. (*B*) A combination of maxillomandibular osteotomy and genioplasty, as well as advancement of genioglossus and geniohyoid muscles can significantly improve the upper airway. (*Courtsey of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA, all rights reserved; with permission.)

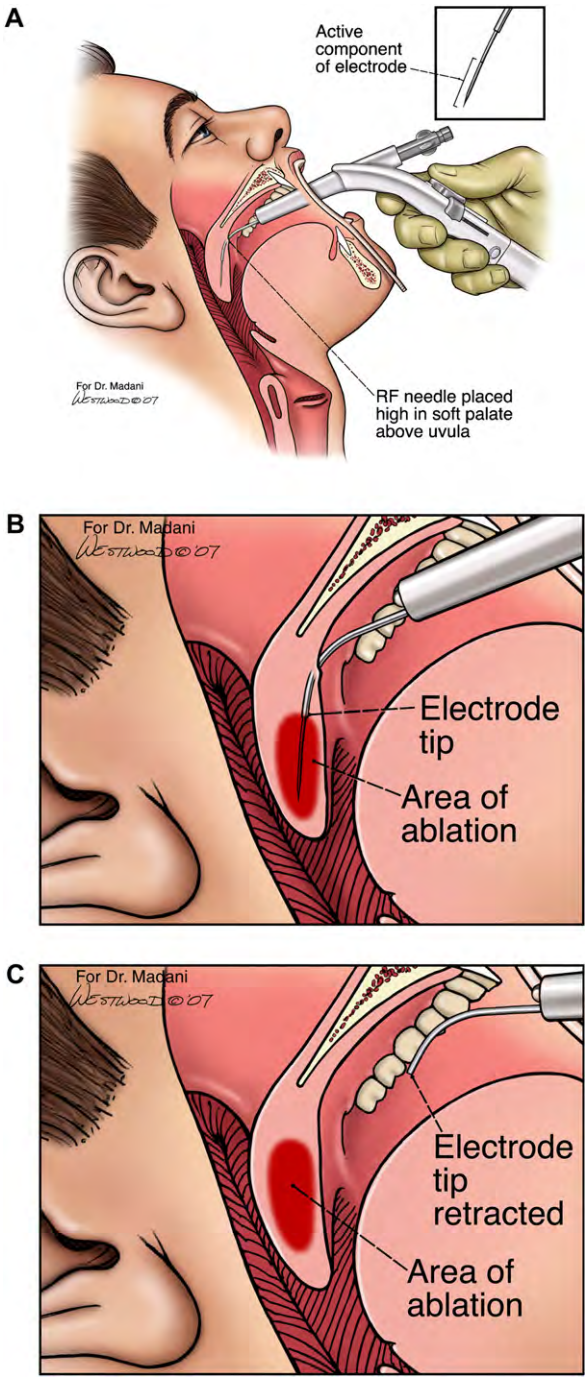

Fig. 10. Palatal radioablation: one of techniques utilized to stiffen the tissues of the soft palate in an attempt to reduce snoring intensity. (*A*) The position and direction of the radiofrequency device (RF) and patient position is shown. Note that these procedures are most beneficial for patients with small-sized uvula and very thick but floppy soft palate. (*B*) The RF delivers heath energy to the site and an internal scar formation leads to tissue stiffing. Note that poor angulation could cause the probe to extrude to the opposite part of the soft palate, creating an unfavorable result. (*C*) Once the RF probe is removed, the patient will have surface tissue charring and mild to moderate pain. Healing will take about 1 to 3 months.

patients is discussed in this issue and seems to be unsatisfactory in case of palatal and base-of-the-tongue ablations.

Uvulopalatopharyngoplasty (UPPP or UP-3): A surgical procedure in which the tissues of the soft palate, including the uvula and possibly the tonsils, are removed to improve upper airway obstruction (Fig. 11A–C). The removal of these redundant/flaccid pharyngeal tissues

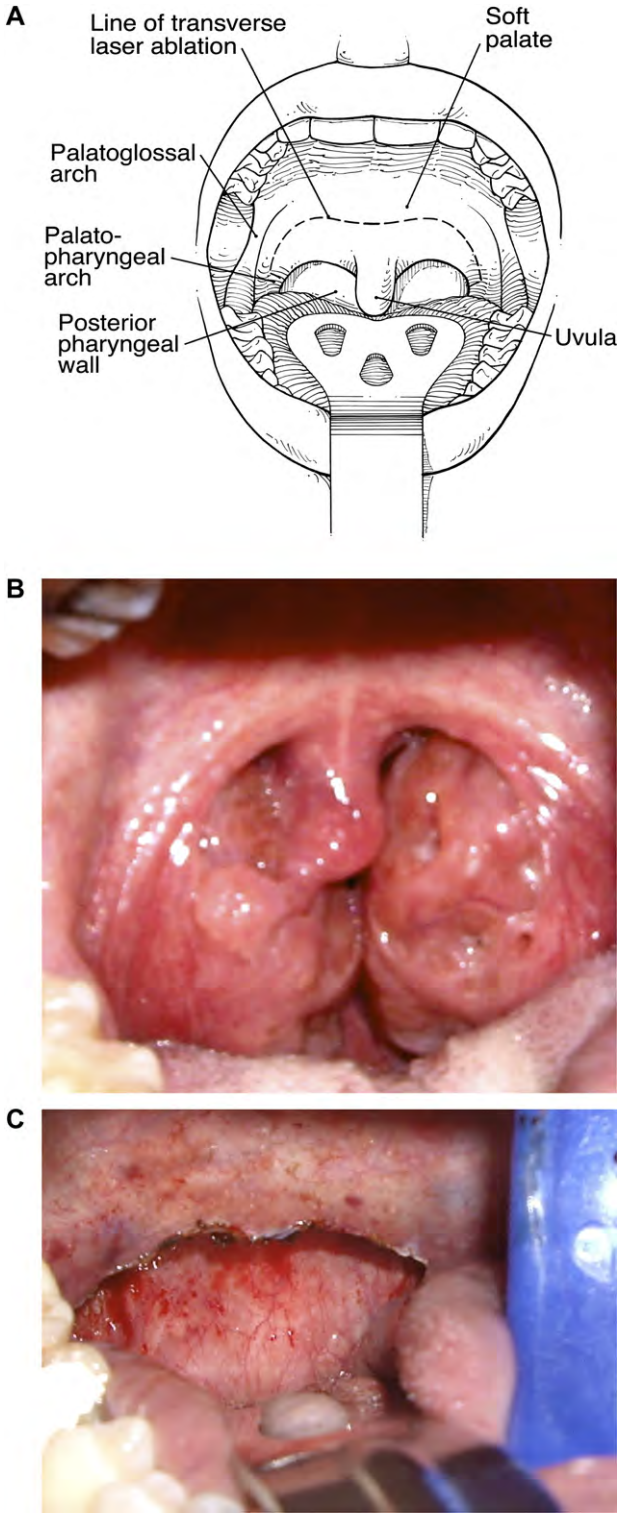

Fig. 11. LA-UPPP and tonsillectomy: two of the most effective soft tissue surgical procedures for the treatment of snoring and obstructive sleep apnea. (*A*) The anatomic landmarks to perform LA-UPPP. Note that excessive soft palate reduction could lead to velopharyngeal insufficiency, nasal fluid reflux, and voice change. (*Modified from* Madani M. Surgical treatment of snoring and mild obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:333–50.) (*B*) A patient with obstructive tonsils enlarged uvula, and extremely narrow airway could obviously benefit from surgical procedures. (*C*) Immediate postoperative view of the LA-UPPP procedure. Note lack of bleeding, excessive tissue charring, and clean surgical cut.

when indicated reduces the sound of snoring significantly. Traditionally this procedure was performed in the operating room. Elsewhere in this issue, laser-assisted UPPP is explained in detail (Fig. 11A).

Laser-assisted uvulopalatoplasty (LAUP): A staged laser surgical procedure designed to reduce the length of the uvula only and alter the soft palate to reduce snoring. It must be noted that this procedure is falling out of favor because it does not address the lateral boundaries of the soft palate. Some authors believe that it narrows the airway after scar contraction.

Uvulopalatoplasty (UPP): A limited adaptation of UPPP designed to shorten and stiffen the uvula and soft palate without involvement of the lateral pharyngeal walls. Many practitioners also have modified LAUP to perform this procedure with laser.

Radiofrequency-assisted uvulopalatoplasty (RAUP): A procedure similar to laser-assisted uvulopalatoplasty. It is done with a radiofrequency (RF) instrument instead of a laser. A special RF electrode is used to make two vertical cuts on either side of the uvula, which are joined by a horizontal cut. The uvula is then removed. Occasionally, the edge of the soft palate is also trimmed.

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Atlas of the Oral and Maxillofacial Surgery Clinics

The Pandemic of Obesity and Its Relationship to Sleep Apnea

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The prevalence of overweight and obesity is increasing worldwide at an alarming rate. The World Health Organization estimates that there are more than 1 billion overweight adults globally, at least 300 million of whom are clinically obese. This significant increase of body mass is a major contributor to the global burden of chronic disease and disability. Increased consumption of more energy-dense, nutrient-poor foods with high levels of sugar and saturated fats, combined with reduced physical activity, has led to obesity rates that have risen threefold or more since 1980 in some areas of North America, the United Kingdom, Eastern Europe, the Middle East, the Pacific Islands, Australasia, and even China. In 1946, 3.4 million babies were born in the US, a jump of 22% from the previous year. This surge of childbirth continued for 18 years, until 1964 when 78 million baby boomers had joined the population, creating a huge demographic bulge that thrived America's post-war prosperity. These children were more educated than any previous generation; many grew up projecting a rebellious, idealistic attitude that promised to reshape society. Boomers were expected to live longer than any previous generation of Americans. Now a new issue has plagued the baby boomers: obesity. Now over half of Americans aged 55 to 64, the oldest of the baby boomers, have high blood pressure, a major risk factor for heart disease and stroke, and 40 percent of people in that age bracket are obese.

The baby boomers' search for comfort of an easier lifestyle, varied dietary needs, and lack of time to devote to physical activities in our opinion has changed them and the generations X and Y to generation "O" for overweight and obese individuals. Obese children and adults have far more medical problems and are a far greater burden on the cost of health care in managing health-related issues of obesity. The health consequences of obesity are numerous and varied and include an increased risk of diseases, such as heart disease, hypertension, stroke, diabetes, obstructive sleep apnea, cancer, and premature death. Individuals with abdominal obesity are said to have an even greater health risk than overweight muscular individuals (Fig. 1). The economic consequences of obesity worldwide are even greater costing—hundreds of billions of dollars annually. Each year approximately 300,000 Americans die from illnesses related to overweight and obesity. Amazingly enough this is one medical epidemic—some call it a pandemic—that is preventable with education and changing the direction of food resources and daily activities.

How do we define obesity and overweight?

Generally speaking, we measure overweight and obesity by using body mass index (BMI), which is defined as weight in kilograms divided by height in meters squared (kg/m^2). A BMI of

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1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.05.005

Fig. 1. One of the major and common consequences of obesity is developing or having greater risk of obstructive sleep apnea. The most common physical findings and symptoms of obstructive apnea are explained in the text. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

more than 25 kg/m^2 is defined as overweight, and a BMI of more than 30 kg/m^2 is considered obese. BMI markers provide common benchmarks for assessment, but the risks of disease in all populations can increase progressively from lower BMI levels. BMI increases among middle-aged to elderly individuals, who also happen to be more medically compromised and are at the greatest risk of health complications. Based on a World Health Organization report, adult mean BMI levels of 22 to 23 kg/m^2 are found in Africa and Asia, whereas levels of 25 to 27 kg/m^2 are prevalent across North America, Europe, and in some Latin American, North African, and Pacific Island countries. Studies have shown that people who were undernourished in early life and then become obese in adulthood tend to develop conditions such as high blood pressure, heart disease, and diabetes at an earlier age and in a more severe form than persons who were never undernourished.

What is the relationship between obesity and obstructive sleep apnea?

Overweight and obesity lead to adverse metabolic effects on blood pressure, cholesterol, triglycerides, and insulin resistance. The other health problems associated with obesity include

respiratory difficulties, chronic musculoskeletal problems, skin problems, and infertility. The more life-threatening problems fall into four main areas: cardiovascular problems, conditions associated with insulin resistance (eg, type 2 diabetes), certain types of cancers (especially hormonally related cancers such as breast, prostate, endometrium, and colon cancers), and gallbladder disease. This article explores in detail its impact on obstructive sleep apnea.

As we gain weight, our neck circumference increases, which constricts the hypopharynx and the oropharynx. Obstructive sleep apnea is caused by repetitive upper airway obstruction during sleep as a result of narrowing of the respiratory passages. The double chin phenomenon causes the tongue muscles to be elevated, and at night drop in the back of the oropharynx, blocking the upper airway (Fig. 2). Base of the tongue obstruction is one of the most common finding in patients with obstructive sleep apnea (Figs. 3 and 4). Thickened lateral pharyngeal wall muscles and fatty tissue infiltration in the peripharyngeal area constrict the airway (Fig. 5). Among the thousands of patients in our center who underwent surgery for snoring procedures, most patients who complained of relapse after surgery of their snoring or sleep apnea were the ones who gained weight or had a constricted airway.

Abdominal obesity is another factor that restricts lung expansion and is considered another important factor in obstructive sleep apnea. Combined with elevated blood pressure, high cholesterol, and other associated medical problems common to obesity, individuals are at a much higher risk of heart attack and stroke.

Obese patients who suffer from skeletal deformities, such as mandibular or maxillary retrognathism or receded chin, are at particular risk because the oral cavity size is already diminished and an enlarged tongue puts them at a much higher risk for upper airway obstruction (Figs. 6 and 7). These anatomic abnormalities decrease the cross-sectional area of the upper airway. Decreased muscle tone in the upper airway during sleep and the pull of gravity in the supine position further decrease airway size, which impedes air flow during respiration (Figs. 8 and 9). Performing orthognathic surgery in patients with BMI of more than 40 is challenging and potentially risky for the period immediately after these types of surgeries.

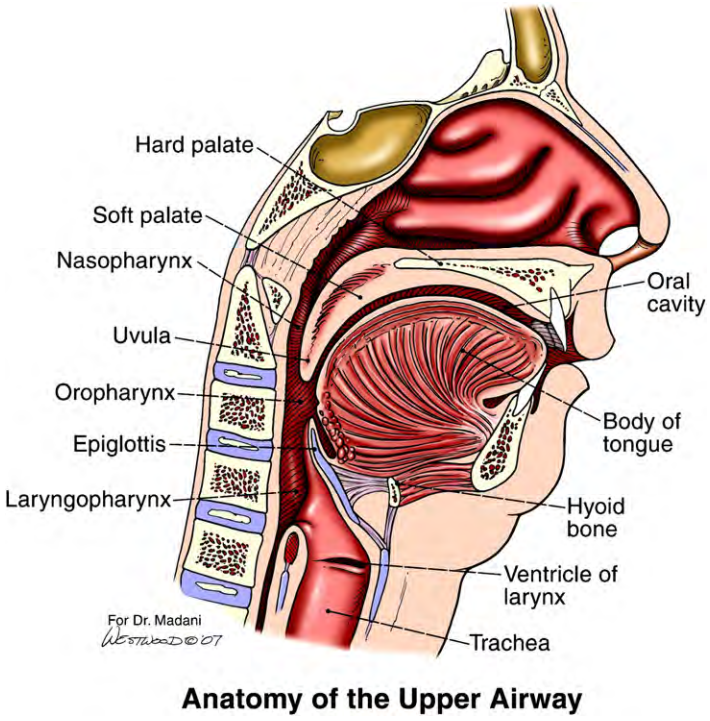


Fig. 2. The double chin phenomenon causes the tongue muscles to be elevated. At night it drops in the back of the oropharynx and blocks the upper airway. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

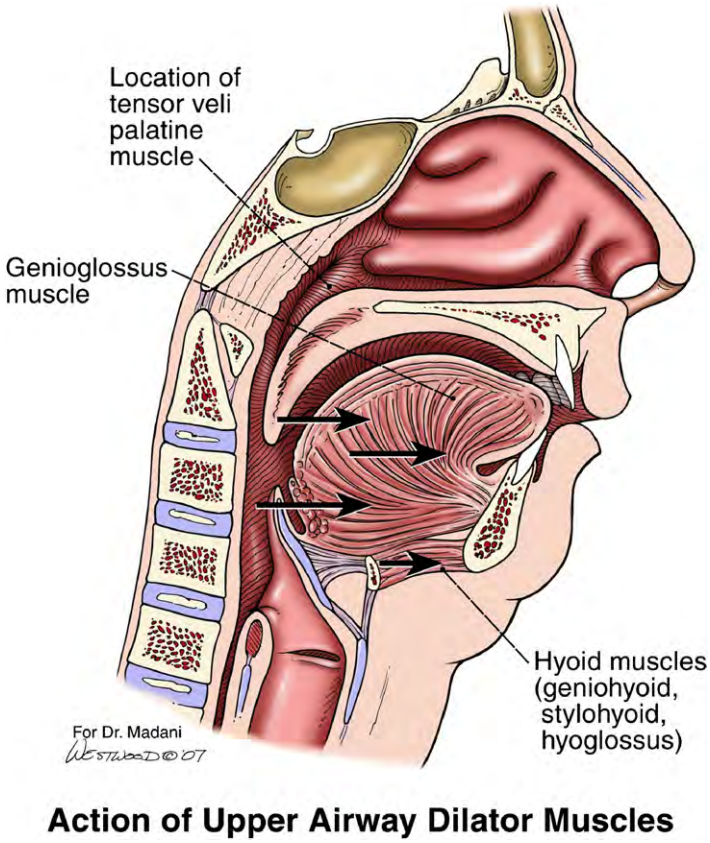


Fig. 3. The base of the tongue obstruction is one of the most common finding in patients with obstructive sleep apnea. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

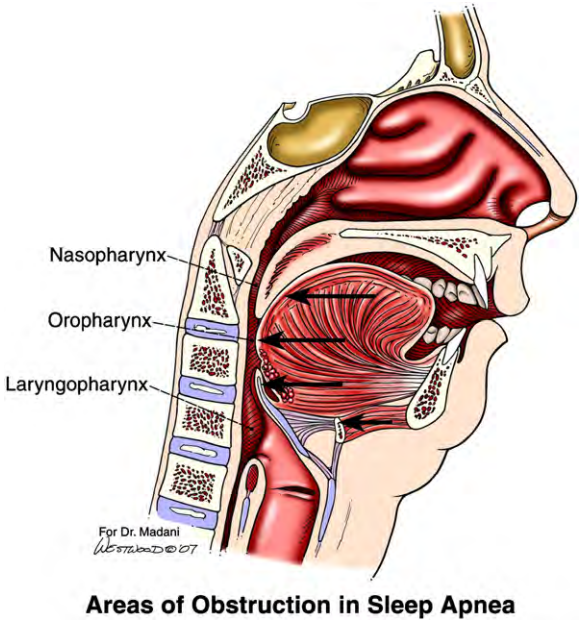


Fig. 4. The most common areas of obstructions are in the nasopharynx, oropharynx, and laryngopharynx. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

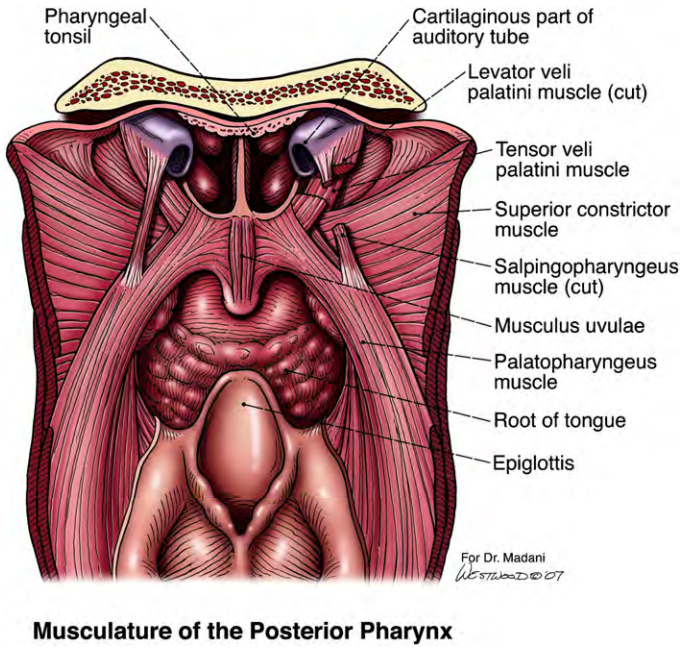
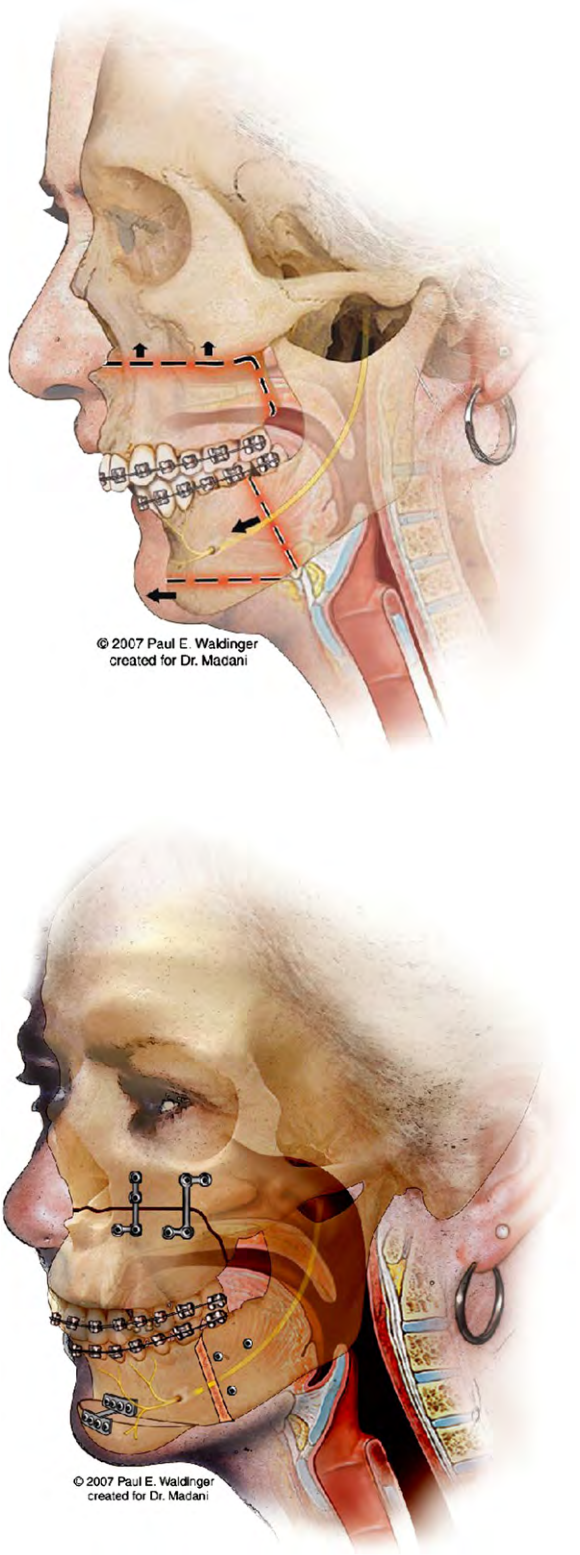


Fig. 5. Thickening of the lateral pharyngeal wall muscles and fatty tissue infiltration in the peripharyngeal area and presence of pharyngeal tonsils, elongated uvula, enlarged soft palate, and retropositioning of the tongue in the pharynx are some of the factors that cause upper airway constriction. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

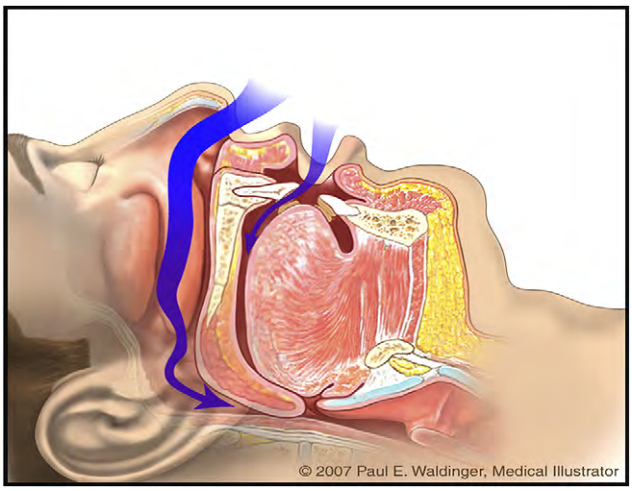
What are the impacts of sleep apnea on economy?

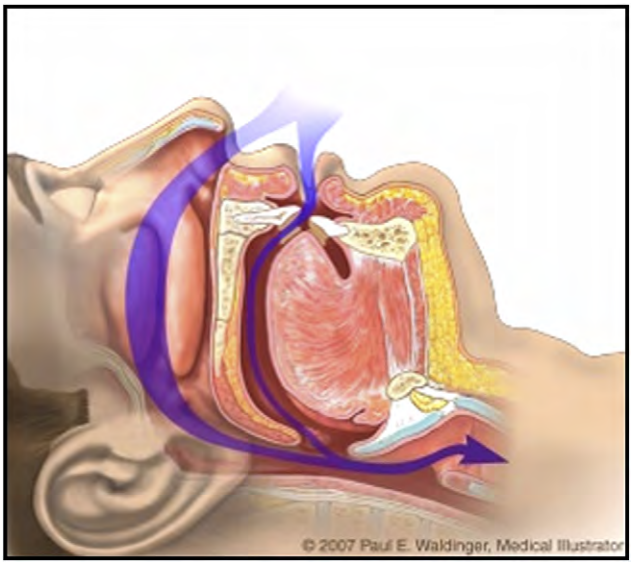
We know the impact of obesity and various related illnesses on the economy to be in of the hundreds of billions of dollars. One of the associated disorders of interest to our practice is sleep apnea. With a few assumptions, we have calculated how much sleep apnea can affect the economy of the United States. The American Academy of Sleep Medicine estimated that 25 million Americans suffer from sleep apnea. The department of transportation reported that more than 200,000 individuals each year are involved in motor vehicle accidents because of sleep problems. Of these accidents, at least 50,000 are estimated to be directly related to sleep apnea. The average expense for a major accident victim in a hospital is $80,000. For more serious injuries, including long-term care, the cost could run to hundreds of thousands of dollars. For the purposes of this article we take the smallest number of $80,000 and multiply that by the number of accident victims (50,000) to find that the estimated insurance cost for motor vehicle accidents related to sleep apnea is $4 billion.

On the other hand, it is estimated that 38,000 persons die each year from complications of sleep apnea (ie, heart attack, stroke). The cost of health care for these patients in the emergency room or intensive care unit is in excess of $50,000 per patient. The total estimated cost is $1.9 billion. There are more than 2500 sleep laboratories in the United States. Each sleep laboratory has an average of four beds, and they operate an average of 5 night per week, 50 weeks a year. The number of studies totals approximately 1000. The cost of sleep studies is approximately $2000 per patient per night, so the total estimated number of people who could be studied per year is 2.5 million (only 10% of people who are estimated to have sleep apnea). The total cost of sleep studies for 2.5 million patients is $5 billion. Currently, sleep apnea's primary mode of treatment is continuous positive airway pressure, which costs $2000 per patient. The cost of continuous positive airway pressure for half of 2.5 million patients (assuming that the other half did not want to use or try continuous positive airway pressure) is $2.5 billion. The productivity ratio is at least 10% less in people who suffer from sleep apnea. Finally, in our estimation, the minimum cost of



Figs. 6 and 7. Patients who suffer from skeletal deformities, such as mandibular or maxillary retrognathism or receded chin, are at particular risk because the oral cavity size is already diminished and an enlarged tongue puts them at a much higher risk for upper airway obstruction. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)





Figs. 8 and 9. For patients with obstructive sleep apnea, the muscle tone in the upper airway is decreased during sleep (Fig. 8), and the pull of gravity in the supine position (while sleeping on their back) further decrease airway size, which impedes air flow during respiration (Fig. 9). (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA.)

sleep apnea to the US economy alone is $75 billion each year (Center for Corrective Surgery, Bala Cynwyd, PA, December 8, 2006).

Further readings

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 89–100

Atlas of the Oral and Maxillofacial Surgery Clinics

Developing a Protocol for the Surgical Management of Snoring and Obstructive Sleep Apnea

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The surgical management of snoring and obstructive sleep apnea (OSA) has evolved over the last 30 years. During that time, an effort has been made to design procedures aimed at reshaping rather than bypassing the upper airway. Tracheostomy historically has been the most definitive—yet least desirable—surgical treatment for OSA. The proliferation of various procedures has nearly eliminated the need for tracheostomy, but several issues remain problematic, including

- How to determine the exact location of obstruction
- How to reliably predict which patients are likely to benefit from surgery
- How to best match the needs of each patient with an appropriate surgical plan
- When to move directly to more aggressive surgical procedures, sparing the patient exposure to procedures that are unlikely to be successful

The keys to addressing these issues are thorough patient evaluation, a clear understanding of the potential levels of obstruction and an evidence-based analysis of the available procedures and their relative success. In the writing of this article, an attempt has been made to provide clinicians with an updated protocol based on the current scientific literature. It is expected that oral and maxillofacial surgeons will collaborate with other clinicians in the treatment of snoring and OSA and ideally will be part of a multidisciplinary team dedicated to the efficient, appropriate, and comprehensive management of these patients.

This collaborative effort begins with an assessment of the problem by the patient and his or her bed partner using a comprehensive snoring and OSA questionnaire followed by an appropriately thorough history and physical examination. Additional assessment is often obtained by fiberoptic pharyngoscopy, lateral cephalometric radiography with airway analysis, and home sleep monitoring systems or more comprehensive polysomnography.

- Direct visualization of the oral and nasal cavities is the first step in assessing the obvious sites of obstruction that could be an enlarged tongue, elongated uvula, or obstructive tonsils. A nasal speculum can be used to detect a deviated septum and the presence of hypertrophied nasal turbinates, polyps or other pathology in the nasal cavity (Fig. 1).
- Fiberoptic pharyngoscopy allows visualization of the nasal airway, soft palate, base of tongue, and beyond, which makes it possible to define the sites of obstruction and uncover occult airway pathologic conditions.

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doi:10.1016/j.cxom.2007.06.001

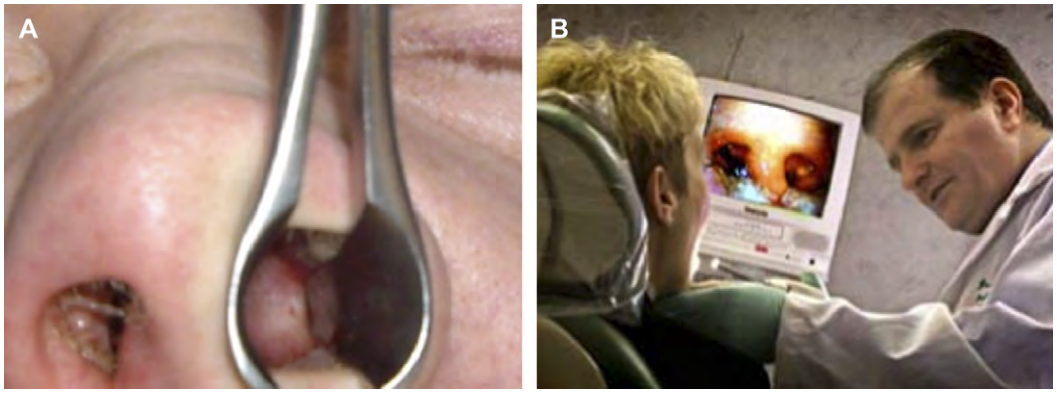

Fig. 1. (*A*) Patient's oral and nasal cavity and pharyngeal areas are evaluated. (*B*) Use of a zero-degree intraoral camera facilitates the visualization of the oral and nasal cavities at the same time. It also could serve as an excellent communication tool between doctors and patients.

- Lateral cephalometric radiography and analysis provide objective measurements of the posterior airway space and the relationships among maxilla, mandible, and base of skull (Fig. 2).
- More advanced imaging techniques include MRI and three-dimensional airway reconstruction, which are capable of providing greater detail (Fig. 3).
- Polysomnography documents the impact of these anatomic variations on breathing during sleep. The apnea-hypopnea index and oxygen desaturations are two of the numerous parameters recorded during polysomnography. They are used in the staging of OSA and to assess the results of treatment when the study is repeated postoperatively.

Although there is general agreement about the database needed to develop a surgical plan, there is no clear consensus to guide the selection of surgical procedures. The authors propose a system that relies on an accurate diagnosis of the level of obstruction and relates surgical procedures to the obstructions diagnosed (Fig. 4). The primary causes of upper airway obstruction include unfavorable soft tissue anatomy, unfavorable skeletal relationships, and altered anatomy caused by obesity. The principal sites of obstruction are the nasal cavity, nasopharynx, oral cavity, and oropharynx, and the hypopharynx. Assuming the appropriate collection of data, an algorithmic approach to the surgical management of snoring and OSA could involve the following steps:

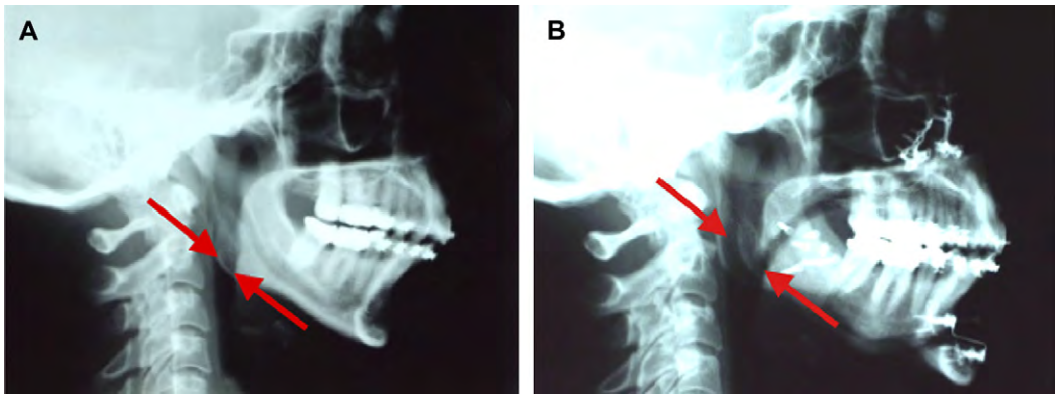

Fig. 2. One of the simplest methods for evaluating the airway is cephalometric radiography, plain lateral neck radiography of the airways. It must be noted, however, that this is a two-dimensional view of the airway and may not represent the actual size of the upper airway. (*A*) Preoperative cephalometric radiograph shows a receded lower jaw and chin. More importantly for the subject of sleep apnea, note the size of the airway as it descends in the proximal part of the mandibular ramus and down to the neck region. (*B*) Radiographs taken from the same patient after a double jaw and chin surgery show significant improvement in the volume of the airway.

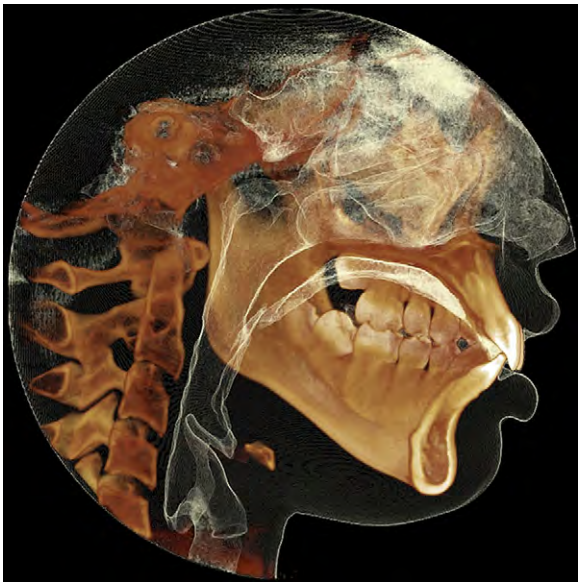

Fig. 3. The three-dimensional reconstruction shows an excellent and precise dimension of the airway; however, the cost of this type of study may preclude its routine use. (*Courtesy of* Anatomage.com by permission from InVivodental, Santa Clara, CA.)

1. The first step, and probably the single most important factor, in managing OSA in most cases is weight loss. Excess body fat, thick neck circumference, double chin, hypertrophic tongue, and many other related tissue abnormalities are associated with obesity. In selected cases, bariatric surgery may be utilized as a method of weight reduction. Recognizing the remarkably small percentage of patients able to maintain significant weight loss even with medically supervised dieting, there might be a role for bariatric surgery, when indicated, as part of the snoring and OSA surgical plan. These procedures do not directly involve the airway; however, the benefits of bariatric surgery in appropriately selected cases must be considered carefully and weighed against its potential morbidity and mortality, and questions arise about its long-term outcomes. For obese patients, weight loss is universally viewed as an important component of any therapeutic regimen aimed at improving the quality of sleep and decreasing morbidity related to sleep-disordered breathing.
2. Non-surgical approaches, including weight loss, should always be offered to patients initially. These include the use of CPAP, BiPAP (Bi-level Positive Airway Pressure), and other more advanced devices that act as pneumatic stents. Dental appliances could play an important role at this level of treatment.
3. The next set of interventions includes surgical procedures designed to address the diagnosed areas of obstruction. This step may involve one individual surgical site or multilevel surgery that involves several procedures. The critical concept is that if there are multiple sites/levels of obstruction, they are all addressed surgically. Once the examination is completed, one must identify soft tissue and hard tissue problems. If hard tissue or skeletal disharmony is judged to have a profound impact on the airway and is the primary issue, it should be addressed by choosing appropriate orthognathic and reconstructive methods (Fig. 5). Maxillomandibular advancement (MMA) may be indicated for patients who have undergone properly selected and executed soft tissue procedures but have not exhibited adequate subjective and objective improvement or patients whose jaw position dictates hard tissue surgery.
4. If abnormal soft tissue findings are discovered, careful analysis of all structures in the airway can guide the practitioner in choosing the appropriate treatment. The treatment planning chart (Fig. 4) suggests different steps or alternatives appropriate for each level of obstruction.

Given the various approaches to surgical management of snoring and OSA, it is beneficial to analyze outcomes in an effort to make evidence-based choices. A comprehensive review of the

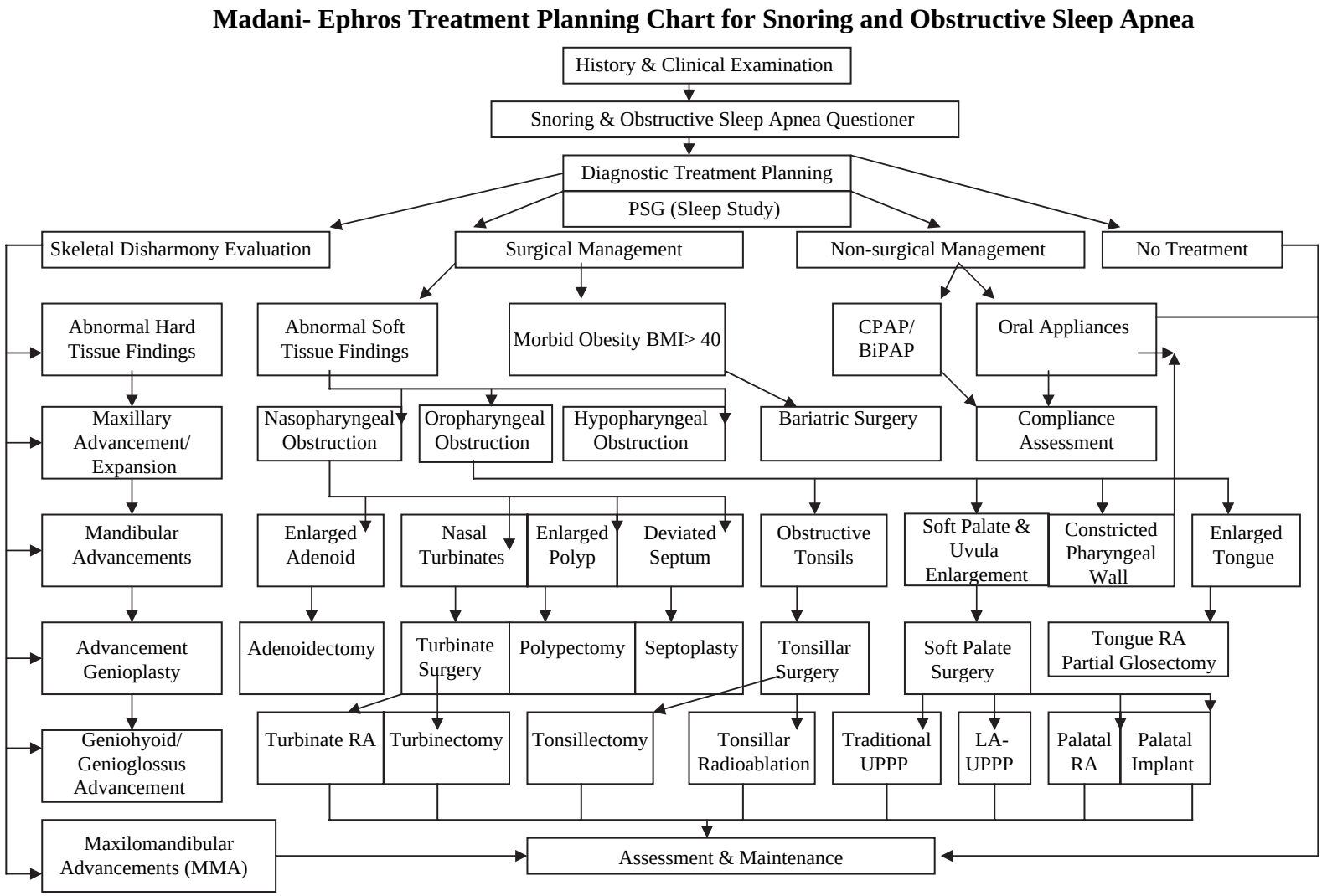

Fig. 4. A comprehensive guideline for evaluation, diagnosis, and treatment planning of snoring and OSA. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

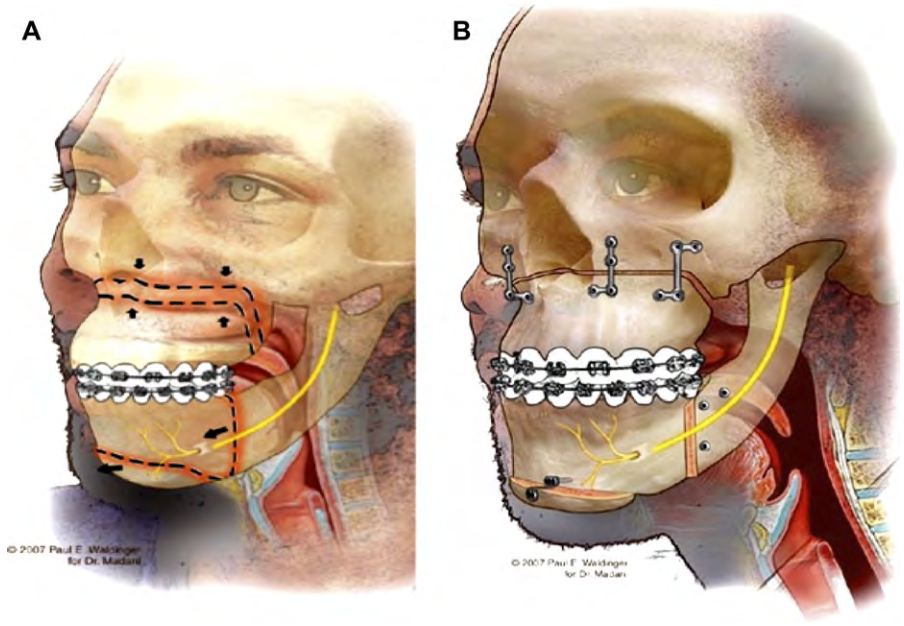

Fig. 5. If hard tissue or skeletal disharmony is judged to have a profound impact on the airway and is the primary issue, it could be corrected by choosing multiple orthognathic and reconstructive methods as described in the chart. (*A*) Note the severe constriction of the airway in the hypopharynx in the picture on the left. (*B*) By advancing the mandible and maxilla and using advancement genioplasty, the upper airway problem is corrected; functional problems and aesthetic issues are addressed simultaneously. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

literature provides much information about the relative merit of the many available surgical procedures and their applicability in patients who have OSA of various types. Direct comparisons are difficult, however, because of variables in study design, the way outcomes are reported, and the definition of success. Reasonable parameters for success shared by many of the cited authors may include RDI (Respiratory Disturbance Index) reduction, symptom elimination/reduction, and absence of significant oxygen desaturations.

Soft tissue surgical intervention

As suggested by the protocols mentioned earlier, careful determination of obstruction is critical to proper procedure selection and is likely to be associated with improved outcomes. An algorithmic approach to the surgical management of snoring and OSA should be based on an understanding that the obstruction may be nasal, nasopharyngeal, oropharyngeal, hypopharyngeal/retrolingual, or any combination of these sites. Surgical procedures that address an unaffected anatomic location are unlikely to produce benefit. Procedures that appropriately address an area of obstruction are also unlikely to be successful when multiple levels of obstruction exist.

Nasal obstruction

Nasal obstruction plays a role in the pathogenesis of sleep-disordered breathing. Increased resistance produces turbulent flow in the nasal cavity, induces oral breathing, and promotes oscillation of the pharyngeal airway, which can lead to snoring. Oral breathing alters the functional dynamics of the upper airway, which predisposes to its obstruction. In patients who have OSA, high nasal resistance increases negative inspiratory pressure, which in turn amplifies the already augmented tendency for upper airway collapse via dilator muscle hypotonicity during sleep. Another consequence of nasal obstruction is increased negative pressure and functional narrowing of the pharyngeal airway, which cause hypoxia and sleep apnea. Nasal obstruction is most easily diagnosed by direct physical examination with a nasal speculum or

a zero-degree intraoral camera, which is readily available in many oral and maxillofacial surgery practices, or by nasal endoscopy. Although it is unlikely that nasal pathology is the sole source of snoring or OSA, these entities should not be overlooked. The most commonly encountered and relevant anatomic abnormalities are nasal polyps and hypertrophic inferior turbinates (Fig. 6).

The treatment for nasal polyps is removal with cauterization, which eliminates the obstruction, achieves immediate hemostasis, and causes shrinkage of any residual edematous or hypertrophic tissue. Such treatment may improve the turbulent airflow through the nasal passage and allow more laminar flow of air with a corresponding decrease in snoring and OSA parameters. Hypertrophic turbinates create an obstructive phenomenon that can potentially eliminate the flow of air through one or both nares. If the flow of air through one nostril is obstructed, then the flow of air through the contralateral nostril becomes turbulent and causes excessive snoring. If both nares are obstructed, the patient becomes an obligate mouth breather, which causes further issues by altering the functional dynamics of the upper airway and predisposes to obstruction at other levels. Treatment may include turbinectomy or nasal radioablation procedures discussed elsewhere in this issue.

Oropharyngeal obstruction

Obstruction at the level of the soft palate, pharynx, and tonsillar pillars is a more common finding in patients with snoring and OSA, and these sites are the focus of many so-called Stage 1 surgical procedures. The goals of surgery are to enlarge the oropharyngeal airway and remove obstructing or redundant tissue, which reduces the resistance to airflow.

Uvulopalatopharyngoplasty (UPPP), initially described by Fujita, is used to correct obstruction at the oropharyngeal level by modification of the uvula, removal of redundant pharyngeal and palatal tissues, and primary closure of the posterior and anterior pillars to enlarge the retropalatal airway. Numerous authors have subsequently attempted to alter the initial procedure, with modifications aimed at enlarging the pharynx and reducing the redundancy and collapsibility of hypopharyngeal tissues. Modifications have involved complete removal of the uvula and distal soft palate, removal of part of the palatopharyngeus muscle, and use of an uvulapalatal flap. A wide range of clinical outcomes for UPPP has been documented in the literature. Unfortunately, in some of these reports, the procedure is bundled with surgery that addresses other levels of obstruction, which makes it difficult to assess the effectiveness of UPPP as an isolated procedure. One meta-analysis by Sher reported a UPPP success rate of only 40%. Some authors attribute most UPPP failures to patient selection, with untreated tongue

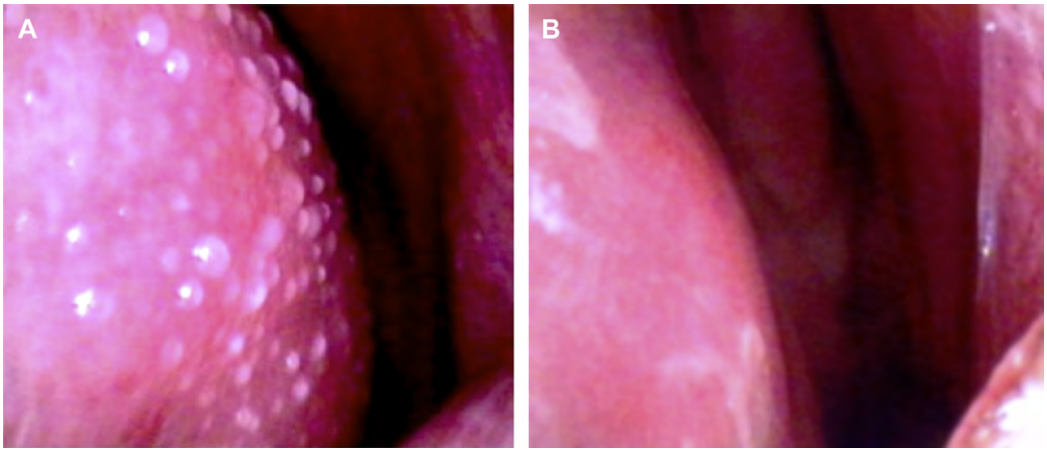

Fig. 6. The most commonly encountered and relevant anatomic abnormalities are nasal polyps and hypertrophic inferior turbinates. (*A*) This photo demonstrates an enlarged nasal turbinate on the left with acute rhinitis and deviated nasal septum on the right side of picture. (*B*) The same patient several months after radioablation procedures. The middle turbinate is visible, and there is volumetric increase in the opening of the nasal cavity. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

base obstruction as a common theme. In general, the potential morbidity and questionable clinical results associated with UPPP have led many clinicians to seek out simpler and more predictable alternatives.

