Maxillomandibular Advancement for Obstructive Sleep Apnea

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Although nasal continuous positive airway pressure therapy is considered the first-line treatment of obstructive sleep apnea, surgery has been shown to be a valid option for patients who are intolerant to positive pressure therapy. In the past 20 years, maxillomandibular advancement has been widely accepted as the most effective surgical therapy for obstructive sleep apnea syndrome. Maxillomandibular advancement has been shown to enlarge the pharyngeal and hypopharyngeal airway by physically expanding the facial skeletal framework. It has also been shown that the forward movement of the maxillomandibular complex increases tissue tension. This decreases the collapsibility of the velopharyngeal and suprahyoid musculature and improves lateral pharyngeal wall collapse, all of which have been shown to be significant components contributing to the upper airway obstruction in obstructive sleep apnea. The outcome of maxillomandibular advancement has been extensively reported, with success rates of 57% to 100%. A recent meta-analysis of 627 patients from 22 studies showed an overall success rate of 86%. The long-term follow-up of 56 patients for 43.7 months from 3 studies showed a surgical success rate of 89%. These data are similar to my experience with an 89% success rate in more than 600 maxillomandibular advancement procedures performed.

J Oral Maxillofac Surg xx:xxx, 2010

Surgery to Treat Obstructive Sleep Apnea

Since the initial report of obstructive sleep apnea (OSA) by Guilleminault et al[1] in 1976, the negative effects of the syndrome on the health and well-being of patients have been well documented. OSA results in daytime hypersomnolence, cognitive dysfunction, impaired work performance, and an increased incidence of cardiovascular disease. Even at mild levels, OSA has been correlated with cardiovascular complications by increasing the risk of hypertension,[2,3] heart attacks,[4] and strokes.[5] Patients with OSA also experience excessive daytime sleepiness and fatigue,[6] a cardinal feature that significantly affects their quality of life.