Laser-assisted uvulopalatoplasty (LAUP) is a procedure that can be performed in the office setting with intravenous conscious sedation and local anesthesia. The procedure reduces the uvula and distal portion of the soft palate without total excision of muscle uvulus. Scar contracture may lead to a further dilatory effect on the pharynx and may reduce the "floppiness" of the soft palate. Although the procedure may be conducted in a single sitting, LAUP has been described in the past as a staged procedure with incremental treatments titrated to effect, avoiding excessive reduction that may result in velopharyngeal insufficiency, particularly if resection includes the levator veli palatini muscle. A review of the literature is inconclusive, as some clinical studies suggest that LAUP is ineffective, whereas other authors advocate the procedure and report good clinical results. In a prospective study by Herford and colleagues, analysis of the data concluded that LAUP is an effective surgical procedure for treatment of snoring and some types of OSA. Direct comparisons among procedures are limited by factors already noted. Madani first described a modified version of the procedure in 1994, using laser to perform traditional UPPP in an office setting. He termed it "laser-assisted uvulopalatopharyngoplasty" (LA-UPPP). He reported, "When patients are appropriately selected, LA-UPPP may help in reducing snoring by 70% and results in an average reduction of mild sleep apnea by up to 50%" (Fig. 7).

Substantial bilateral tonsillar hypertrophy (obstructive tonsils) in adults seldom occurs (Fig. 8). Few studies are available to determine the extent to which tonsillar hypertrophy can be considered a cause for snoring and OSA in adults and whether tonsillectomy is an effective

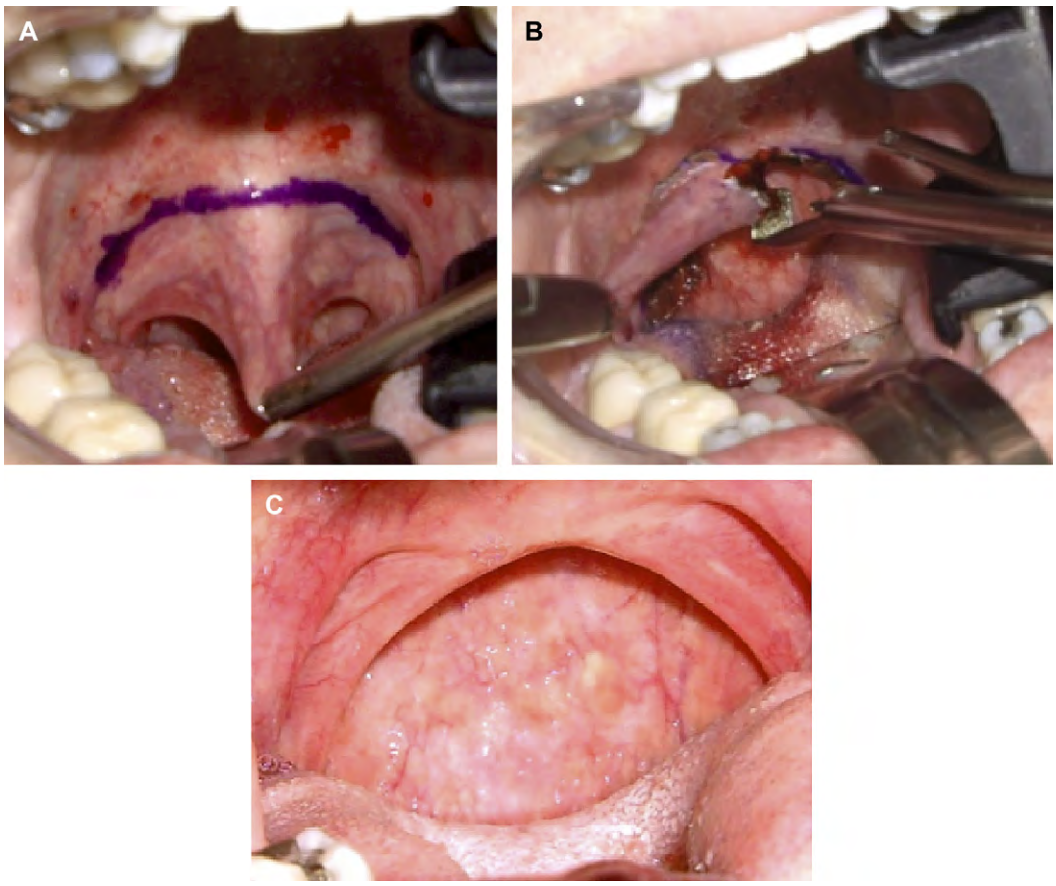

Fig. 7. When patients are appropriately selected, LA-UPPP may help in reducing snoring by 70% and results in an average reduction of mild sleep apnea by up to 50%. (*A*) Initial steps in LA-UPPP: making the areas of incision. (*B*) Using laser, the tissue is trimmed. Note the lack of bleeding. (*C*) The final result shows a much more open airway and elimination of the elongated uvula. (*Courtesy* of Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

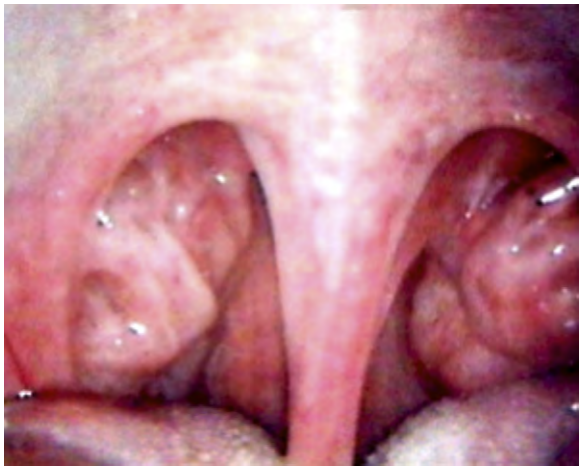

Fig. 8. Obstructive tonsillar hypertrophy in adults seldom occurs, but when present it can cause significant upper airway obstruction leading to OSA. Enlarged tonsils and adenoids are the most common cause of snoring and OSA in children.

intervention. In some severe cases of obstructive tonsillitis, it is obvious that removing them at any age could be beneficial in treating patients with upper airway obstruction. Verse reported that when the diagnosis of isolated tonsillar hypertrophy was made appropriately, all patients in the study had favorable outcomes from tonsillectomy with respect to the respiratory parameters of OSA and snoring.

Radiofrequency volumetric tissue reduction uses a radiofrequency energy source to perform submucosal ablation of palatal tissue. Radiofrequency generates frictional heating of the tissue around an electrode caused by ionic agitation; thus, the electrode is not heated and the heat actually emanates from the tissue. The procedure involves placing a radiofrequency electrode tip into the soft palate. A lesion is created in the submucosal tissue, which spares soft palate mucosa. These procedures are repeated several times until clinical success is accomplished as manifest by a reduction in snoring sounds or in the degree of obstruction. Reports of long-term success managing snoring with radiofrequency ablation are 59% and 38% by Li and Madani, respectively. In these two series, Li re-treated eight of nine patients who experienced relapse with additional radiofrequency treatments. Madani re-treated 62% of patient who had relapse after palatal radioablation with LA-UPPP. His conclusion was that radioablation procedures and palatal implants are only effective if patients are chosen properly and the length of the uvula is short, the tongue is not enlarged and not significantly retropositioned, and the patient is not significantly overweight or obese (Fig. 9).

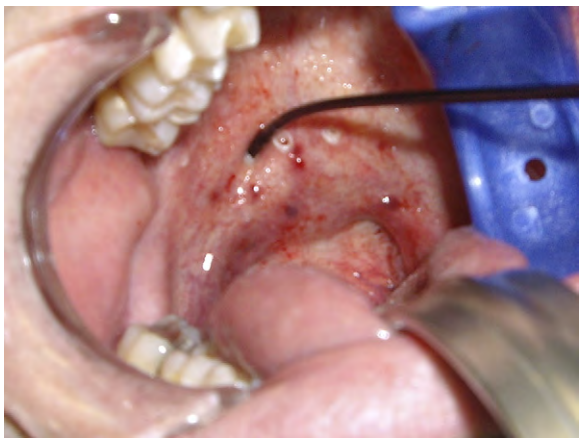

Fig. 9. Palatal radioablation procedures are only effective if patients are chosen properly and the length of the uvula is short, the tongue is not enlarged or not significantly retropositioned, and, most importantly, the patient is not overweight or obese.

Hypopharyngeal obstruction

The third area of obstruction in sleep-disordered breathing is the hypopharyngeal or retrolingual area. Surgical management is directed toward either a reduction in the volume of tongue mass or advancement of the tongue's anterior attachments. Radiofrequency tissue ablation of the tongue follows the principles described for the soft palate. This procedure, as described by Powell and colleagues, can be performed on an outpatient basis with conscious sedation and local anesthesia. Numerous modifications of this procedure have been reported; however, most of them still involve radiofrequency ablation at various sites located near the circumvallate papillae, with treatment taking place in several sessions a few weeks apart. Madani reported significant relapse with this procedure, particularly in patients who have gained weight.

The advancement genioplasty is a skeletal procedure used to reposition the insertion point of the genioglossus musculature. The genial tubercles also bear the attachments of the geniohyoid muscles, whereas the anterior bellies of the digastrics attach laterally to the genial tubercles, along the posterior aspect of the mandibular symphysis (Fig. 10). As such, the muscle attachments of the digastrics and geniohyoid muscles are also advanced when the bony segment is repositioned. The procedure not only results in a more anterior postoperative position of the tongue but it also improves the postoperative position of the hyoid bone. As such, horizontal osteotomies with genial advancement may offer more benefit than anterior positioning of the genial tubercles and their connections using anterior mandibular osteotomies. This more limited genial advancement procedure does not reposition the digastric muscle or the hyoid bone, and delayed muscle detachment associated with these procedures has been reported.

Genioglossus advancement with hyoid myotomy/suspension (GAHM) is indicated when the hypopharynx is a site of obstruction. Published data on outcomes do not accurately reflect the success of GAHM as an isolated procedure because it was often performed in conjunction with UPPP for patients with multiple levels of obstruction. As expected, patients with more severe OSA are less likely to benefit from LAUP, UPPP, LA-UPPP, or GAHM.

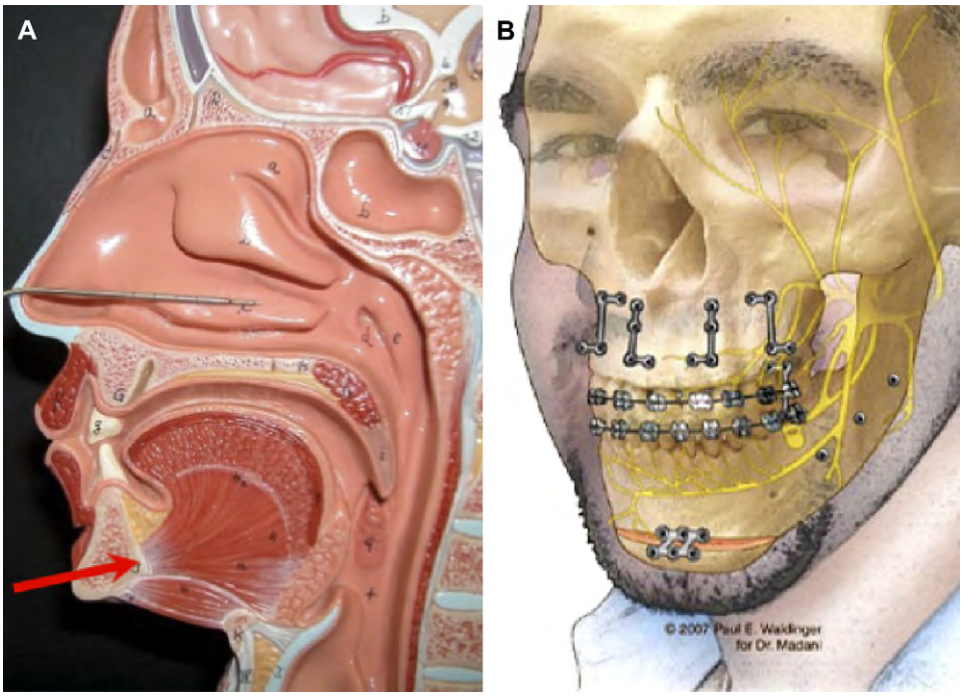

Fig. 10. The advancement genioplasty is a skeletal procedure used to reposition the insertion point of the genioglossus musculature. The genial tubercles also bear the attachments of the geniohyoid muscles, whereas the anterior bellies of the digastrics attach laterally to the genial tubercles along the posterior aspect of the mandibular symphysis. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

Multilevel surgery

The success of airway surgery depends on an accurate diagnosis of the sites of obstruction and the appropriate selection of procedures to address these sites. Rather than following traditional "cookbook" approaches to the surgical management of OSA, it seems preferable to tailor treatment to the specific needs of each patient. For example, in some practices, the initial surgical treatment for snoring and OSA is often palatal surgery. Only 25% of patients have strictly palatal obstruction, however. Currently, a growing body of evidence supports the effectiveness of multiple site surgery to effectively treat snoring and OSA in patients. The results of extended follow-up studies suggest that multilevel radiofrequency tissue ablation therapy provides significant prolonged improvements in snoring and OSA-related quality of life, daytime sleepiness, psychomotor vigilance, and polysomnographic parameters of sleep-disordered breathing.

Maxillomandibular advancement (MMA)

Patients who have severe maxillofacial skeletal disharmony, particularly mandibular and maxillary retrusion, and patients who suffer from severe OSA (respiratory disturbance index >75) are candidates for MMA. The mean age for MMA in the OSA population is significantly higher than for patients undergoing traditional orthognathic surgery. The ASA status of patients who have OSA is also likely to be higher, and complications may occur more frequently. Gilon and colleagues compared 17 patients who had OSA to 33 patients who underwent surgery for skeletal discrepancies. The incidence of intraoperative complications during Bilateral Sagittal Split Osteotomy (BSSO) and postoperative infection was higher for patients who had OSA, and these patients generally had longer hospital stays than others undergoing traditional orthognathic surgery.

Riley and colleagues demonstrated that patients with mild to moderate OSA had 70% to 80% success with LAUP, UPPP, or GAHM, whereas only 42% of patients who had severe OSA benefited from these procedures. A 97% success rate was reported for patients who failed the treatment mentioned earlier but opted for MMA. Lee and colleagues reported on 35 patients in whom a positive response to surgical reconstruction was noted as a reduction of the RDI to 20 or less while maintaining oxygen saturations at 95% or more. Of these patients, 24 (69%) responded positively to soft tissue airway surgery. Of the remaining 11 patients, 3 proceeded to MMA, all of whom were positive responders. The mean preoperative RDI for all responders was 53, and the mean postoperative RDI was 7. Snoring was eliminated in all responders, with a decrease in daytime somnolence and an increase in energy levels.

The Epworth Sleepiness Scale, a subjective evaluation of OSA symptoms, has been used in some studies as an additional measure of success (Fig. 11). In one report by Datillo and Drooger, success was defined as RDI reduction to 15 or lower and a postoperative Epworth Sleepiness Scale value less than 11. In this study, 42 patients underwent soft palate surgery, hyoid suspension, and genioglossus advancement along with tonsillectomy and adenoidectomy when indicated. In this group, success was close to 80% as measured by both RDI reduction and Epworth Sleepiness Scale improvement. Among the 15 patients who underwent MMA, there was 100% success reducing the Epworth Sleepiness Scale to the normal range, and 93% of the subjects had postoperative RDI less than 15.

It is generally accepted that the production of measurable improvements in the airway is nearly universally with MMA. Li asserted that the procedure not only enlarges the airway but also may decrease the collapsibility of the pharyngeal tissues. In another investigation, Waite and colleagues demonstrated that patients who responded well to MMA showed not only enlargement of the airway but also exhibited a configurational change that included a lateral stretching of the upper pharyngeal tissues. Potential morbidity from MMA includes all of the complications generally associated with orthognathic surgery, some made more likely by the nature of the population.

Concerns about velopharyngeal incompetence (VPI) with MMA are not borne out by published outcomes. The results of MMA in the OSA population, together with data gathered from potentially higher risk patients with cleft lip and palate, suggest that VPI is not a significant

Situation	*Chance of Dozing or Sleeping*
Sitting and reading	____
Watching TV	____
Sitting inactive in a public place	____
Being a passenger in a motor vehicle for an hour or more	____
Lying down in the afternoon	____
Sitting and talking to someone	____
Sitting quietly after lunch (no alcohol)	____
Stopped for a few minutes in traffic while driving	____
Total score (add the scores up) (This is your Epworth score)	____

Fig. 11. Epworth Sleepiness Scale: This chart is used to determine the level of daytime sleepiness. A score of 0 to 10 is considered within normal range, a score of 10 to 12 is borderline, and a score of 12 to 24 is considered abnormal, indicating a patient with possible sleep apnea. It must be noted that this is only a subjective score; many practitioners use it to help assess the need for treatment. The following key is used for each situation: 0 = would never doze or sleep, 1 = slight chance of dozing or sleeping, 2 = moderate chance of dozing or sleeping, 3 = high chance of dozing or sleeping.

issue. A more serious concern is the impact of MMA on the airway in the immediate postoperative period. In view of reported airway complications with potentially catastrophic results, some authors have conducted endoscopic evaluations and have found mild to moderate lateral pharyngeal wall swelling and edema and ecchymosis of the pyriform sinus and aryepiglottic fold in a significant number of their MMA patients. Despite these findings, patients in this series did not have adverse outcomes. Those authors currently include postoperative endoscopic evaluation of the airway in their treatment protocols.

Although there is no consensus algorithmic approach to snoring and OSA, it seems that the potential morbidity of MMA should be weighed carefully against its extraordinary success. Few clinicians would argue that it is indicated when other 1 surgery has failed. Many clinicians would agree that many patients, including patients who have significant mandibular retrognathia, might be best served by avoiding procedures that are unlikely to succeed and by moving directly to MMA.

Surgery for snoring and sleep apnea in children

In the pediatric population, airway anatomy is different than in adults, as are the most the likely causes of sleep-disordered breathing. Central causes of sleep apnea must be ruled out, and tonsils and adenoids should be evaluated carefully. Other surgical procedures, such as those described previously for adults, are generally deferred in children.

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 101–109

Atlas of the Oral and Maxillofacial Surgery Clinics

Polysomnography Versus Home Sleep Study: Overview and Clinical Application

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Historically, polysomnography (PSG)—or nocturnal, laboratory-based sleep studies—has been the most commonly used test in the diagnosis of sleep disordered breathing. PSG is often considered the criterion standard for diagnosing sleep apnea, determining the severity of the disease, and evaluating various other sleep disorders that can exist with or without apnea. PSG consists of a simultaneous recording of multiple physiologic parameters related to sleep and wakefulness. It can directly monitor and quantify the number of respiratory events and, when scored properly, can determine if the apneic episode is obstructive in nature or derived from a central source, such as the brain or lungs. The resultant hypoxemia and arousals related to the respiratory events are also determined.

Although a single-night PSG is usually adequate to determine if patients suffer from apnea, many variables may affect the final results. Variables include, but are not limited to, laboratory equipment, scoring technique, interscorer reliability, and, most importantly, how efficiently the patient slept during the night in the laboratory. PSG scoring also varies from laboratory to laboratory. In this article we discuss a novel method of evaluating sleep apnea at home, which, in the opinion of the authors, may be an effective substitute for traditional PSG. Before we embark on discussing at-home sleep studies, however, let us explore PSG assessment base in detail.

When assessing staging of sleep, we must evaluate several main areas of the body: first and foremost are the brain waves, which are evaluated by using electroencephalography to monitor stages of sleep (Fig. 1). How our respiratory, circulatory, and muscular systems are functioning is evaluated using EKG, pulse oximetry, and surface electromyography, which is helpful for assessing periodic limb movements and determining effort during respiratory events.

In most scientists' opinions, these are the most crucial parts of the study. To assess the rapid eye movement stage and note the presence of slow-rolling eye movements that usually accompany the onset of sleep, electro-oculography is performed simultaneously (Fig. 2). Many other parameters are studied during a complete PSG, including airflow (nasal and/or oral), respiratory effort (thoracic and abdominal), sound recordings to measure snoring,

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1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.06.002

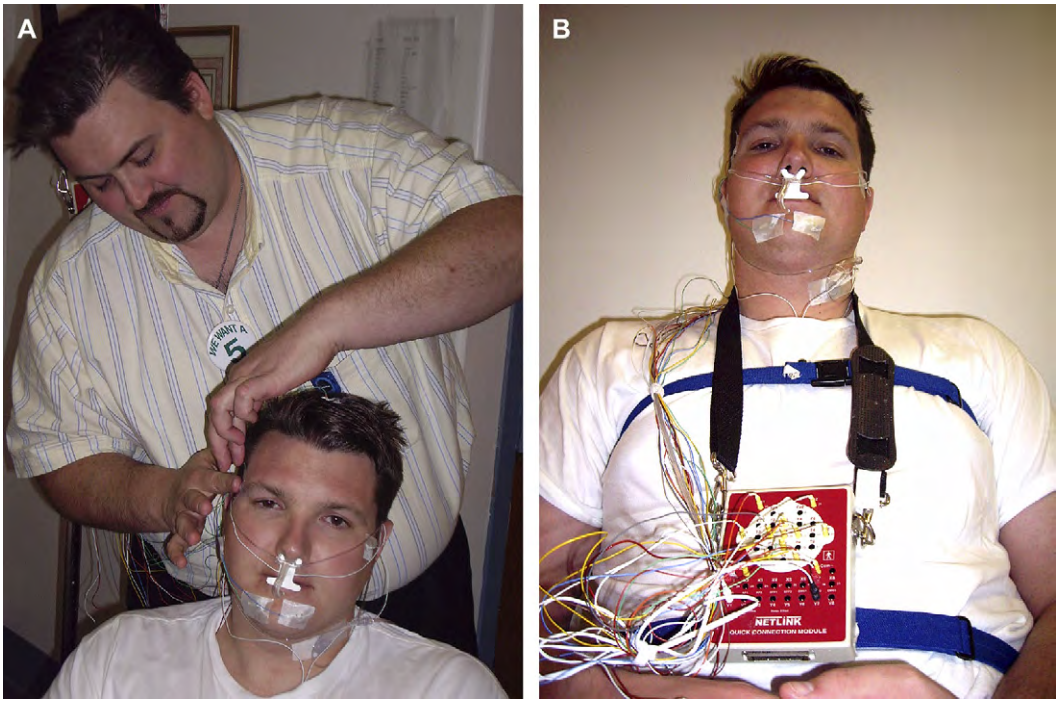

Fig. 1. (*A, B*) When assessing staging of sleep, we need to evaluate several main areas of the body: first and foremost are the brain waves, which are evaluated by using electroencephalography to monitor stages of sleep.

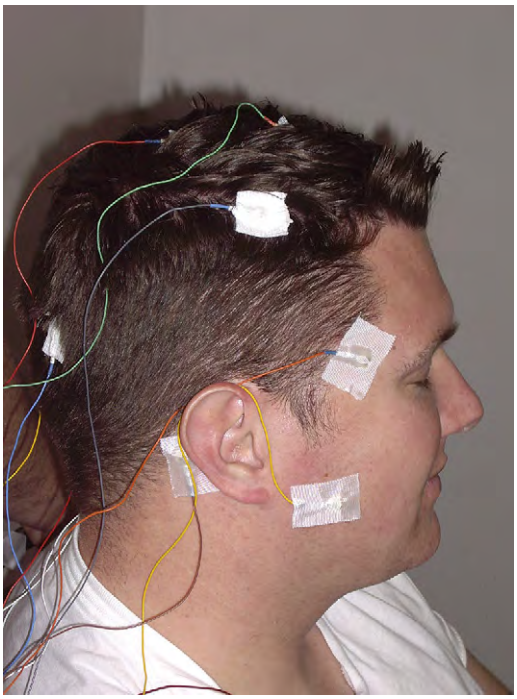

Fig. 2. To assess rapid eye movement stage and note the presence of slow-rolling eye movements that usually accompany the onset of sleep, electro-oculography is also performed simultaneously. Surface electromyography is helpful for assessing periodic limb movements and determining effort during respiratory events.

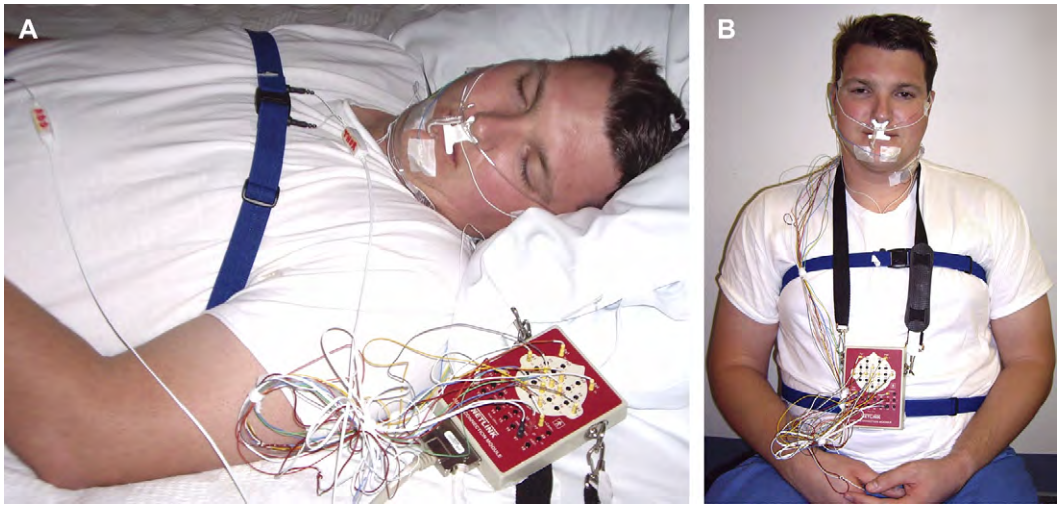

Fig. 3. (*A, B*) Many other parameters are studied during a complete PSG, including airflow (nasal and/or oral), respiratory effort (thoracic and abdominal), and sound recordings to measure snoring. The unit can be detached from the system if necessary (*B*).

continuous video monitoring of body positions, core body temperature, incident light intensity, penile tumescence, pressure, and pH at various esophageal levels (Fig. 3). Some of these additional parameters have research benefits rather than routine use in the diagnosis of sleep disorders.

The data collected from this study are used to calculate various indices, such as respiratory desaturation disturbance index (RDI), apnea hypopnea index (AHI), and oxygen desaturation index (ODI) (Fig. 4). The RDI represents the total number of respiratory disturbances per hour of sleep. The RDI is the recommended measurement of the severity of OSA as listed by the American Academy of Sleep Medicine. The AHI is defined as the number of apneas or

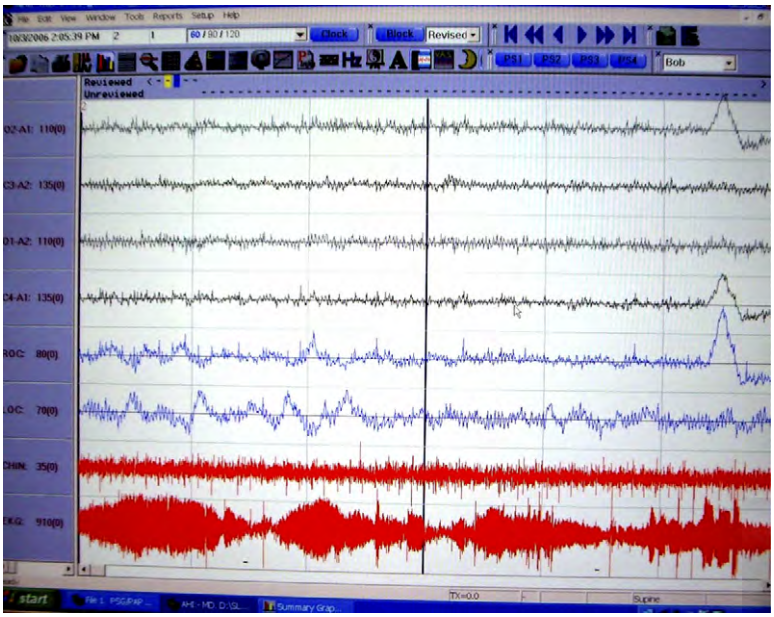

Fig. 4. The data collected from this study are used to calculate various indices, such as RDI, AHI, and ODI.

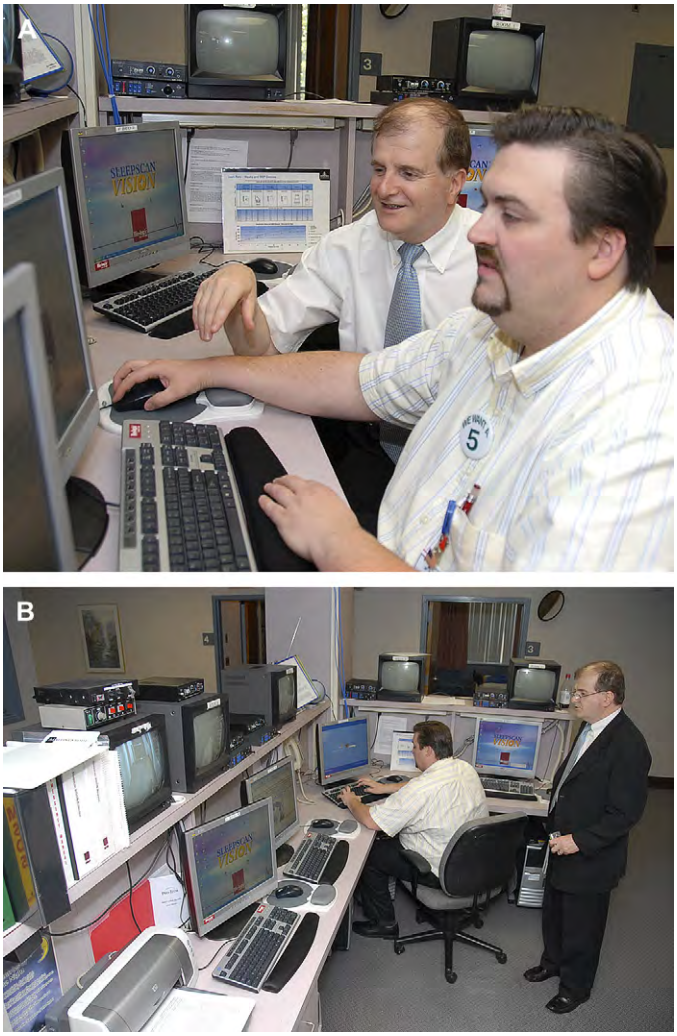

Fig. 5. (*A, B*) A single-night PSG is usually adequate to determine if patients suffer from apnea; however, many variables may affect the final results. The variables include—but are not limited to—laboratory equipment, scoring technique, interscorer reliability, and, most importantly, how efficiently the patient slept during the night in the laboratory. PSG scoring also varies from laboratory to laboratory.

cessation of respiration during sleep for 10 seconds or more; and hypopneas are defined as reductions in respirations followed by a desaturation of at least 3% on arousal. Finally, the ODI expresses the number of oxygen desaturation events during an hour of sleep. A desaturation event is determined as a reduction of 4% or more of the oxygen saturation lower than baseline level.

Portable monitoring device for diagnosis of sleep apnea

The hospital- or laboratory-based PSG, although accurate, is unfortunately expensive and uses a tremendous amount of funds and resources (Fig. 5). It is more complicated by the fact that a sleep center is unavailable in many areas. As a result, many attempts at developing an ambulatory diagnostic tool for OSA have been undertaken. One new technology is the Watch-PAT 100 (Itamar Medical Ltd., Caesarea, Israel), which is a wrist-worn device for at-home OSA testing (Fig. 6). The device continuously monitors and records a peripheral arterial

Fig. 6. (*A–C*) One new technology is the Watch-PAT 100, which is a device worn on the wrist for at-home OSA testing.

Fig. 7. There are several simple steps to using PAT 100. Analysis is done automatically by specialized software, and the practitioner can readily read and assess the findings and direct the patient to the most appropriate treatment. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

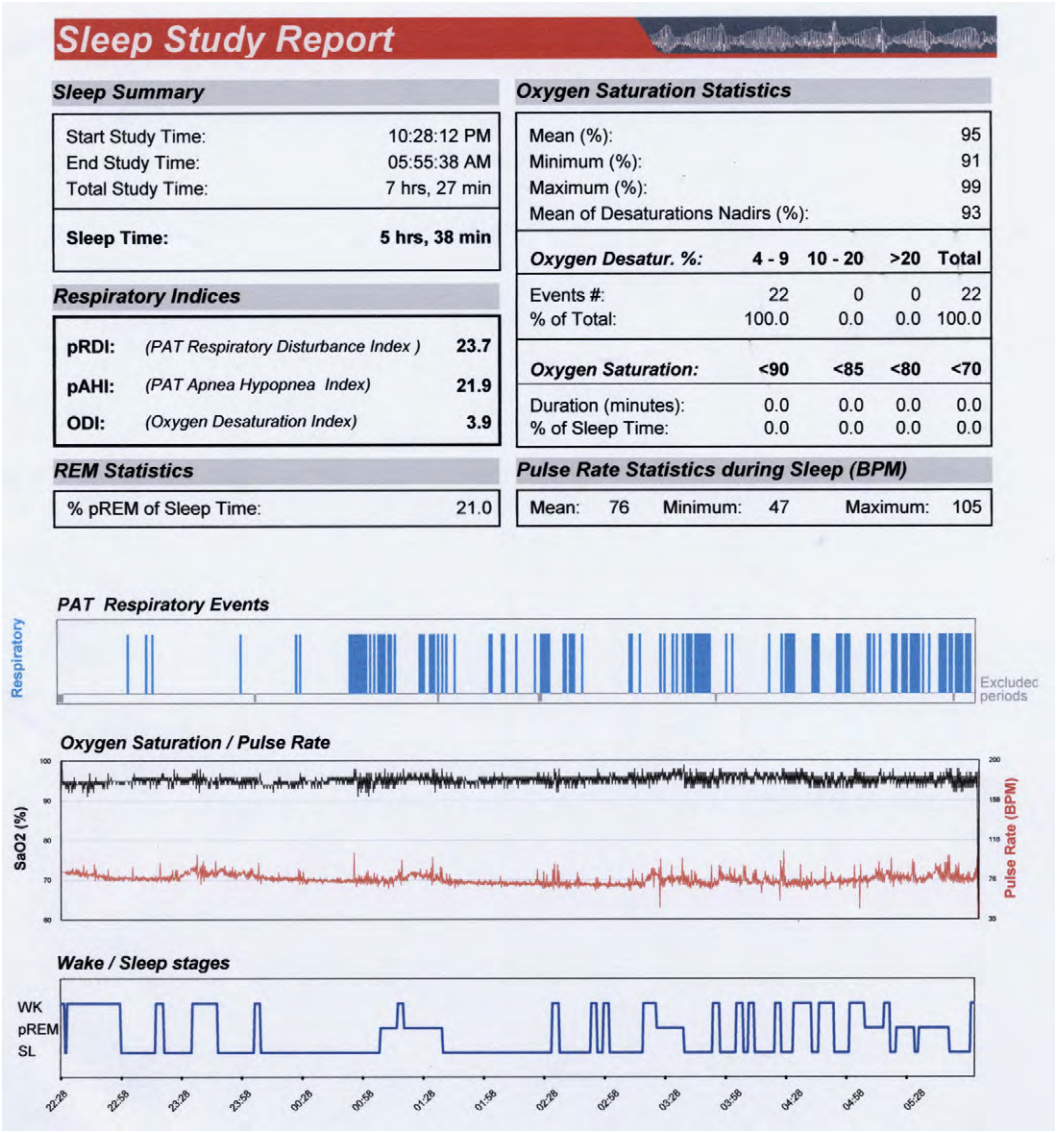

Fig. 8. The data collected from the Watch-PAT and the standard PSG were analyzed for indices or values most likely to detect and evaluate the severity of OSA. These values included RDI, AHI, ODI, respiratory events total, mean oxygen saturation, mean pulse rate, and rapid eye movement sleep.

tone (PAT) via a finger-mounted pneumo-optical probe and a pulse oximetry probe to detect arterial oxygen saturation and heart rate.

One of the devices used in our centers for outpatient sleep apnea monitoring is Watch-PAT 100. This system is a finger plethysmograph coupled to a constant volume, variable pressure, and pneumatic system. The plethysmograph's tip (measurement site) is composed of two parallel, opposing, longitudinal half thimbles, which is attached to a contiguous annular cuff. Each compartment consists of an internal membrane surrounded by an outer rigid wall, which provides a uniform pressure field and imparts a two-point locking action that prevents axial and longitudinal motion of the finger. Subdiastolic pressure is applied to prevent venous pooling, engorgement, and stasis to inhibit retrograde venous shock wave propagation and partially unload arterial wall tension. The annular cuff extends the effective boundary of the pressure field beyond the measuring site.

Our study showed the statistical correlation of AHI of standard PSG(r) versus the tested device (p) to be r = 0.968 ($P < .05$) and RDI correlation to be r = 0.896 (P, .05). We agree with previously reported findings that the fingertip exemplifies the scope of peripheral vascular

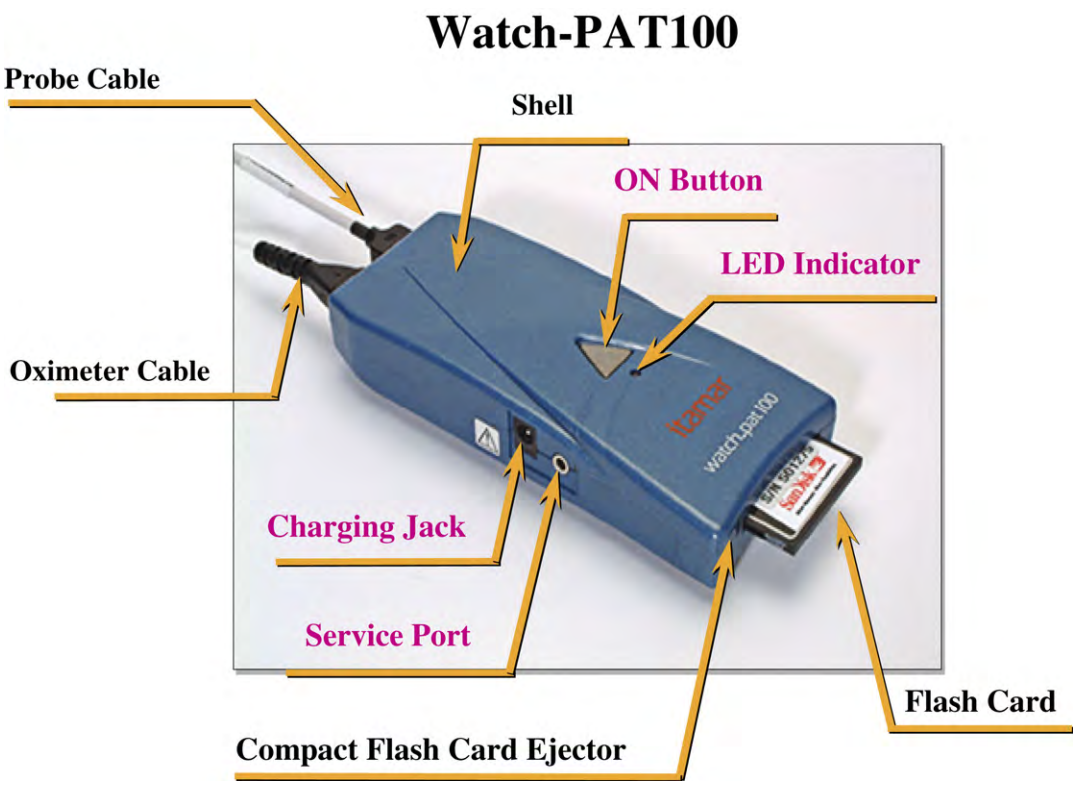

Fig. 9. The unit is simple to use and is composed of a device worn on the wrist, an LED indicator, a compact flash card, and cables in the back. (*Courtesy of* Mansoor Madani, DMD, MD, Bala Cynwyd, PA; all rights reserved.)

responsiveness because of its high density of alpha sympathetic innervations and its high degree of blood flow rate reliability. Because elevated peripheral resistance and tightly linked transient heart rate elevation are consistent parts of the hemodynamic response to arousal and OSA, we also believe that pulsatile finger blood flow patterns can be used for diagnosis of OSA and other sleep-disordered breathing conditions.

Watch-PAT 100 has a finger probe coupled to a constant volume, variable pressure, and pneumatic system that is worn around a patient's wrist throughout the study. The Watch-PAT 100 is a noninvasive device that consists of a finger plethysmograph (finger probe) that contains an opticopneumatic sensor, which measures the peripheral arterial tone. The other probe is a pulse oximeter that measures oxygen saturation. The body of the device also contains an actigraph, which is an accelerometer capable of detecting limb activity to interpret and

Fig. 10. Remove the compact flash card from the Watch PAT (WP) and insert it into the reader. When done, remove the compact flash card and insert it into the device.

differentiate between sleep and wake time. There are several simple steps for using Watch-PAT 100. Analysis is done automatically by specialized software, and the practitioner can readily read and assess its finding and direct the patient to the most appropriate treatment (Fig. 7). The values measured by this device include RDI, AHI, ODI, respiratory events total, mean oxygen saturation, mean pulse rate, and rapid eye movement sleep (Fig. 8).

The unit is simple to use and is composed of a wrist-worn device, an LED indicator, a compact flash card, and cables in the back (Fig. 9). Once the unit is returned by the patient, the compact flash card is removed from the device and inserted into a reader connected to a computer. The analysis takes less than 2 minutes, and the results can be printed and explained to the patient (Fig. 10).

Summary

The cost, complexity, availability, and limitations of PSG have led to the development of simpler diagnostic techniques in the field of sleep-disordered breathing. Growing insight from clinicians indicates that diagnosing OSA may affect prognosis of hypertension, stroke, and other cardiovascular-related disorders. If there were a convenient way to diagnose and treat OSA at early onset, treatment could be expedited to avoid serious comorbidities associated with sleep apnea. In this study, the Watch-PAT 100 was evaluated simultaneously against a standard in-laboratory PSG for detecting OSA with reasonable sensitivity and specificity as measured by AHI and RDI. It is not our belief that the wrist-worn PAT will replace standard PSG completely, because there are inherent limitations.

Because of the nature of interpretation of an arterial signal, one must believe that certain medical conditions, such as peripheral vascular disease or obstructive lung disorders, which require supplemental oxygen, may generate false results if the Watch-PAT 100 was used exclusively. A real application exists for the use of this device in patients suspected of having OSA. These individuals could have their diagnosis verified by Watch-PAT 100 followed by in-house PSG for continuous positive airway pressure titration. The ambulatory OSA test would not be a replacement, but the device would be an adjunct. As the device becomes available to professionals more readily, more patients could be tested, and if they believed that a false-negative result existed from the home sleep study or if they had medical conditions that rendered the home trial problematic, they could follow-up with a PSG. This treatment modality would greatly increase diagnoses to individuals not able to travel to a sleep center and inpatient cases that require a study at bedside, which could dramatically cut the cost because no laboratory time would be used.

The Watch-PAT 100 represents a new era in the field of sleep medicine. It offers the opportunity for thousands of people who were previously unable to obtain treatment to improve their quality of life through early treatment and avoid the many harmful sequelae that affect persons who have OSA.

Acknowledgments

The authors wish to acknowledge Dr. Masoud Sadighpour and thank the staff at the Capital Health System's sleep laboratory in Trenton, NJ, for their help and input.

Further readings

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 111–128

Atlas of the
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Flexible Endoscopic Nasopharyngoscopy

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As the number and types of surgical procedures performed by oral and maxillofacial surgeons have expanded over time, the need for better diagnostic tools also has increased proportionately. This is especially true for diseases related to the airway, in which endoscopic procedures are easily performed and highly diagnostic.

Although a thorough airway examination always has been important in the preparation for many oral and maxillofacial surgical procedures, the recent increase in the use of diagnostic nasopharyngoscopy is related to the increase in recognition and management of snoring and obstructive sleep apnea (OSA). This disease—and its associated syndrome—results from narrowing and obstruction of the airway during sleep secondary to either an absolute increase in airway tissue mass (resulting in a decreased airway cross section) or increased tissue compliance and collapsibility during inspiratory airflow. Over the past decade, researchers and clinicians have come to understand the origin and pathophysiology of this disease to a much greater extent. This understanding has led to an ever-increasing number of treatment procedures and protocols aimed at decreasing the mass volume or collapsibility of the targeted tissues within the airway.

It is imperative that before making any treatment decisions in the management of OSA, an accurate determination be made of where the tissue or tissues are causing the obstruction so that an appropriate surgical procedure may be chosen that will target the correct tissue for diminution or tightening. Historically, this was done using direct visual speculum examination of the nasal airway along with mirror retrograde nasopharyngoscopy and laryngoscopy. This procedure was of limited value because it was often difficult to perform on patients with a gag reflex, provided a limited view of the anatomy, and was time constrained by patient tolerance.

Advantages and disadvantages of flexible nasopharyngoscopy

The use of flexible endoscopic nasopharyngoscopy has many advantages for diagnosis of airway-related breathing disorders. When done with appropriate topical anesthesia, it can be performed painlessly and slowly, which allows for excellent visualization, without gagging, of the entire airway from the nares to the vocal cords. It allows for dynamic examination with the patient inspiring, expiring, swallowing, and speaking in the upright and supine positions. Recent studies also have suggested that when used for diagnosis in OSA, nasopharyngoscopy may be best performed with the patient sedated to increase correlation to actual sleeping conditions. Finally, nasopharyngoscopy is easily learned and generally associated with minimal morbidity.

Relative to indirect examination, there are few disadvantages of using flexible endoscopic examination other than the cost of the equipment, which is significantly greater. A more direct comparison might be to rigid endoscopic examination, which allows for more in-depth evaluation of the sinus cavities and functional endoscopic sinus surgery (Fig. 1). Rigid

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doi:10.1016/j.cxom.2007.05.004

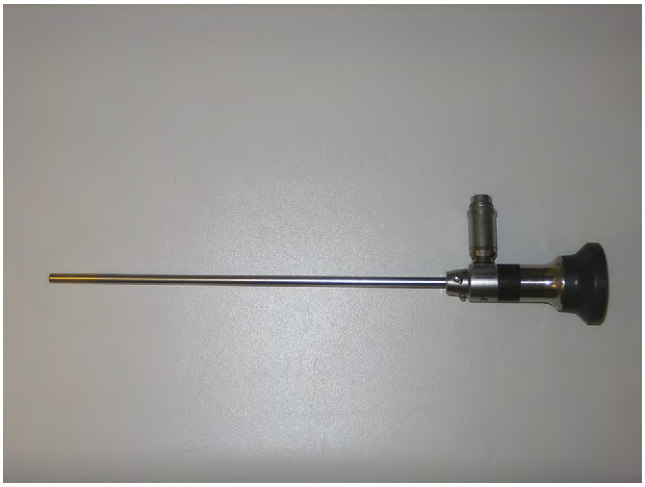

Fig. 1. Rigid endoscope. Although some areas of the airway, such as the sinuses, can only be examined totally with a rigid scope, it is difficult to perform under topical anesthesia in an office environment.

endoscopy, conversely, is limited by the extent of what can be performed in an office environment under topical anesthesia.

Indications and contraindications

It is generally considered standard of care for any patient undergoing surgical management of a sleep-related breathing disorder to have a diagnostic nasopharyngoscopy, which provides two vital pieces of information to the surgeon. Although a chronic (as opposed to acute) sleep-related breathing disorder is unlikely to be caused by a neoplastic process, it is imperative to rule this out before any surgical intervention by examining the entire length of the airway. This examination is easily and rapidly accomplished with flexible endoscopy.

It also assists the surgeon in determining the likely level—or more likely, levels—of obstruction. Using static and dynamic evaluation techniques (eg, Müller's maneuver, to be discussed later in this article), the surgeon can better identify potential sources of obstruction. These data can be used to create a treatment plan that specifically isolates the tissues to be addressed at the time of surgery.

Although primarily used for airway evaluation in patients with snoring and sleep apnea, there are many other uses for flexible airway endoscopy in oral and maxillofacial surgery. Before orthognathic surgery, nasopharyngoscopy can identify potential pathology or structural abnormalities that could affect the success and safety of maxillary downfracture, ascertain airway conditions that might require attention to prevent postoperative complications (eg, impingement on hypertrophic turbinates), and aid in determining any alterations in the nasal septum that might to be addressed pre- or postoperatively.

Patients with fascial space infections of the head and neck also can be evaluated for airway compromise and, along with radiographic correlation, the extent of the spaces involved. This assessment can be especially useful in the postoperative period, when the surgeon is unsure of the patient's ability to maintain an adequate airway because of airway edema after incision and drainage. In general, any patient undergoing procedures that are performed within the airway or are associated with swelling that may extend to the airway (eg, tongue surgery) can benefit from diagnostic airway evaluation. Its relative ease of use, wide availability, and low morbidity make it an invaluable resource for the oral and maxillofacial surgeon.

Contraindications to flexible nasopharyngoscopy

Because of its generally benign nature, there are few real contraindications to flexible endoscopy. The main concern during this procedure is significant (although rarely catastrophic)

bleeding. As such, patients on anticoagulant therapy or patients with significant coagulopathies must be regarded with extreme caution. Vascular lesions, such as lesions associated with hereditary hemorrhagic telangectasia or nasal angiofibromas, may be traumatized by the endoscope and result in traumatic hemorrhage. In these cases, reversal of the anticoagulated state may be entertained before the examination or a risk-versus-benefit analysis may be performed. An allergy or sensitivity to any of the medications used also would be a contraindication.

Armamentarium

With the exception of the endoscope itself, most of the items necessary to perform flexible nasopharyngoscopy are things that are commonly found in most oral and maxillofacial surgeon's offices. The primary instrument that must be considered is the endoscope. For the reasons mentioned previously, diagnostic (as opposed to therapeutic) nasopharyngoscopy is almost always executed using a flexible endoscope rather than a rigid scope. Flexible endoscopes vary in diameter and length, depending on their intended use. Larger diameter endoscopes (often used for bronchoscopy, gastroscopy, colonoscopy) are usually 7 to 10 mm in diameter and often contain a suction port and perhaps a hollow channel to pass instrumentation through (Fig. 2).

Because suction is not often needed during simple diagnostic examination, however, the smaller diameter scopes are more comfortable to the patient and allow for easier passage through the nasal cavity. For diagnostic purposes, there is no need for a secondary instrumentation port. Generally, a scope measuring 4 mm in width provides adequate visibility with relative ease of passage through all but the smallest nasal airways at a cost that is well balanced against its functionality. If therapeutic intervention is indicated through the scope (such as with a biopsy), this may necessitate a larger scope, which is usually passed orally rather than nasally. Often, however, a separate instrument may be used for the intervention while visualization is accomplished simultaneously through the scope.

Because the scope must be capable of passing through tortuous channels and able to examine the entire length of the airway, it is imperative that the end of the scope have a highly bendable profile. In general, the scope should be able to flex at least 120° in upward and downward directions (Fig. 3).

Fig. 2. Large diameter and small diameter endoscope. The larger scopes are most commonly used for large cavity endoscopy, such as bronchoscopy or colonoscopy. Note the instrument channel and the suction port. The smaller diameter scope does not contain an instrument port but may contain a suction port.

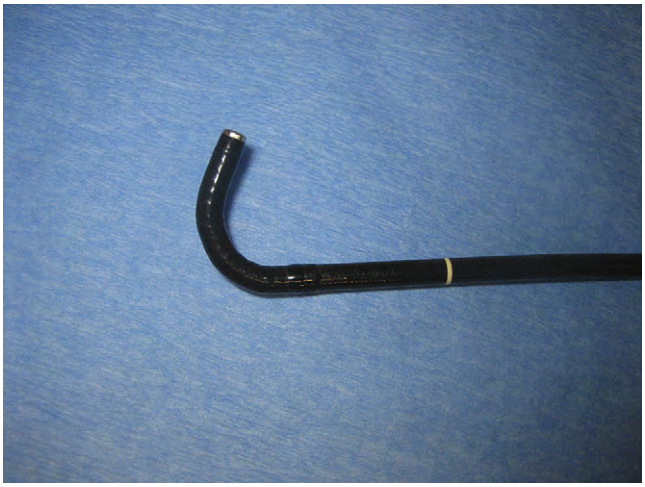

Fig. 3. Bendable scope end. Note the great degree of flexibility of the end of the scope, which is important for passing the scope through tortuous airway anatomy.

Similarly, the length of the scope should be considered in light of its intended use. Because diagnostic nasopharyngoscopy is meant for evaluation of the upper airway only, it need not be any longer than is necessary to visualize—but not pass through—the vocal cords. If the procedure is intended to evaluate the trachea or bronchi or if the scope is to be used for endoscopic endotracheal intubation (as is commonly done for management of the difficult airway, such as in patients with OSA), then a longer fiberoptic laryngoscope or bronchoscope may be considered.

A light source is also necessary for adequate visualization through the endoscope. Although most scopes are matched up to a particular light source, almost all endoscopes have the availability of an adaptor to meet the needs of most commercial light sources. Because most oral and maxillofacial surgeons already have some sort of fiberoptic light source in their offices, they should be able to adapt a connection between the scope and light source without difficulty.

Although it adds significant expense to the equipment costs, a video camera and monitor can be attached to the scope and provide several advantages. Using a video monitor provides a much larger image for the surgeon to more easily analyze and assess, making diagnosis a simpler process. It involves the office staff and the patient in the procedure, which is especially useful when attempting to explain the necessity of surgery in the management of anatomic obstruction. When used with a capture device, it also allows for video and digital still photo documentation for presurgical review, postsurgical comparison, and medicolegal purposes. There are significant differences in digital video cameras and monitors (eg, one- versus three-chip cameras, CRT versus LCD screens), which affect the quality and size of the picture and the cost of the system dramatically. For surgeons who already own a video camera and monitor for other purposes (eg, arthroscopy, sialography), the cameras are almost always fitted with a standard scope connector that allows any endoscope to be attached to the camera.

The only tray instruments needed to perform nasopharyngoscopy are those needed for administration of the topical anesthesia (Fig. 4). A tongue retractor enables visualization and access to the pharyngeal wall and soft palate, whereas a few cotton tipped applicators can be used to apply some topical anesthetic directly to the nares if needed. A small container of sterile saline and some gauze is also useful for cleaning the scope as needed during the procedure.

Anesthesia

With few exceptions, diagnostic nasopharyngoscopy can be comfortably and reliably executed using only topical anesthesia. This is routinely done by using a vasoconstrictor and a topical anesthetic spray or pledgetts.

Fig. 4. Tray instruments. Relatively few instruments are needed to perform nasopharyngoscopy. Primarily, they are used to provide topical anesthesia.

The purpose of the vasoconstrictor is to decrease the size of the intranasal tissues for access and visibility and limit the risk of traumatic bleeding. The vasoconstrictor should be administered before the topical anesthesia, although some people prefer to administer them simultaneously. Any currently used vasoconstrictor, such as neosynephrine drops or spray or oxymetazoline (Afrin) spray, may be used. Because diagnostic examination should be performed on both sides of the nasal cavity, the vasoconstrictor and anesthetic agents also should be placed in both nares. A few drops of neosynephrine or two sprays of oxymetazoline should be adequate for routine examination.

Topical anesthesia is most easily applied using a spray or an atomized liquid. Atomizers can be purchased as manual glass spray bottles or can be run off a pressurized air or oxygen source. Lidocaine, 2% to 10%, and tetracaine (Pontocaine), 0.5% to 1%, are the most commonly used anesthetic agents. Using two to three sprays in each nostril along with two short sprays to the pharyngeal wall should be adequate for most patients. Alternatively, the liquids can be placed on cotton pledgetts or cotton swabs and left in place in the nares for a few minutes. Some surgeons have the local pharmacy custom-mix a combination of lidocaine or tetracaine and neosynephrine or oxymetazoline, which is then atomized together for a single application rather than as two separate applications. Cetacaine spray, although commonly used by oral and maxillofacial surgeons for intraoral topical anesthesia, should be reserved for spraying in the mouth or throat and avoided in the nasal cavity because it is uncomfortable to the patient.

A particularly useful technique used by the author has proved to be easy, highly effective, and inexpensive. A 15-mL bottle of vasoconstrictor, such as generic oxymetazoline or neosynephrine, is emptied of 10 mL. A dental syringe with a 25-gauge needle is used to inject 5 mL of 2% dental lidocaine into the bottle containing the remaining 5 mL of vasoconstrictor. The mixture can be sprayed directly into the nose. Three to four sprays to each nostril is usually adequate for a comfortable procedure (Fig. 5).

Technique

Before beginning the procedure, the patient should be given a thorough explanation of what is to be done, the indications for the procedure, and any alternatives, if they exist. A consent form should be obtained.

The patient is typically placed in a sitting, slightly reclined position for comfort. The surgeon should sit or stand in the normal position and place from which he or she operates (Fig. 6A, B). After waiting for suitable anesthesia, the scope is grasped with the surgeon's dominant hand such that the movable lever that controls the tip angulation is moved by either the thumb or forefinger (Fig. 7). The nondominant hand is used to guide the scope tip and prevent inadvertent

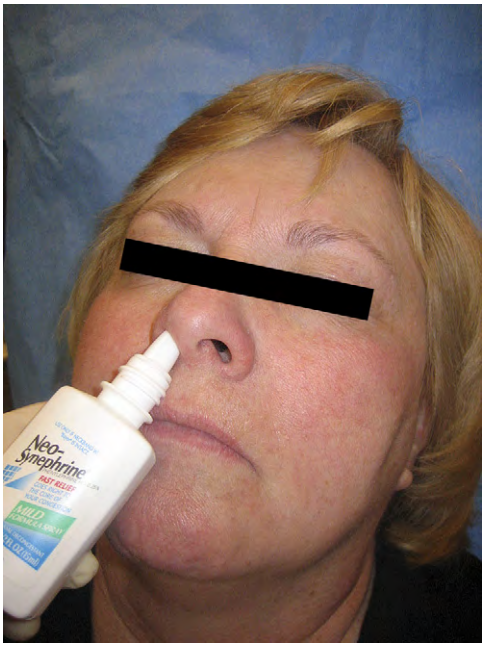

Fig. 5. Removing 10 mL of material from a 15 mL bottle allows the surgeon to add 5 mL of lidocaine to the bottle using a dental syringe. The resultant mixture can then be sprayed directly into the nose.

extrusion using a finger rest on the nose (Fig. 8). Although it does not matter which finger is used to control the scope angulation lever, the examiner should be consistent and ensure that the scope is angling properly with each deflection of the lever.

The scope is slowly advanced into the nares. Should fogging be an issue, the scope lens can be wiped with a commercial antifogging agent or mild soapy solution. Gently touching the scope to the inferior turbinate also defogs it. If necessary, the scope can be removed and gently wiped with wet gauze or a lens tissue.

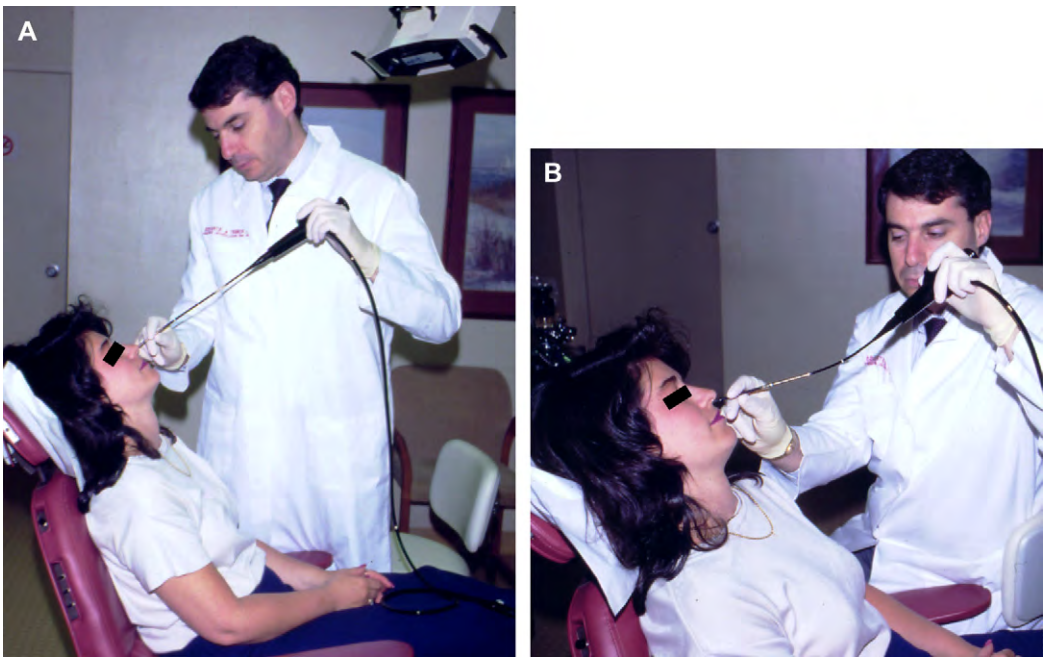

Fig. 6. (*A*) The patient should be placed in a slightly reclined but comfortable sitting position. The surgeon may perform the procedure either from a standing position or a sitting position (*B*).

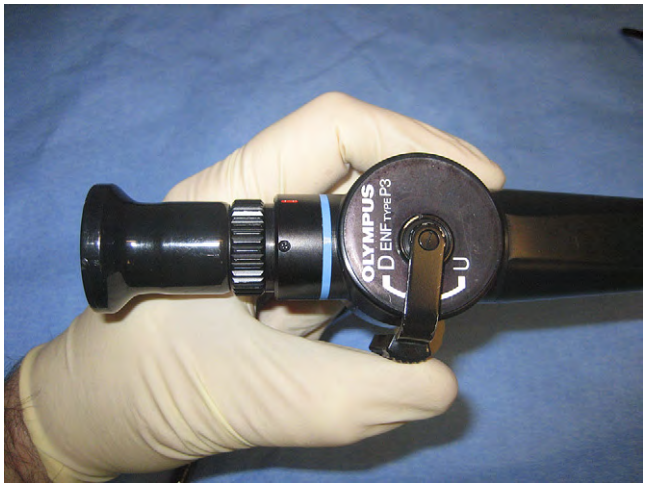

Fig. 7. The control lever should be grasped with the surgeon's dominant hand.

As with most surgical procedures, the technique for diagnostic nasopharyngoscopy should be done in an organized, repeatable, stepwise fashion. The basic steps include are shown in Box 1. Adhering to this protocol ensures that a complete examination is done every time and that no area is missed.

Nasal cavity

Normal examination

The structures of the nasal cavity are shown in Fig. 9. The anterior nares is inspected and the camera is oriented such that the nasal septum and inferior turbinate are visualized in their correct orientation (the septum medially and the turbinate laterally). The septum and inferior turbinates are examined anteriorly (Fig. 10A–C). The scope is turned up to visualize the middle turbinate, middle meatus, and the other superior structures. Using a flexible scope, the superior turbinate is difficult to examine; if it is in question, it may require rigid endoscopy.

Although it is difficult to see the natural ostium of the sinus in most cases, a more anterior and inferior accessory ostium may be seen occasionally. The middle turbinate, hiatus semilunaris, uncinate process, and a prominent bulla ethmoidalis may be seen in this area (Fig. 11A, B). The scope is then withdrawn and passed posteriorly along the floor of the nose

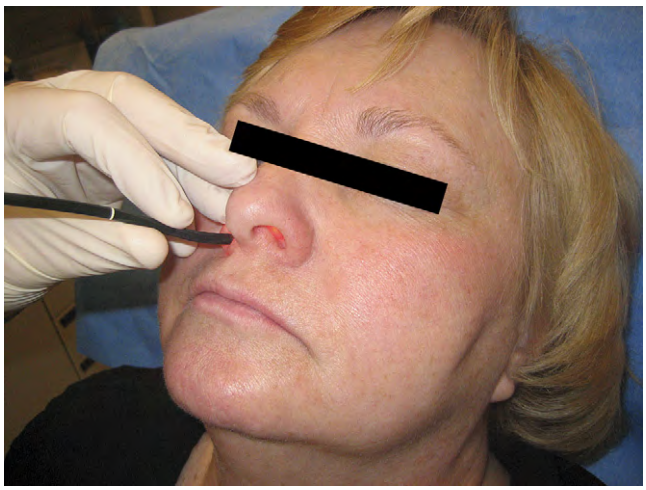

Fig. 8. The nondominant hand is used to provide a nasal finger rest for guiding the scope and preventing inadvertent extrusion.

Box 1. Basic steps for diagnostic nasopharyngoscopy

Patient positioning and anesthesia
Examination of the five basic areas
  Nasal cavity
  Nasopharynx
  Oropharynx
  Hypopharynx
  Larynx
Diagnostic maneuvers
  Vocalization
  Müller's maneuver

below the inferior turbinate. The entire length of the nasal septum can be examined during this posterior pass. At the end of the inferior meatus the nasal cavity joins the nasopharynx at the choana (Fig. 12).

Abnormal examination

Common abnormal findings on the nasal examination include deviations, deflections, perforations or spurring of the nasal septum, antral polyps emanating from the sinus ostia, and maxillary sinus drainage in the case of sinusitis (Fig. 13). Allergic or other rhinitis demonstrates inflammation, obstruction, and crusting of the septum and turbinates. Synechiae are fibrous connections between the septum and turbinate after surgery or trauma. Tumors of the nasal cavity, although rare in this scenario, must be looked for. Finally, the opening of the choana should be evaluated for atresia or stenosis.

Nasopharynx

Once the choana is examined, the scope should be advanced slightly into the nasopharynx (Fig. 14). Further inferior examination requires that the scope be angled downward as it is progressed.

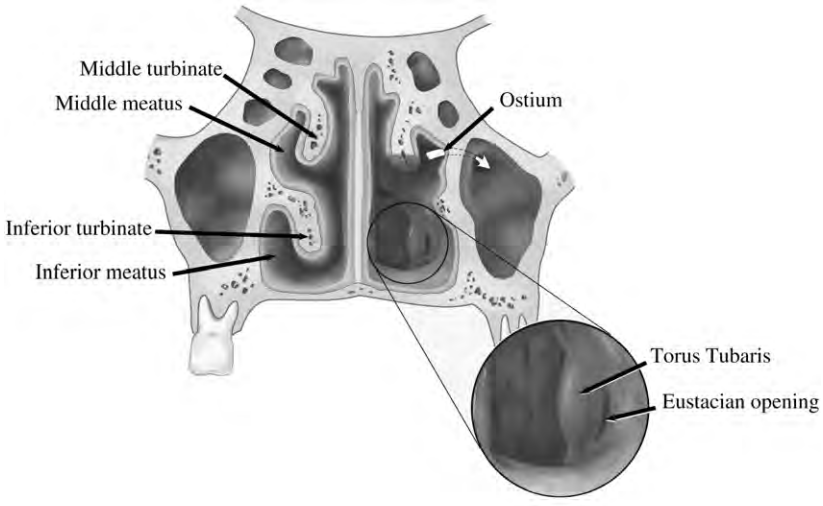

Fig. 9. The structures of the nose. Anteriorly the inferior and middle turbinates are visualized, along with the nasal septum medially. The sinus ostium is high within the middle meatus. On the right side the turbinates have been removed to visualize the lateral and posterior pharyngeal walls beyond the choana. In this manner the Eustachian cushion and Eustachian tube can be seen laterally.

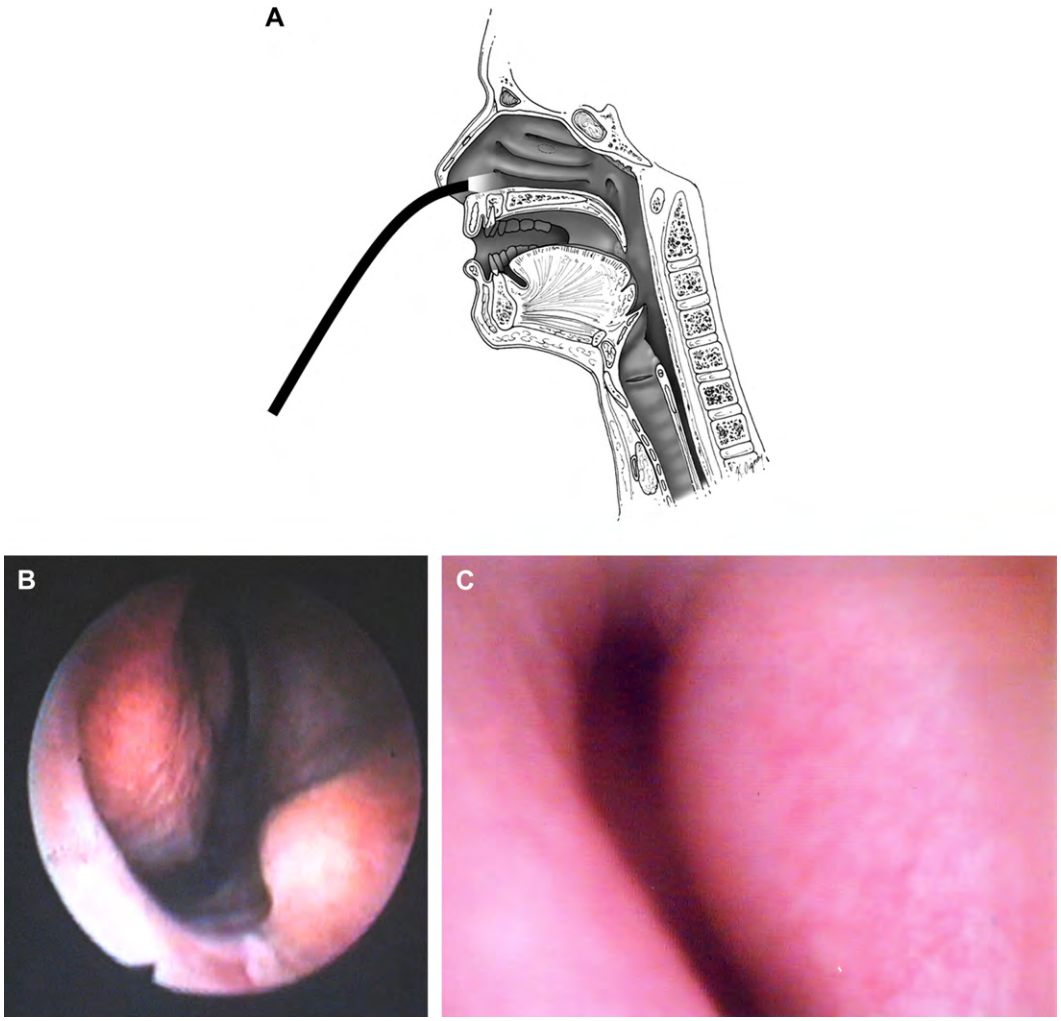

Fig. 10. (*A*) The scope is placed in the anterior nasal fossa. (*B*) The inferior turbinate laterally and the nasal septum medially. (*C*) On the right, the enlarged nasal turbinate; on the left, a slight deviation is noted.

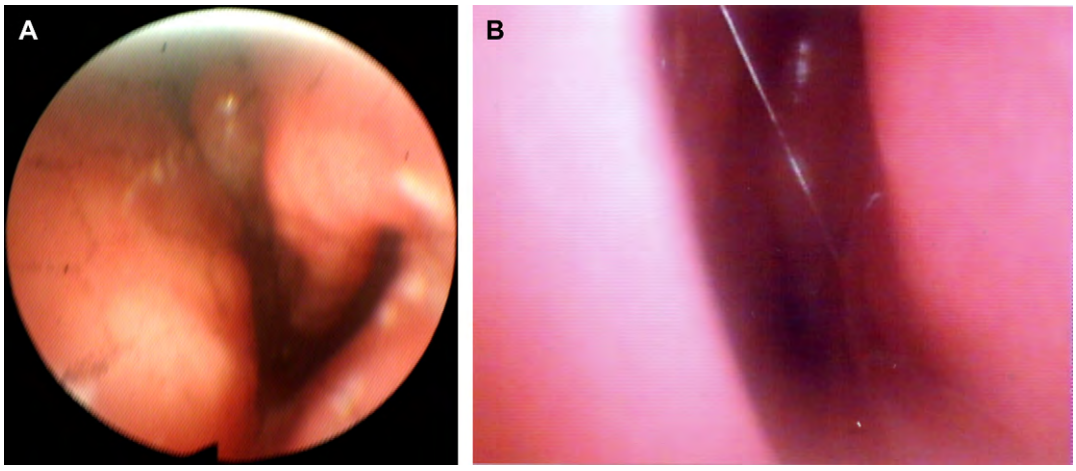

Fig. 11. (*A*) The middle meatus and middle turbinate. (*B*) An accessory ostium is occasionally seen in the middle meatus.

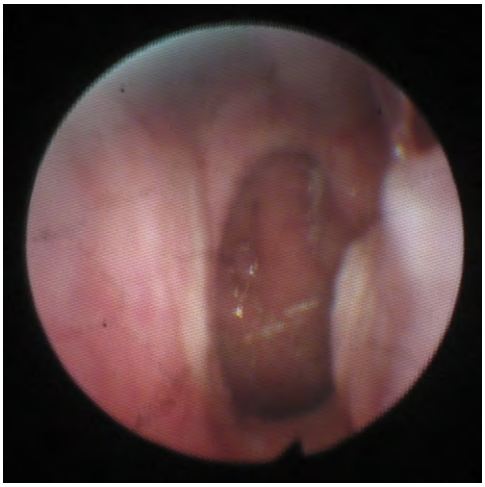

Fig. 12. The choana, gateway of the nasal cavity to the nasopharynx.

Normal examination

As the scope is passed through the choana, the roof of the nasopharynx and posterior pharyngeal wall become visible. Also seen laterally are the Eustachian cushion, or torus tubaris, and the Eustachian opening anterior to it. Behind the torus tubaris is the fossa of Rosenmüller (Fig. 15). The Eustachian opening can be more easily seen when the patient swallows, thereby dilating the opening. Rotating the scope inferiorly reveals the superior side of the soft palate.

Abnormal examination

In the child or adolescent examination, enlarged adenoidal tissue or its remnants may be seen in the roof of the nasopharynx. If enlarged, it may partially obstruct the choana. In adults, remnants of the adenoids are seen as the adenoidal pad, a series of vertical striations in the region (Fig. 16).

The Eustachian opening may be obstructed or may have enough inflammation in the area to not function normally during swallowing. Drainage may be seen from the opening in some conditions. Cysts and masses are sometimes seen in the fossa of Rosenmüller but may be seen in the posterior pharyngeal wall.

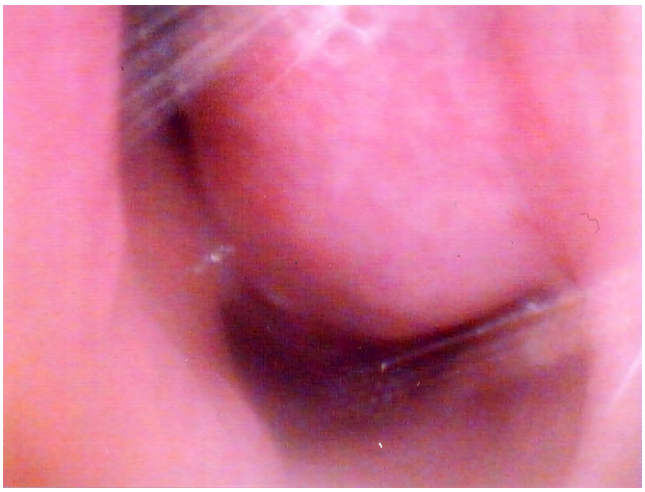

Fig. 13. The entry point to the nose. Nasal turbinate is on the right; the lowest part of the inferior turbinate is contacting the nasal septum on the left.

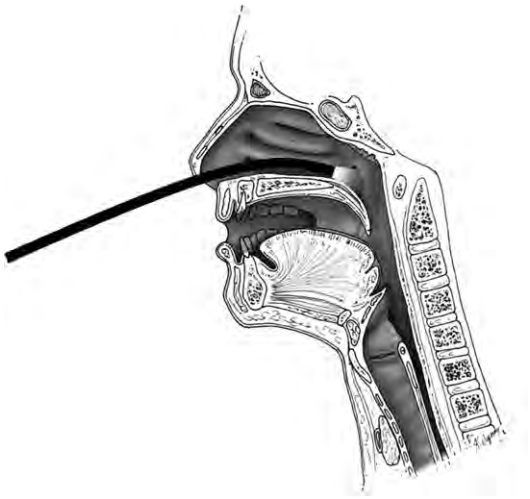

Fig. 14. Placement of the scope at the level of the nasopharynx.

Oropharynx

Normal examination

As the scope is passed further inferiorly, the soft palate and oropharynx come into view (Fig. 17). The soft palate should be freely mobile during swallowing and should contact the pharyngeal wall to allow for velopharyngeal closure. The uvula may be seen inferiorly on the soft palate (Fig. 18). Laterally, the tonsillar fossa and pillars become evident. Posteriorly, the pharyngeal wall is seen continuing down from the nasopharynx. Often, the patient is asked to swallow, which activates the pharyngeal wall musculature and allows assessment of the degree of muscle activity and closure of the pharynx laterally.

Abnormal examination

Especially in snoring patients and persons with OSA, the soft palate may be noted to be long or thickened. The uvula also may be elongated, or both may be shortened if that patient has previously undergone uvulopalatopharyngoplasty (UPPP) or laser-assisted uvulopalatoplasty (Fig. 19). There may be little space between the soft palate and the posterior pharyngeal wall. The tonsils may be enlarged and hypertrophic, often occluding much of the airway in this region, especially in children. During swallowing, one may see excessive mobility of the lateral

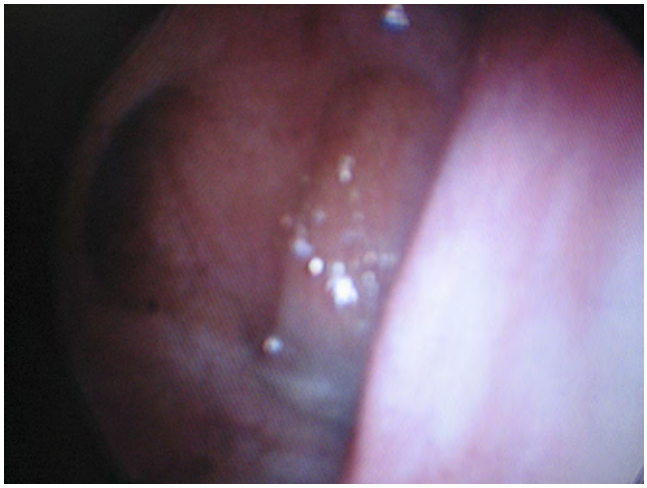

Fig. 15. The normal nasopharynx. Note the Eustachian cushion posterolaterally and the Eustachian opening anterolaterally.

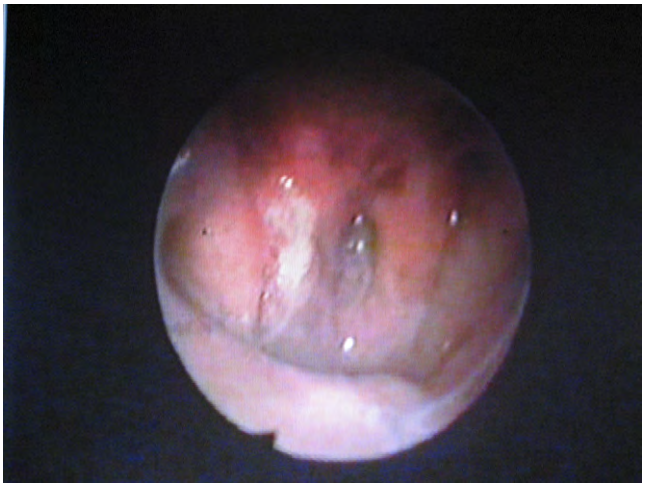

Fig. 16. The remnants of the adenoids in an adult patient.

tissues with hypertrophic pharyngeal wall tissue (which is difficult to see on lateral cephalogram and other two-dimensional radiographic aids).

Hypopharynx

Normal examination

The scope is continued inferiorly posterior to the base of the tongue, which is visualized along its length (Fig. 20). The epiglottis is easily seen at the inferior portion of the tongue base, with the valecula representing the space between the tongue and the epiglottis (Fig. 21). The circumvallate papilla and lingual tonsillar tissue should be seen along the lateral tongue base just superior to the epiglottis.

Abnormal examination

The base of the tongue is an important anatomic structure in the cause of OSA. As the scope passes down along the base of the tongue, the lingual tonsillar tissues become evident. These structures may become enlarged, either from tumor or inflammation. The base of the tongue itself may be larger than normal because of a developmental deformity or compensatory enlargement. The epiglottis may be floppy or elongated, sometimes even being visible on routine

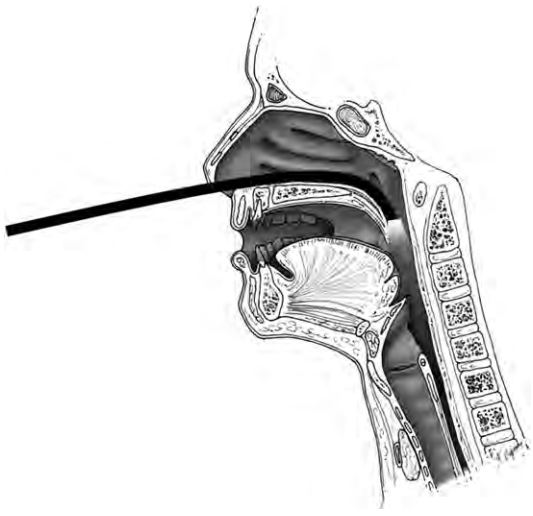

Fig. 17. Placement of the scope at the level of the oropharynx.

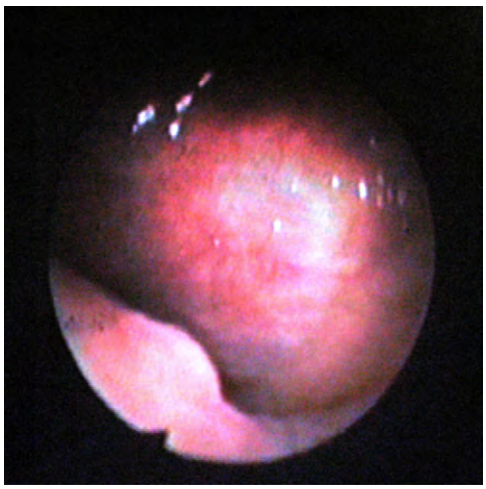

Fig. 18. The oropharynx. Note the posterior aspect of the soft palate anteriorly and the pharyngeal wall posteriorly.

oral examination (Fig. 22). The valecula should be examined carefully for cysts and various tumors. The lateral pharyngeal walls provide resistance to deformation during inspiration under normal conditions; when they are redundant or demonstrate excessive compliance, obstruction may result during forceful inspiration. This is most easily visualized during swallowing or when performing a Müllers maneuver (discussed later in this article).

Larynx

Normal examination

As the scope descends past the hypopharynx, the larynx is seen inferiorly and anteriorly (Figs. 23 and 24). The arytenoids cartilages are evident bilaterally. Below these lie the false and true vocal cords, which should contract and relax equally on both sides during vocalization. Behind the arytenoids the examiner finds the piriform recesses. Inferior to the vocal cords is the trachea. The first cartilaginous ring, the only complete ring, is the cricoid, which is often seen just inside the trachea.

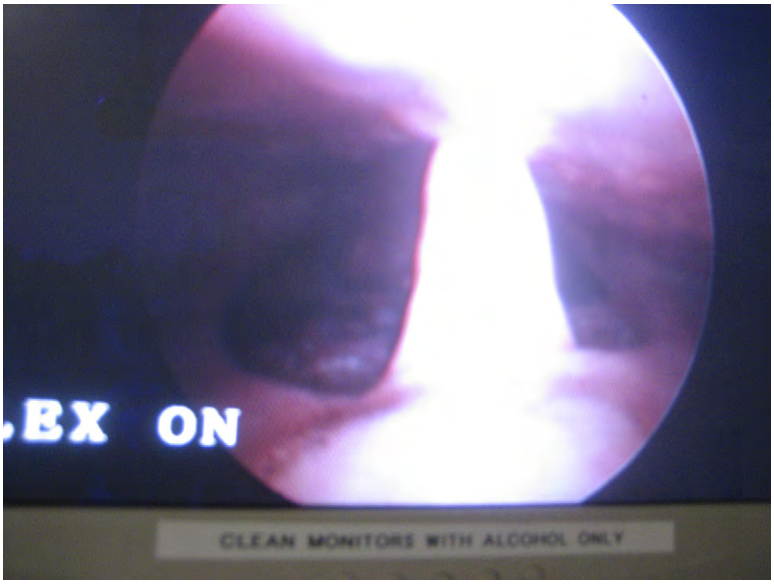

Fig. 19. An elongated uvula as seen from the level of the oropharynx.

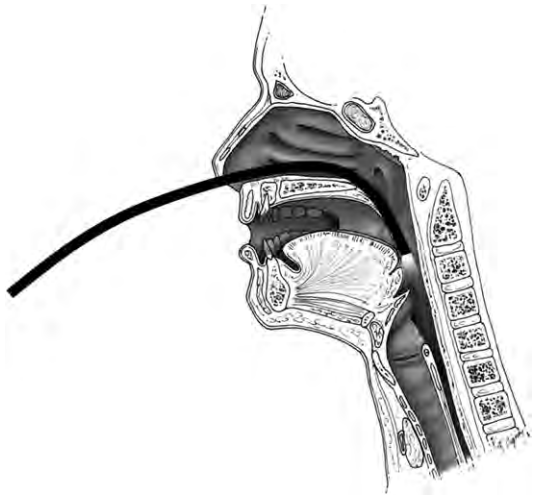

Fig. 20. Placement of the scope at the level of the hypopharynx.

Abnormal examination

The most likely source of obstruction in the larynx is the vocal cords themselves, specifically a paralyzed vocal cord, leading to closure of the glottis. This condition should be easily confirmed during prolonged vocalization of the letter "E." Another source of obstruction would be a mass or stenotic area in the subglottic region. Although they are unlikely causes of obstruction, vocal cord nodules ("singer's nodules") are common. Finally, lesions of the piriform recesses also may be seen on occasion and should be looked for.

Müller's maneuver

The final part of a nasopharyngoscopic examination is the Müller's maneuver, which is a technique that is used to attempt to locate one or more anatomic areas within the airway that are the most likely sources of obstruction by simulating closure of the airway during an obstructive event.

After completing the routine examination of the airway in the upright position, the patient is rotated to the full supine position with the scope still within the nasal cavity. The scope is then placed just above the soft palate and the patient is requested to close his or her mouth. The operator then pinches the nose around the scope and asks the patient to attempt an inspiratory breath (Fig. 25). The patient is unable to move air because of the closure of the nose and mouth, which results, at least theoretically, in a negative inspiratory pressure and subsequent collapse of

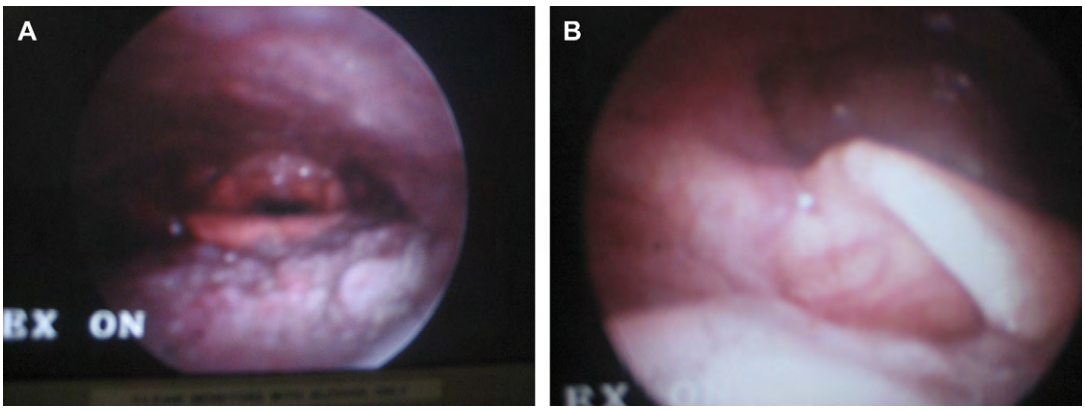

Fig. 21. (*A*) View of the normal hypopharynx shows the base of the tongue, lingual tonsillar tissue, the epiglottis, and the posterior pharyngeal wall. Inferiorly, the larynx is becoming visible. (*B*) The valecula, which is the space between the tongue and the epiglottis and occasionally is the site of cysts or small neoplasms.

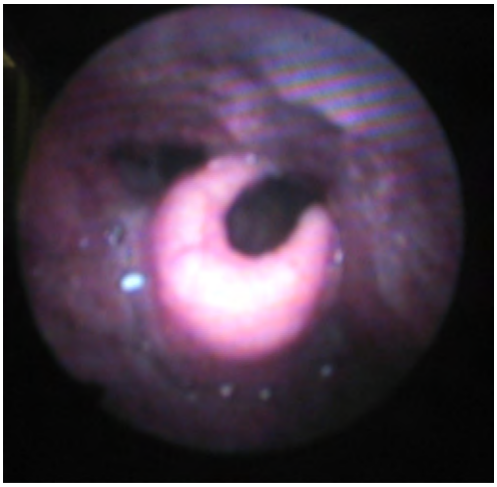

Fig. 22. A floppy and elongated epiglottis that is obstructing the airway.

the airway in the anatomic spot that occurs during an obstructive event. The examiner notes the degree of closure of the airway at the level of the soft palate (Fig. 26). The scope is then advanced further down the airway until it is just above the base of the tongue. The maneuver is repeated and the degree of closure at the level of the tongue base is noted (Figs. 27 and 28).

The classification system of Fujita is often used to describe the degree of obstruction at the two levels. The Fujita I classification shows obstruction almost solely at the level of the oropharynx. The Fujita IIa and Fujita IIb classifications have variable amounts of obstruction at both levels, with the oropharynx and hypopharynx being the predominant levels, respectively. The Fujita III classification describes obstruction almost solely at the level of the hypopharynx. It has been suggested that this procedure be done several times, because the results may demonstrate some level of variability even from breath to breath.

The usefulness of the Müller's maneuver has been a source of great controversy in the literature. Although some studies have found a correlation between the findings of the maneuver and the effectiveness of procedures such as UPPP, which affect only one area of the airway, others have found no such correlation. It is generally accepted that the results of the Müller's maneuver be considered as just one piece of a much larger pool of diagnostic data that must be weighed when formulating a diagnosis and treatment plan.

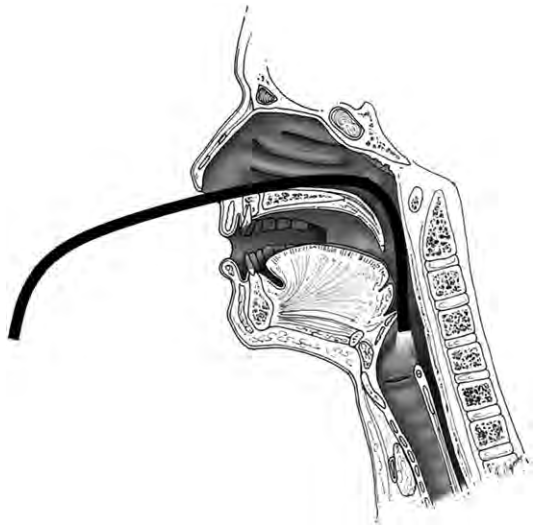

Fig. 23. Placement of the scope at the level of the larynx.

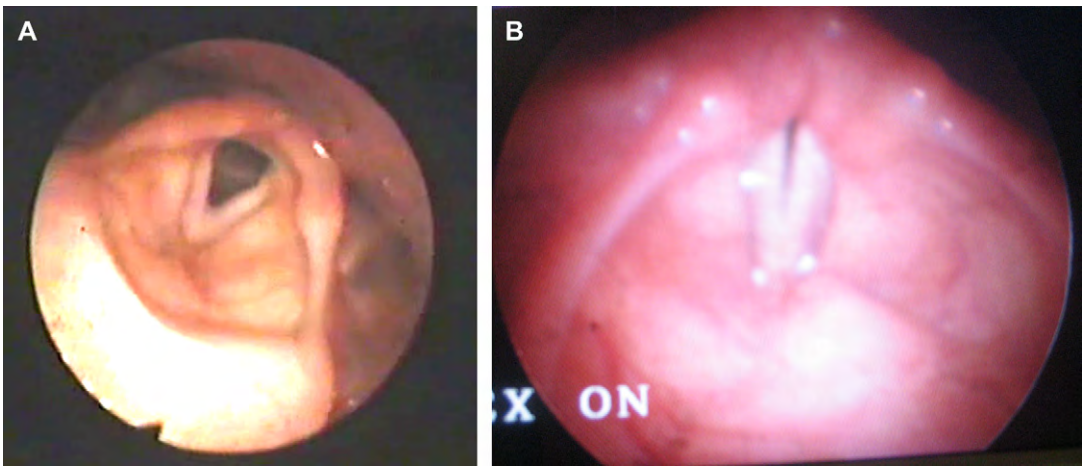

Fig. 24. (*A*) The larynx. Note the cricoid cartilage, visible within the trachea. (*B*) The trachea with the cords closed during vocalization.

Finally, in some cases it is possible and desirable to perform a retrograde nasopharyngoscopy. In this situation the scope is placed in the mouth and curved upward and anteriorly behind the soft palate to visualize the posterior aspect of the nasal cavity and soft palate (Fig. 29).

Documentation

It is important that the results of any diagnostic nasopharyngoscopy be noted in the chart, specifying the results of all five basic examination levels plus the results of the Müller's maneuver. If a video camera is used on the scope, a digital record also may be kept on a suitable storage media (eg, a CD-ROM) and kept in the patient's chart, which allows for follow-up examination and increased reliability.

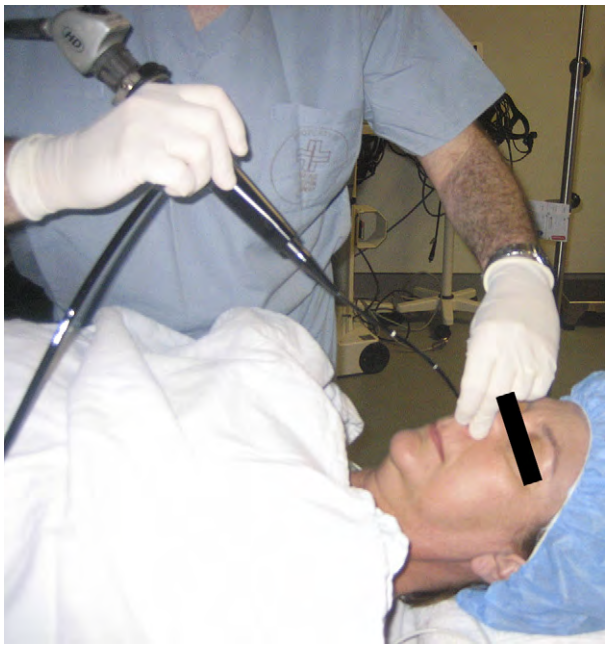

Fig. 25. Positioning of the patient for the Müller's maneuver. The patient is placed in the supine position, the mouth is closed, and the nose is pinched closed by the surgeon.

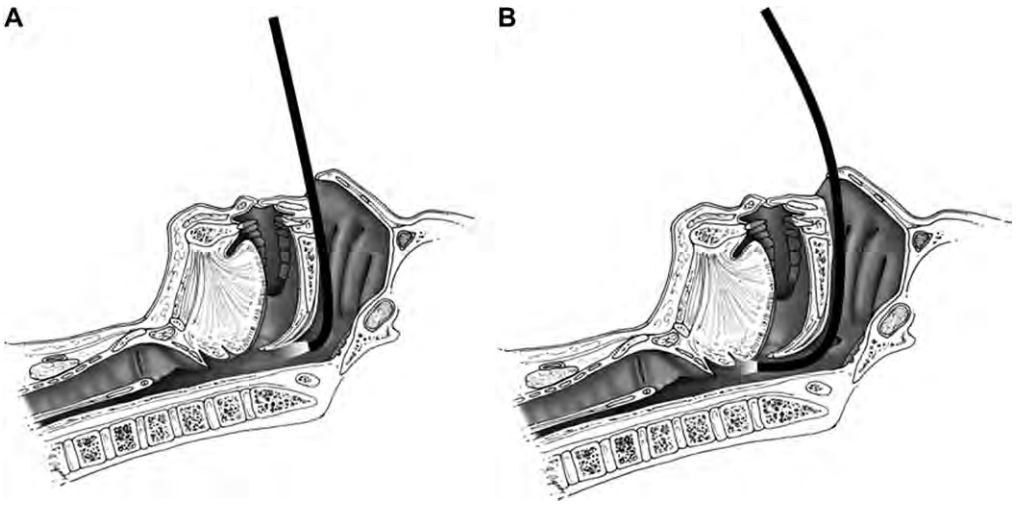

Fig. 26. Positioning of the scope for the Müller's maneuver. (*A*) Placing the scope at the level of the oropharynx. (*B*) Placing the scope at the level of the hypopharynx.

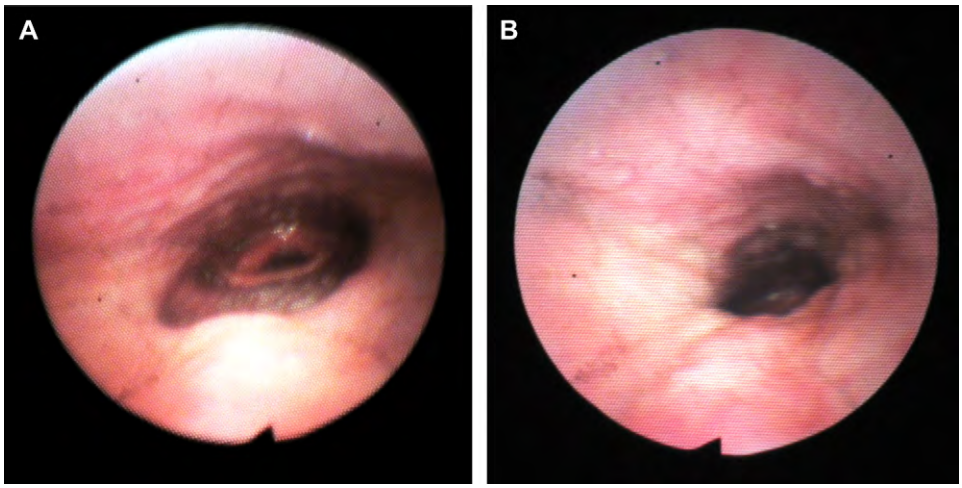

Fig. 27. (*A*) View of the oropharynx before the Müller's maneuver. (*B*) During the maneuver. Note the degree of closure.

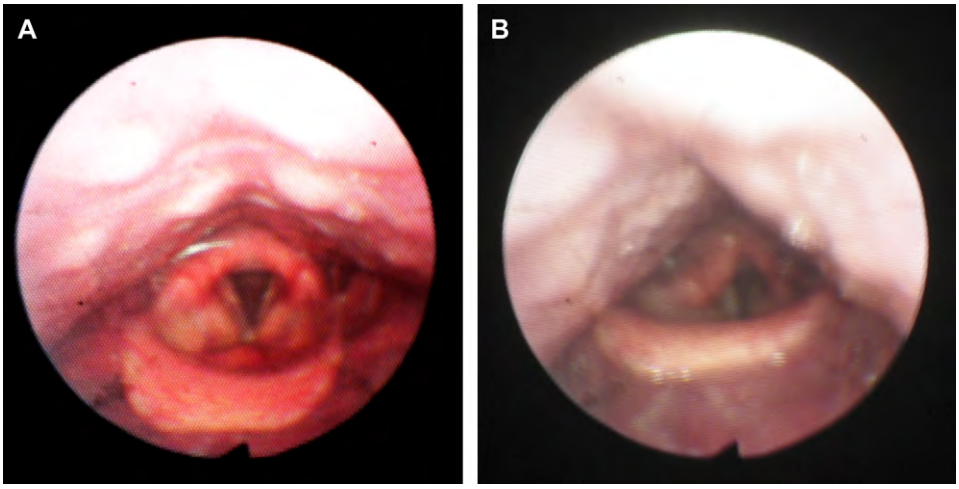

Fig. 28. (*A*) View of the hypopharynx before the Müller's maneuver. (*B*) During the maneuver. Note the degree of closure.

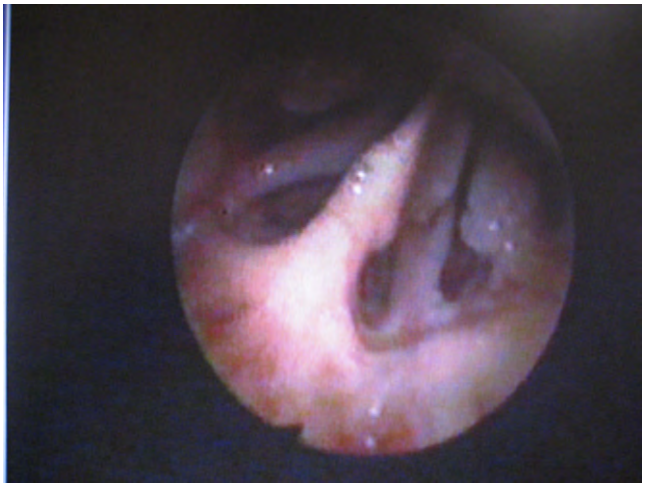

Fig. 29. Retrograde view of the nasal cavity taken by bending the scope upward from the oral cavity approach.

Complications

Flexible endoscopy of the nasopharynx is generally a benign examination. The most common complications are pain and bleeding. Pain should not be an issue during the examination, and its presence indicates a failure on the part of the surgeon to provide adequate topical anesthesia. Any indication by the patient that the procedure is causing pain should be responded to by the use of additional local anesthetic measures. Bleeding may result from traumatic passage of the scope, inadequate vasoconstriction, anatomic abnormality, or systemic anticoagulation that may not have been recognized by the operator (eg, undocumented intake of over-the-counter aspirin). Pressure on the nose for a few minutes usually stops any bleeding, but packing or chemical or electrical cauterization may be considered if this fails. Gagging is not as common as might be expected and usually can be prevented with good spray topical anesthesia of the pharyngeal wall and base of tongue.

One potentially significant complication of nasopharyngoscopy is inadvertent passage of the scope to the level of the vocal cords themselves, which results in acute laryngospasm. Careful passage of the scope under constant direct vision should prevent this from ever occurring. In the unlikely event it does occur, it should break spontaneously as the patient attempts forceful ventilation.

Summary

Diagnostic nasopharyngoscopy is an important tool in the diagnosis and treatment planning for management of patients with OSA. When done properly and carefully, it is a low morbidity, office-based procedure that can provide invaluable information on the possible anatomic causes of the disease.

Further readings

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 129–137

Atlas of the Oral and Maxillofacial Surgery Clinics

Laser Assisted Uvulopalatopharyngoplasty (LA-UPPP) for the Treatment of Snoring and Mild to Moderate Obstructive Sleep Apnea

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Since the late 1960s, snoring and sleep apnea have been identified as a disease entity and numerous procedures have been developed to address these issues. Unfortunately, however, because of the multifocal nature of obstructive sleep apnea, the cure has been an ongoing challenge. Continuous positive airway pressure treatment has proved to be among the most effective modes of treatment. Compliance has been a major factor in many cases, however. One of the earliest methods of surgical treatment was tracheostomy to bypass the upper airway altogether. For obvious reasons this invasive procedure could not be considered for most cases of obstructive sleep apnea. Uvulopalatopharyngoplasty (UPPP) has been the most common method of surgery performed to treat snoring and sleep apnea. This procedure is generally performed under general anesthesia in the hospital setting and has been reported to have various degrees of complications, including velopharyngeal insufficiencies, voice changes, difficulties in swallowing, and even death from complications of anesthesia. In the late 1980s, laser-assisted uvulopalatoplasty surgery was introduced to trim the uvula in a step size fashion and multiple stages using a CO_2 laser.

This article describes a modification of UPPP using laser (LA-UPPP) as an office-based procedure. Although LA-UPPP is a commonly performed procedure, the reader must understand that no single procedure can be hailed as a cure for obstructive sleep apnea. With our best estimate, the reduction of snoring intensity after these procedures is between 50% and 70%, whereas the rate of treatment benefit for obstructive sleep apnea is generally less than 50%.

Patient evaluation

A comprehensive health and snoring questionnaire, is first provided to the patient. The patient's oral and nasal cavity and pharyngeal areas area are evaluated next (Fig. 1). It must be stressed that snoring is caused by multiple factors, and one procedure does not correct all problems. Patients can make or create multiple sounds from various areas of the oral, nasal, and pharyngeal areas on the upper airways. For this reason, any procedure that addresses only one site (eg, soft palate and uvula) does not eliminate all snoring sounds. In some cases, the presence of bifid uvula or obstructive tonsils could pose as additional factors to determine which procedure is the most appropriate method to treat a particular patient (Figs. 2 and 3). Once it is determined that a patient could benefit from such procedures, a detailed discussion of

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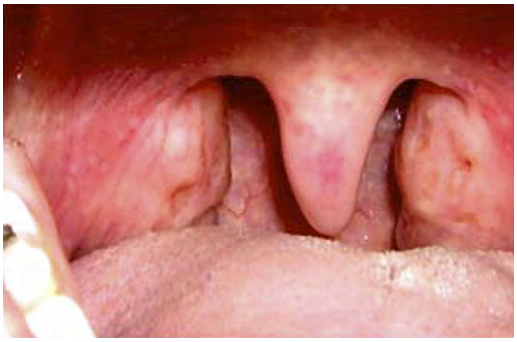

Fig. 1. Examination of the airway shows bilaterally enlarged tonsils and elongated uvula. Note constricted and narrow airway and elevated base of tongue, which may contribute to the upper airway obstruction.

LA-UPPP, its advantages and limitations, and the patient's expectations and potential benefits are discussed.

LA-UPPP is a single-step, short, office-based procedure performed under intravenous sedation, and recovery is rapid. The part of the uvula between the two arches of the posterior pillars and the tonsils, when indicated or enlarged, are removed during this procedure.

Patient education

Once all diagnostic and clinical assessments are completed and before any surgical interventions are attempted, patient education and counseling must be stressed, as are the

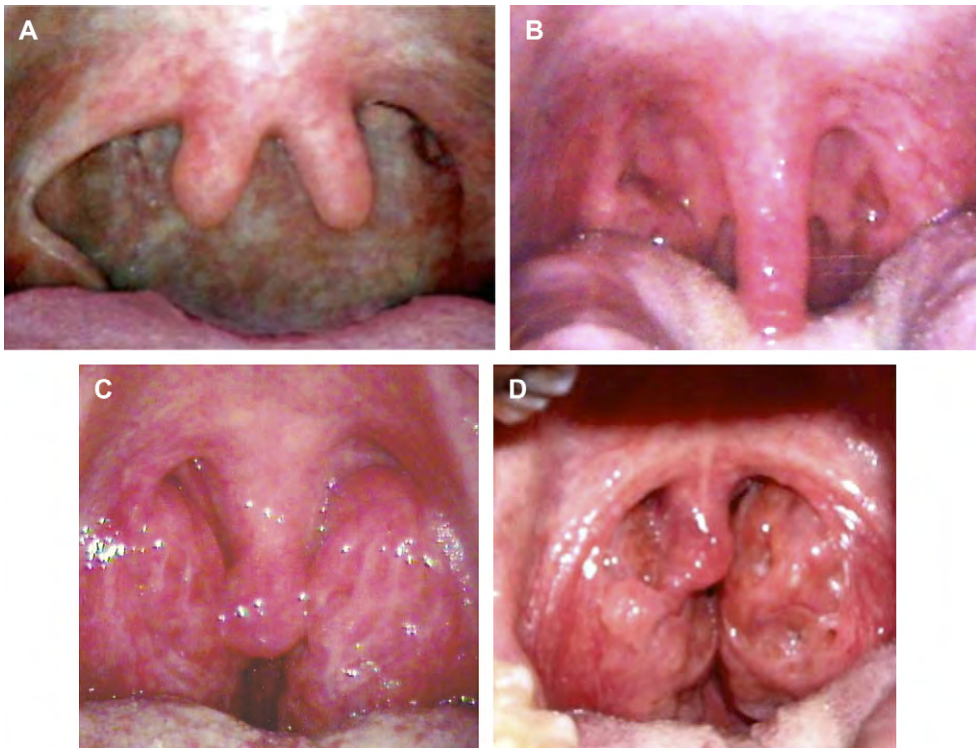

Fig. 2. (*A*) Oral examination may reveal a bifid uvula and elongated soft palate. Note a fairly large airway with minimal lateral pharyngeal hypertrophy. (*B, C*) Picture on the left shows another variation of an elongated uvula that rests on the dorsal surface of the tongue and in this case interfered with normal swallowing and speaking. Picture on the right (*C*) shows presence of enlarged uvula and obstructive tonsils. (*D*) Obstructive tonsils in a patient with severe obstructive sleep apnea. Removal of these tonsils will facilitate breathing.

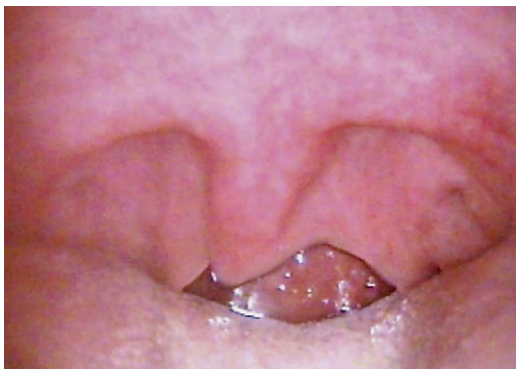

Fig. 3. Webbing of the soft palate and consequent fluttering are major factors in this patient's snoring.

extent of benefits and the patient's expectations. The risks and complications of surgery must be reviewed in detail. Weight loss instructions, the need for follow-up care, and continuation of continuous positive airway pressure or other modalities already used by the patient should be stressed. When appropriate, patients should be advised to avoid sleeping on the back, alcohol before bedtime, and smoking. They also should be vigilant of other underlying conditions and consider appropriate treatments.

Surgical technique for CO_2 laser-assisted uvulopalatopharyngoplasty

Although in the past these procedures generally were performed under local anesthesia, we currently recommend intravenous sedation for all LA-UPPP procedures. The use of 20% benzocaine (Hurricaine) is not recommended because the anesthetic effect of this spray may cause patients to aspirate blood or saliva, which results in unnecessary complications. The general medications and dosage we use for intravenous sedations are as follows. After initiation of an intravenous line with a #20 gauge angiocatheter in the antecubital fossa using D5W and lactated Ringer's solution, robinol, 0.2 mg, and decadron, 4 mg, are given in the intravenous line. After approximately 2 minutes, 50 μg of fentanyl is administered, followed by 3 mg of versed intravenously. The next drug that is administered is propofol, 20 to 40 mg, for an average-sized adult. The patient is monitored at the same time with electrocardiography, pulse oximetry, and blood pressure.

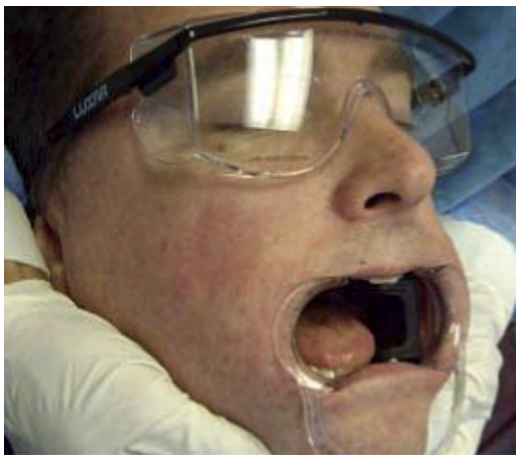

Fig. 4. LA-UPPP is performed with patient under intravenous sedation. As the anesthesiologist or surgical assistant supports the patient's head, a double check retractor and mouth prop are placed in the patient's mouth to allow the most optimal visualization of the surgical site. Protective laser shield is used during CO_2 laser surgery.

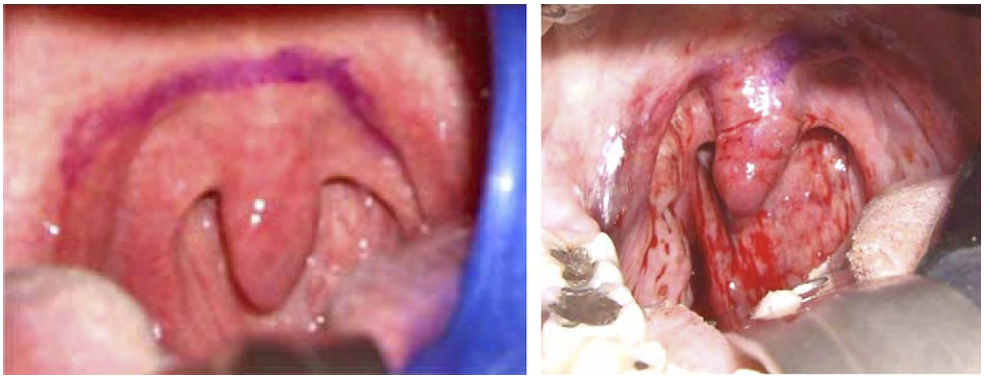

Fig. 5. The enlarged and edematous uvula was identified as one of the causes of snoring. Note the position of posterior palatal pillar and constricted airway. On the left side tonsils are visible but are not enlarged or obstructive and may be left alone in this case. The superior edge of the incision was marked with blue marker, and local anesthesia was infiltrated in a semicircular fashion to the soft palate.

The most common local anesthetic agents are lidocaine, 2% with 1:100,000 epinephrine, and marcaine, 0.5% with 1:200,000 epinephrine. The anesthesia is injected in a semicircular fashion in the soft palate away from the site of incision. The total amount of injection is approximately 1.8 to 2 mL. An excess amount of anesthetic solution in the area may interfere with the function of CO_2 laser surgery and is not needed. With the patient sitting in the chair in a reclining position, a mouth prop and double cheek retractor are placed in the mouth to give the best visualization and protect the corners of the lips (Fig. 4). The area of incision is marked with a marking point, Dr. Thompson's color transfer applicator, which is available from most dental supply companies and is used most often in prosthodontics, or a surgical marking pen (Fig. 5). After administration of anesthesia, a specialized pharyngeal handpiece with backstop is used to initiate the ablation of the soft palate. The power setting of 15 W is normally sufficient with CO_2 laser and a straight laser tip (Fig. 6). Additional fiberoptic light to the handpiece makes visualization of the site clearer (Fig. 7).

Using a curved Kelly, the uvula is grabbed and pulled to one side. In a careful manner the CO_2 laser is used to remove the marked area bilaterally (Figs. 8–11). Attention is directed to the posterior wall of pharynx to avoid touching the area with the laser back stop, because the extreme heat generated causes tissue damage and may lead to nasopharyngeal adhesions (Fig. 12). In most cases the laser could control any bleeding encountered during the procedure. We

Fig. 6. Laser wattage setting could range from 10 to 15. The higher the wattage setting of the laser, the faster the soft tissue ablation; however, it causes more charring of tissue and more intense pain afterward.

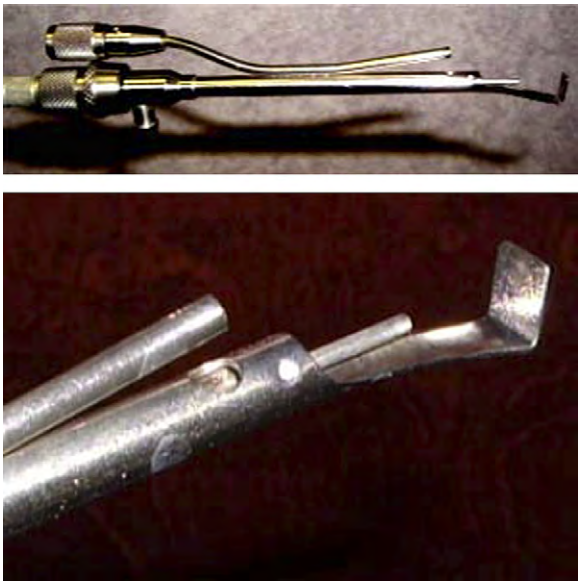

Fig. 7. Laser handpiece has been modified with fiberoptic lighting on top and back stopper to avoid forward soft tissue damage. Note that the end plate gets hot during the procedure. Careful attention must be directed to this part to avoid contacting tissues in the posterior wall of the pharynx, which may cause unsatisfactory healing, adhesion, and additional pain.

strongly recommend placing sutures if a patient's airways are too narrow to expand the airway or there is any bleeding encountered, however. Chemical cauterization using silver nitrate should be avoided because it may lead to delayed bleeding (Fig. 13). If the tonsils are excessively large, they also can be removed with the laser. It has been our experience that within several weeks, partial ablation of the tonsils leads to significant reduction in the size of the tonsils and they may not have to be removed. Tissue healing takes place 3 weeks after surgery, and duration of the most intense pain is approximately 12 to 14 days (Fig. 14).

Complications of CO_2 laser surgery

Of more than 7000 patients who underwent surgery in our center, only a 3% complication rate was noted. Severe sore throat is common in more than 70% of patients, and it lasts between

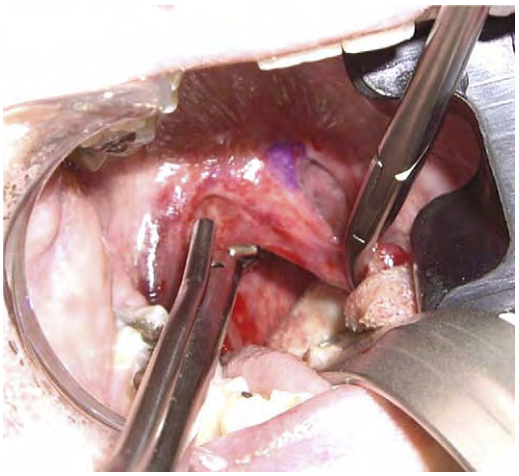

Fig. 8. As the tip of the uvula is grasped with a long curved Kelly and pulled gently to one side, the laser handpiece is positioned in place. Note that the additional fiberoptic light on top of the handpiece brightens up the field of surgery and makes it easier to visualize the path of laser ablation.

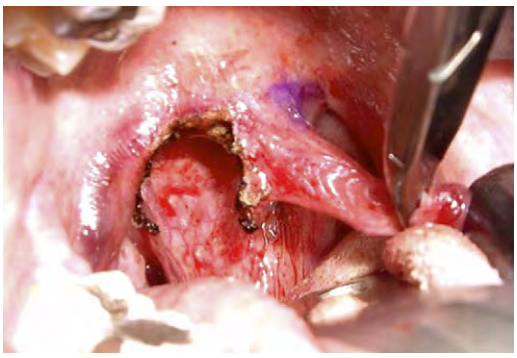

Fig. 9. One side of the soft palate laser ablation is completed in a single swipe with CO_2 laser. Note that by pulling the tissues forward, the operator avoids touching the back surface of the throat. This maneuver prevents unwanted traumatic injuries to the lateral pharyngeal wall and future palatal adhesion or poor healing of the tissue.

12 and 14 days. The soreness responds to oral narcotic analgesics and a special combination of one third Maalox, one third benadryl, and one third lidocaine (Magic Mouth wash). Although patients have difficulty swallowing, they are encouraged to chew gum. The chance of bleeding particularly increases as the amount of dissection is increased in the lateral part of the soft palate and areas of the tonsillar pillars if a tonsillectomy is done at the same time as the UPPP. As a general rule, the author believes that any bleeding encountered during surgery necessitates placement of sutures to avoid delayed bleeding. We encountered approximately a 9.5% bleeding rate and recommend managing bleeding with sutures rather than electrocautery or chemical cauterization. In anticipation of tissue edema in the treated areas, we recommend placing patients on oral steroid treatment with decadron, 4 mg, for 4 days or a Medrol dose pack.

Another common complaint patients may have is dryness at the back of throat, which is caused by several factors but primarily is caused by an expanded upper airway and fewer minor salivary glands. This sensation gradually returns. A feeling of tightness or lumpiness and foreign body sensations also occurs in approximately 5% of cases. This feeling can be prevented by continued chewing gum, swallowing, and raising the tongue to touch the roof of the mouth in such a way that the palatoglossus muscle is stretched and not allowed to scar down. Temporary swallowing difficulty has been noted in 11% of patients. None of our treated cases developed fluid reflux (velopharyngeal insufficiency) or experienced voice changes and loss of taste, however. All patients were covered with antibiotics for a 5-day period after LA-UPPP. A small number of patients ($<5\%$) reported continued snoring after surgery.

Complications of traditional UPPP (performed in the operating room) have been reported to include a wide range: 20% to 60% postoperative nasal regurgitation, although mostly on

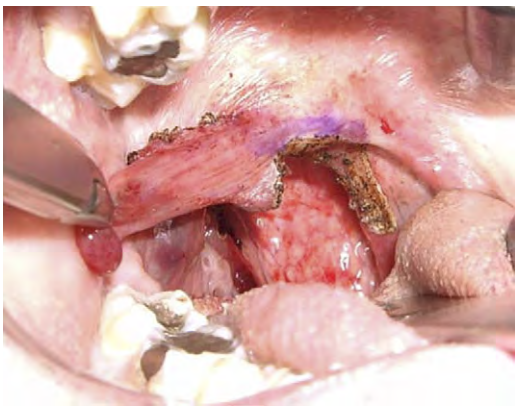

Fig. 10. Similar procedure is done on the opposite side to ablate the posterior pillar of the soft palate. Note that the incision must not be performed above the previously marked lines to avoid excessive tissue reduction and further velopharyngeal insufficiencies.

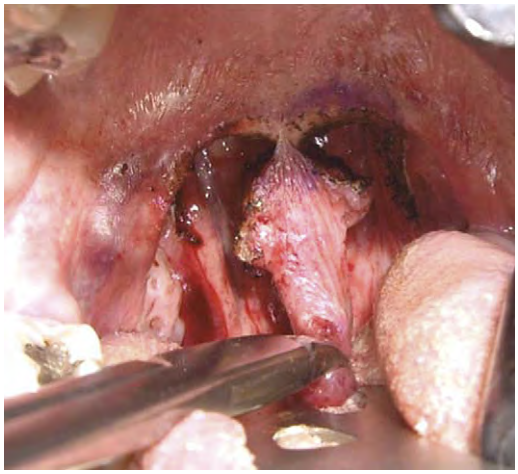

Fig. 11. At this point the midline ablation using the CO_2 laser is completed. This procedure has been demonstrated with CO_2 laser, but by using other devices, including Elman or Coblation and standard electrocautery, the procedure could be performed successfully.

a temporary basis; 2% to 9% hemorrhage; 0.5% to 10% velopharyngeal insufficiency and nasopharyngeal stenosis. Seven deaths were reported after traditional UPPP in the earliest cases, which occurred during the 1970s and 1980s.

Clinical outcome

We have performed more than 7000 cases of laser-assisted modified UPPP during the past 14 years. The snoring sound was reduced by an average of 70% in intensity and reportedly is not as disturbing to bed partners as before surgery. Patients reported that they continued to have heavy breathing after surgery, primarily from their nasal passage or the areas in the base of the tongue and epiglottis regions. On the other hand, sleep apnea, which is caused by numerous other factors, was reduced to an average of 50%. Most patients reported a significant reduction in daytime sleepiness and fatigue after surgery. Improved upper airway passage also has allowed easier breathing. Less than 5% of patients reported that this procedure did not improve any of the conditions significantly. We have been able to do a follow-up report on 5600 patients 2 to 12 years after surgery, and the results have been stable, with the exception of patients who gained weight. After gaining only a few pounds, patients noticed the return of snoring and obstructive sleep apnea.

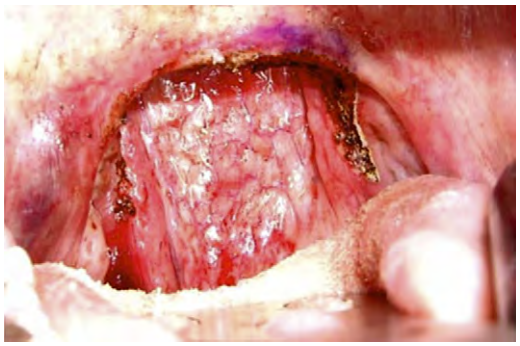

Fig. 12. The immediate postoperative results demonstrate a clean edged bilateral and symmetrical ablation without any major bleeding or damage to the posterior wall.

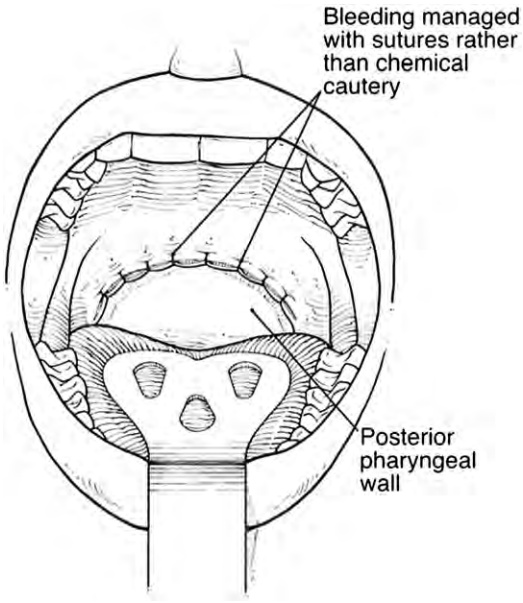

Fig. 13. Use of sutures ensures bleeding control and expanding and securing the soft palate at a higher and more lateral level. (*Modified from* Madani M. Surgical treatment of snoring and mild obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:347; with permission.)

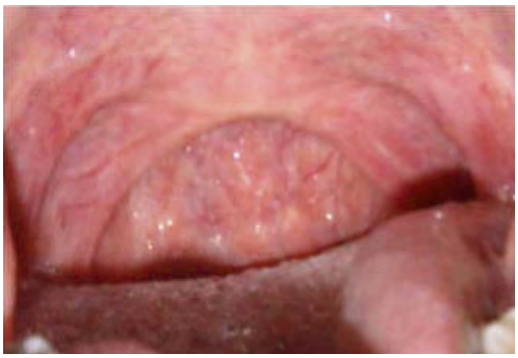

Fig. 14. One month postoperatively the airway is open and snoring is significantly reduced. Note the presence of asymptomatic tonsils bilaterally.

Summary

UPPP traditionally has been performed in an operating room setting, and it requires a minimum of a 1-night hospital stay, general anesthesia, complicated suturing techniques, potential complications of bleeding, velopharyngeal insufficiency, nasal reflux, and several weeks of pain. With the advent of laser surgery and the modifications of LA-UPPP to expand the upper airway and remove the area of obstruction in the soft palate area, the risks and complications have been reduced drastically. The initial treatment of choice for moderate to severe obstructive sleep apnea is weight loss (if indicated) and continuous positive airway pressure therapy. Patient compliance for continued use of continuous positive airway pressure could only be strengthened by the surgical team. The role of the operating surgeon in discussing the important issue of obstructive sleep apnea as a disease entity is crucial. Promising to cure sleep apnea should be avoided because airway obstruction is multifactorial and one procedure does not correct the problem. If needed, nasal and tonsillar problems should be addressed at the same time.

Further readings

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 139–153

Atlas of the Oral and Maxillofacial Surgery Clinics

Radiofrequency Treatment of the Soft Palate, Nasal Turbinates and Tonsils for the Treatment of Snoring and Mild to Moderate Obstructive Sleep Apnea

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Radiofrequency (RF) treatment using heat to ablate an enlarged organ or mass has been described in the literature for more than a century. Only within the past decade has its use been evaluated for treatment of snoring, chronic nasal congestion, obstructive tonsils, and even sleep apnea. Unfortunately, however, the long-term results have not always been stable, and significant amount of relapse has been observed. In the author's opinion, success relies on appropriate patient selection and careful follow-up. This article discusses indications, patient selection, operative techniques, and complications of radioablation procedures.

Innovative procedure

In search of a minimally invasive procedure to treat snoring, sleep apnea, chronic nasal congestion, and obstructive tonsils, after many years of observation and careful research scientists noted that by applying heat the volume of an enlarged tissue could be reduced without adverse effects or inflicting pain on patients. Initially electrocautery and, later, laser were used at high temperatures. Those procedures caused tissue charring and significant scar contraction. With the help of pathologists and physicists, researchers noted that with a much lower temperature but slightly longer duration and repeated procedure a satisfactory result could be achieved.

In the late 1990s, several companies introduced RF treatment for treatment of snoring and sleep apnea. The concept was to introduce a tiny probe in the tissues to be treated to create a submucosal coagulative lesion with no cutting, tissue charring, or external scar, which reduced pain. The lesions created by these procedures are naturally resorbed in approximately 8 to 10 weeks, which reduces excess tissue volume. Procedures are generally performed in an outpatient setting, and no general anesthesia is required for most procedures. The effectiveness of each procedure depends on patient selection, site of the lesions, number of repeated procedures, and surgeon experience.

Currently, the most commonly used RF devices are Somnoplasty, Coblation, and Ellman. We briefly describe each system and review the relevant procedures.

Somnoplasty

Somnoplasty, a monopolar-type RF system, was created by Somnus Medical Technologies, Inc. (Sunnyvale, CA), one of the first companies to focus on treatment of snoring and sleep apnea. It requires a ground pad to complete the electrical circuit and is designed to deliver submucosal coagulative lesions by heating tissue to a temperature of 120° to 200°F around the

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1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.05.003

active portion of the electrode. Within the affected tissues it causes vacuolar degeneration and creates an internal scar, which causes stiffening of the tissues. The system consists of a programmable generator with temperature and impedance monitoring and a disposable surgical handpiece (Fig. 1). Having used other similar systems in our center, we do not believe that this degree of sophistication is crucial to the success of the procedure. Proper patient selection and training, however, are essential for achieving more satisfactory results.

Coblation

Coblation (Arthrocare Corp., Sunnyvale, CA) is a bipolar device that does not require a grounding pad (Fig. 2). The return electrode is located within the handpiece and requires saline gel as a conductive medium. It is designed to cut, coagulate, and ablate the treated tissues on command; it also can be used to remove certain soft tissues. Because of its simplicity, short duration of procedures, and effectiveness of its radioablation property, the author uses this system most often to achieve the desired effects.

Ellman, Surgitron

These systems are most practical and useful in many aspects of surgical practice. They are readily available in most offices, easy to use, and less expensive than other RF systems. They also can be used to cut, coagulate, and ablate tissues. This Ellman Dual Frequency Surgitron 4.0 MHz unit (Ellman International, Inc., Oceanside, NY) is a high frequency/low temperature technology which has an easily adjustable power range to ''dial-in'' the level of RF energy suitable for any given procedure (Fig. 3). Just like any other surgical device of this type users should be aware that the probe temperature could increase rapidly and has the potential for mucosal tissue surface damage. As with all other radioablation devices, care must be taken to insert the needle directly into the treated area, because superficial placement leads to mucosal sloughing (Fig. 4). The instructions for use of this and any other devices must be followed properly and visual evaluation must be maintained at all times (as is recommended by all of the manufacturers) to avoid harming the tissues. We have not found that the Ellman system poses any greater danger than other technologies as long as the practitioners follow the manufacturer's recommendations.

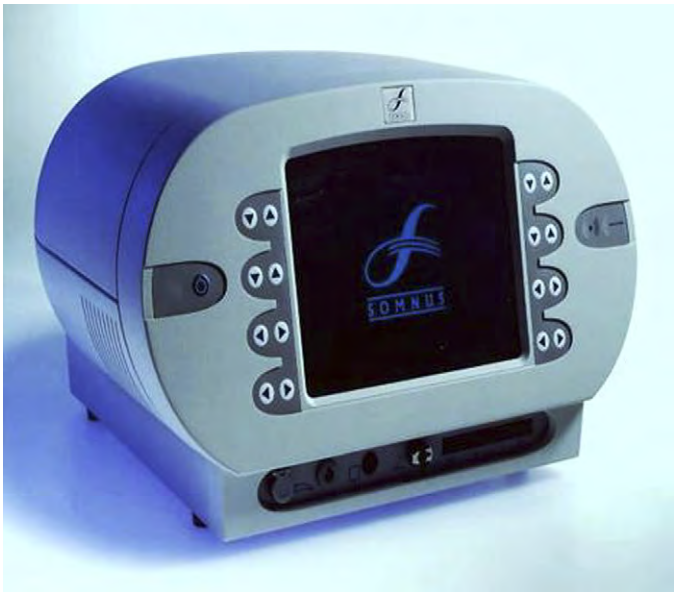


Fig. 1. The Somnus radioablation unit consists of a programmable generator with temperature and impedance monitoring and a disposable surgical handpiece. This was the first US Food and Drug Administration–approved unit specifically for treatment of sleep apnea. (*Courtesy of* Gyrus ENT, LLC, Bartlett, TN; with permission.)

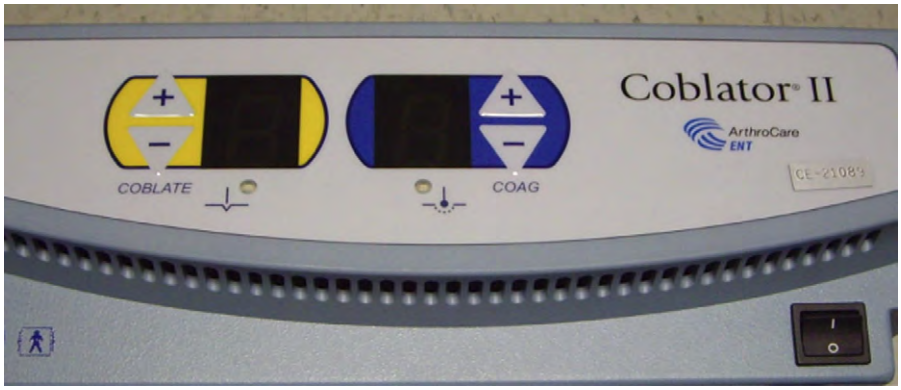


Fig. 2. The Coblator is a bipolar device and does not require a grounding pad. This device can generate energy of up to 6 W and works faster than the Somnus unit.

Indications

To achieve successful results, the operator must choose the patient and procedures that help the patient most effectively. Radioablation procedures could be indicated in patients with mild to minimal obstructive apnea, habitual snorers, and patients with chronic nasal congestion. Patients who have a small uvula with a thick soft palate, as demonstrated on a cephalometric radiograph, or who were previously treated with traditional surgeries, such as uvulopalatopharyngoplasty, could be excellent candidates for these procedures. It must be emphasized, however, that repeat procedures are not guaranteed to achieve a more complete elimination of snoring, and patients must be evaluated for obstructive sleep apnea first. In cases in which chronic nasal congestion is caused by a hyperplastic nasal turbinate or obstructive tonsils, these procedures have had the most promising results with less relapse.

Contraindications

Patients with an excessively long and bulky uvula or severely hypertrophic soft palate do not benefit from palatal radioablation for an extended time period. In these types of cases, relapse was noted within 2 years of treatment in 60% of our patient population. Palatal or nasal radioablation could be ineffective in patients with an anatomic abnormality in a different location. Palatal radioablation is not commonly recommended by this author in patients who

Fig. 3. The Ellman Dual Frequency Surgitron 4.0 MHZ unit has an easily adjustable power range to "dial-in" the level of RF energy suitable for any given procedure. Just like any other surgical device of this type users should be aware that the probe temperature could rapidly increase and has the potential for mucosal tissue surface damage. (*Courtesy of* Ellman International, Oceanside, NY; with permission.)

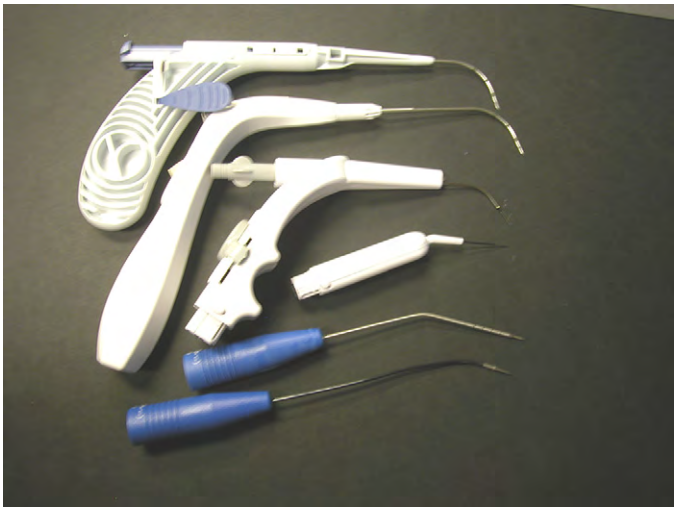


Fig. 4. Various probes have been introduced to treat snoring, sleep apnea, nasal congestion, and obstructive tonsils. The top of the figure shows the six different probes; the bottom two are Coblation probes, the two in the middle are Somnus probes, and the two on top are the new Pillar palatal implant probes.

suffer from moderately severe to severe obstructive sleep apnea with a respiratory disturbance index of more than 25 or obese patients with a body mass index of more than 27 (Table 1).

General preoperative preparation

As with any other surgical procedures, a patient's medical history and extensive history of the chief complaint are documented. An oral, nasal, pharyngeal, and head and neck examination is completed. With a comprehensive physical examination, all sites of obstructions can be identified and addressed. A cephalometric radiograph may best suggest the thickness of the soft palate. A flexible transnasal laryngoscope also can be used to perform the Muller maneuver to make additional assurance of palatal component of obstructive apnea. A snoring questionnaire is given to the patient to answer.

Patients who use any types of anticoagulant, including aspirin, are asked to stop taking them 5 days before surgery with consent from their primary care physician or cardiologist. Patients at risk of subacute bacterial endocarditis are advised to take the appropriate prophylaxis as recommended by the American Heart Association before surgery. Bleeding, infection, prolonged pain, and impaired healing are rare but potential complications of these procedures. Generally, pain medications and antibiotic treatment are not required after procedures, with the exception of tonsillar radioablation. Nasal regurgitation after this procedure has not been observed as a complication, but as with any palatal surgery, potential complications require discussion with patients. Radioablation procedures may be performed in multiple stages, and patients should be advised of that possibility.

Table 1
Risk of associated disease according to body mass index and waist size

Body mass index risk ratio chart		Waist $\leq$40 in (men) or 35 in (women)	Waist $>$40 in (men) or 35 in (women)
$\leq$18.5	Underweight	—	N/A
18.5–24.9	Normal	—	N/A
25.0–29.9	Overweight	Increased	High
30.0–34.9	Obese	High	Very high
35.0–39.9	Obese	Very high	Very high
$\geq$40	Morbid obesity	Extremely high	Extremely high

Body mass index uses a mathematical formula that takes into account a person's height and weight. Body mass index equals a person's weight in kilograms divided by height in meters squared (BMI = kg/m^2).

Palatal radioablation

Before the procedure, patients should be advised of the risks, benefits, and possible need for repeat procedures. An informed consent should be obtained. Patients should be advised that after the palate is anesthetized, the throat feels numb and peculiar and gives a false impression that the act of swallowing is impossible. This procedure is easily performed as an outpatient procedure with the patient in a sitting position. The Coblation system does not require any conductive pad, but the other monopolar RF systems require a conductive pad placed on the lower back area. Topical anesthesia (benzocaine 20%) is applied to the palate and the patient is asked to swish it around the mouth for 30 seconds. The topical anesthesia should reduce gagging and any pain at the injection sites. Using a 27-gauge dental needle, 3 to 4 mL of local anesthesia (0.5% marcaine with epinephrine 1:200,000 or 2% xylocaine with epinephrine 1:100,000) is injected at the junction of the hard and soft palate, continuing down and on the sides of the soft palate and the base of the uvula. Unlike the CO_2 laser, the RF procedures require an adequate amount of local anesthesia to avoid discomfort. It allows tissue expansion and better conduction of current to the area of the internal ablation.

The desired angle of the RF electrode is 35° to 45°, depending on the anatomy of the hard and soft palate. Placement of the electrode is important. The electrode is entered high in the soft palate so that the end point of the electrodes is just above the uvula but not in the uvula itself (Fig. 5A, B). To ensure proper placement of the electrode, it can be placed over the soft palate to clinically visualize the exact location and position of the electrode entry point before insertion. Care also must be taken to fully deploy the active component of the electrode into the patient's soft palate.

The Coblation reflex wand 55 is used for palatal radioablation. It comes pre-bent and only requires saline gel as its conductive medium. The unit is generally set at number 6 and the probe is kept in place for 10 to 12 seconds. It must not be kept in place for more than 15 seconds because the surface temperature rises and can cause mucosal erosion and ulceration. The probe temperature reaches approximately 120°F within 10 seconds. The distal end of the probe is the active end, and the proximal end is coated to avoid unwanted mucosal burns. After the single midline lesion is created, two additional sites just lateral to the first lesion are selected, aiming the probe at a 30° angle from the center and toward the side corners of the soft palate.

The Somnoplasty electrode tip has two sections, each of which is 1 cm long. The tip of the electrode is not insulated and is the point where the heat is generated. It is maintained at a constant temperature of 120°F (85°C). The proximal end of the electrode near the handpiece is coated to avoid thermal burning of the palatal mucosa. As the tip temperature approaches body temperature, impedance should be less than 500 Ω. The generator automatically shuts down if the impedance exceeds 500 Ω, an indication that the electrode is improperly placed or is outside the tissue. Once the electrode is in the proper position, the foot pedal is depressed and the amount of energy (up to 750 J on each lesion) is monitored. After the appropriate amount of energy is delivered, the foot pedal is depressed again to stop the procedure; the electrode is fully retracted and removed from the patient's oral cavity. The lateral electrode placement is generally 10 mm away from the midline on both sides and at the same temperature, but less energy is applied (Fig. 6A–E). In our experience, 350 J is sufficient energy for the lateral lesions. We have experienced even better results by placing two additional far lateral lesions with 300 J, which makes a total of five submucosal lesions 10 to 15 mm apart from other lesions. Similar procedures have been done using the Ellman unit.

Postoperative care and preventive measures of complications

Patients must be monitored carefully during the first 24 hours after the radioablation procedure. No postoperative antibiotics or narcotic pain medication is needed. Normally, patients experience a feeling of fullness in the back of the throat. They must be advised to sleep on a reclining chair or with the head elevated at a 45° angle for the first night after surgery.

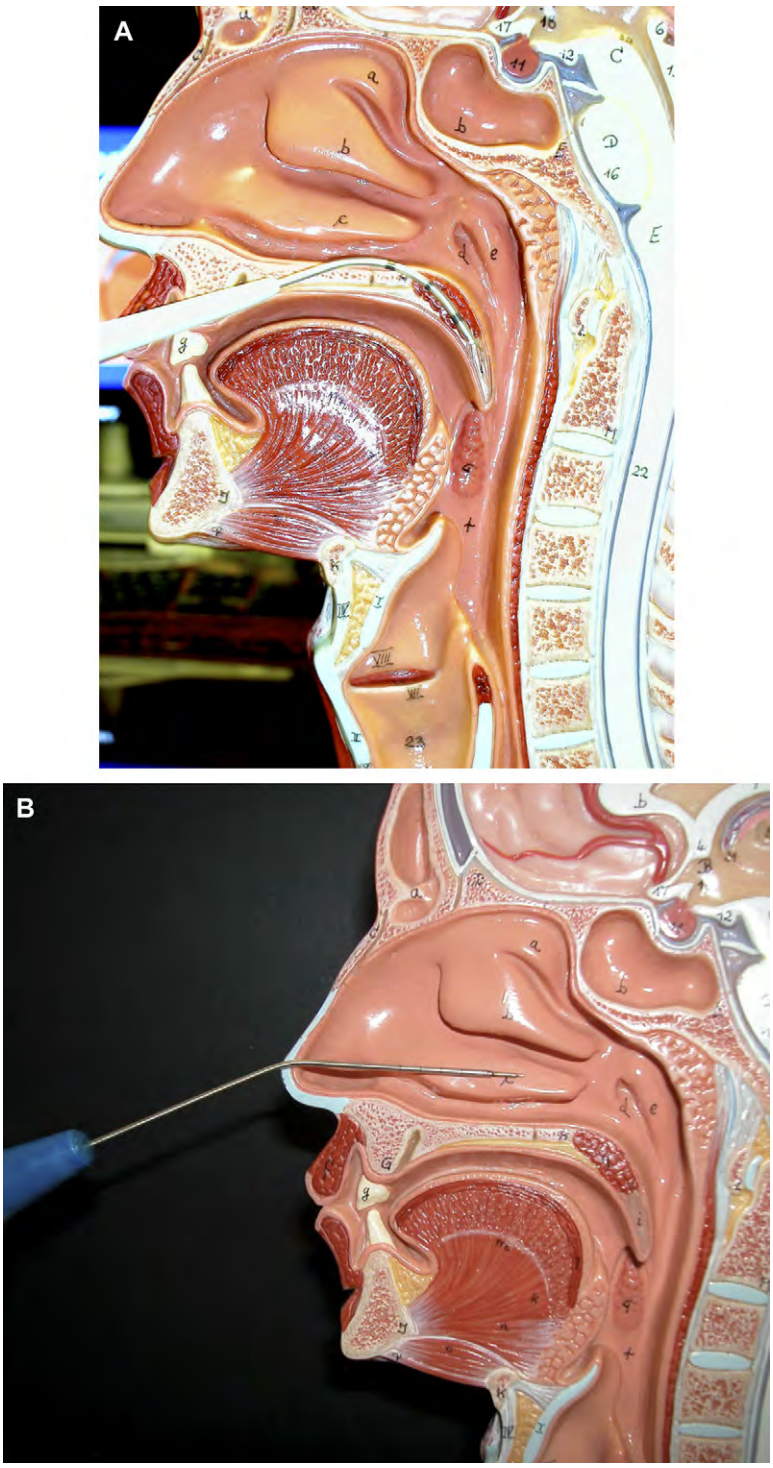


Fig. 5. (*A*) The anatomy of the soft palate dictates patient and procedure selection and probe angulation. The radioablation and palatal implant probes must stay within the boundary of the soft palate. (*B*) The same concept is true in performing nasal radioablation. Excessive heat generation in and around the nasal septum may lead to bone necrosis, scab formation, nasal adhesions, and consequent nasal bleeding.

The soft palate and uvula become edematous to a variable degree during the first 48 to 60 hours after the procedure. Usually, a minimal sore throat is noted after the procedure, and an over-the-counter pain medication is sufficient for pain management. Mucosal burn and subsequent ulceration and intense pain are generally attributed to positioning of the electrode

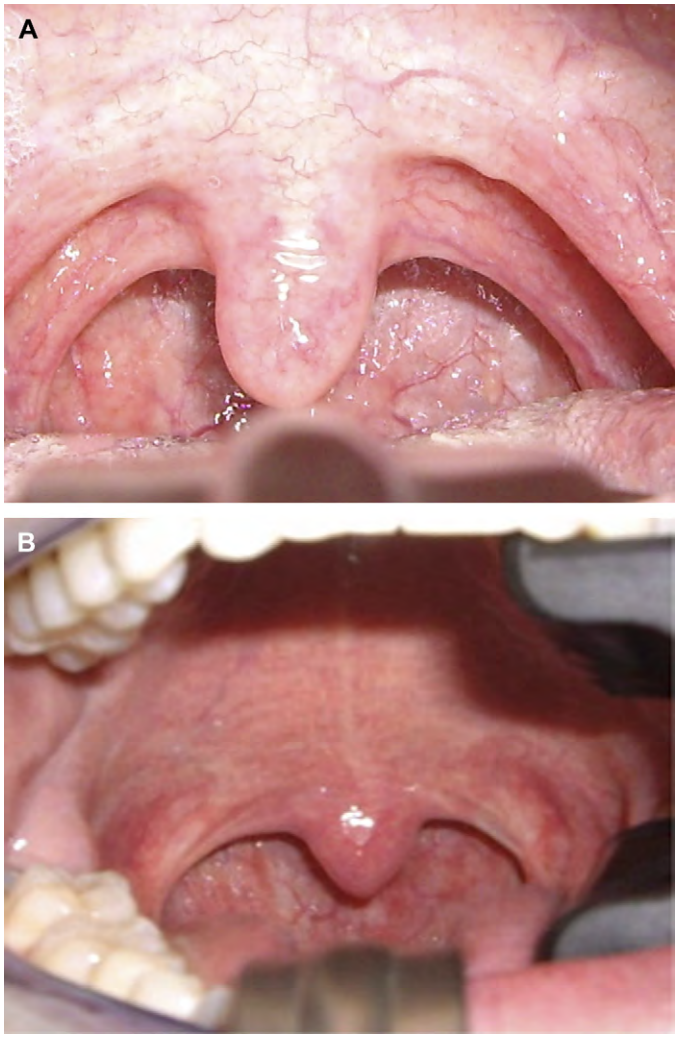
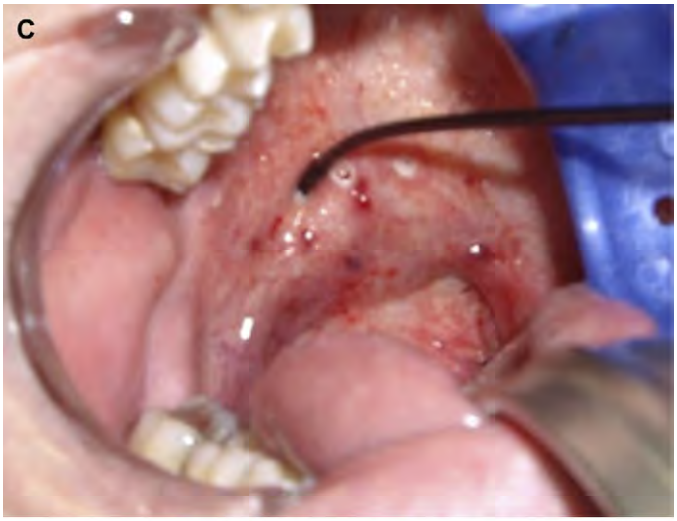


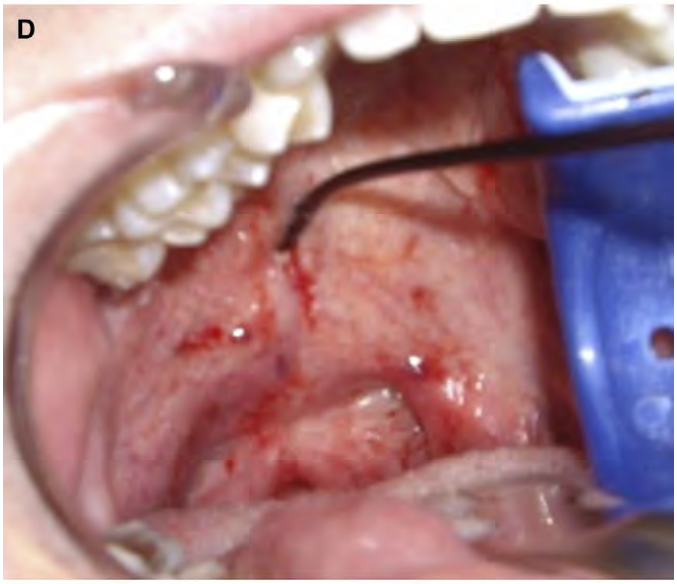
Fig. 6. (*A, B*) Palatal radioablation and palatal implants work best if patients are properly chosen. Low body mass index, small uvula, and thick and floppy soft palate are among the many considerations. (*C–E*) One midline and two lateral ablations are performed for soft palate RF treatments.

too close to the surface of the treated tissues. Overheating also may cause tissue sloughing and evulsions of the uvula. Postoperatively, patients are placed on a cold, soft diet for 24 hours; they can resume a normal diet the second day after surgery. The palatal stiffening and volumetric reduction process takes 3 to 4 months, and patients notice a change in the intensity of snoring but not complete elimination of snoring after the first procedure. A second procedure is usually needed in patients who snore severely 6 months after the initial treatment. Patients must be advised that effects of radioablation treatments are not permanent and recurrence of symptoms is possible.

Nasal radioablation

Chronic nasal obstruction, or a stuffy nose, is caused by either enlargement of the inferior nasal turbinates or a deviated nasal septum (Fig. 7A, B). The nasal turbinates—small, shelf-like structures composed of thin bone and covered by mucous membranes (mucosa)—protrude into the nasal airway and help to warm, humidify, and cleanse air as it is inhaled and before it reaches the lungs. Chronic enlargement (hypertrophy) of the turbinates and the accompanying symptom of nasal obstruction affect people throughout the day and during





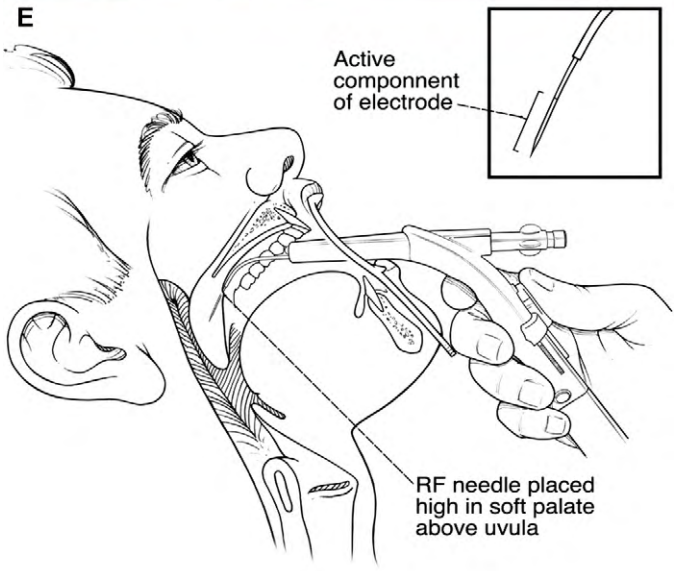


Fig. 6 (*continued*)

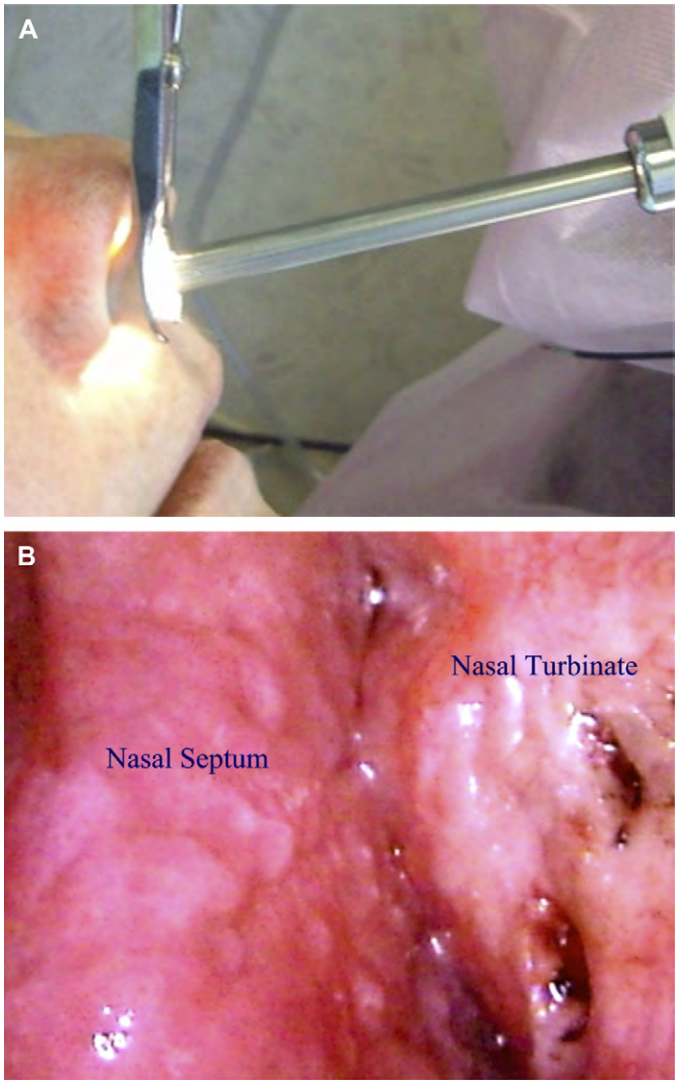


Fig. 7. (*A, B*) The nasal cavity is examined using a 0° fibro-optic camera. Obstructive nasal passage caused by a combination of deviated septum and enlarged nasal turbinates can make nasal breathing impossible.

sleep. A chronic stuffy nose can impair normal breathing, force patients to breathe through the mouth, and affect their daily activities. Enlarged turbinates and nasal congestion also can contribute to headaches and sleep disorders, such as snoring and obstructive sleep apnea, because the nasal airway is the normal breathing route during sleep. Chronic turbinate hypertrophy is often unresponsive to medical treatment such as nasal sprays, so surgical treatment is required. It is commonly associated with rhinitis, which is inflammation of the mucous membranes of the nose. When the mucosa becomes inflamed, the blood vessels inside the membrane swell and expand, causing the turbinates to become enlarged and obstruct the flow of air through the nose.

Current surgical treatments include nasal septum reconstruction and turbinectomies. These procedures can be associated with lengthy recovery periods, crusting, edema, scab formation, bleeding, and significant patient discomfort, however. The nose also must be packed for several days with gauze that contains antibiotic ointment. Another method for improving nasal obstruction is outward fracture of the turbinate bone(s), which moves the turbinate away from its obstructive position in the airway. This approach, however, does not address the usual source of obstruction; enlarged submucosal tissue and the fractured turbinate often return to their

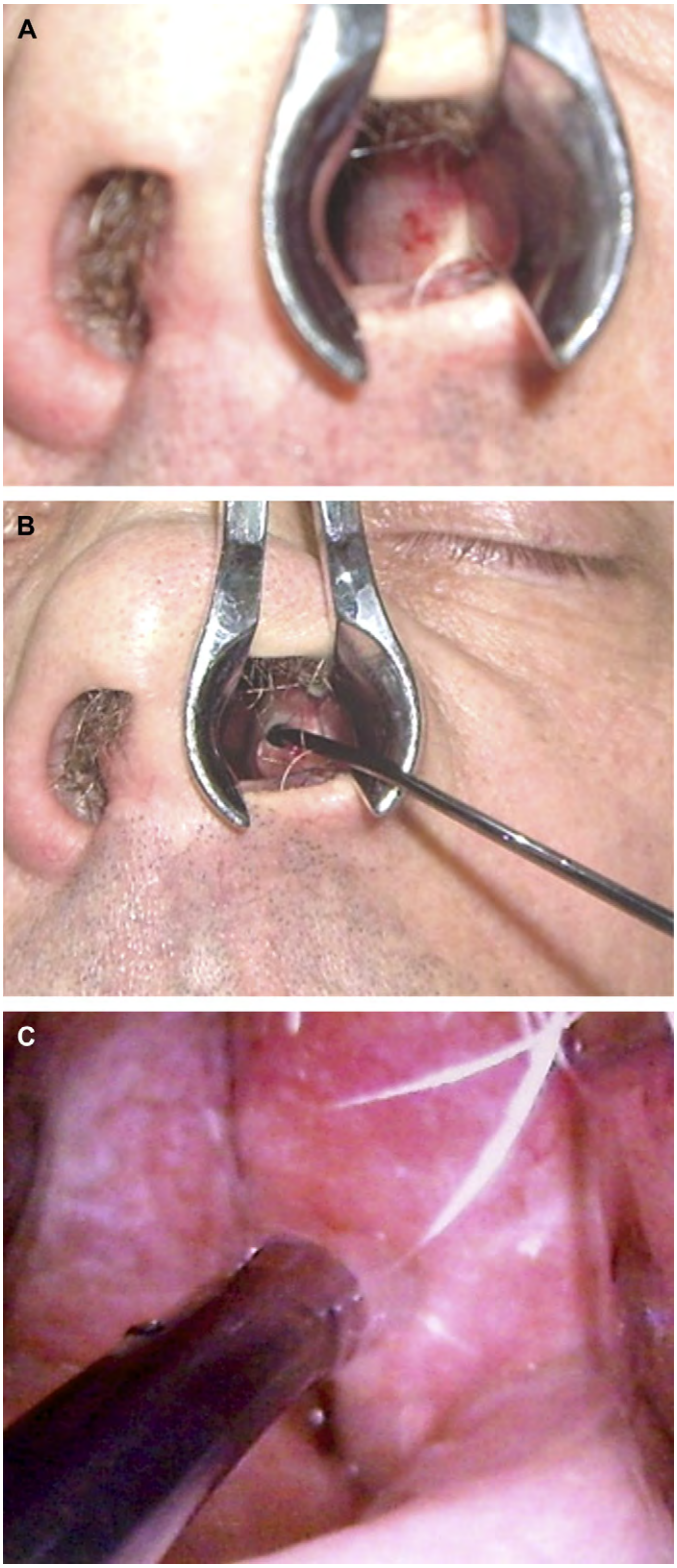


Fig. 8. (*A–C*) Enlarged nasal turbinate and positioning of the probe. A Coblation reflex wand 45 (or similar devices, such as Somnus nasal probe or Elman nasal tip) is used to deliver heat energy to the site.

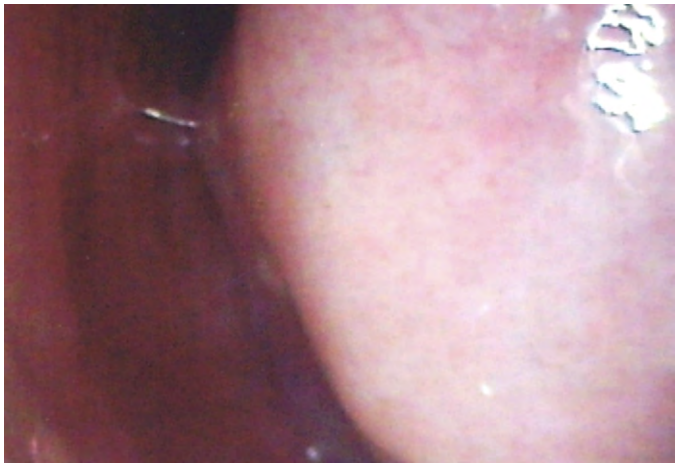


Fig. 9. At the conclusion of this procedure the nasal turbinates also are outfractured using a nasal speculum and a flat surfaced instrument.

previous positions. Bleeding, which usually can be managed by packing the nose, is the greatest risk for patients undergoing standard turbinate resection.

Nasal turbinate radioablation is a simple outpatient procedure similar to the other ablation techniques (Fig. 8A–C). First, a cotton roll soaked equally with 4% xylocaine and a nasal decongestant is placed in the nasal cavity for a period of 1 minute. Approximately 2 mL of 2% xylocaine with epinephrine 1:100,000 is injected in the inferior turbinate with a 27-gauge needle. A Coblation reflex wand 45 (or similar device, such as Somnus nasal probe or Ellman nasal tip) is used to deliver heat energy to the site. In the author's opinion the Coblation probe is the safest and easiest to use with a setting of 6, which is placed in the inferior turbinate only and kept for a period of 10 seconds in each spot (Figs. 9 and 10). For excessively large turbinates, two lesions may be required. Repeated ablation may lead to scab formation, bleeding, and dryness. Because of its rapid rise in temperature, if other radiofrequency units are used caution should be taken to avoid overheating of the tissue, which leads to inferior turbinate bone necrosis. At the conclusion of this procedure the nasal turbinates are outfractured using a nasal speculum and a flat surfaced

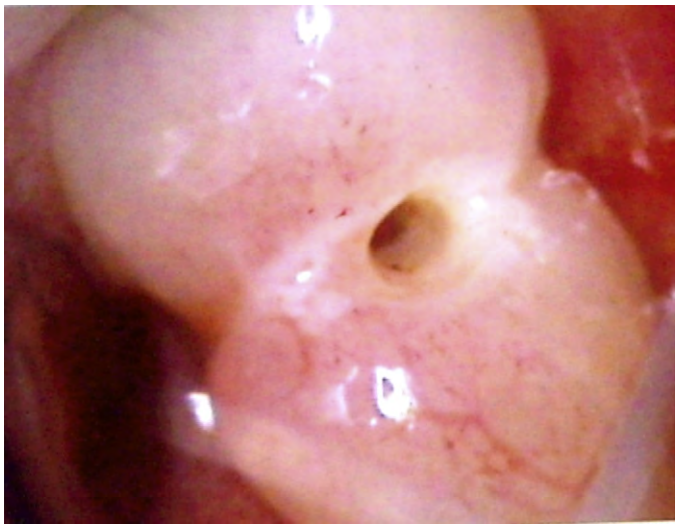


Fig. 10. The Coblation probe is the safest and easiest to use with a setting of 6, which is placed in the inferior turbinate only and kept for a period of 10 seconds in each spot. The figure depicts the site of radioablation of the left nasal turbinate. Note lack of char formation.

instrument. This technique allows mechanical bony expansions and RF-assisted thermal ablation. The nasal cavity is then packed with a small cotton roll soaked with a nasal decongestant (Fig. 11A, B). The packing is removed by the patient the next day. Postoperatively, patients are advised to avoid vigorously blowing their nose for 4 weeks and use a nasal saline spray to avoid dryness and crust formation, which can lead to nasal bleeding.

Tonsillar radioablation

Patients with obstructive tonsils or chronic inflammation, multiple cases of tonsillitis, multiple streptococcal throat infections that require frequent antibiotic treatment, obstruction of the airway, and snoring problems could benefit from a fairly new procedure using RF (Fig. 12A, B). Two procedures are used with RF: one involves debulking the enlarged tonsils and the other removes it totally. The debulking process may require repeat sessions for further reduction of the tonsils.

Certain precautions are recommended with this procedure to avoid complications. Two days before surgery, patients are placed on antibiotic prophylaxis or they receive intravenous antibiotics 1 hour before surgery for a noninfected and noninflamed tonsil. Chlorhexidine (Peridex) mouth rinse is given several days before surgery, and patients are asked to use it twice

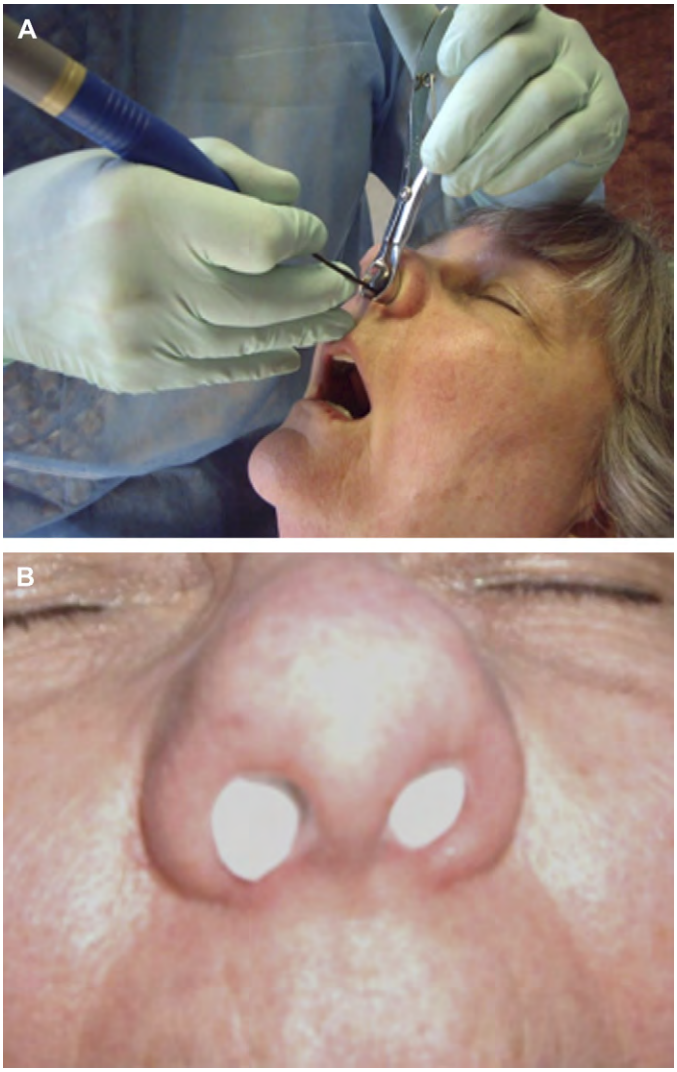


Fig. 11. (*A, B*) After nasal radioablation, a cotton roll soaked with decongestant and lubricated with saline gel is placed in the nasal cavity.

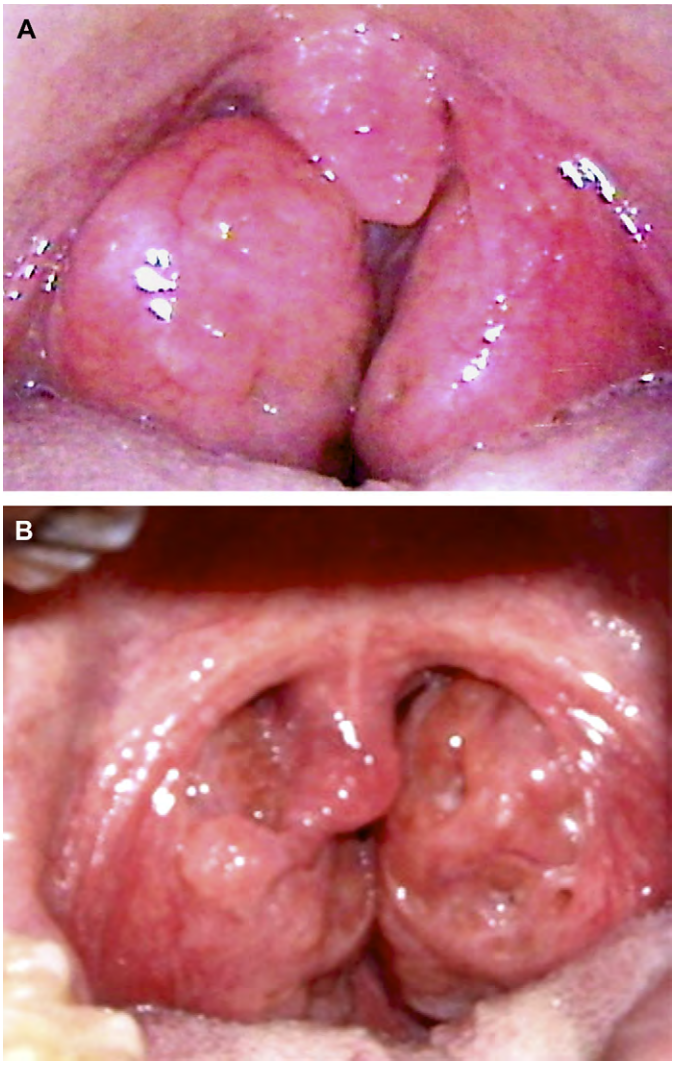


Fig. 12. (*A, B*) Obstructive tonsils or chronic inflammation, multiple cases of tonsillitis, multiple streptococcal throat infections that require frequent antibiotic treatment, obstruction of the airway, and snoring problems are among the problems associated with enlarged tonsils.

daily for at least 2 months postoperatively. Any pre-existing infection, fever, and sore throat is identified and managed.

The tonsillar debulking procedure can be performed easily in an outpatient office setting. The patient is placed in the supine position. Chlorhexidine (Peridex) mouth rinse is given to the patient to keep in the mouth, gargle, and rinse for 1 minute. Three to 4 mL of marcaine 0.5% with 1:200,000 epinephrine is injected into the base of the tonsil starting in the lateral part of the soft palate and extending to the area of the lateral wall of the pharynx (tonsillar bed). A plastic double-cheek retractor is placed on the inside of the cheek to give the best visualization and protect the patient's lips.

The Coblation unit is set to 6 and the Coblation reflex wand 55 is used to deliver the appropriate energy (Fig. 13A, B). A conductive saline gel is applied to the entire uninsulated portion of the probe and placed on the most prominent surface of the tonsil. The foot pedal is used for a short period to activate the unit and insert the probe into the tonsil. Superficial heating of the tonsillar mucosa must be avoided to prevent superficial erosion. This procedure is a submucosal procedure and does not include resection of the tonsils. Once the uninsulated probe is completely inserted in a horizontal direction, the energy is applied for approximately 10 to 15 seconds. This procedure is repeated four to six times on each side (Fig. 14).

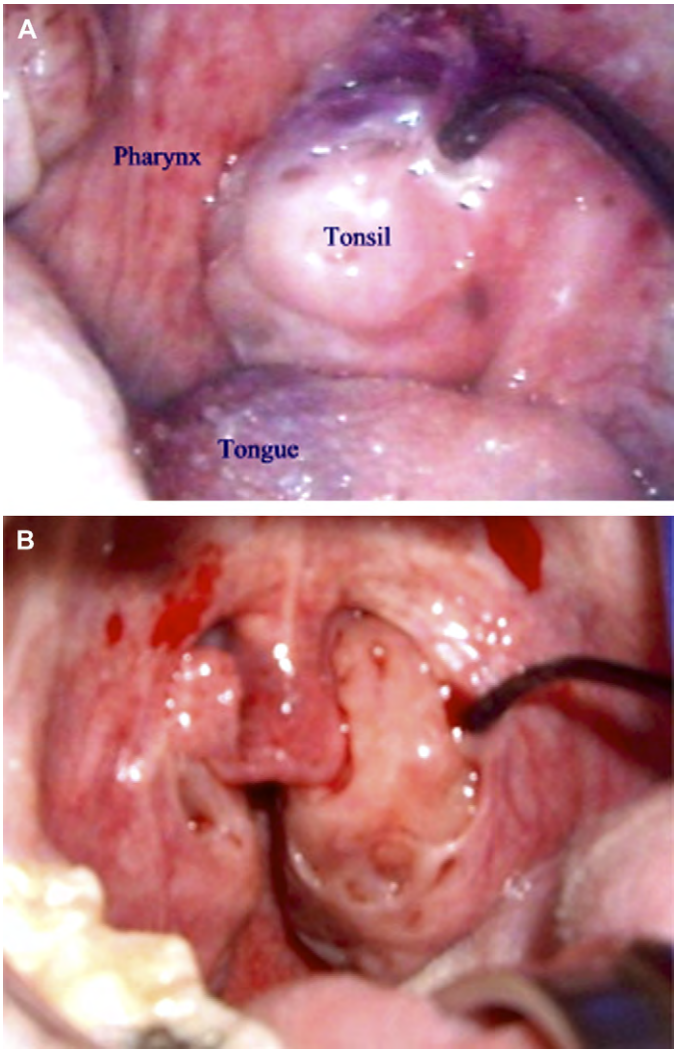


Fig. 13. (*A, B*) The Coblation unit is set to 6 and the Coblation reflex wand 55 is used to deliver the appropriate energy. A conductive saline gel is used and applied to the entire uninsulated portion of the probe, which is placed on the most prominent surface of the tonsil.

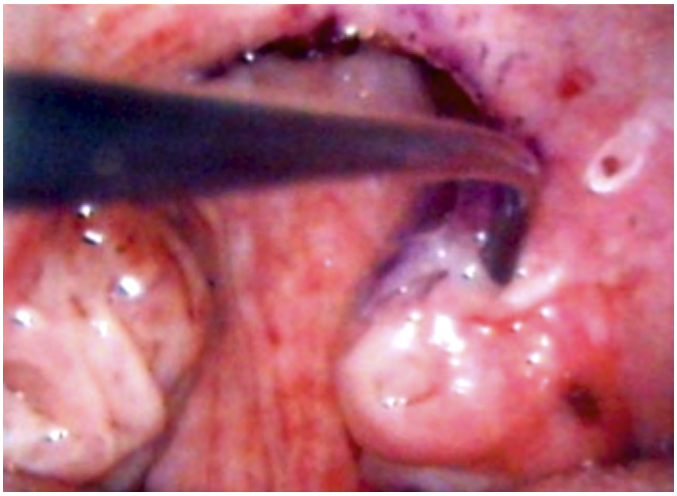


Fig. 14. Once the uninsulated probe is completely inserted in a horizontal direction, the energy is applied for approximately 10 to 15 seconds. This procedure is repeated four to six times on each side.

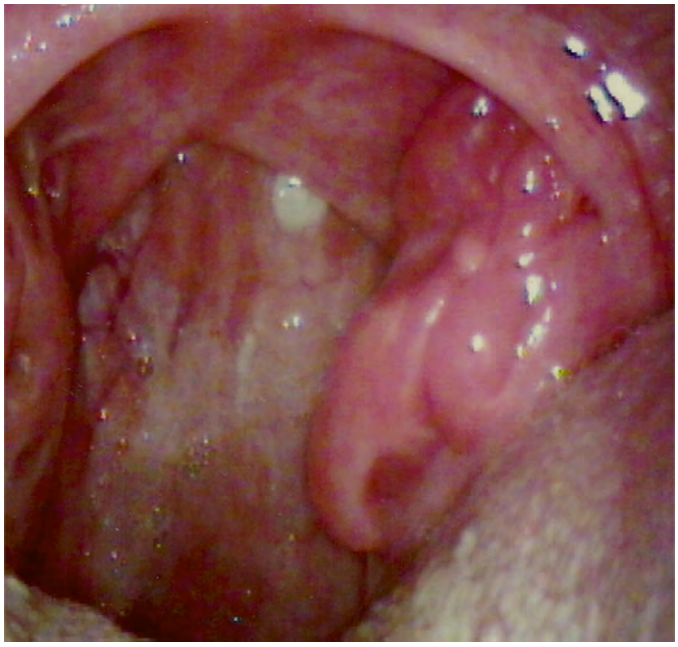


Fig. 15. One month after single-stage radioablation and laser-assisted uvulopalatopharyngoplasty. An additional procedure can be done to repeat the tonsillar radioablation only if the patient is symptomatic.

Patients are monitored carefully and evaluated for need of additional procedures (Fig. 15). Patients are advised that the healing process takes up to 3 months after surgery and additional treatments may be necessary. These procedures do not remove the tonsils in their entirety or cure sleep apnea; they do not necessarily prevent a common cold or future streptococcal infections. Patients are discharged after assurances that there is no bleeding and a detailed explanation of the postoperative instructions is given. With the exception of the first day after the procedure, patients can eat anything they can tolerate.

Generally, a prophylactic antibiotic, such as Cipro (ciprofloxacin hydrochloride), Keflex (cephalexin), or Cleocin (clindamycin hydrochloride), is given to patients before the surgery, and they must continue to take it for a period of 10 days after the procedure. They also are asked to use a chlorhexidine mouth rinse twice daily for a period of 2 months after surgery and then use a regular mouth wash as often as possible. Pain medication is generally limited to an over-the-counter pain reliever. A sensation of tightness in the back of the throat is normal for the first week after the procedure. Patients are advised to return in 1 week unless there is a need to return earlier, and then they return weekly thereafter.

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 155–161

Atlas of the Oral and Maxillofacial Surgery Clinics

Palatal Implants for Treatment of Habitual Snoring: Techniques, Indications, and Limitations

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After the initial success of radiofrequency to treat snoring by applying heat to reduce tissue volume, create submucosal scar, and diminish palatal vibration, another innovative technique was introduced using polyester suture type material to achieve similar results. Pillar palatal implant system (Restore Medical, Inc., St. Paul, MN) received US Food and Drug Administration clearance for snoring in 2002 and for mild to moderate obstructive sleep apnea in 2004. It uses a specially designed delivery tool to place three implants into the soft palate to stiffen and support the soft palate. There is no need for repeated procedures, extensive operating room equipment, or expensive laser systems of radiofrequency generators. Procedures are generally performed in one visit in an outpatient setting under local anesthesia. The effectiveness of each procedure depends on patient selection, the surgeon's experience, and the patient and bed partner's expectations. In our experience, long-term results have not always been stable, and significant amount of relapse has been observed. This article discusses indications, patient selection, operative techniques, indications, limitations, and complications of the palatal implant procedure.

Indications

Palatal implant procedures are indicated in snoring patients with mild to minimal obstructive apnea. Patients who have a small uvula with a thick soft palate, as demonstrated by clinical evaluation, nasopharyngoscopic examination, and cephalometric radiographs or three-dimensional MRI, could benefit from this procedure. It also may be valuable for patients who were previously treated with traditional surgeries, such as uvulopalatopharyngoplasty. Although this procedure reportedly has been approved by the US Food and Drug Administration for treatment of snoring and obstructive sleep apnea, the author believes that it only may improve obstructive sleep apnea if the exact site of obstruction is the soft palate. Further long-term studies are needed to evaluate the continuing benefit of this technique.

Contraindications

Patients with markedly elongated and bulky uvula or severely hypertrophic soft palate do not benefit from palatal implant for an extensive time period. We have observed extensive relapse within a 24-month period after the treatment. An anatomical obstruction in a different location may suggest that palatal implant could be ineffective since they only stiffen and support the soft palate. Palatal implants are not commonly recommended by this author in patients who suffer

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1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.05.002

from moderately severe to severe obstructive sleep apnea with a respiratory disturbance index of more than 25 or in obese patients with a body mass index of more than 30.

General preoperative preparation

Proper patient selection is the key to success when treating patients with palatal implant or radioablation procedures. Small uvula, thick soft palate, and low body mass index are among the few requirements for long-term success (Fig. 1A,B). A cephalometric radiograph, which is available in most oral and maxillofacial surgeons' offices, may best suggest the thickness of the soft palate. If head and neck standard or three-dimensional MRI imaging is available, the palatal thickness and airway evaluation could be best assessed and evaluated (Fig. 2A,B). A flexible transnasal laryngoscope also could be used to perform the Muller maneuver to make additional assurance of palatal component of snoring and obstructive sleep apnea. Patients who use any types of anticoagulant, including aspirin, are asked to stop taking them 5 days before surgery with consent from their primary care physician or cardiologist. Patients at risk of subacute bacterial endocarditis are advised to take the appropriate prophylaxis as recommended by the American Heart Association and American Dental Association before surgery. Bleeding, infection, prolonged pain, impaired healing, implant rejection, and displacement are rare but potential complications of these procedures. Generally, pain medication and antibiotic treatment are not required after these procedures. The handpieces used for radioablation and palatal implants bear a striking resemblance. The lower right hand picture in Fig. 3 shows a Somnus radioablation device and the other two pictures are examples of palatal implant system handpieces.

Surgical techniques

The palatal implant procedure is generally performed in a single stage under local anesthesia. The patient is asked to rinse his or her mouth with chlorhexidine mouthwash for a minute just before the procedure. Topical anesthesia (benzocaine 20%) is applied to the palate and the patient is asked to swish that around the mouth for 30 seconds. The topical anesthesia should reduce gagging and pain at the injection sites. Using a 27- or 30-gauge dental needle, 3 to 4 mL of 2% xylocaine with epinephrine 1;100,000 is injected at the junction of the hard and soft palate, continuing down and on the sides of the soft palate and the base of the uvula. Injecting an adequate amount of local anesthesia has a twofold benefit: the primary benefit is anesthetic property and the secondary benefit is palatal tissue expansion, which allows easier placement of palatal implants. Currently, surgeons recommend placing three implants in the soft palate: one in the midline and one, 2 mm apart, on either side (Fig. 4).

The desired angle of entry into the soft palate is 35° to 45°, depending on the anatomy of the hard and soft palate. Placement of the implant device is important. It is entered high at the junction of the hard and soft palate to ensure that the implant is not placed in the uvula itself

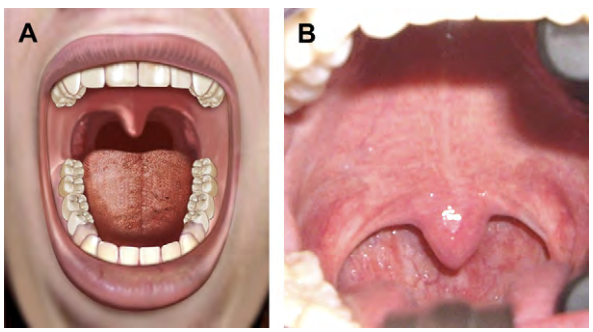

Fig. 1. (*A, B*) Proper patient selection is the key to success when treating patients with palatal implant or radioablation procedures. Small uvula, thick, soft palate, and low body mass index are among the few requirements for long-term success.

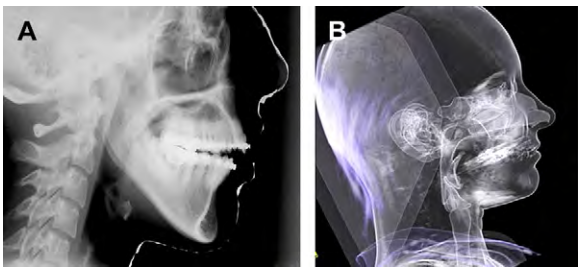

Fig. 2. When available, cephalometric imaging (*A*) or three-dimensional MRI (*B*) clearly demonstrates the airway and thickness of the soft tissues in the soft palate and uvula regions.

(Fig. 5). To ensure proper placement of the implants, the delivery tool can be placed over the soft palate to clinically visualize the exact location and position of the delivery tool entry point before insertion (Fig. 6). Determine insertion point and target zone for midline and lateral implant placements. At this point remove the transport lock (blue tab) by grasping the blue tab and pulling the lock away and out of the handle (Fig. 7). Insert the needle through the mucosa layer into the muscle. Continue needle advancement in an arcing motion up to the full insertion depth marker. This marker must remain visible. Care also must be taken to fully deploy the active component of the electrode into the patient's soft palate and ensure that the needle does not exit any portion of the soft palate and become exposed.

Unlock the slider by applying downward pressure to the arms of the lock just beneath the slider and the back of the handle. Begin deploying the implant by advancing the slider from the start position. Stop advancing the slider when it reaches the halfway deployment position. You may hear an audible "click" and receive tactile feedback, which indicates the halfway deployment position. Viewing the side of the delivery tool also indicates the slider position. Withdraw the needle until the halfway depth marker is visible. When the halfway depth marker on the needle is visible, continue advancing the slider until it comes to a stop at the full

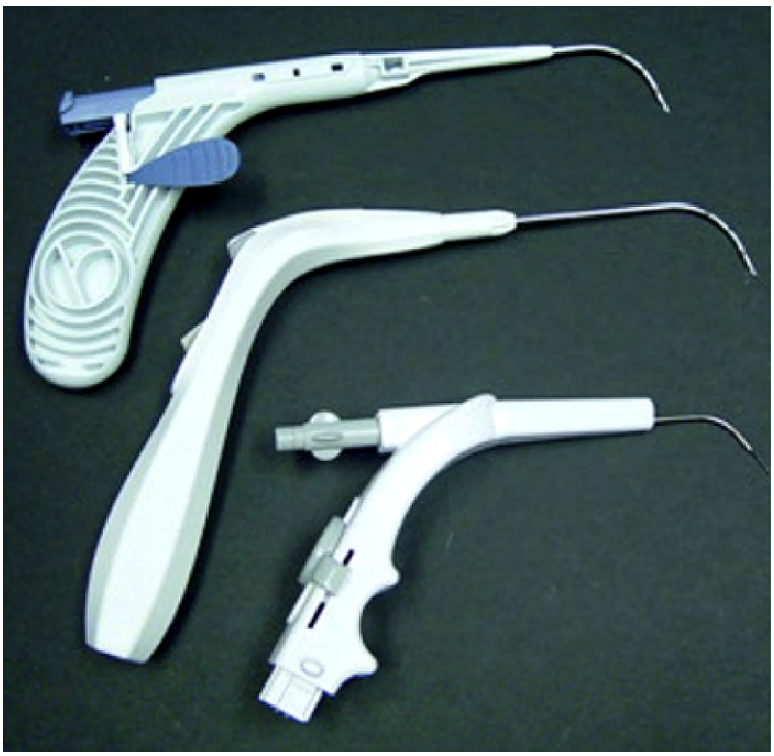

Fig. 3. The handpieces used for radioablation and palatal implants have striking resemblance. The bottom device shows the Somnus radioablation handpiece, and the other two are examples of palatal implant system handpieces.

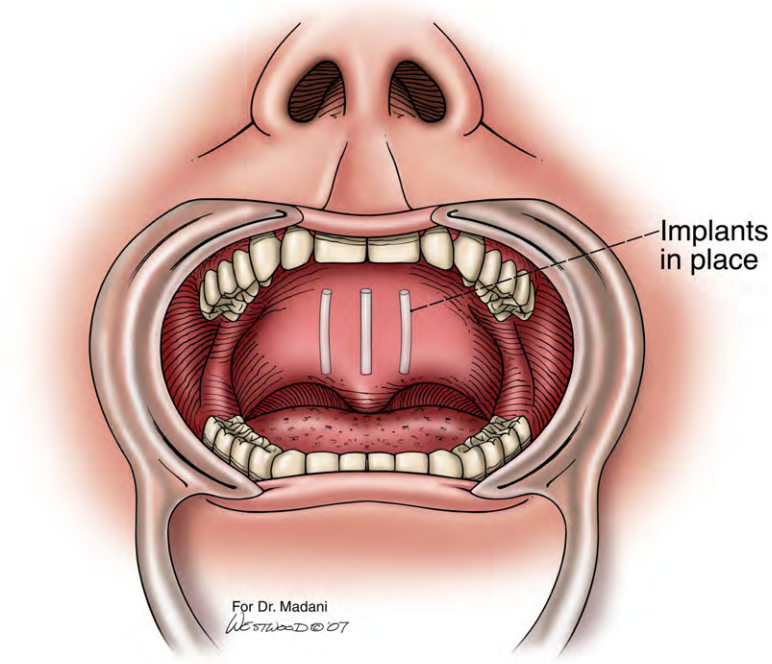

Fig. 4. Currently it is recommended to place three implants in the soft palate: one in the midline and two, placed 2 mm apart, on either side.

deployment position (Fig. 8). When advancing the slider into the full deployment position, the contact of the implant with tissue at the distal end of the needle track may result in a feeling of resistance and naturally cause the needle tip to push up or out. After the implant is fully deployed, withdraw the needle from the palate while following the insertion path (move the

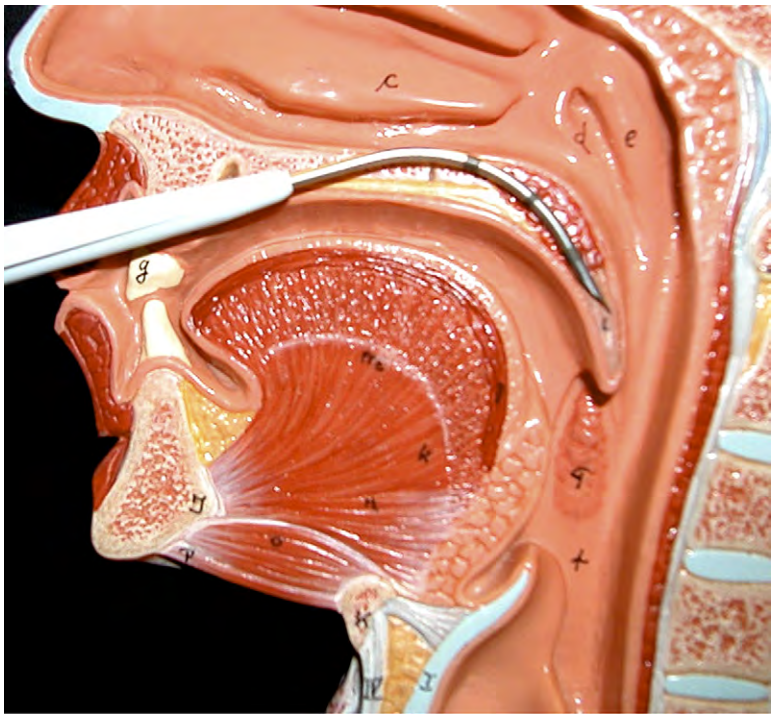

Fig. 5. The desired angle of the entry into the soft palate is 35° to 45°, depending on the anatomy of the hard and soft palate. Placement of the implant probe is important. It is entered high at the junction of the hard and soft palates, making sure that the implant is not placed in the uvula itself.

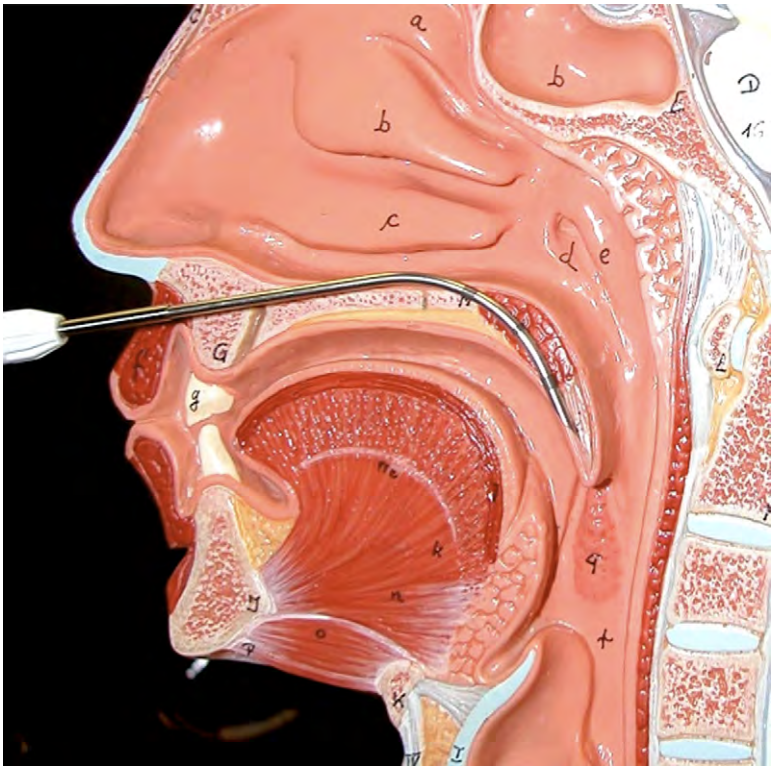

Fig. 6. To ensure the proper placement of the probe, it can be placed over the soft palate to clinically visualize the exact location and position of the electrode entry point before insertion.

handle in an arcing fashion). Repeat the procedure for lateral implants. The target distance between implants is approximately 2 mm. Inspect the needle insertion site. If a portion of the implant is exposed, it must be gently removed with forceps to mitigate the risk of infection or extrusion. Inspect the dorsal (nasal) surface of the soft palate. If the implant is visible, it must be removed.

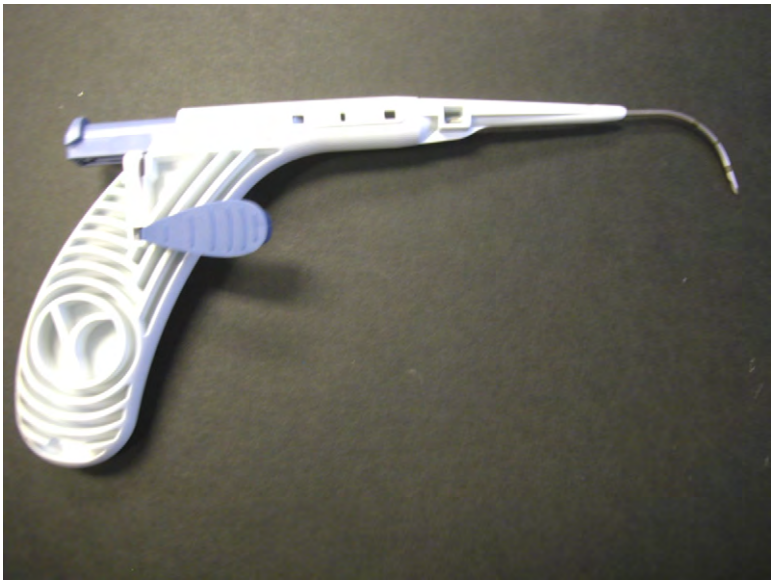

Fig. 7. The transport lock (*blue tab*) must be removed by grasping the blue tab and pulling the lock away and out of the handle to activate the device.

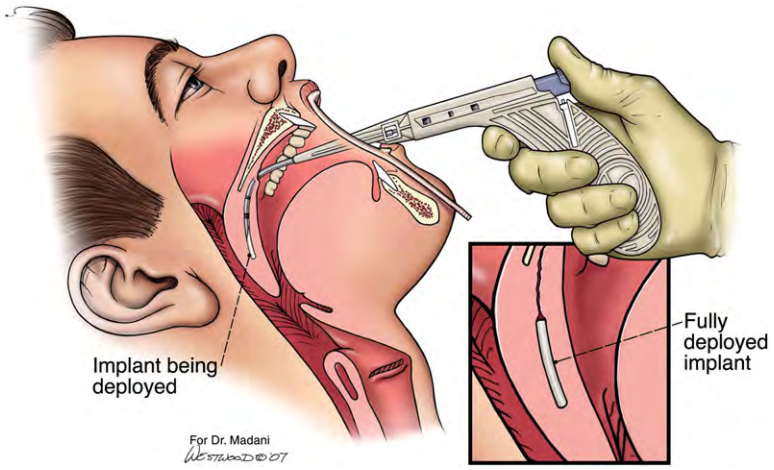

Fig. 8. Insert the needle through the mucosa layer into the muscle. Continue needle advancement in an arcing motion up to the full insertion depth marker.

Postoperative care and preventive measures of complications

Postoperative care after placement of three palatal implants is fairly easy, and patients require minimal pain medications. The device manufacturer recommends pre- and postoperative antibiotic treatment. The author has not found a reasonable justification for postoperative antibiotics or narcotic pain medication, however, except in less than 10% of patients. Patients may experience a temporary feeling of fullness in the back of the throat after this procedure. Careful monitoring of patients is essential because we have seen cases of implant rejection or protrusion through mucosa; in two cases (less than 4% of cases) infection required antibiotic treatment.

Postoperatively, patients are placed on a cold, soft diet for 24 hours; they can resume a normal diet the second day after the procedure. The palatal stiffening process takes up to 90 days for maximum effect. Patients notice a change in the intensity of snoring but not complete elimination of snoring. Finally, patients must be advised that effects of palatal implant treatments may not be permanent and recurrences of symptoms are possible.

Summary

Pillar implant in selected patients who have a short uvula, hyperplastic soft palate, and body mass index of less than 25 with minimal indication of obstructive sleep apnea is an effective, simple method of reducing snoring sound intensity. It is imperative that surgical cases be selected meticulously for this procedure because in the author's experience the long-term results in 45% of cases involved relapse of snoring problem, and the effectiveness of this procedure for correcting obstructive sleep apnea is highly questionable.

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 163–177

Atlas of the Oral and Maxillofacial Surgery Clinics

Maxillomandibular Advancement Surgery: An Alternative Treatment Option for Obstructive Sleep Apnea

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Obstructive sleep apnea (OSA) is a potentially fatal disorder that affects millions of adults in the United States. By definition, apnea is a cessation of airflow at any level of the repository tract, most notably in the nasal and oral pharynx, that lasts at least 10 seconds. In *The Posthumous Papers of the Pickwick Club*, originally published in 1837 by Charles Dickens, there was an extremely obese boy named Joe who could not help falling asleep during the day. 119 years later the name "Pickwickian" came up, when, in 1956, Dr. C.S. Burwell and colleagues published a medical case report titled "Extreme Obesity Associated With Alveolar Hypoventilation, a Pickwickian Syndrome." Syndromes such as this usually include obesity, hypersomnolence, periodic breathing with alveolar hyperventilation, and cor pulmonale.

Since the first tracheostomy was completed by Kuhlo for the treatment of upper airway obstruction in a Pickwickian subject, more than a few key surgical advances have noticeably contributed to the comprehension and treatment of OSA. Maxillomandibular advancement (MMA) has been definitively shown to be the most effective surgical method for the management of OSA. MMA was originally advocated based on the fact that maxillofacial skeletal abnormality is a well-recognized predictor of OSA and that maxillomandibular deficiency results in reduced airway dimension (Fig. 1), which in turn leads to ultimate nocturnal obstruction. MMA achieves improvement of the pharyngeal and hypopharyngeal airway by physically expanding the skeletal structure (Fig. 2). The forward movement of the maxillomandibular complex enhances the tension and collapsibility of the suprahyoid and velopharyngeal musculature.

Although MMA traditionally has been set aside for patients with unbalanced maxillofacial features, it is currently encouraged for the treatment of OSA in patients who lack such features, primarily because of recent evidence that suggests that earlier unease about MMA resulting in compromised facial aesthetics has been of no consequence in most patients surveyed.

This conclusion is caused by the fact that most patients who have OSA are middle-aged adults. Many of these patients are already showing visible signs of facial aging secondary to the drooping of their soft tissue. MMA provides facial skeletal expansion and consequently augments aesthetics through increased soft tissue support.

Preoperative evaluation

A thorough head and neck assessment combined with radiographs (lateral cephalometric and panoramic radiographs) and fiberoptic pharyngolaryngoscopy is vital for the diagnosis of OSA.

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doi:10.1016/j.cxom.2007.05.006

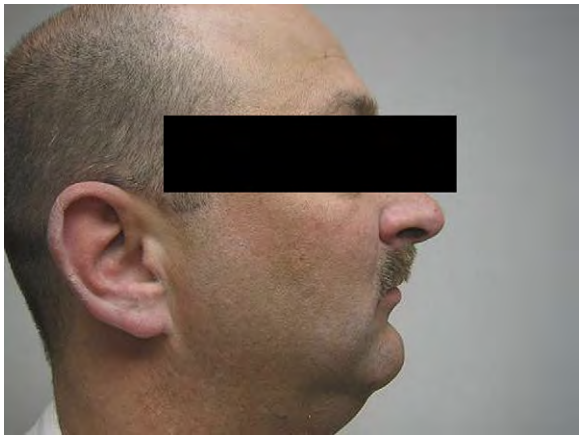

Fig. 1. A typical lateral profile of a patient who suffers from OSA. Note the obvious maxillomandibular deficiency.

A Müller maneuver during fiberoptic pharyngolaryngoscopy is also useful for evaluating the extent of intraoral tissue collapse. The Müller maneuver consists of having the patient complete a forced inspiratory effort against an obstructed airway, with fiberoptic endoscopic visualization of the upper airway. A panoramic radiograph is also a crucial tool for assessing mandibular morphology, the patient's existing dentition, and the position of the inferior alveolar neurovascular bundle. The lateral cephalometric radiograph provides accurate insight to the skeletal and airway dimensions (Fig. 3). Knowing the position of vital anatomic structures during surgical treatment of OSA greatly diminishes the chances for intraoperative injury.

Hans and Goldberg noted that cephalometric analysis of patients in the upright standing position has confirmed that patients who have OSA are unlike healthy, young control groups for several reasons: (1) Their tongue and soft palate are considerably enlarged and are positioned posteriorly and downward. (2) There is a correlation between total posterior displacement of the mandible (relative to both size and position) and the number of apneic episodes per sleep hours. (3) The maxilla is retropositioned and the hard palate is elongated. (4) The oropharynx and hypopharynx airway have reduced area, whereas the nasopharynx airway remains normal. (It is interesting to mention that patients with obstructed nasopharyngeal

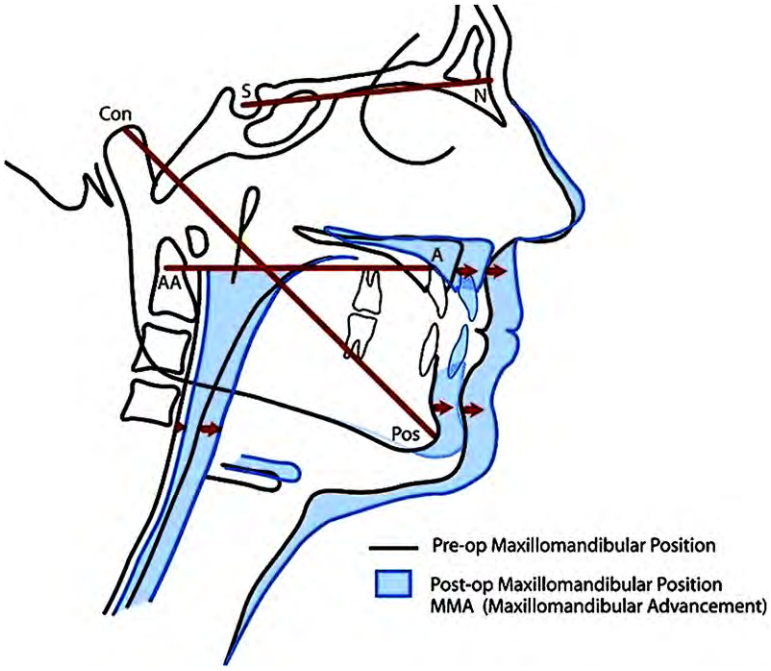

Fig. 2. MMA is a highly effective treatment for improving skeletal structure and widening the posterior airway space.

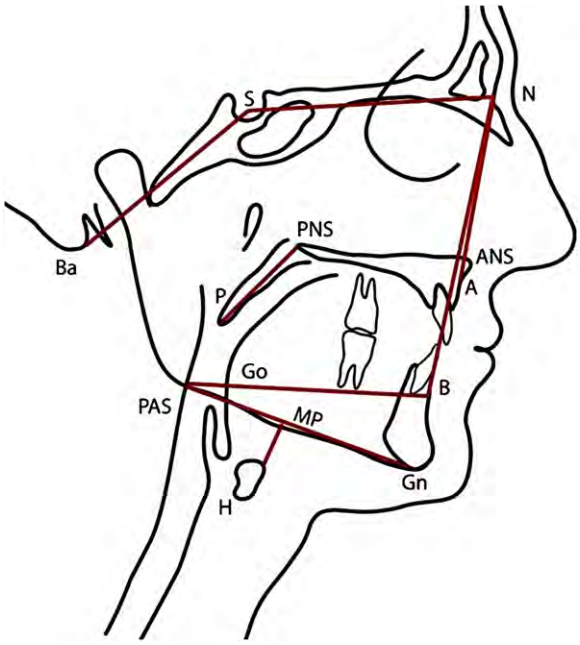

Fig. 3. Cephalometric analysis is a fundamental tool used in accurately diagnosing OSA.

airways (leading to mouth breathing) also display a large craniocervical angle, small mandibular dimensions, mandibular retrognathism, posterior downward mandibular posture, and downward forward tongue position.) (5) The hyoid bone is displaced inferiorly. Jamieson and coworkers hypothesized that an acute cranial base flexure (<NSBa) leads to abnormal development of the hypopharyngeal soft tissues associated with lower position of the hyoid bone.

Finally, high-resolution CT scans are also useful in concisely evaluating the airway space in relation to a patient's given soft tissue structure. They clearly display an accurate loss of posterior airway space dimension and provide a clear diagnostic picture to the patient regarding his or her condition (Figs. 4 and 5).

Patient consideration

Despite the debate on whether patients should initially select less invasive procedures, such as uvulopalatopharyngoplasty (UPPP) with genioglossus/hyoid advancement, many patients currently are opting to proceed directly to MMA. Factors that affect whether to proceed directly to MMA include personal preferences of the surgeon, the patient's own body habitus and airway/skeletal anatomy, the severity of the OSA, the patient's desire, and other existing comorbidities.

Studies currently indicate that combining MMA, UPPP, and the associated tonsillectomy is strictly contraindicated because the management of postoperative bleeding under general anesthesia may be required. Because of the limited mouth opening and subsequent edema after MMA, the ease of access to the pharynx for the purpose of hemostasis is restricted, which unquestionably makes intubation a difficult task and could render severe consequences if performed.

Surgical technique and postoperative care

The classical technique of MMA for OSA is comparable to that of any orthognathic procedure. Several dissimilarities exist, however, between this procedure and others and have not yet been studied sufficiently. Subjects of difference include the vascular supply in an older age group, bone healing, predictability, stability, and adjunctive procedures and their

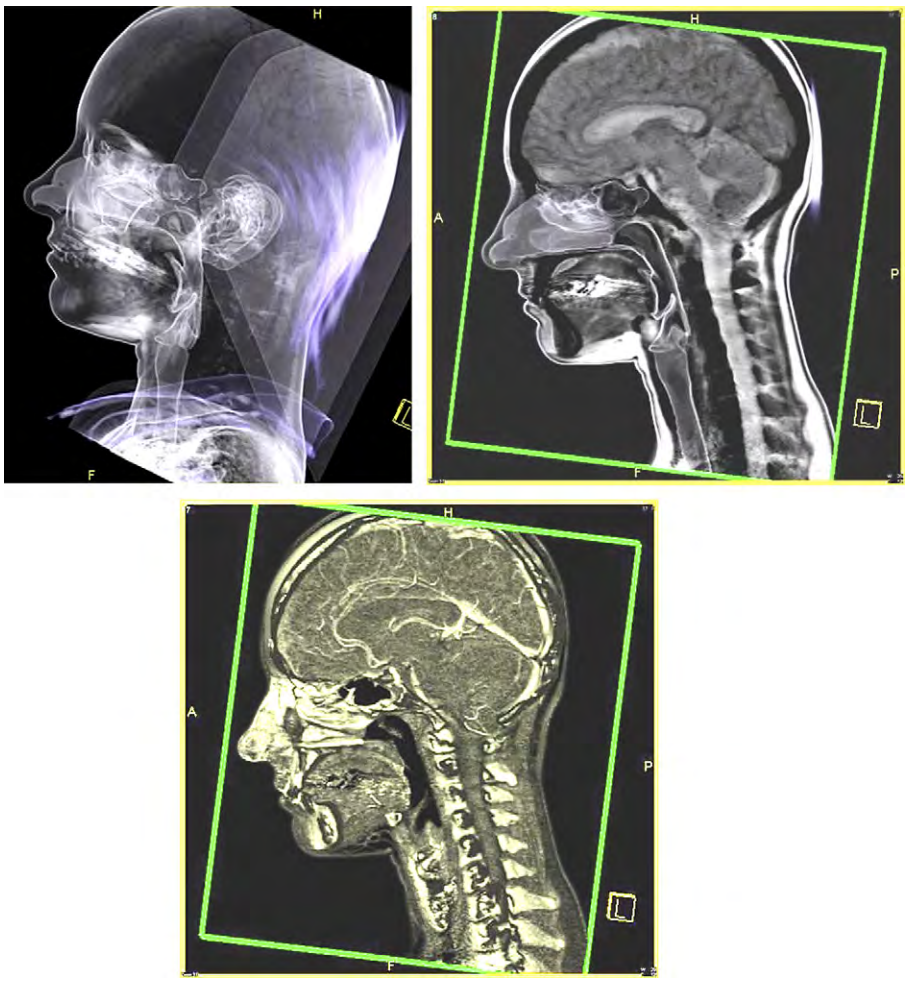

Fig. 4. High-resolution CT scan of a healthy patient. Note the clear and appropriate dimensions of the posterior airway space.

consequences on speech, vascularity, and healing. Many patients who do undergo MMA surgery have previously been treated with UPPP unsuccessfully. Possibility of velopharyngeal insufficiencies must be assessed before reconstructive surgeries, such as MMA. Scar formation in the soft palate also may prevent maxillary advancement or lead to compromised blood supply. Advancement of the maxilla by a Le Fort I osteotomy theoretically may advance the soft palate markedly and, as a result, produce obvious hypernasal speech.

Because most of OSA population includes obese patients with cardiopulmonary disease and airway compromise, it naturally benefits the surgeon to take every sensible preventive measure. In the past it has been suggested that patients with OSA may require elective tracheostomy during the perioperative period to ensure a patent airway. This is particularly true if adjunctive procedures, such as glossectomy and UPPP, are simultaneously performed. Such an aggressive approach is not routinely recommended unless the disease is severe (usually a respiratory disturbance index >60) and the patient has a long soft palate with a maxillofacial deformity. Even then, it is best to stage the procedures unless the patient is not willing to undergo multiple surgeries.

Preoperative model surgery displays the proposed orthognathic movements and requires the fabrication of surgical splints, which are used in the operating room (Fig. 6). In the preoperative model surgery for patients who have OSA, the mandible is usually advanced first. This step is suggested because the amount of advancement is random and not based on the normal functional and aesthetic position of the incisors.

Landmarks for the intraoral incision include the anterior border of the ramus and the external oblique ridge. A bite block is placed on the contralateral side, and a retractor is placed

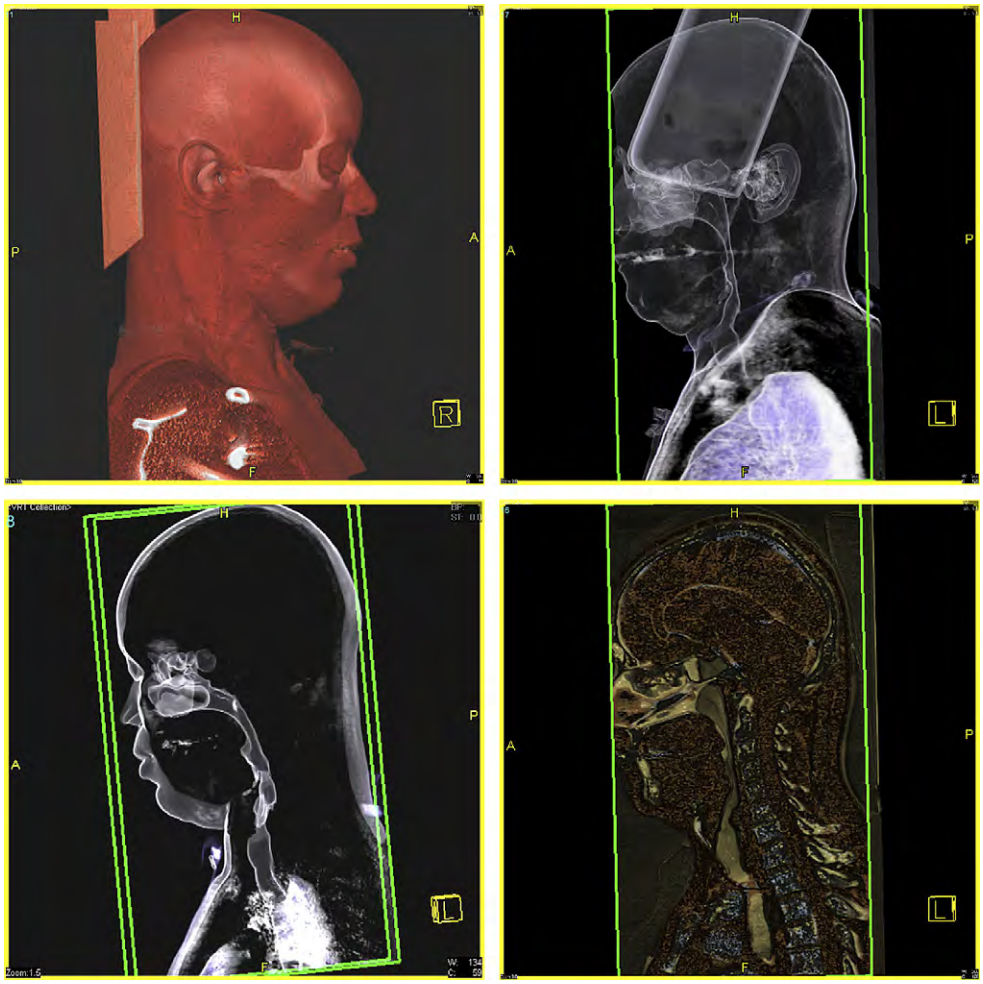

Fig. 5. High-resolution CT scan of a patient with diagnosed OSA. Note the excessive soft tissue and the decreased posterior airway space.

lateral to the external oblique ridge, exposing the intraoral mucosa that overlies the anterior border of the ramus. Starting superiorly two thirds up the anterior border of the ramus, an incision is made through the mucosa. Either a scalpel or an electrocautery device can be used. The incision is then carried inferiorly, lateral to the external oblique ridge to the area of the

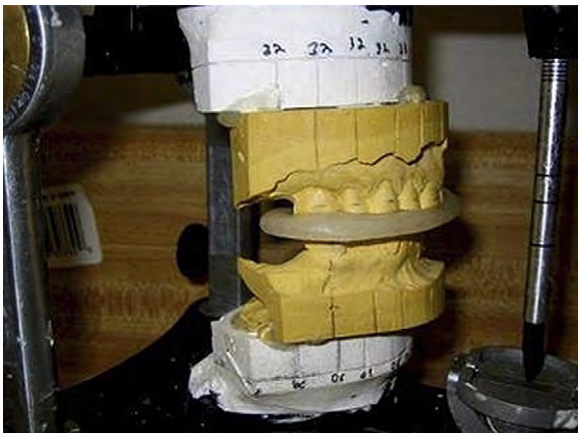

Fig. 6. Preoperative model surgery displays the proposed orthognathic movements and requires the fabrication of surgical splints to be used in the operating room.

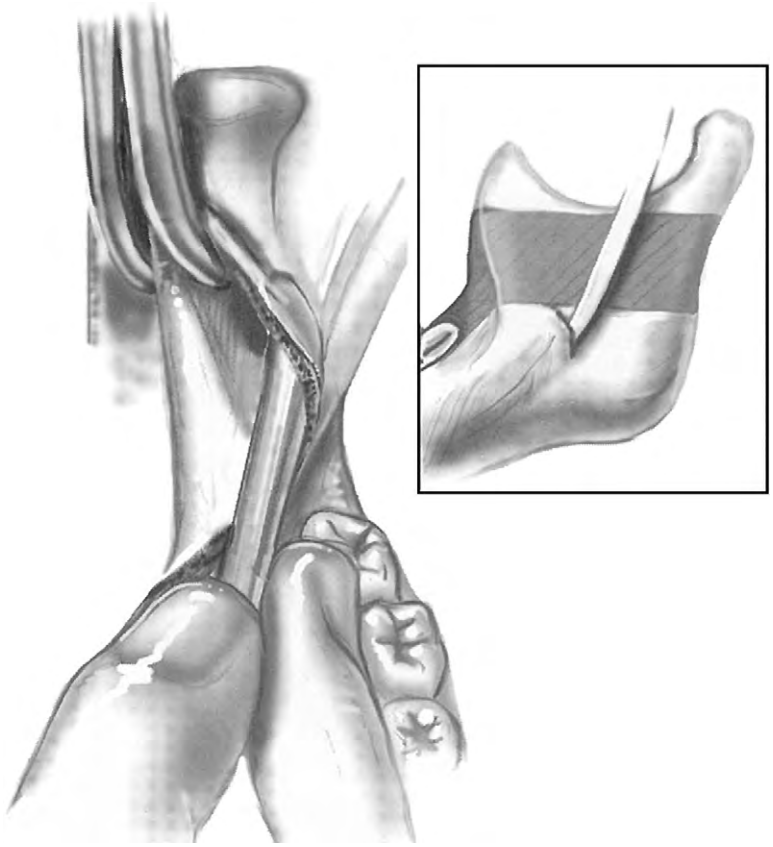

Fig. 7. A subperiosteal dissection along the internal oblique ridge is carefully performed using a periosteal elevator. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1083.)

second molar, where it is made more lateral into the vestibule up to the distal of the first molar and then down through the periosteum itself.

Next, the periosteum is elevated, and the external oblique ridge should be exposed. A notched coronoid retractor is inserted into the wound and used to retract the tissue superiorly until the tip of the coronoid process is reached. Once the coronoid is observed, a curved Kocher clamp is

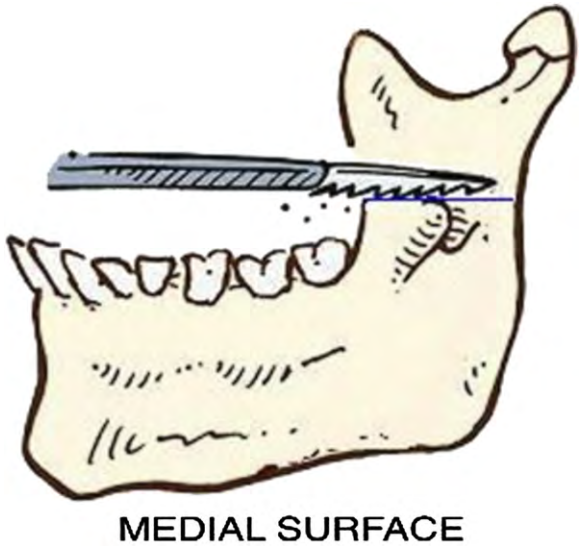

Fig. 8. The medial cut is made just superior to the lingula.

placed and secured to the surgical drape. To allow access to the ramus's medial aspect, the Kocher clamp is placed as close to the coronoid tip as possible. A subperiosteal dissection along the internal oblique ridge is then performed carefully (Fig. 7).

When the medial cut is made, it is preferably carried through the medial cortex into medullary bone from just above the lingula (Fig. 8). The bone on the medial aspect should be examined cautiously and the location of the fusion of the plates noted, after which assessment of the external oblique ridge divulges the contour of the lateral cortex. As the reciprocating saw is later carried down the ascending ramus, the contour of the lateral cortex should be examined, and the saw blade should be parallel to this lateral contour.

It is commonly advantageous to use a spatula chisel to first check the medial cut. Once the lingula has been visualized and the medial osteotomy has been completed, the clamp and the mouth prop are removed. Dissection along the ascending ramus is carried inferiorly and laterally. Visualization of the occlusal plane is a prompt guide to the orientation of the mandible's inferior border. Next, a J-stripper is inserted into the gonial notch and used to carefully release the periosteum anteriorly. This procedure is performed until the region of the first molar region is reached.

A beveled cut is made through the inferior border perpendicular to the occlusal plane and up to the external oblique ridge between the first and second molars (Fig. 9). The cut is stopped after extending the osteotomy approximately 2 cm superiorly to the inferior border of the mandible. Using a fissure bur or reciprocating saw, the two cuts are joined carefully (Fig. 10).

A 0.25-inch chisel is used to initiate the osteotomy. The chisel is steadily malleted in place from superior to inferior. Altering directions to match the ramus's contour is important to ensure a balanced split. As the bone is separated, it is essential to observe whether it is dividing evenly. The cortices never should be pried apart but rather gently separated to look for the neurovascular bundle. If the bundle is observed in the proximal segment, it should be lifted carefully out of its medullary encasement and positioned properly.

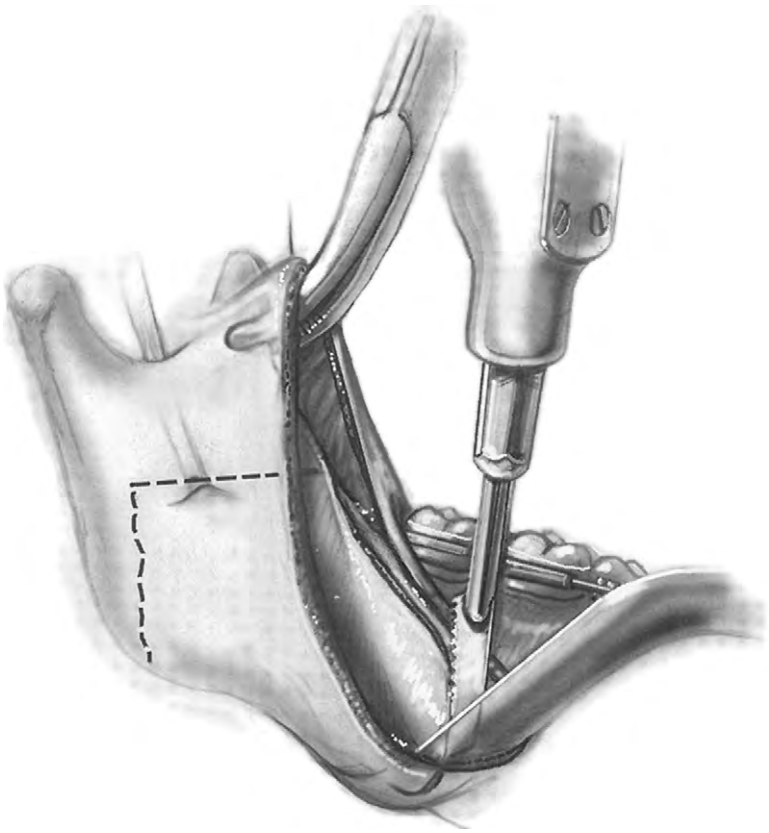

Fig. 9. The reciprocating saw is positioned to make the cut through the inferior border perpendicular to the occlusal plane up to the external oblique ridge between the first and second molar of the mandible. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1084.)

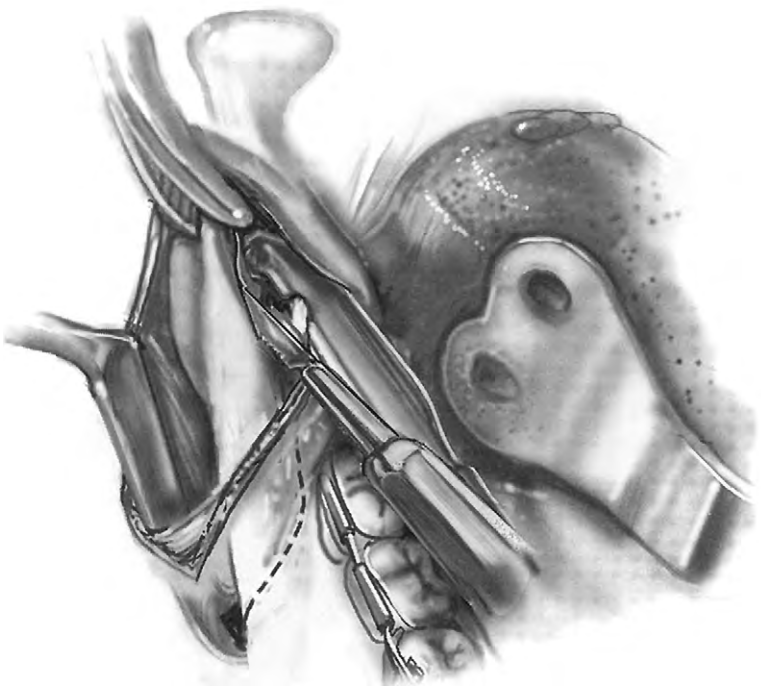

Fig. 10. Using a fissure bur or reciprocating saw, the lateral and medial osteotomies are joined. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1084.)

When certain that the proximal segment is intact, the distal segment is advanced ahead of the desired position. A prefabricated acrylic mandibular advancement splint is used to orient the distal segment and maintain the proper plane of occlusion. Temporary maxillomandibular fixation is then achieved.

If the space between the proximal and the distal segments is small, the intraoral placement of bicortical screws is achievable. The cheek is retracted and a drill is directed as perpendicular to the bone as possible. When placed in this manner, the screw alignment always is moderately oblique. If the gap between the segments is large, there may be limited overlap of the proximal and distal segments; other techniques may be required. These techniques may include the use of supplemental bicortical screws with suspension wires and a period of MMF.

An alternative method is the percutaneous approach. A stab wound is made paralleling the direction of the facial nerve. A trochar is then inserted, which allows for some flexibility. It is important to drill the first hole into the area of the greatest bone contact. The screw should be inserted and tightened. Supplementary screws should be placed in areas in which bone contact is not present. Care should be taken, however, not to compress the bone segments in areas of minimal bone contact. The mandible ideally should be rigidly fixed with three 2- or 2.4-mm bicortical screws in an L-shaped pattern to produce a stable prognathic profile.

At this point, once the Bilateral Sagittal Split Osteotomy (BSSO) is completed and the mandible is advanced at least 1 cm, the maxillomandibular fixation is then removed and evidence of immediate condylar relapse is evaluated. If made, the stab incisions can be closed with one or two 5-0 prolene sutures at this point in the procedure or be closed at the procedure's end.

The surgeon's attention turns next to the maxilla. Because enough soft tissue mobilization to allow an advancement of at least 1 cm is required in older patients, it is judicious to preserve the vascularity. Experience indicates that the maxilla can be advanced further with the palatine arteries intact when a high Le Fort osteotomy is performed. These arteries are maintained if possible. The vestibular mucosal incision begins high on the zygoma and extends anteriorly a few millimeters above the mucogingival junction (Fig. 11). The area posterior to the zygomatic buttress or beyond the first molar is approached by tunneling.

Once the dissection of soft tissue is completed with a periosteal elevator, vertical reference points should be made at the region of the piriform aperture region and at the

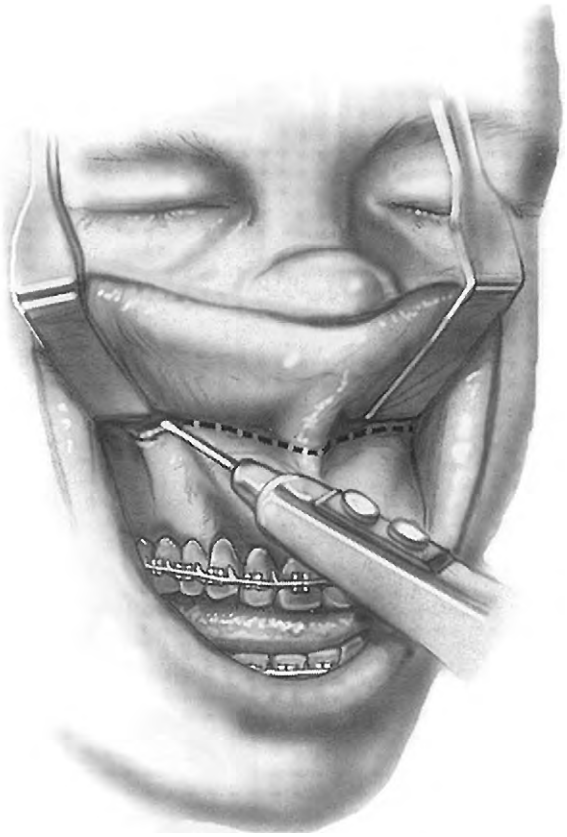

Fig. 11. A circumvestibular incision is made from the distal of the first molar anteriorly toward the midline. It is important to remain deep in the vestibule and leave a sufficient amount of gingival tissue adjacent to the cervical margins of the teeth. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1085.)

zygomaticomaxillary buttress area. The osteotomy is initiated at the zygomaticomaxillary buttress. A reciprocating saw is used for this cut and proceeds anteriorly to the nose (Fig. 12). The posterior lateral wall of the maxilla is sectioned under the mucosal tunnels with direct visualization using the reciprocating saw.

The posterior osteotomy is then directed inferiorly as it proceeds posteriorly from the zygomaticomaxillary buttress to the junction of the maxilla and the pterygoid plate, which minimizes the risk of damaging the maxillary artery or any of its terminal branches as they descend from the pterygopalatine fossa. The posterior osteotomy should be 5 mm superior to the second molar, which is approximately 25 mm from the occlusal plane, which further minimizes the risk of devitalizing the existing teeth. After the posterior wall is cut, the saw should be reversed so that the blade is placed into the maxillary sinus. The osteotomy is then completed from the sinus to the outside. When the cuts are completed, the wound is packed and the matching steps are repeated in the same manner on the contralateral side.

With careful attention to preserving the nasal mucosa, a septal osteotome is then malleted posteriorly (Fig. 13), which frees the cartilage and bone of the nasal septum and the vomer from the maxilla. Consideration is next directed to the lateral nasal walls. A periosteal elevator is placed subperiosteally on the medial aspect of the lateral wall of the nose to provide protection to the nasal mucosa. The osteotome should be placed at the piriform rim and directed posteriorly and inferiorly along the lateral nasal wall toward the perpendicular plate of the palatine bone. The lateral nasal wall is thin and offers little opposition to sectioning until the palatine bone is reached. Complete sectioning of the palatine bone should be performed.

The next step in the Le Fort I osteotomy is separation of the maxilla from the pterygoid plates. A curved osteotome is used for this process. Its direction should be medial and anterior at the lowest point of junction of the maxilla and the pterygoid plate. The osteotome is

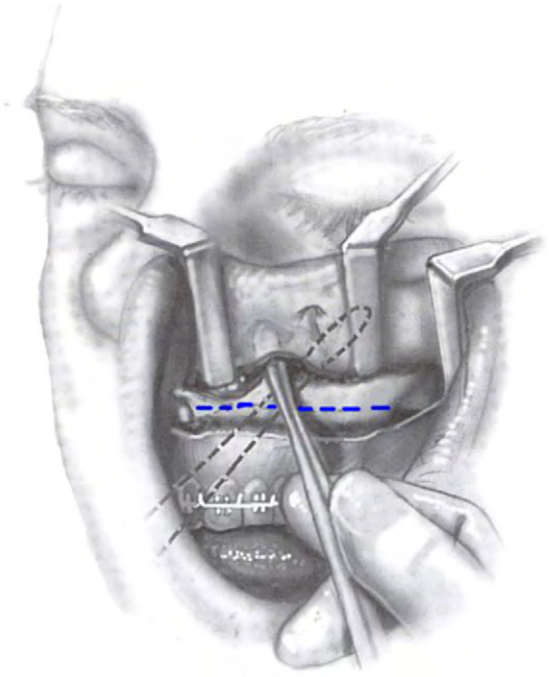

Fig. 12. A periosteal elevator is used for subperiosteal dissection of the anterior maxilla superiorly toward the infraorbital nerve and medially to expose the anterior nasal spine. Note the proposed maxillary osteotomy depicted in blue. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1085.)

cautiously malleted to accomplish the desired bony separation. As the instrument sections the juncture, its tip is palpated on the soft palate (Fig. 14).

The maxilla is then ready to be downfractured. With gentle hand pressure, the anterior aspect of the maxilla is depressed. As the maxilla moves downward, the remaining attached nasal soft tissues should be elevated from the nasal floor (Fig. 15). It is advantageous to keep the nasal mucosa

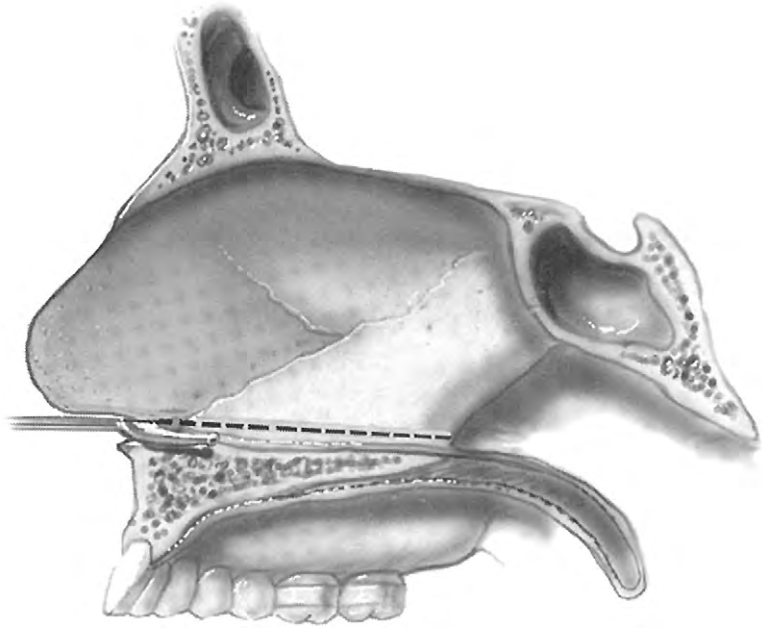

Fig. 13. The osteotomy line between the nasal septum and the maxilla. The septal osteotome is malleted posteriorly. (*From* Posnick JC. Craniofacial and maxillofacial surgery in children and young adults. Volume 2. Philadelphia: W.B. Saunders; 2000. p. 1087.)

undamaged because it minimizes postoperative congestion and discomfort. Mobilization devices are positioned bilaterally posterior to the tuberosity of the maxilla. Being mindful of the descending palatine neurovascular bundle, the maxilla is subsequently moved interiorly.

During the downfracture of the maxilla, the septum and inferior turbinates must be evaluated for deviation and obstruction (Fig. 16). If necessary, a septoplasty can be performed and the turbinates partially reduced. The maxilla is then placed into the desired occlusal relationship dictated by the final splint. If the maxilla cannot be advanced far enough to fit the predetermined position by the mandible, it must be further mobilized.

Temporary maxillomandibular fixation is then applied, and the maxillomandibular unit is rotated upward until the teeth fit the splint in proper occlusion. Four miniplates are placed bilaterally at the piriform aperture and at the zygomatic buttress (Fig. 17). This technique provides adequate fixation without relapse. If large gaps exist in the walls of the maxilla after the repositioning and stabilization stages, then bone grafts are recommended. Either autogenous bone or allogeneic materials are suitable. The mucosal incision is closed with a running suture. A slight V-Y closure is recommended. No alar base cinch suture is suggested, however, to ensure that the alar valve opens properly.

After the Le Fort I and sagittal split osteotomies of the mandible are accomplished, a geniotomy can be performed (Fig. 18). The geniotomy-tongue advancement is designed to advance the genial tubercle and anterior digastric muscles. It is imperative to understand that this procedure differs from the classic ''aesthetic genioplasty.'' Its sole function is to draw the geniohyoid and genioglossus muscles forward and increase the posterior airway space accordingly. Alternatively, when a patient cannot aesthetically tolerate extreme chin advancement, an inferior mandibular osteotomy with hyoid myotomy suspension is clearly indicated. This technique allows substantial advancement of the genial tubercle but does not actually change the digastric muscle's position or the chin point itself. This method is also much less likely to result in a fracture of the mandible.

In most instances, the Le Fort I and sagittal split osteotomies and a geniotomy-tongue advancement can be done with a routine nasoendotracheal tube. Excessive swelling can occur as

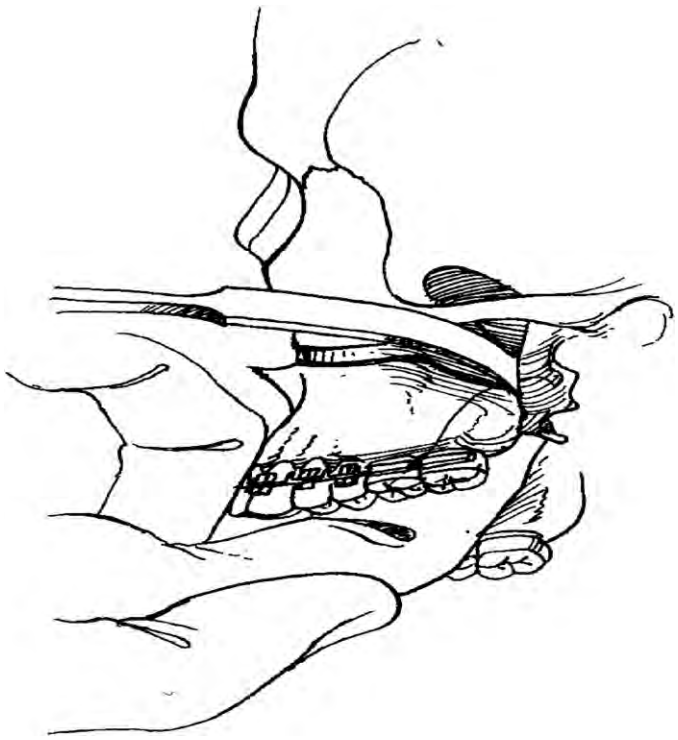

Fig. 14. The osteotome sections the juncture of the maxilla and the pterygoid plates, and its tip is palpated on the soft palate. (*From* Turvey TA, Scardt-Sacco D. Lefort I Osteotomy. In: Fonseca RJ. Oral and Maxillofacial Surgery. Volume 2: Orthognathic Surgery. Philadelphia: W.B. Saunders Co.; 2000. p. 237; with permission.)

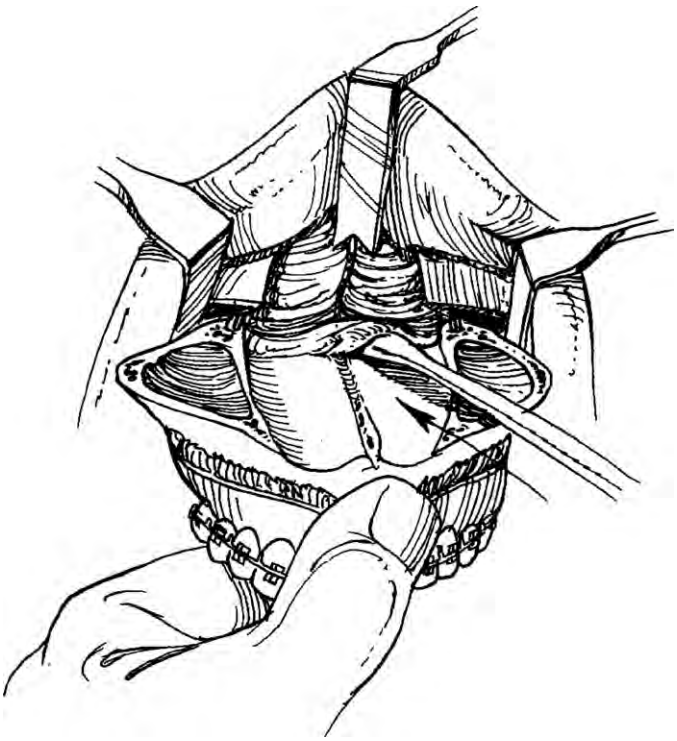

Fig. 15. As the maxilla moves downward, the remaining attached nasal soft tissues should be elevated from the nasal floor. (*From* Turvey TA, Scardt-Sacco D. Lefort I Osteotomy. In: Fonseca RJ. Oral and Maxillofacial Surgery. Volume 2: Orthognathic Surgery. Philadelphia: W.B. Saunders Co.; 2000. p. 237; with permission.)

late as 3 days after the surgery, and immediate extubation may be premature. The endotracheal tube can be kept in place and the patient placed on positive end-expiratory pressure for an extended period, as deemed necessary by the surgeon. This ventilation support is essential to prevent apnea and allow the proper narcotic administration.

Patients usually tolerate standard positive end-expiratory pressure (+5 cm H_2O), intermittent mandatory ventilation (four per minute), and 40% inspired oxygen well. Logically, these settings can be adjusted as indicated by the needs of the patient. During the period of intubation, it is suggested that the patient be kept in wire maxillomandibular fixation, which seems to reduce

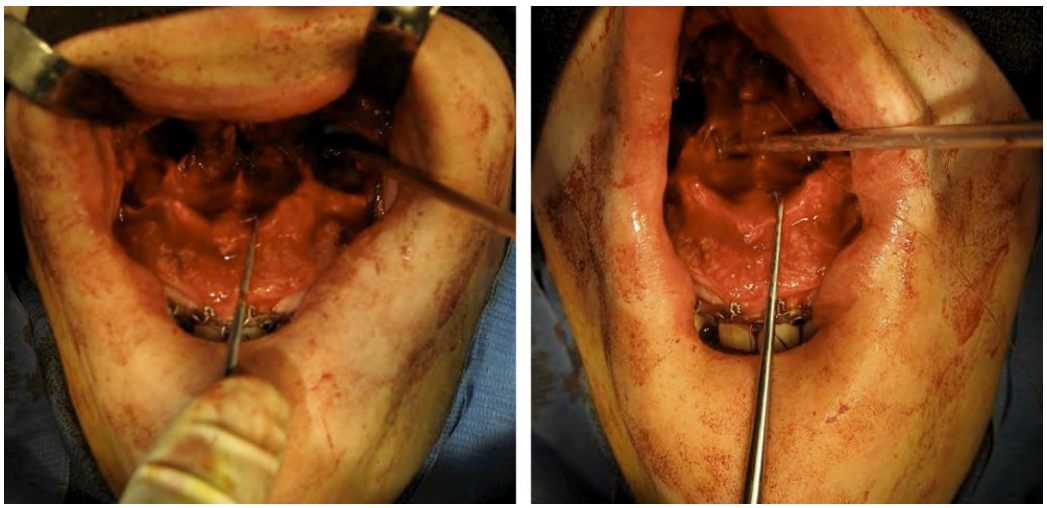

Fig. 16. During the downfracture of the maxilla, the septum and inferior turbinates must be evaluated for deviation and obstruction.

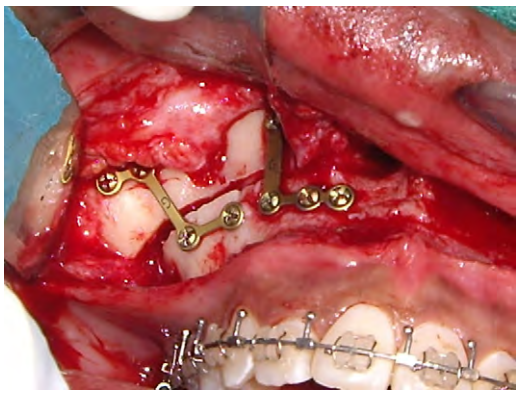

Fig. 17. Following advancement of maxilla, two bone plates with four to five screws in each plate are used to secure the segments in place. Note the close approximation of the segments and position of the infraorbital nerve in relation to the plates. (*Courtesy of* Mansoor Madani DMD, MD, Bala Cynwyd, PA.)

the incidence of malocclusion. If the patient is unable to tolerate wire fixation secondary to postoperative airway difficulty, then training elastics are indicated to provide the necessary support.

In some cases, patients are immediately extubated after being awakened in the operating room with the intermaxillary fixation in place. Regardless of this, wire cutters always should accompany the patient. It is recommended that every patient be monitored in the intensive care unit for the first postoperative day. Either humidified oxygen (35%) via face tent or nasal continuous positive airway pressure should be used during the patient's hospitalization. Nasal trumpets are necessary if nasal continuous positive airway pressure is used to prevent subcutaneous emphysema from the intraoral incisions.

Ideally, patients are transferred to the general floors on the following day. Suitable discharge criteria must include a stable airway, sufficient oral intake of fluids, and acceptable pain control. The intermaxillary fixation, with elastics, is left in place for at least 7 to 10 days on average.

Distraction osteogenesis

In the past, when orthognathic surgery was used, often only the anteroposterior dimension was addressed while the transverse dimension remained overlooked. Research, however, has demonstrated the important role that transverse expansion of the mandibular and maxillary arches can play for patients who have severe OSA. In Conley's study, an initial stage of maxillary and mandibular transverse distraction osteogenesis was performed, followed by fixed orthodontic management. Coupling this with a second surgical stage consisting of MMA, obvious improvements in OSA symptoms, occlusion, and facial morphology were observed.

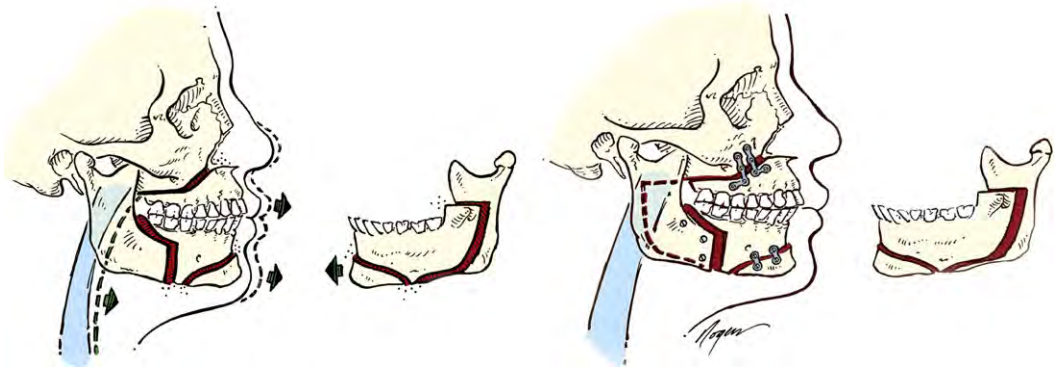

Fig. 18. The above illustration depicts MMA surgery with associated geniotomy. Note the widening of the posterior airway space and the balanced skeletal movements.

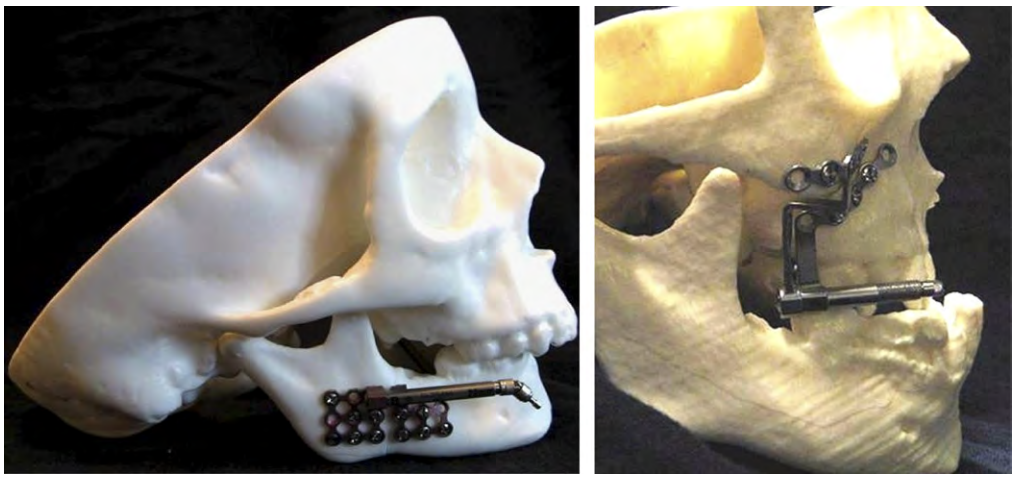

Fig. 19. Synthes Craniomaxillofacial Distraction System comes in a variety of shapes and sizes to meet the anatomical needs of the patient. The pictures above demonstrate the device position in mandible and the maxilla.

Li and colleagues demonstrated that distraction osteogenesis is appropriate in selected adult patients for skeletal advancement in the treatment of OSA. The surgical procedures performed in this study were mandibular advancement and simultaneous MMA. Distraction devices were placed on the indicated jaw(s) immediately after the surgical osteotomies (Fig. 19). These distraction devices were activated four times daily starting 7 days postoperatively at a rate of 1 mm/d. This procedure was performed until the appropriate advancement was achieved (Fig. 20). Simultaneous distraction was performed in the bi-jaw cases.

Distraction osteogenesis presents some marked advantages over the traditional MMA surgical technique in terms of improved soft tissue accommodation, elimination of the necessity of a bone graft, and less direct surgical dissection. Although this technique can improve the stability of the new skeletal position, it is not without noteworthy disadvantages. These disadvantages include the highly technique-sensitive nature of the procedure, the strong possibility of postoperative orthodontia to ensure proper occlusion, and the extended length of treatment time.

Additional techniques

Over the past two decades, the emergence of radical surgeries such as MMA has resulted in dramatically better surgical outcomes in the treatment of OSA. MMA has proved to be the most effective surgical procedure for the management of OSA. In the recent literature, Riley and colleagues reported a 97% cure rate with a respiratory disturbance index less than 20, whereas Waite and colleagues demonstrated a 65% cure rate with a respiratory disturbance index of less than 10.

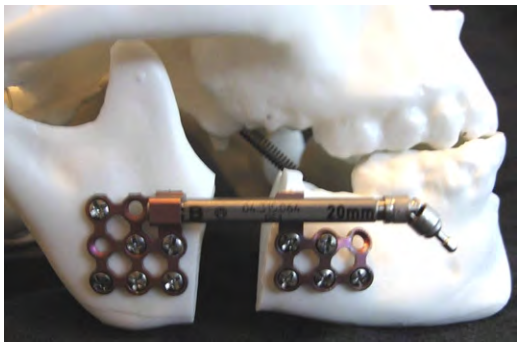

Fig. 20. Activating the device results in distraction of the bony segments, which produces similar results to MMA surgery.

MMA is so successful because it actually increases the space of the upper airway at many levels. An anterior movement of the maxilla and mandible draws the base of the tongue and soft palate forward. By doing so, the surgery effectively opens the nasal valve and improves nasal air flow. MMA has been shown to reduce upper airway resistance by nearly two thirds.

One drawback of MMA surgery is that it still may result in an unfavorable aesthetic facial change. Recent studies have been performed to modify the MMA technique to overcome the effects of this aesthetic dilemma. The modified MMA technique involves intraoperative extractions of selected bilateral premolars from the maxillary and mandibular arches. Segmental surgeries are performed in the anterior subapical maxillary region and the anterior subapical mandibular region. This technique has had early successes, especially among the Asian population, which tends to exhibit bimaxillary protrusion.

Specific possible disadvantages to using this technique exist, including an increase of surgical time, trauma to dentition adjacent to the osteotomies, and increased risk of segment necrosis. Further studies into this proposed modified technique are warranted to compare its results with those of the classic MMA surgical approach, which is still regarded as a gold standard of care.

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 179–192

Atlas of the Oral and Maxillofacial Surgery Clinics

Genioglossus Muscle Advancement Techniques for Obstructive Sleep Apnea

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Obstructive sleep apnea (OSA) is partially caused by pharyngeal narrowing and the repeated collapse of the airway during sleep. It is associated with other symptoms and signs, such as snoring, episodes of apnea/hypopnea sleep fragmentation, daytime drowsiness, cognitive impairment, and arterial hypertension. Among many factors that cause upper airway obstruction are receded jaws and chin (micro- or retrognathia, Pierre-Robin syndrome, Klippel-Feil syndrome, Prader-Willi syndrome). Some of the muscles involved in the control of the upper airway diameters are attached to the maxillary bones, and others are attached to the mandibular bone. Consequently, we find many cases of constricted upper airway caused by these facial deformities, and correcting them can enhance a patient's overall breathing and improve facial balance and other functional advantages.

The sequence of events leading to airway obstruction involves decreased upper airway muscle activity with sleep-onset, which causes pharyngeal narrowing. Increased negative intraluminal pressures result, which produce further pharyngeal narrowing. This process leads to ineffective activation of the upper airway muscles relative to the respiratory pump muscles that fail to counteract the negative intraluminal pressure, and pharyngeal closure results.

The genioglossus muscle acts as a dilator of the pharynx, and the base of the tongue is one of the most crucial factor in reducing the upper airway diameter while an individual sleeps. The role of the genioglossus muscle in posterior airway occlusion has been investigated at length. A study of 10 patients who have OSA and 4 symptom-free controls found that during subsequent tidal breathing, the timing of genioglossus onset progressively decreased after the onset of inspiration until the next OSA occurred. This finding suggests that the timing relationship between genioglossus inspiratory activity and inspiratory effort is physiologically important in the pathogenesis of OSA. The rationale for advancement of the genioglossus muscle is as follows: the hypopharyngeal airway is stabilized by the forward movement of the genial tubercle and genioglossus muscle, which places tension on the base of tongue and decreases the probability that it will prolapse into the posterior airway space during sleep.

The functional genioplasty for surgical reconstruction of the upper airway was first described by Riley and colleagues as the inferior sagittal osteotomy. The hyoid was also suspended and fixed to the inferior border of the mandible as an adjunct to the genioglossus advancement. This technique was referred to as genioglossus advancement-hyoid myotomy. In a later study, the

Portions of the text were previously published in Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84.

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1061-3315/07/$ - see front matter
doi:10.1016/j.cxom.2007.06.003

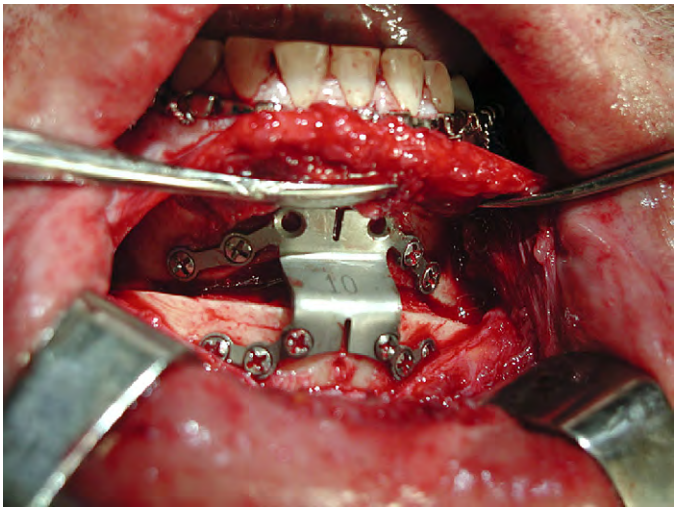

Fig. 1. Inferior sagittal osteotomy/inferior border advancement genioplasty. One of the most common techniques is the anterior/inferior genioplasty, in which the traditional genioplasty is performed with assurance that the genial tubercle is part of the cuts and is advanced an average of 10 mm forward. We use an additional nonresorbable suture or, in some cases, a 23-gauge stainless steel wire to place additional forward pull on the genioglossus and geniohyoid muscles.

hyoid suspension was modified by suturing the hyoid to the thyroid cartilage. The inferior sagittal osteotomy was modified by Powell and Riley because of an increased number of midline mandibular fractures; however, this osteotomy and all future modifications of the technique maintained the same objective: advancement of the genial tubercle and genioglossus muscle. The inferior sagittal osteotomy was modified and described by Riley and colleagues to retain continuity of the inferior border of the mandible by limiting the osteotomy to a rectangular window, including the genial tubercle. This osteotomy is called an anterior mandibular

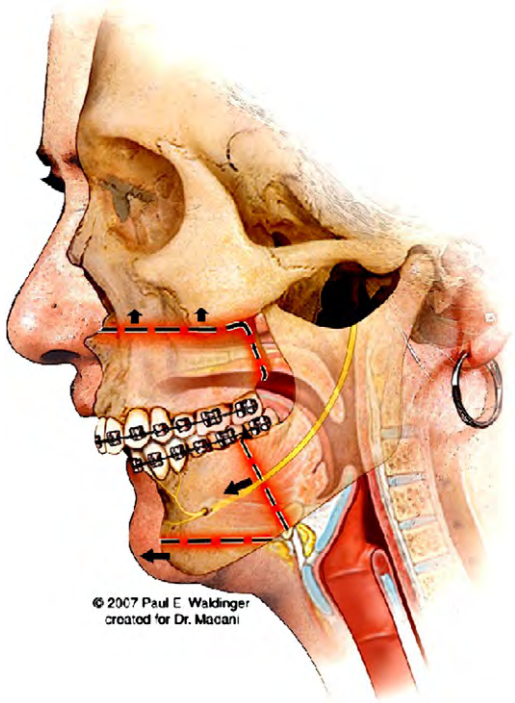

Fig. 2. One of the most commonly found dentofacial deformities is a combination of severe mandibular retrognathism, maxillary hyperplasia, and receded chin. In many cases a narrow and constricted oropharynx, as well as hypopharynx, is noted. Note the position of the epiglotis and the hypopharynx. (*Courtesy of* Mansoor Madani DMD, MD, Bala Cynwyd PA; all rights reserved.)

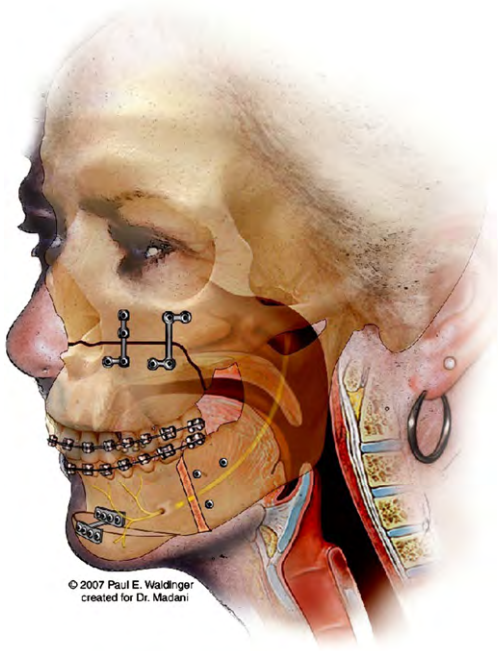

Fig. 3. In such cases, advancement genioplasty is the most appropriate procedure combined with double jaw surgery. These types of procedures improve a patient's occlusion, cosmetic outlook, and airway. It must be stressed that placing allograft materials for chin augmentation must be avoided, as they have no effect in improving the patient's upper airway. (*Courtesy of* Mansoor Madani DMD, MD, Bala Cynwyd PA; all rights reserved.)

osteotomy. Further modification of this procedure was described by Lee and Woodson as a circular osteotomy of the genial tubercle.

All procedures have the same objective of ultimate stabilization of the hypopharyngeal airway by advancing the genioglossus muscle. Johnson and Chinn reported a positive response rate of 77.8% in nine patients treated with a combination of upper airway procedures and genioglossus muscle advancement. Lee and colleagues reported a positive response rate of 69% in 35 patients treated with upper airway procedures and genioglossus muscle advancement. When combined with other upper airway procedures, the genioglossus muscle advancement is a viable surgical treatment for OSA.

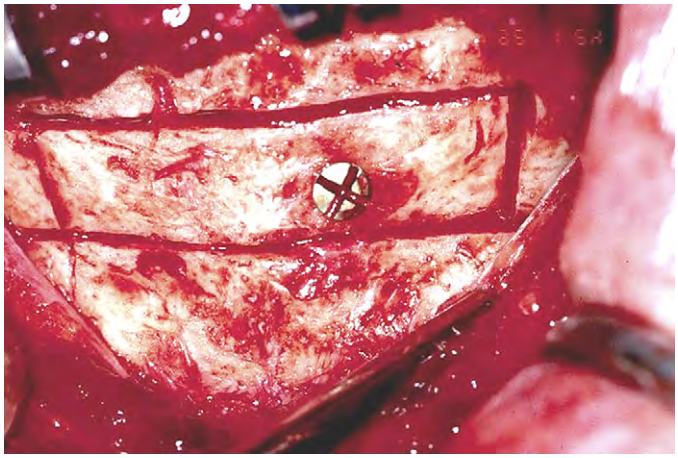

Fig. 4. Anterior mandibular osteotomy (modified genioplasty). A bicortical 2-mm bone screw is placed at the midpoint of the genial tubercle location. A microsagittal oscillating saw is used to complete a rectangular osteotomy, with the screw serving as a central guide for a symmetrical segment that contains the genioglossus muscle. Care must be taken not to shorten the lingual plate by excessive angulation of the saw during the osteotomy, with emphasis directed toward parallel walls of the symphysis osteotomy.

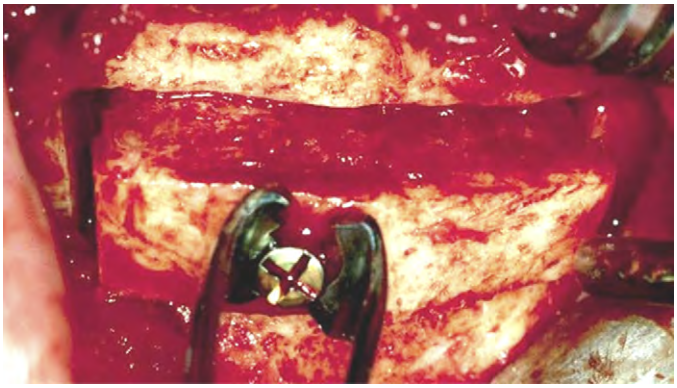

Fig. 5. The lingual cortical plate is positioned anterior to the lateral cortical plate and rotated 90°. The medullary bone and lateral cortical plate are osteotomized, which leaves the lingual cortical plate and genioglossus muscle attachment. The segment is then stabilized with one unicortical 2-mm bone screw placed in an inferior position.

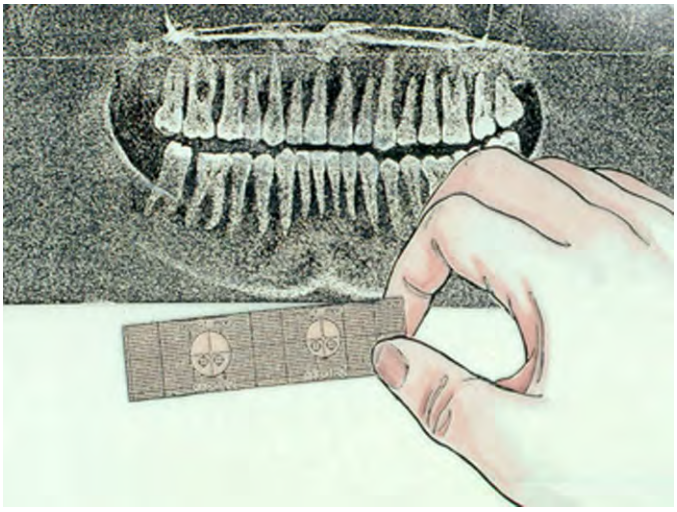

Fig. 6. Trephine osteotomy approach. The appropriate size template is selected and placed over the lateral aspect of the symphysis at the location for the genial tubercle. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

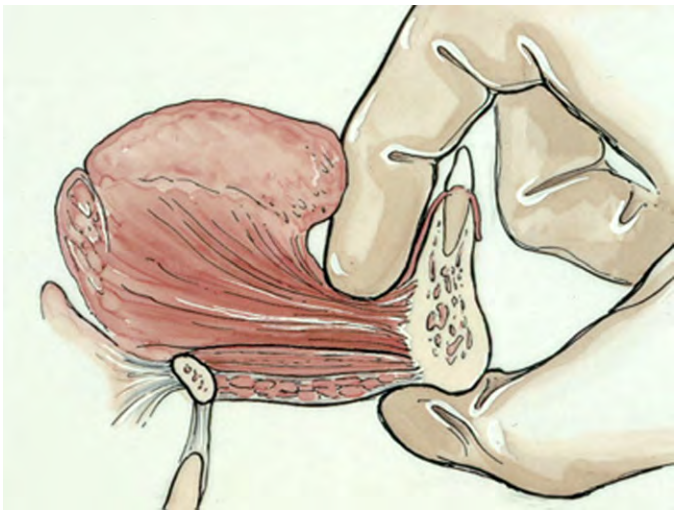

Fig. 7. The position of muscle attachment and the location of the soft tissue incisions are measured. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

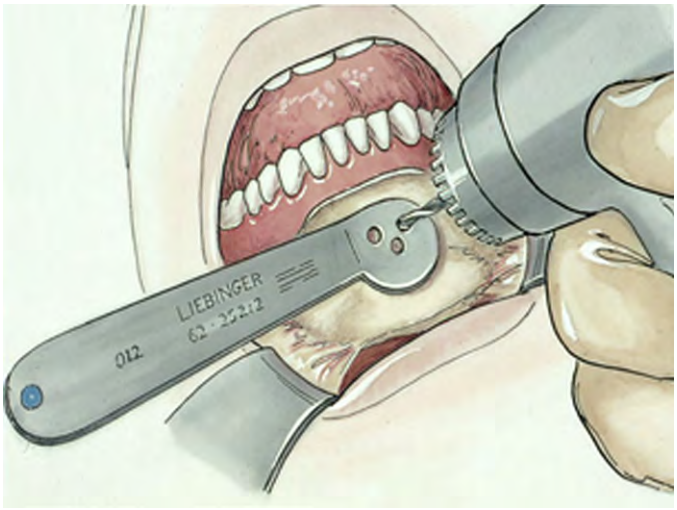

Fig. 8. A bicortical hole is drilled and the depth is measured. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

Genioglossus muscle advancement is a viable adjunctive procedure in the reconstruction of the upper airway. The authors have not experienced the complications of osseous segment necrosis with the anterior mandibular osteotomy and trephine osteotomy techniques, the risk of infection is low. Neurosensory changes and dental-pulp necrosis may occur, so patients must be informed accordingly. Genioglossal advancement has the advantage of not altering the jaw position or occlusion. Osteotomies that are performed are angled to include the genial tubercle. Hyoid suspension and myotomy include advancement of the hyoid bone anteriorly to the mandible or alternatively advanced onto the laryngeal cartilage. Advancement of the hyoid bone through its attachments draws the epiglottis, valecula, and tongue base forward.

Inferior sagittal osteotomy/inferior border advancement genioplasty

Inferior sagittal osteotomy—or inferior border advancement genioplasty—is the most commonly performed type of genioplasty advancement used by most surgeons to improve position of the genioglossus muscle and assist patients with obstructive upper airway (Fig. 1).

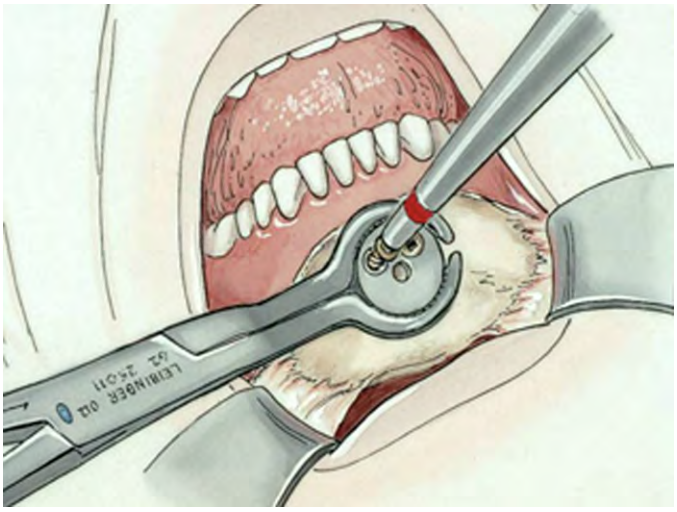

Fig. 9. An appropriate guide plate is placed and secured with a bicortical screw. The remaining bicortical screw is then placed to secure the guide plate. The appropriate size trephine is placed with the trephine drill stop at the indexed depth of mandible thickness. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

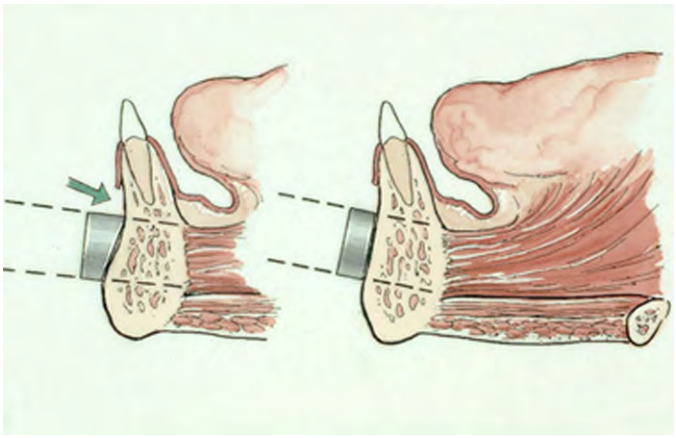

Fig. 10. Direction of the trephine is chosen to assure that genioglossus muscle is part of the section advanced to assist opening of the airway. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

This technique is reserved for patients with significant anteroposterior deficiencies in the horizontal menton position (microgenia) and a clear narrowing of the airway in the base of the tongue region. It could be done simultaneously with a sagittal split osteotomy of the mandible in selected cases. When sagittal split osteotomy is not simultaneously performed, the inferior border of the mandible is sectioned and advanced only with the dentoalveolar process intact. Using a lingual splint and securing it with interdental stainless steel 24-gauge wire ensures stabilization of the jaw. This splint aids in stress shielding the forces of mastication and is removed in 6 weeks. All patients who undergo this procedure are requested to restrict their diets to soft and nonchewable foods for 6 weeks after the procedure.

The soft tissue approach is the same as for cosmetic intraoral genioplasty. The osseous midline is scored on the anterior surface of the symphysis. The genial tubercle pedicle is outlined with an oscillating saw in the anterior surface, with emphasis on completion of a full-thickness osseous pedicle that contains the entire genioglossus muscle attachment. The inferior portion of the osteotomy is the same as the horizontal augmentation genioplasty, and it extends bilaterally and posteriorly toward the gonial notch region. The osseous pedicle is mobilized and advanced anteriorly full thickness. The lingual cortex superior to the genial tubercle is brought to rest on the lateral plate of the dentoalveolar process with attention to coordination of the midline. Stabilization can be achieved by applying two precontoured chin plates at either side of the

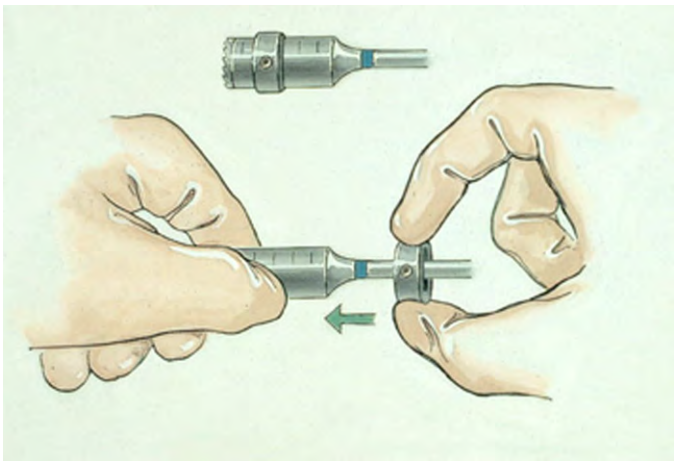

Fig. 11. The guide rod is inserted through the minidriver and threaded counterclockwise into the guide plate. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

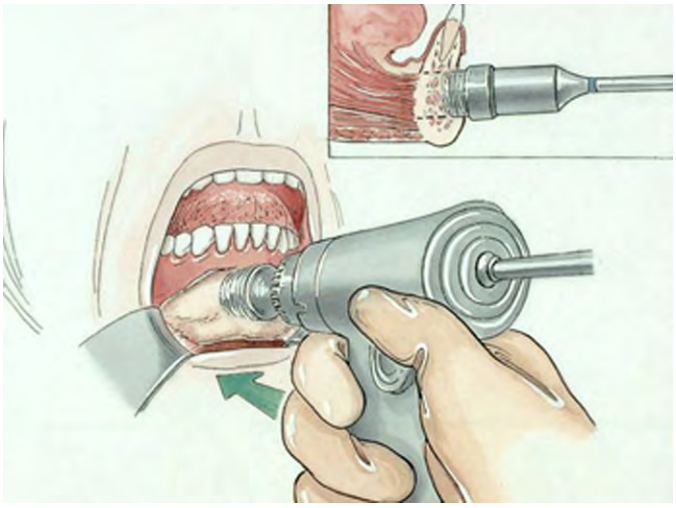

Fig. 12. Position the trephine osteotomy over the bony segment and initiate the cuts. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

midline symphysis tubercle process. A nonresorbable suture or a small gauge stainless steel wire could be used to advance and secure the chin plate through the osteotomy site. This simple step can help maintain the genioglossus and geniohyoid muscles in a forward direction. Soft tissue closure is accomplished in two layers, mentalis muscle and mucosa.

The final results of this type of genioplasty, particularly if combined with double-jaw surgery, can improve facial balance and increase the airway diameter at the same time (Figs. 2 and 3).

Anterior mandibular osteotomy

The anterior mandibular osteotomy technique is reserved for patients who have OSA with a normal, horizontal, soft tissue menton position. The objective is the same as for the inferior sagittal osteotomy—to advance the genial tubercle and genioglossus muscle without disrupting the inferior border of the mandible to improve stability of the hypopharyngeal airway. The soft tissue approach is the same as described for the intraoral genioplasty, except that osseous

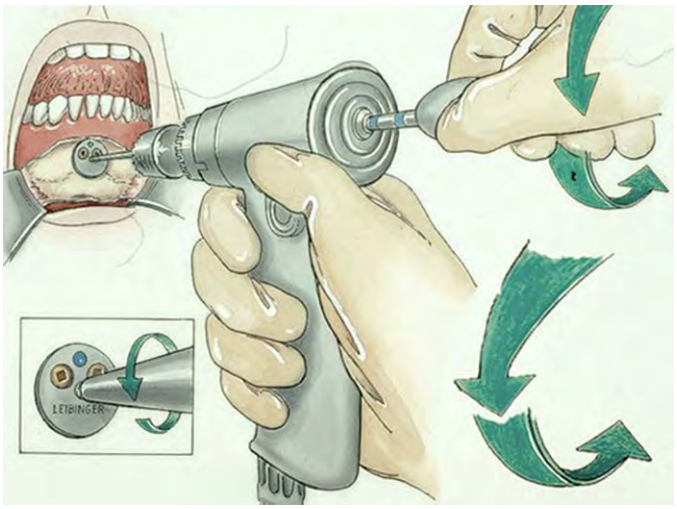

Fig. 13. It is important not to operate the minidriver in reverse or release the guide rod handle, either of which can allow the genioglossus muscle to be avulsed. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

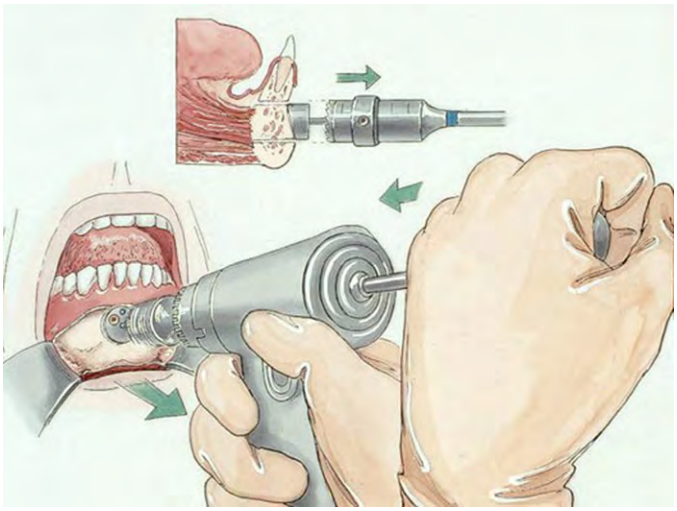

Fig. 14. After completion of the osteotomy, the segment is grasped with bone-holding forceps and the guide rod is removed to free the minidriver. The guide rod is rethreaded and the segment is transpositioned anteriorly full thickness. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

exposure is significantly reduced posteriorly. Periosteal dissection is accomplished posterior to and just distal to the cuspids bilaterally. The mental nerves do not require exposure and neurosensory deficit is minimal. The patient may experience dental-pulp necrosis of the mandibular anterior dentition, and amputation of the cuspid root tips may occur. This complication is treated by endodontic therapy when the tooth is diagnosed as nonvital. The genioglossus muscle attachment is located by lingual palpation. The muscle bundle cannot be palpated through the mylohyoid muscle; however, accurate interpretation of the position of the tubercle can be achieved with the anatomic knowledge that the genial tubercle is approximately 5 to 8 mm inferior to the apices of the mandibular incisors.

A bicortical 2-mm bone screw is placed at the midpoint of the genial tubercle location. A microsagittal oscillating saw is used to complete a rectangular osteotomy, with the screw serving as a central guide for a symmetrical segment that contains the genioglossus muscle (Fig. 4). Care must be taken not to shorten the lingual plate by excessive angulation of the saw during the

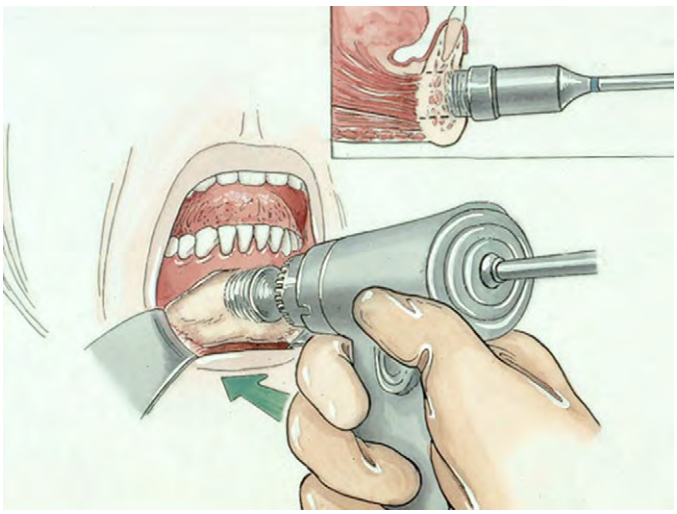

Fig. 15. After completion of the osteotomy, the segment is grasped with bone-holding forceps and the guide rod is removed to free the minidriver. The guide rod is rethreaded and the segment is transpositioned anteriorly full thickness. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

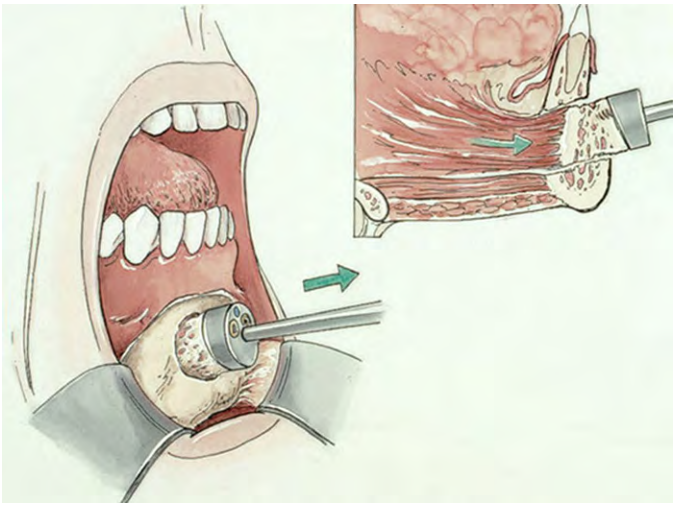

Fig. 16. After completion of the osteotomy, the segment is grasped with bone-holding forceps and the guide rod is removed to free the minidriver. The guide rod is rethreaded and the segment is transpositioned anteriorly full thickness. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

osteotomy, with emphasis directed toward parallel walls of the symphysis osteotomy. The bicortical bone screw ensures mobilization of both cortical plates. If the segment does not mobilize, the lingual osteotomy may not be complete and, with force, the lateral cortical plate could fracture with the medullary bone, leaving the lingual plate intact. A bicortical bone screw placement helps prevent this complication. After mobilization, the segment is transpositioned full thickness anteriorly. The lingual cortical plate is then positioned anterior to the lateral cortical plate and rotated 90°. The medullary bone and lateral cortical plate are osteotomized, which leaves the lingual cortical plate and genioglossus muscle attachment (Fig. 5). The segment is then stabilized with one unicortical 2-mm bone screw placed in an inferior position. The soft tissue closure is accomplished in two layers, and a 0.25-in Penrose drain is placed transmucosally and removed in 24 hours. This drainage reduces seroma formation. A pressure dressing is then placed on the closure for 48 hours.

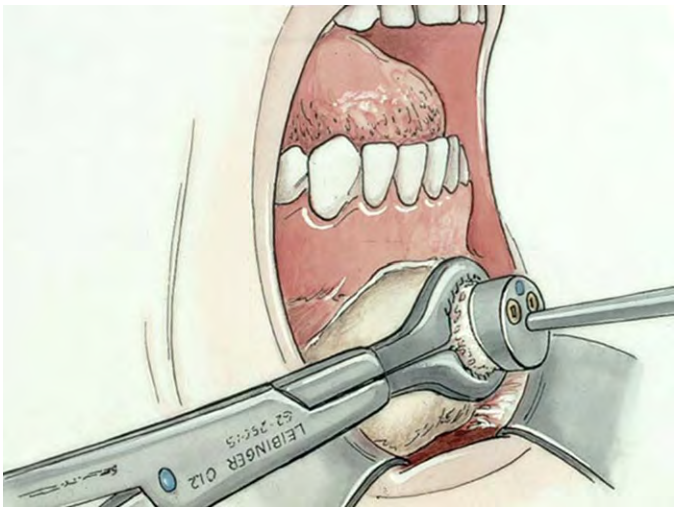

Fig. 17. The segment-holding forceps are then applied to the lingual cortex, and the bicortical screws and guide plate are removed. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

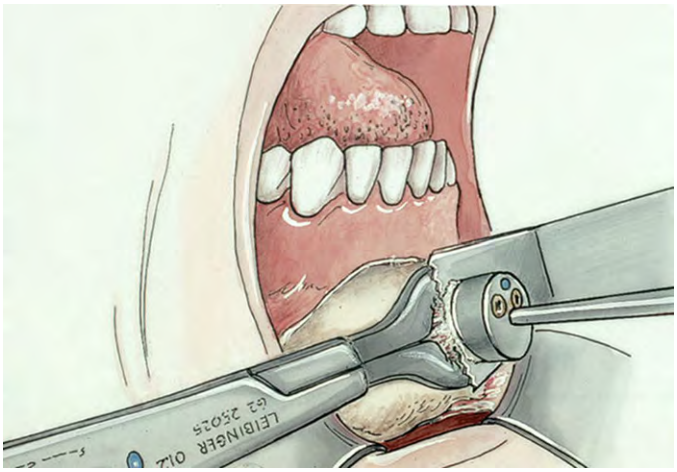

Fig. 18. The medullary bone and lateral plate are osteotomized with an oscillating saw. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

Trephine osteotomy approach

The trephine osteotomy technique was designed to reduce the risk of amputation of the cuspid root apex and simplify the osteotomy design for advancing the genioglossus muscle. The soft tissue dissection is the same as for the anterior mandibular osteotomy technique. The appropriate size template is selected and placed over the lateral aspect of the symphysis at the location for the genial tubercle (Fig. 6). The position of muscle attachment and the location of the soft tissue incisions are measured manually in addition to use of cephalometric measures (Fig. 7). A bicortical hole is drilled and the depth is measured (Fig. 8); the appropriate guide plate is placed and secured with a bicortical screw. The remaining bicortical screw is then placed to secure the guide plate. The appropriate size trephine is placed with the trephine drill stop placed at the indexed depth of mandible thickness (Fig. 9). Direction of the trephine is chosen to ensure that the genioglossus muscle is part of the section advanced to assist opening of the airway (Fig. 10). The guide rod is inserted through the minidriver and threaded counterclockwise into the guide plate (Fig. 11). Attention is directed to completing the trephine osteotomy. Position the trephine osteotomy over the bony segment and initiate the cuts (Fig. 12). It is important

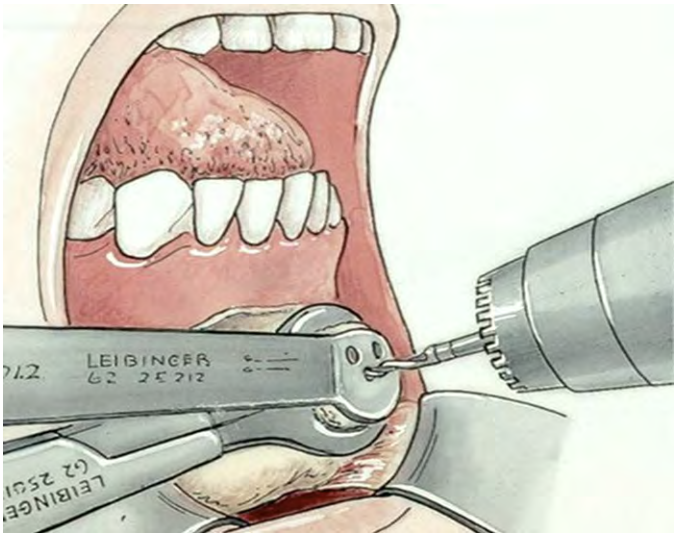

Fig. 19. The template is used to drill and then place a central bone screw. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

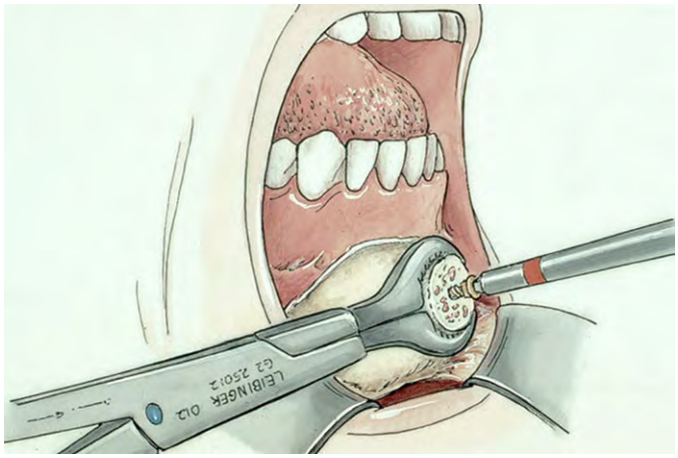

Fig. 20. The screw-holding forceps are placed, and the segment is stabilized with the lingual plate resting in a superior position and overlapping the lateral plate of the symphysis. An elevator placed in an inferior position may be helpful to maintain segment stability and full-thickness augmentation. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

not to operate the minidriver in reverse or release the guide rod handle, either of which can allow the genioglossus muscle to be avulsed (Fig. 13).

After completing the osteotomy, the segment is grasped with bone-holding forceps and the guide rod is removed to free the minidriver. The guide rod is rethreaded and the segment is transpositioned anteriorly full thickness (Figs. 14–16). The segment-holding forceps are then applied to the lingual cortex, and the bicortical screws and guide plate are removed (Fig. 17). The medullary bone and lateral plate are osteotomized with an oscillating saw (Fig. 18). The template is used to drill and then place a central bone screw (Fig. 19). The screw-holding forceps are placed, and the segment is stabilized with the lingual plate resting in a superior position and overlapping the lateral plate of the symphysis. An elevator placed in an inferior position may be helpful to maintain segment stability and full-thickness augmentation (Figs. 20–22). The custom rigid fixation plate is placed, engaging the bone screw into the central groove of the plate. The feet of the plate are secured to the symphysis with bicortical screws, and a lateral screw is placed into the face of the plate to secure the segment (Fig. 23). The central screw is then secured to complete the segment stabilization (Fig. 24). The soft tissue closure is the same as that for the anterior mandibular osteotomy closure, with placement of a transmucosal 0.25-in

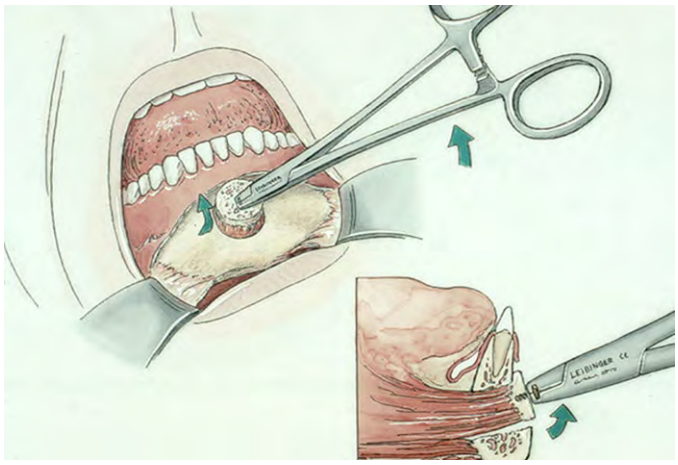

Fig. 21. The screw-holding forceps are placed, and the segment is stabilized with the lingual plate resting in a superior position and overlapping the lateral plate of the symphysis. An elevator placed in an inferior position may be helpful to maintain segment stability and full-thickness augmentation. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

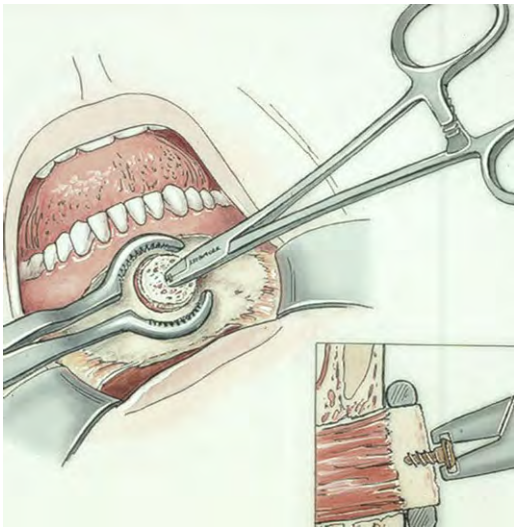

Fig. 22. The screw-holding forceps are placed, and the segment is stabilized with the lingual plate resting in a superior position and overlapping the lateral plate of the symphysis. An elevator placed in an inferior position may be helpful to maintain segment stability and full-thickness augmentation. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

Penrose drain. The drain is removed after 24 hours. Follow-up Panorex and cephalometric radiographs are then obtained (Fig. 25). The patient is placed on antibiotics, steroids, and pain medications.

Summary

OSA syndrome is not only a disease that presents with symptoms that are troubling to the patient and family but also a disease with severe complications that may be life threatening.

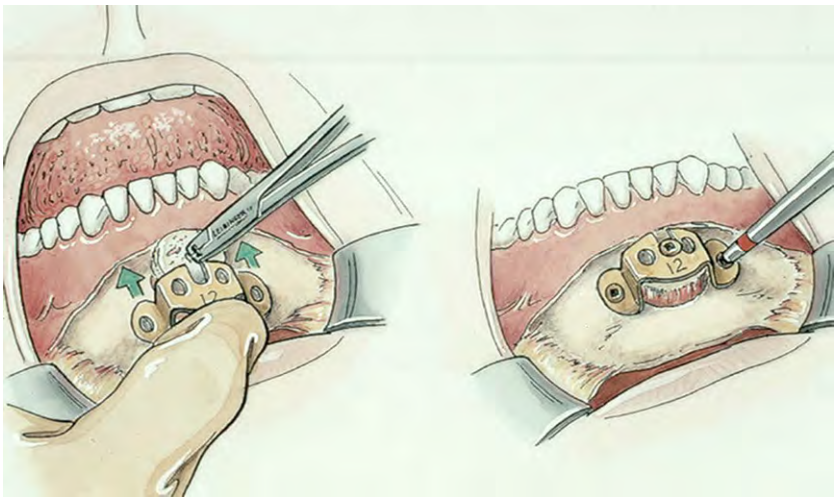

Fig. 23. A customized rigid fixation plate is placed, engaging the bone screw into the central groove of the plate. The feet of the plate are secured to the symphysis with bicortical screws, and a lateral screw is placed into the face of the plate to secure the segment. The central screw is then secured to complete the segment stabilization. (*Adapted from* Lee NR. Genioglossus muscle advancement techniques for obstructive sleep apnea. Oral Maxillofacial Surg Clin N Am 2002;14:377–84; with permission.)

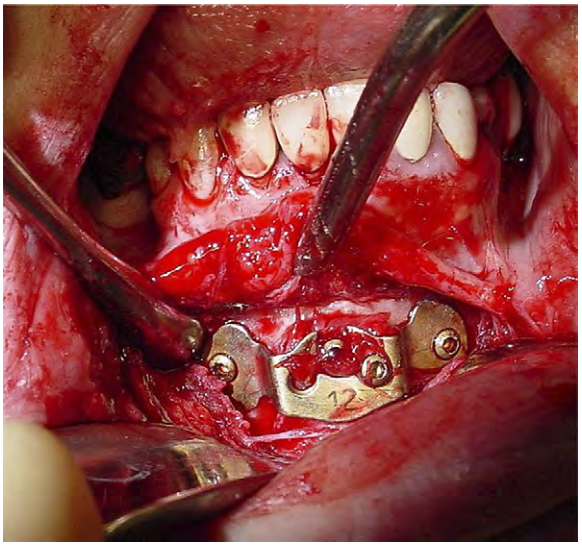

Fig. 24. The customized rigid fixation plate is in its correct position. The soft tissue is closed.

Despite new insight into the causes of the syndrome, treatment modalities remain suboptimal. Nonsurgical treatments are limited by poor patient compliance, whereas surgical procedures have variable outcomes. Proper patient selection and long-term follow-up may increase the effectiveness of the therapies and decrease the morbidity and mortality associated with the syndrome.

Genioglossus muscle advancement is among the many surgical options available to improve upper airway constrictions and, in selected patients, could be of significant value. The risks and complications are far less than those involved with most orthognathic surgery cases. The authors have not experienced complications of osseous segment necrosis. Each author has a different technique as for placement of drainage; some surgeons do not use the drain and cover the patient with proper antibiotic treatment, and some use a short course of steroid therapy. The risk of infection in either situation is low. Another important risk is fracturing the jaw in the symphysis region, which also is low but deserves attention and careful surgical management. Neurosensory changes and dental-pulp necrosis could be avoided by careful dissection and placement of screws and chin plate. A transient hypoesthesia or paresthesia is not uncommon, however, and patients must be informed accordingly.

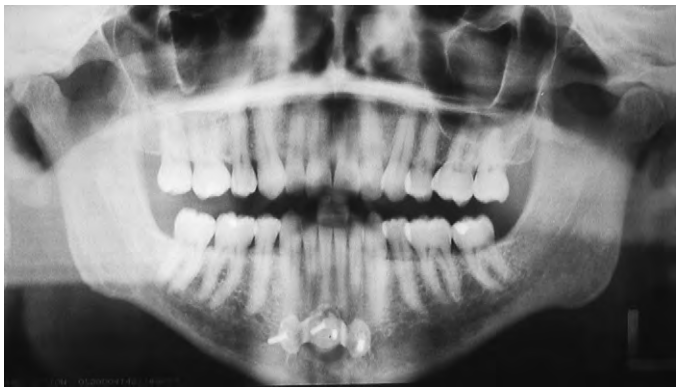

Fig. 25. Follow-up panoramic and cephalometric radiographs are obtained.

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Atlas Oral Maxillofacial Surg Clin N Am 15 (2007) 193–211

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Oral Appliances in the Treatment of Obstructive Sleep Apnea

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Obstructive sleep apnea has become an increasingly more prominent national health concern, with more than 18 million sufferers in the United States. It has been estimated that more than 30 million Americans snore. The snoring population progressively tends to advance into obstructive sleep apnea, with the associated medical risks. As our population ages, the incidences of obstructive sleep apnea for men and women are on the rise. In men older than age 65, 28% have sleep apnea. Daytime sleepiness is common among 60% of the American population, the result of which is an increase in accidents, injuries, and other risks. Sleep disorders and sleep deprivation take their toll on public health, at a cost annually to the national health care bill of more than $16 billion. Other estimates of the indirect costs of sleep disorders are $41 billion per year from lost productivity, $22 billion per year from motor vehicle accidents, $7 billion per year in work-related accidents, and $4 billion per year in home and public accidents. The prevalence of sleep apnea currently ranks equivalent to diabetes and asthma.

Signs and symptoms of obstructive sleep apnea include a chronic history of loud snoring, daytime fatigue, daytime sleepiness, morning/awakening headaches, decreased sex drive, poor memory, personality changes, breathless awakenings, limb jerkiness, witnessed sleep disruption events, gasping and shortness of breath, and labored noisy breathing. Up to 50% of patients who have sleep apnea have high blood pressure, and there is a direct correlation between this disease entity and heart attack, stroke, and cardiovascular disease. Snoring and obstructive sleep apnea can be eliminated or controlled in many of these patients by the use of oral appliances.

The diagnosis of obstructive sleep apnea (ICD-9 code 327.23) is based on an overnight polysomnography test. A full sleep study incorporates numerous measurements to assess type of sleep, depth of sleep, amount of REM sleep, oxygen desaturation, and absence of breathing. Cardiac, ocular, respiratory, and electroencephalogram/brainwave measurements are integrated. Respiratory distress is categorized by frequency and duration of the cessation of airflow. Diagnosis should come through a certified sleep center. A baseline polysomnogram must be done with accurate diagnosis before dental intervention for obstructive sleep apnea treatment. The baseline oxygen saturation is contrasted to the lowest oxygen saturation event. Changes in oxygen saturation above 4% with a 30% decrease in airflow are recorded as hypopneas. An 80% or more reduction in airflow for 10 seconds or longer is recorded as an apneic event. An apnea/hypopnea index is derived from the number of apneas and hypopneas per hour. A score of 10 to 20 is indicated as mild apnea, a score of 20 to 40 is considered moderate, and a score of 40 or more is considered severe. Other alternative statistics have indicated 5 to 15 events per hour as mild obstructive sleep apnea, 15 to 30 as moderate, and 30 or more as severe.

The goal of therapy, whether surgery, continuous positive airway pressure (CPAP), or oral appliance, is to significantly impact oxygenation and reduce the apnea/hypopnea index. Success rates of oral appliances tend to be higher in the mild to moderate index level compared to the

Statistical sources for this article include American Academy of Sleep Medicine, American Sleep Apnea Association, National Sleep Foundation, and Academy of Dental Sleep Medicine.

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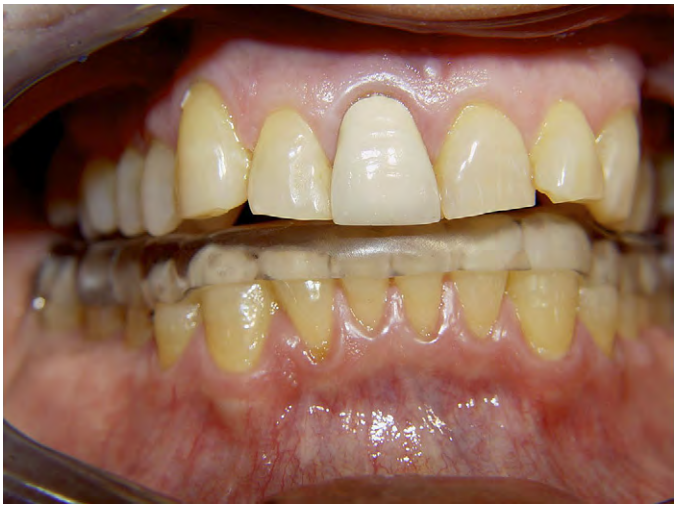

Fig. 1. TMJ splint.

severe level. A survey of literature from 1995 to 2000 by the Academy of Dental Sleep Medicine indicated that oral dilator appliance success rates averaged as follows: mild obstructive sleep apnea, 76%; moderate obstructive sleep apnea, 61%; and severe obstructive sleep apnea, 40%. More advancement of the mandible generally produced a more favorable outcome. Self-reported compliance with mandibular repositioning devices after 3 years was high at 70% to 90%. Follow-up sleep testing is usually not indicated for patients with primary snoring as a diagnosis.

The use of oral repositioning appliances for the treatment of obstructive sleep apnea has gained wide acceptance among the medical/dental sleep disorders community. The 1999 publication of the American Academy of Sleep Medicine [1] clearly indicated the use of oral appliances as part of the protocol for management of mild to moderate sleep apnea. The most recent protocol publication was entitled ''Practice Parameters for the Treatment of Snoring and Obstructive Sleep Apnea with Oral Appliances: An Update for 2005'' [2]. Salient features of this publication standard indicated that oral appliances should be fitted by qualified dental personnel trained in temporomandibular joint (TMJ), dental occlusion, and associated structures who have had serious training in sleep medicine and sleep-related breathing disorders. Oral appliances should be placed by a dental specialist who is well versed in dental sleep

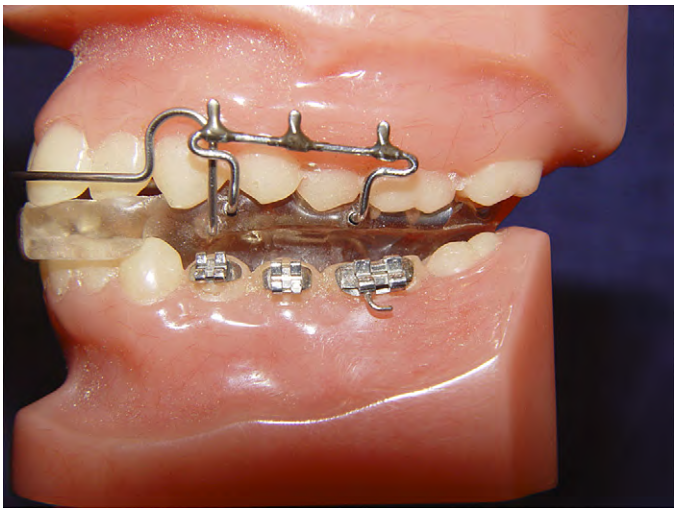

Fig. 2. BioCorrector TMJ/jaw repositioning splint.

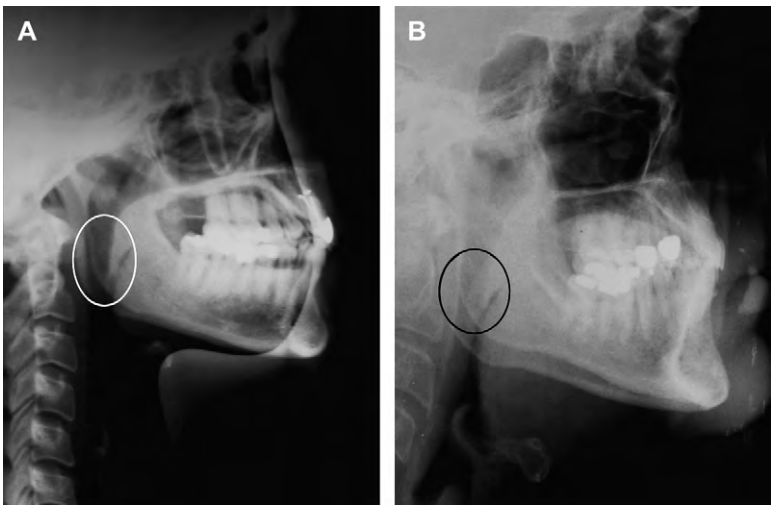

Fig. 3. Airway space. (*A*) Normal. (*B*) Narrowed-constricted.

medicine procedures. Periodic follow-up visits are necessary once patients have been provided with sleep apnea oral appliances.

Treatment for obstructive sleep apnea includes weight loss, nasal CPAP, surgery, and oral appliances. Oral appliances are indicated as a primary treatment mode for mild to moderate sleep apnea. In cases of severe sleep apnea, oral appliances may not be as efficacious as CPAP devices. It is more difficult to predict oral appliance outcome with higher body mass index (eg, >30). Where CPAP failure and intolerance are involved, however, oral appliances can be considered for more advanced cases of obstructive sleep apnea. In such cases, they should have adjustability and be carefully titrated. The consideration of upper airway surgery, including removal of tonsils and adenoids, may take precedence over oral appliances. An otolaryngologic evaluation is essential. Craniofacial distortions and airways that are compromised because of severe class II retrusions or retrognathias also may be indications for surgery.

The other 2006 position paper in *Sleep* [3] involved the assessment and statistical analysis of more than 25 different oral appliances used in the treatment of snoring and sleep apnea. The American Academy of Sleep Medicine recommended oral appliances as the primary treatment for mild to moderate sleep apnea. It recommended CPAP for more severe apnea cases. Mandibular advancement devices, or oral appliances, are the most commonly used devices. Most appliances on which extensive research has been conducted have been mandibular advancement-type

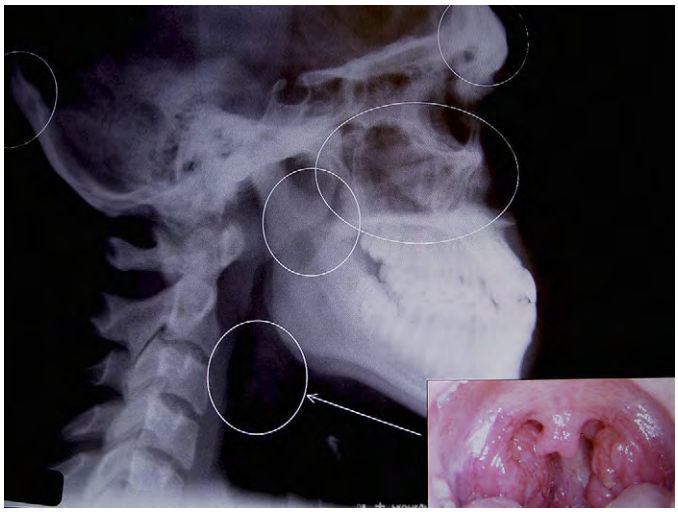

Fig. 4. Obstruction sources.

Fig. 5. Adjustable Therasnore.

devices. Tongue retaining devices also have been cited, as have palatal lift appliances, but indications for tongue retaining devices are more restrictive. Palatal lift appliances are rarely used because of difficulties with gag reflex.

The current considerations of oral devices for airway dilation include comfort, durability, laboratory processing precision, adjustability, types of connectors and attachments, and amount of TMJ repositioning. Also to be considered are tongue room, head posture, lip seal, forward protrusion variability, vertical adjustment variability, and ability to allow increments of nighttime lateral jaw movement. Currently, more than 70 different types of appliances are being used by the dental profession. This article features several of the more common ones with which the author has had experience. The appliances featured have appeared in recent scientific literature and scientific dental sleep medicine meetings whose clinical trials have proved efficacious. Factors that affect the success of a nighttime oral appliance include TMJ stress, bruxism/clenching, fit of the appliance, soft and hard tissue comfort, ability for adjustments, adaptability of the TMJ, and oral reflexes and tongue space.

Patients who have myofascial pain disorder are often provided occlusal stabilization splints. Patients with TMJ dysfunction and joint displacement often have posterior condylar positioning and anterior disk displacement. Often these patients are provided with a nighttime repositioning splint to decompress the jaw joint and rotate the mandible forward (Fig. 1). Initially such a splint

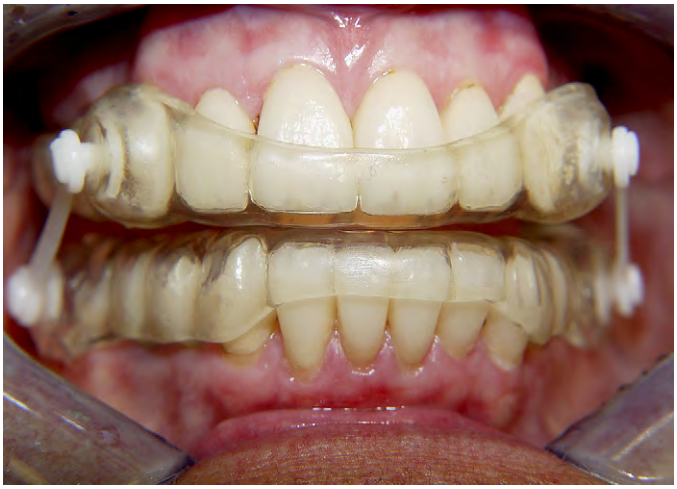

Fig. 6. Silent Night Transitional.

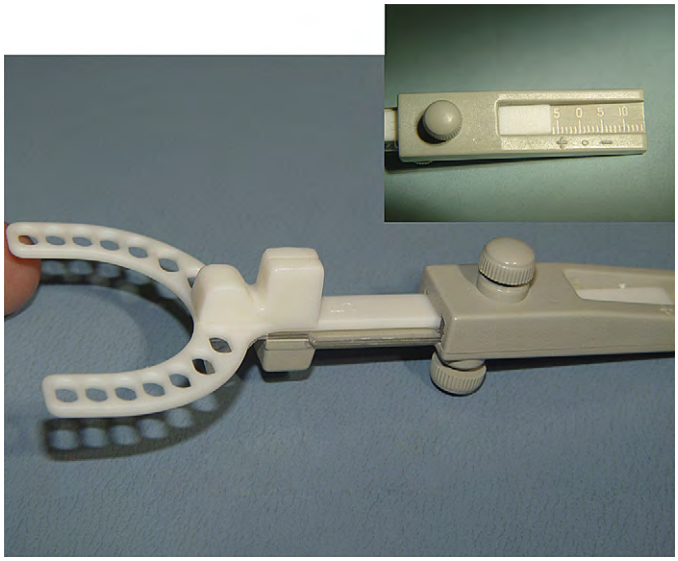

Fig. 7. George Gauge.

may be prescribed for all day and night use, with gradual reduction to long-term night use. Subsequent to splint therapy, the patients' jaw position may need to be stabilized by orthodontics or orthopedic eruption after mandibular advancement. The Biocorrector type appliance, as designed by Terry Spahl, DDS, and John Witzig, DDS (Fig. 2), allows for arch eruption biomechanics and the positioning and settling of the occlusion. An Invisalign or Orthoclear retainer series also may be used for occlusal stabilization. The oral appliance design for airway dilation, by contrast, usually requires considerably more mandibular advancement than in TMJ therapeutic positioning.

In the dental examination, the size and shape of the tongue and competency of maxillary and mandibular arches are important to note. The examination must include the oropharynx and retropharyngeal tissues, including blockage of the airway by the tonsils. Included in the

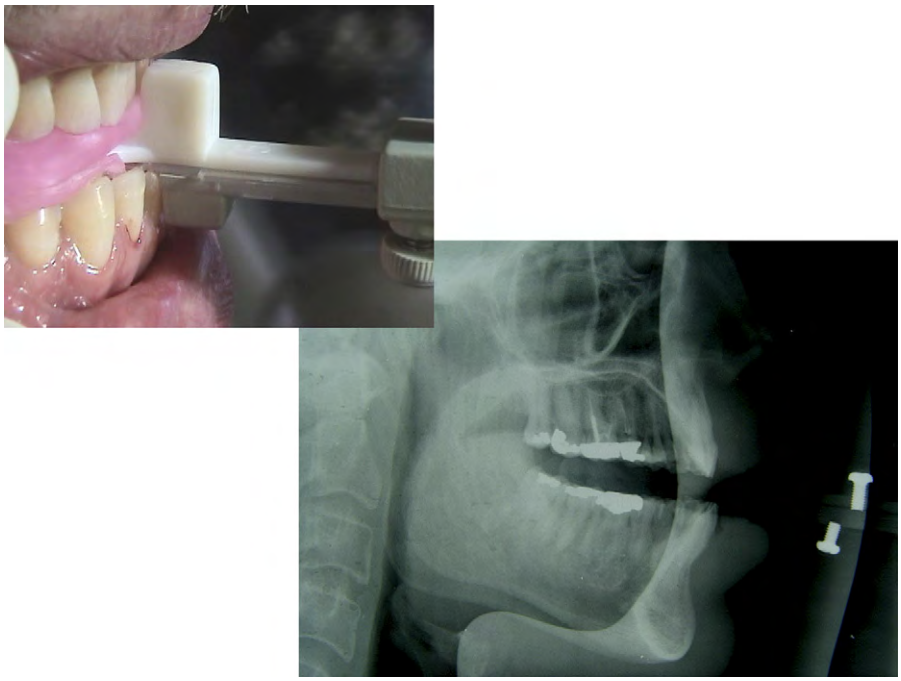

Fig. 8. George Gauge with lateral cephalometric radiograph. Mandibular repositioning at 70% protrusive.

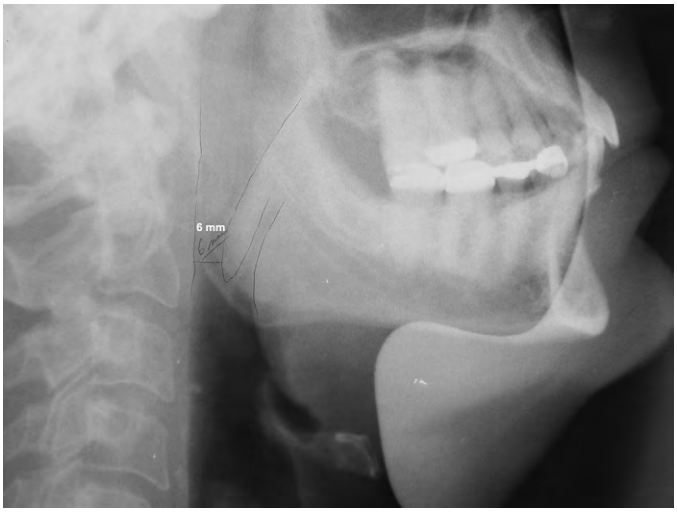

Fig. 9. Baseline: narrow PAS of 6 mm.

assessment should be a standard panoramic radiograph and cephalometric airway radiographs (Fig. 3). Viewing the lateral head plate/cephalogram includes soft tissue assessment, tongue space, and airway shape. Is the area normal or constricted? Sources of airway obstruction (Fig. 4) include nasal passage restriction, deviated septum with enlarged turbinates, and adenoids. Retropharyngeal narrowing may include bulky tonsillar tissue, pillar restriction, and a hypertrophied uvula. The base of the tongue may be enlarged. Tongue scalloping and crenations, which reflect restriction, may indicate that the dental arch size is too small. This is an indication for orthodontic arch expansion as a treatment potential. From a growth and development standpoint, the prevention of future sleep apnea and respiratory complications can be accomplished with the ideal development of the dental arches, which should allow maximal room for the tongue, nasal passages, and breathing volume.

The use of a transitional appliance may be indicated as a test device to determine the suitability of the patient for a longer term laboratory processed appliance. Does the patient have a successful history of wearing other dental night appliances? The transitional appliance may be used during dental reconstruction procedures, with the ability to realign as different crowns are modified or as restorative dental work is in progress. The Adjustable Therasnore (Distar Dental, Albuquerque, NM) is one such device (Fig. 5). The upper and lower preformed splints are softened in hot water, quickly cooled, and placed in the mouth for shaping. The appliance's

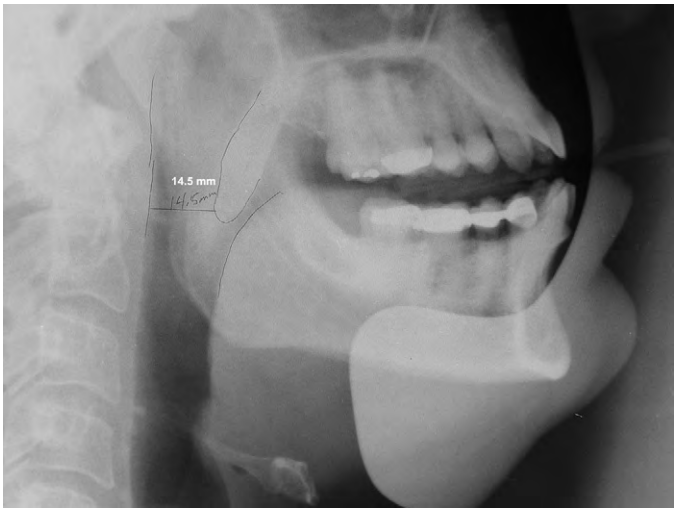

Fig. 10. Seventy-five percent protrusion increased PAS to 14.5 mm.

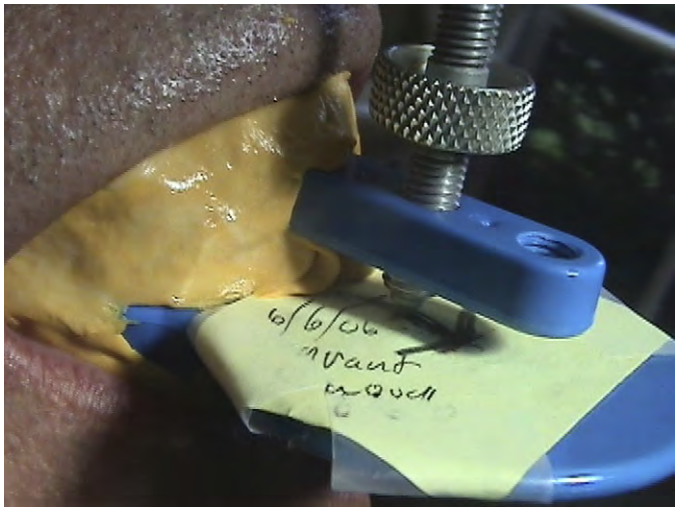

Fig. 11. Gothic arch tracing 70% of protrusive path.

preformed splints also can be adapted on dental study casts and articulated into a selected closed protrusive position. The appliance can be adjusted forward incrementally along a preformed track. There is no lateral movement capability. Such an appliance can be used as a trial for patient adaptability and compliance issues. Some of the problems with transitional appliances are potential bulkiness, durability, and adjustability.

The typical use of transitional appliances is for a 6-month period. The Snorefree (Space Maintainers Laboratory, Chatsworth, CA) mouth guard is another transitional appliance that can be provided in the office. It features a soft elastomeric material that has a placement holder, which upon removal becomes an oral vent. Another transitional appliance that may last up to 1 year is the Silent Night (Glidewell Dental Laboratory, Newport Beach, CA) anti-snoring device (Fig. 6). The appliance provides a thin, hard outer shell with a soft inner liner for upper and lower splints. It has lateral nylon struts and grommets with a mandibular protrusion capability. It uses 21- to 24-mm long connectors. The mandible can be advanced sequentially. The grommet attachments into the splint framework, however, are somewhat susceptible to strain and can require frequent replacement. The appliance is comfortable and appropriate for the initial trial.

The George Gauge (Great Lakes Orthodontic Lab, Tonowanda, NY) measures mandibular protrusion motion (Fig. 7). The lower incisal position at centric occlusion is compared with the

Fig. 12. Silencer.

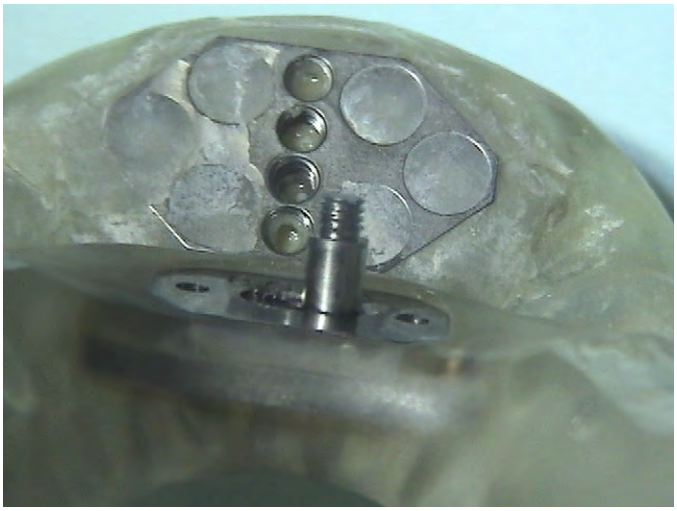

Fig. 13. Heavy-duty 1.5 mm pin and maxillary retaining box for bruxers.

measurement at maximal protrusion. The typical therapeutic position is at approximately 60% to 80% of the total protrusive pathway of the mandible. Mandibular repositioning with the use of the George Gauge involves testing the mandibular advancement. At chairside, observe the patient's breathing in the supine position. The repositioning can be assessed via airway dimension analysis from a lateral cephalometric tracing (Fig. 8). Wax or vinyl material may be placed around the bite fork to register the appliance positioning, along with the dental casts/models for laboratory oral appliance prescription.

The lateral cephalometric head plate is an important visual tool for assessing the benefit of an oral appliance for airway dilation. Cephalometric assessment (Fig. 9) shows the lateral radiographic view, in centric occlusion, of the nasopharynx and oropharynx in a moderately restricted patient. The posterior airway space measures 6 mm. The same patient is shown with 75% repositioning (Fig. 10), which indicates the airway structures and dimensional changes. Most notable is the increase of posterior airway space to 14.5 mm, with the movement of the soft palate uvula and tongue downward and forward. It should not be expected that all patients will show such a dramatic change, but the cephalometric approach is one more useful tool in oral airway assessment. Another tool for airway volume assessment is acoustic reflection via the Eccovision Pharyngometer (Hood Laboratories, Pembroke, Massachusetts), which can provide a computerized graphic analysis of oral airway size, shape, and flow changes.

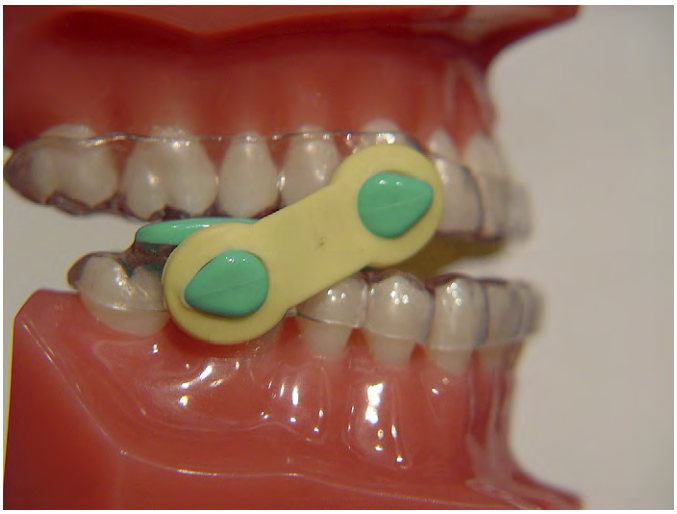

Fig. 14. Elastomeric mandibular appliance.

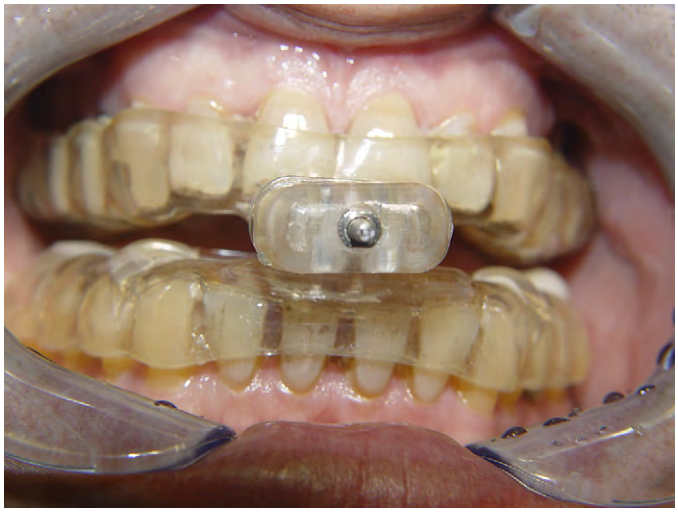

Fig. 15. Thornton adjustable positioner (TAP).

The Gothic Arch Tracer (Silencer International Products, Surrey, BC) (Fig. 11) is another instrument for measuring and recording jaw three-dimensional repositioning. It relates the forward and lateral pathways of the mandible in full excursions. The marking register is placed along the protrusive pathway at approximately 65% to 70% of the forward path from centric occlusion. This placement usually represents the second hole of five holes in the Silencer hinge. It represents the starting point of the long-term appliance at laboratory processing. The position is locked in; the upper and lower relationship is recorded in polyvinyl impression material. The Silencer was developed by Wayne Halstrom, DDS, of Vancouver, BC. It features a titanium precision attachment connecting hinge (Fig. 12). The upper and lower splints are connected by a titanium pin, which can be placed at five anterior/posterior settings (Merlin Dental Laboratory, Scottsdale, AZ; Professional Dental Arts, Lincoln, NE; John's Dental Laboratory, Terre Haute, IN). The Silencer's precision attachment has a lower mounting box that allows the connector pin to slide laterally 3 mm to the left and 3 mm to the right. The pin also has 1 mm of vertical release. The titanium pins, in heights of 5 to 10 mm, are screw-threaded to the maxillary plate. The standard Silencer titanium pin can be replaced by a thicker attachment if the patient demonstrates breakage from persistent clenching and bruxism. Standard pins of 1-mm thickness can be replaced by 1.5-mm pins (Fig. 13) along with the use of a replacement mounting box for the maxilla, which has four insertion holes 2.5 mm part.

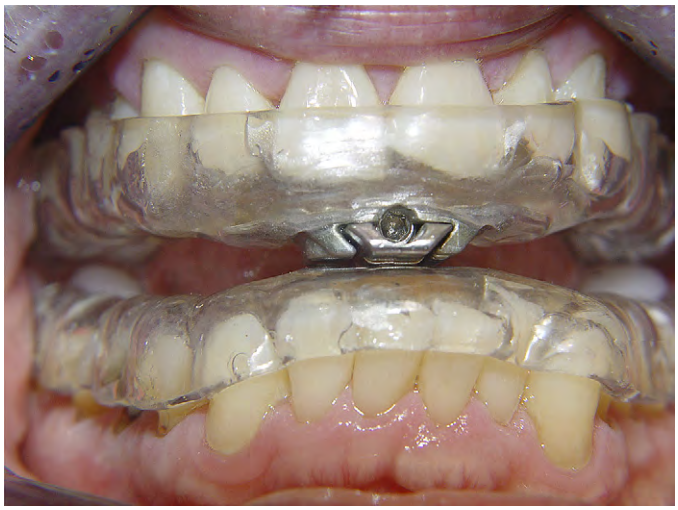

Fig. 16. TAP II appliance.

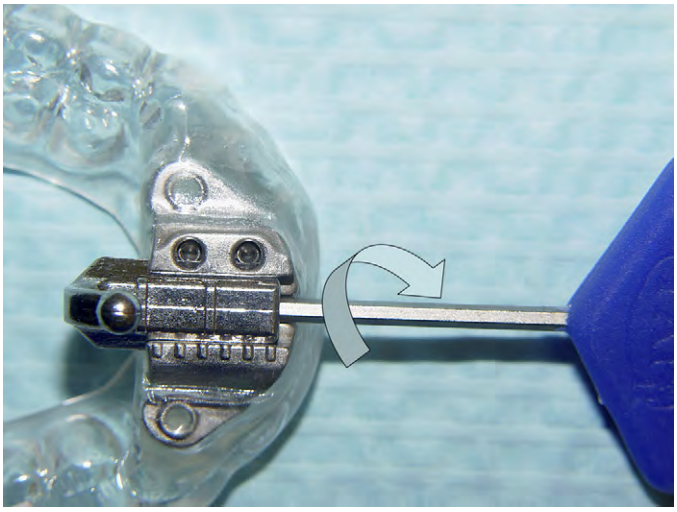

Fig. 17. TAP II turnkey.

The Elastomeric Mandibular Appliance (Merlin Dental Laboratory; John's Dental Laboratory) (Fig. 14) was developed by Donald Frantz, DDS, of Tacoma, Washington. The appliance consists of two splints connected by variable length removable elastics. There are 13 different elastic modules with different lengths and thicknesses. The posterior occlusal support pads can be modified for vertical changes.

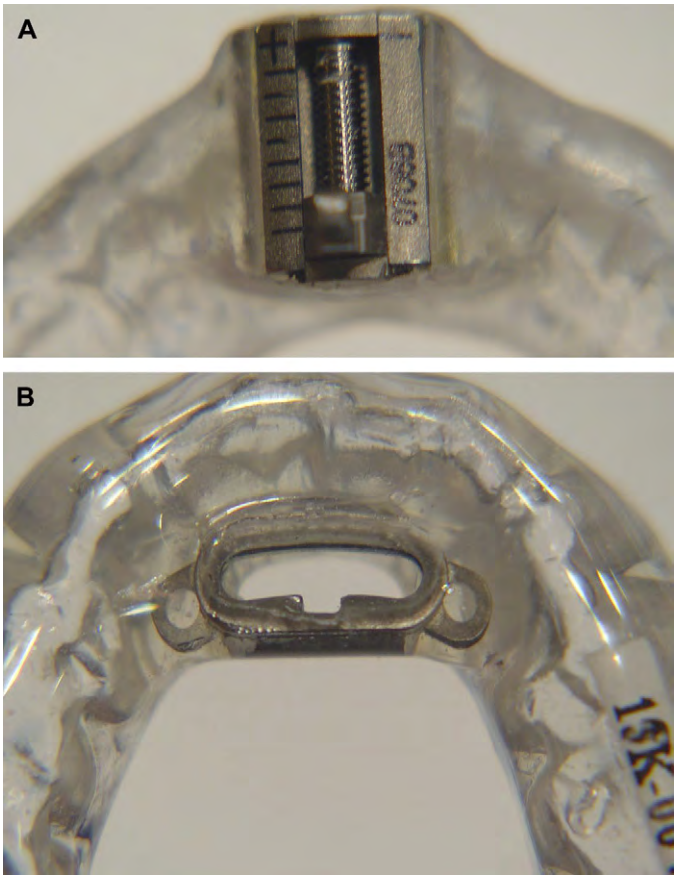

Fig. 18. TAP T. (*A*) Maxillary splint. (*B*) Mandibular splint.

Fig. 19. Klearway appliance airway dilator for sleep apnea.

The Thornton Adjustable Positioner (TAP) (Airway Management Laboratories, Dallas, TX) system of appliances was developed by Keith Thornton, DDS, of Dallas, Texas. The TAP (Fig. 15) consists of an upper and lower splint connected by a twist screw mechanism. The appliance engages the mandibular splint with a hook and bar attachment. The twist screw mechanism attaches to the maxillary component. Each 180° clockwise turn allows for 0.25-mm incremental advancements. Such an appliance design, with its external adjustment mechanism, allows not only patient adjustment but also advancement by the sleep laboratory technician on follow-up study. The TAP II appliance (Fig. 16), developed by Dr. Thornton, eliminated the extraoral adjustment mechanism. Posterior support pads can be added to provide a tripod stabilizing effect. The screw turnkey attachment featured in this design has a ''ball and trailer hitch'' connection. The use of a turnkey (Fig. 17) allows for 0.167-mm incremental advancements up to a total of 12 mm.

The TAP T (Glidewell Dental Laboratories; Airway Management Laboratories) titanium appliance is a third-generation attachment that allows greater lateral flexibility while providing 0.25-mm incremental changes. A twist key is inserted by the patient or clinician and the appliance is advanced in stages. The TAP T has a 12-mm advancement measuring gauge in the maxillary framework. The lower titanium assembly allows for lateral movement in which the maxillary pin/guide drops into the mandibular attachment opening (Fig. 18).

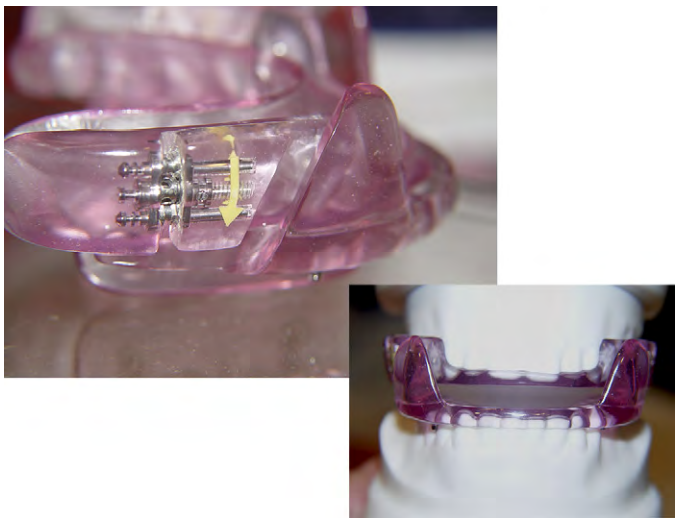

Fig. 20. SomnoMed.

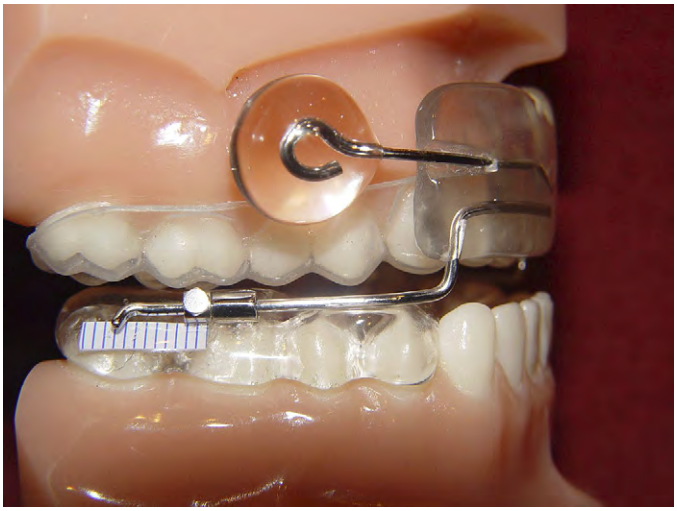

Fig. 21. OASYS (Space Maintainers Laboratory, Chatsworth, California; John's Dental Laboratory, The Barnes Group Inc., West Palm Beach, Florida).

The Klearway (Great Lakes Orthodontic Laboratory) appliance was developed by Alan Lowe, DDS, of the University of British Columbia. It uses an orthodontic expansion screw soldered to a palatal framework to advance the mandible (Fig. 19). Appliance retention is secured with ball clasps. The anterior framework bars attach to a sliding tube, which allows lateral movement and slight stretch opening. The connection tube slot is at the cuspid level, which engages the upper body wire. The appliance allows for significant freedom of movement.

The SomnoMed (SomnoMed Inc., Denton, TX) mandibular advancement splint appliance was developed by Peter Cistulli, DDS, of New South Wales University, Australia (Fig. 20). This appliance allows for opening and closing by way of the frictional attachment against an adjustable wedge, which is located on the buccal segment of the appliance. There is bilaterally an adjustable screw plate, which is an angulated flange or fin that holds the jaw forward. It can be adjusted in 0.25-mm increments.

The OASYS (Space Maintainers Laboratory, Chatsworth, California; John's Dental Laboratory, The Barnes Group Inc., West Palm Beach, Florida) oral airway nasal system was developed by Mark Abramson, DDS, of Redwood City, California. The appliance design maximizes room for the tongue, particularly in the anterior portion. The splint connectors are placed on the buccal segments (Fig. 21). The appliance consists of a thin splint against which a facial flange or foil is engaged to hold the mandible forward. The flange can be moved forward or backward

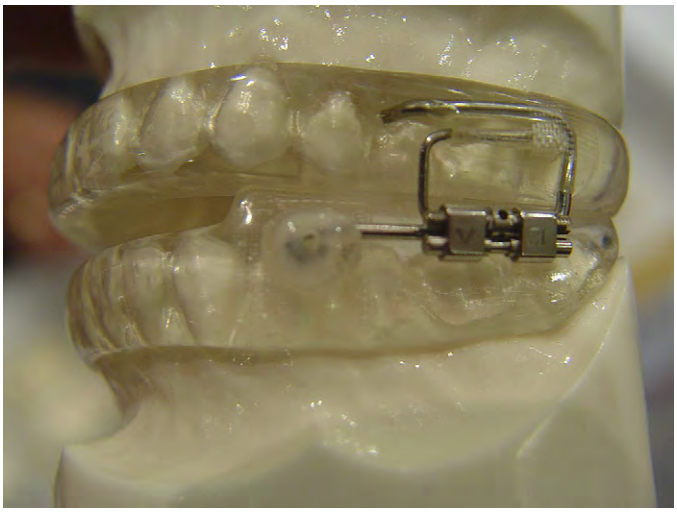

Fig. 22. PM Parker positioner.

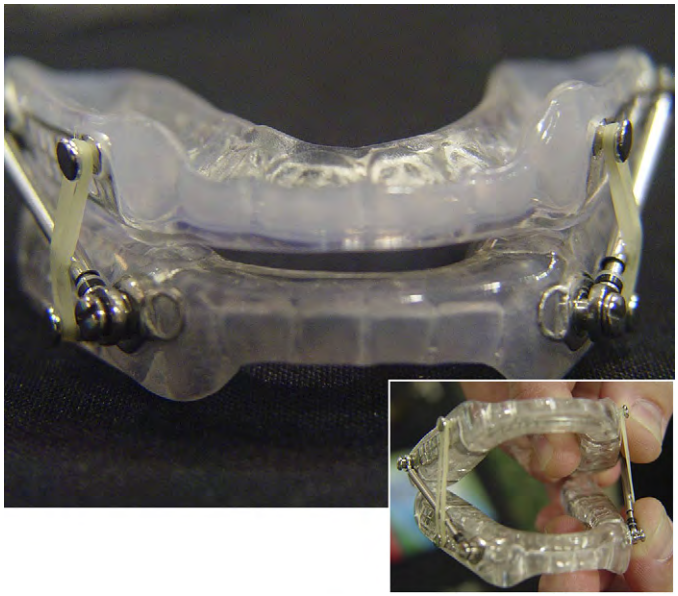

Fig. 23. Strong upper airway appliance.

with a wire attachment into the tube slot. A lateral view of the OASYS appliance shows the upper flange attachment to the lower body support wire and locking screw, which is adjusted to slide the lower splint forward. The labial button at the upper cuspid/bicuspid region is designed to open the nasal valve by drawing the orofacial musculature away from the nares. This specific design provides for greater nasal airflow, coupled with airway enlargement by mandibular advancement.

The PM Positioner (Davis Dental Lab, Wyoming, Michigan, Great Lakes Orthodontics Laboratory, Tonawanda, New York) was developed by Jonathan Parker, DDS, of St. Louis Park, Minnesota (Fig. 22). The maxillary and mandibular splints are connected by a buccal orthodontic expander. The appliance allows for lateral movement with a buccal air pocket compartment housing the lower wire attachment. The screw mechanism provides for incremental mandibular advancement.

The SUAD Strong (Strong Dental Laboratory, Detroit, MI) upper airway device was developed by Jonathan Strong, DDS, of Leamington, Ontario, Canada. The appliance design features an adjustable buccal arm/telescope (Fig. 23). This Herbst-type of design is adjustable, with a metal O-ring inserted around the lateral tube and telescope. The devices come in 0.5- and

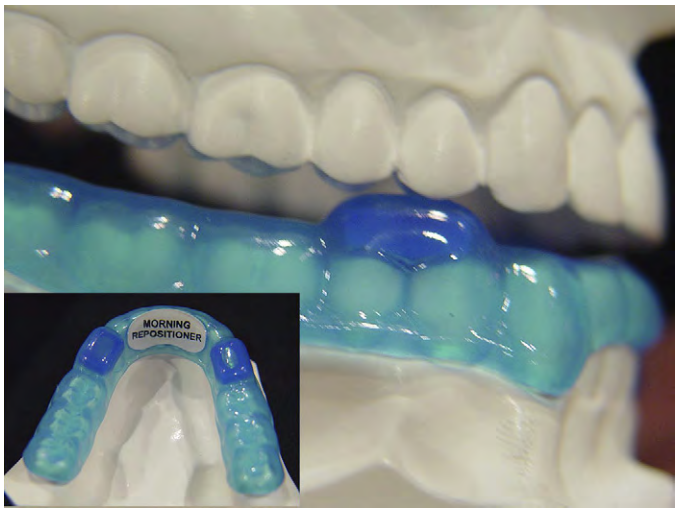

Fig. 24. Morning repositioner.

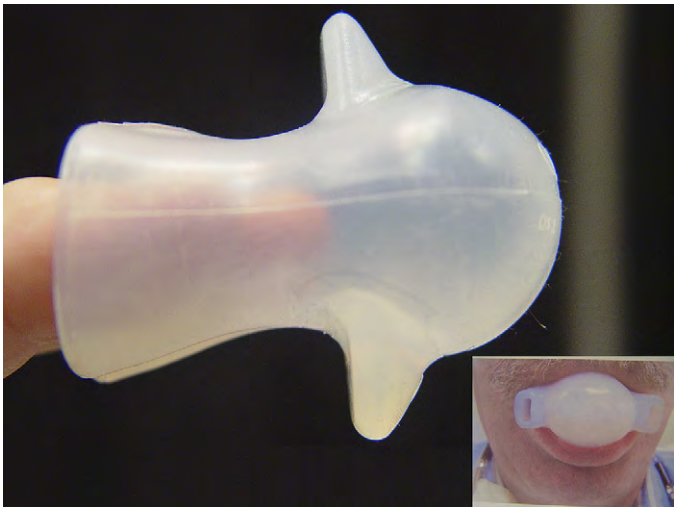

Fig. 25. Tongue retaining device.

1-mm widths. The internal Vitallium framework supports the stability of the appliance and is appropriate for patients who have severe bruxism. The SUAD provides gentle distraction on opening, which is provided by vertical elastics. Room for the tongue is provided. Lateral movement is provided in the design to a minimal extent. The inner liner is a softer, thermally sensitive material, whereas the outer shell is made of hard, processed acrylic. The metal casting framework is the substructure. The patient can yawn and sip liquids, with closure occurring via the elastic traction.

Various exercisers can be used to help reorient the mandible after the removal of the appliance. Typically after 8-hour appliance use during the night, the jaw has accommodated to the forward position. Often the occlusal contacts are more toward the incisal region, with the bite ''open'' in the posterior region, which is caused by distraction and fluid/ligamentous changes of the TMJ from the advancement. Exercises are recommended, such as with the use of the Morning Positioner (Strong Dental Laboratory) (Fig. 24). To encourage the jaw to settle in the ''up and back'' position, exercises should be done, such as squeeze closure, chewing gum, or biting on a soft vinyl exerciser to reposition the jaw. Use of a Leaf gauge, vinyl bite wafers, or the soft cuspid pivots, as in the Morning Positioner, is advised. Exercises should be done over a 5-minute period upon removal of the oral appliance.

Tongue retaining devices (Fig. 25) have been used for some time and were first developed 45 years ago by Rosalind Cartwright, MD, of Chicago, Illinois. The tongue retaining device

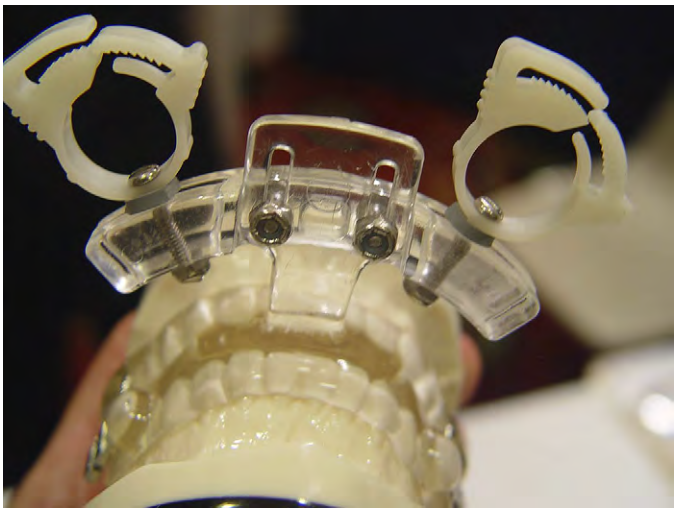

Fig. 26. CPAP Pro nasal oral attachment.

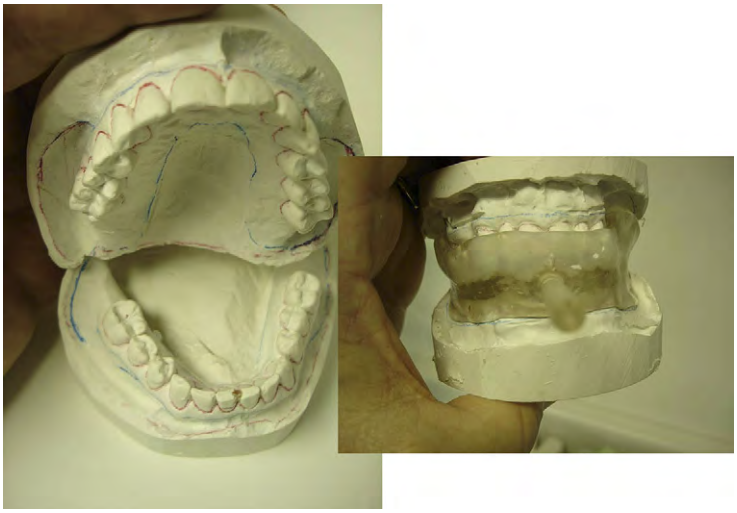

Fig. 27. JPAP Jeppesen system: oral orthosis component.

features an oral bulb that draws the tongue forward with negative pressure. Lateral flanges are set outside the oral periphery at the edge of the lips to hold the device in place. The appliance is indicated in edentulous cases in which a mandibular repositioning appliance cannot be used successfully. The most recent design modifications in this area have been by Michael Alvarez, DDS, of Fremont, California and Arthur Strauss, DDS, of Falls Church, Virginia. A custom tongue retaining device may include air suction vents. The maxillary and mandibular splint components are integrated together to allow at least a 12-mm vertical interincisal opening. Measurements of tongue size can be taken along with wax bite repositioning for laboratory fabrication. The appliance is not adjustable. The problems that can be anticipated with this type of appliance include tongue soreness and redness. It is, however, a viable alternative when there are periodontal involvement issues, looseness of the teeth, and partially edentulous retention problems.

The use of the CPAP-Pro (Space Maintainers Laboratory) nasal oral attachment (Fig. 26) provides a method of attaching the intraoral appliance to the nasal assembly. Particularly with patients who have more advanced severe sleep apnea, a combination of oral appliance and CPAP often can be beneficial and necessary. After clinical trials, particularly with a patient who has severe sleep apnea, the oral appliance still may not reach an acceptable result (in apnea/

Fig. 28. JPAP nasal attachment to oral component.

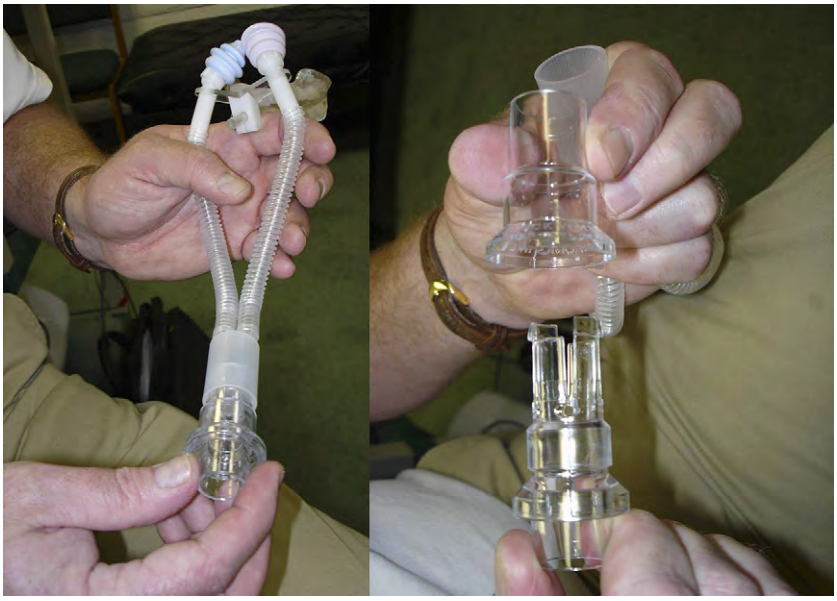

Fig. 29. Breathing tube assembly.

hypopnea index reductions). The combination of oral appliance use and CPAP usually results in being able to reduce the effective CPAP to a more tolerable volume. A mandibular advancement device may be coupled with an oral attachment to the nasal CPAP. Such a device is available with a bite fork attachment, the CPAP Pro. It is bonded interocclusally to the splints. The sliding framework allows adjustment of the breathing tubes and nasal pillow positions and provides clasps for position modification.

The JPAP (JPAP Laboratory, LLC, Ventura, California) is one of the latest innovations combining CPAP and an oral airway appliance (Fig. 27). It was developed by John Jeppesen, DMD, of Ventura, California. A full-bodied impression, including hamular notch and deep vestibular tissue, is necessary to seal the oral periphery. The jaw registration position is done via neuromuscular jaw relaxation transcutaneous electrical neutral stimulation without significant forward protrusion. The amount of jaw protrusion is minimized. The nasal attachment for CPAP is via a rod that is embedded in the oral prosthesis. This design reduces the amount of mouth breathing to a minimum. The appliance design in the JPAP system includes nasal pillows (Fig. 28), which swivel on attachment wings of the assembly. Shown is the oral/CPAP interface. The nasal CPAP tubes extend from the nasal pillows to a coupling sleeve, which inserts into the CPAP machine breathing tube assembly (Fig. 29). The JPAP oral obturator is a ''pneumodontic'' device and is particularly applicable to patients who have severe obstructive apnea and need CPAP. Orthodontic development of the maxilla and mandible during adolescence is critical in preventing the narrow airway typically seen in the adult sleep apnea profile. The Homeoblock Appliance System has recently been used to improve airway volume via orthodontic expansion of the adult dental arches. Developed by Theodore R. Belfor, DDS, and G. Dave Singh, DDSc, PhD, the appliance is used at night or 10 hours out of 24 to improve tongue room and unravel the crowded dentition. The removable functional device incorporates Adams' clasps, flap springs, an expansion screw, Hawley labial bow, and unilateral biteblock (Fig. 30). The expansion screw is usually advanced .25 mm per week. Over a period of months, the dental arches can accommodate better tooth form and tongue function. Daytime wear is not necessary. Critical to this appliance is the before vs. after measurement of airway space by cephalometric analysis or acoustic pharyngometry. A clinical case example of such a change is attached (Fig. 31), from cephalometric tracing. Typically subjective improvement of apnea/snoring will occur within a few months, besides the visual change in dental arch shape and teeth position. The appliance can be used as long-term retainers. The objective measurement of respiratory improvement via home monitoring (pulse oximetry, apnea/hypopnea index) or follow-up polysomnography sleep study is advised. This may be one year after beginning the Homeoblock therapy. If a severe

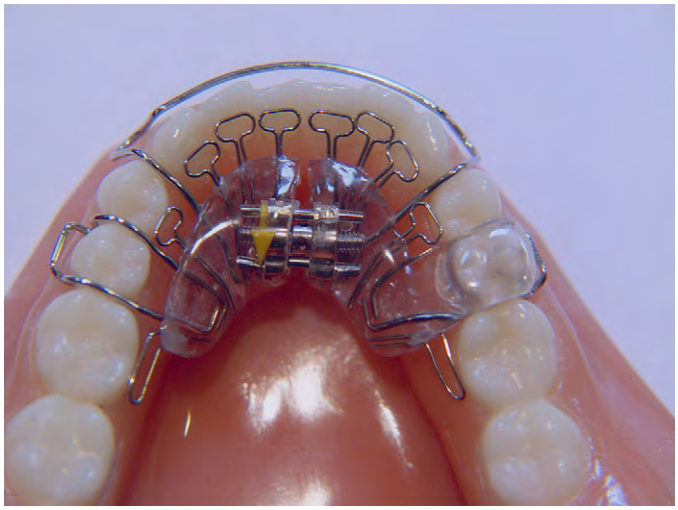

Fig. 30. The Homeoblock appliance.

apnea case still indicates the need for treatment, a traditional oral apnea appliance can be utilized once the dental arch is idealized.

Regardless of the type and design of oral appliance design chosen, it is imperative that the dentist see the patient for periodic follow-up, including within 1 to 2 weeks after the initial appliance insertion, and follow up on a monthly basis for the first 3 to 4 months. Thereafter the patient should be seen on a 6-month and yearly interval basis. It is also proper protocol to refer the patient to the referring physician/sleep medicine specialist to keep him or her informed of the dental sleep medicine progress. Appliance readjustments and occlusal change evaluation are necessary. At return visits, a subjective evaluation/symptom review, TMJ and palpatory assessment, and Epworth Sleepiness Scale should be done. Spousal input also should be part of the record update. The additional use of home monitoring devices via pulse oximetry and nasal flow instruments is helpful in providing further objective data.

The definition of success in oral appliances for sleep apnea is subjective symptom reduction/elimination and improvement in oxygen saturation. The appliance should fit comfortably after appropriate adjustments. The patient should feel more alert and report less snoring or elimination of the snoring. There should be fewer arousals, improved breathing, and improved cognitive function. The apnea/hypopnea index should be reduced by at least 50% or optimally to an index of 10 or lower. Some studies have accepted an index below 15 to 20 as successful in oral appliance therapy. Another definition of success for ''before versus after'' oral appliance therapy involves a reduction in number of arousals and reduction in the snoring sound intensity.

Use of oral appliances in the treatment of obstructive sleep apnea should be considered a first line of defense in mild to moderate cases. Its design should be weighed carefully in cases of severe obstructive apnea, in comparison to the use of CPAP. The dentist involved with

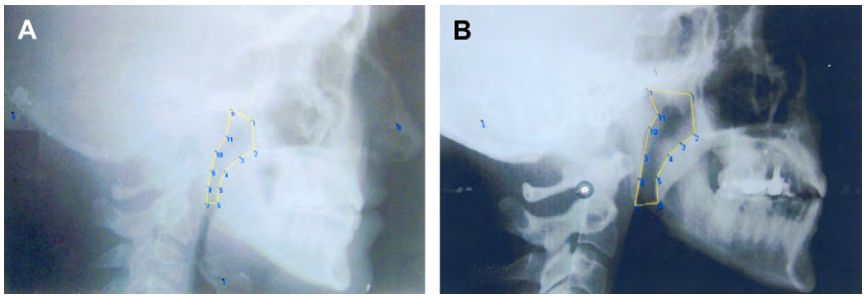

Fig. 31. Airway ''before'' (*A*) versus ''after'' (*B*) Homeoblock appliance treatment. (*Courtesy of* Theodore R. Belfor, DDS, Catskill, NY.)

obstructive sleep apnea must be directly involved with the otolaryngology/surgery/sleep medicine team. Close integration with the sleep medicine specialist and polysomnogram laboratory is essential in successfully managing this disease entity.

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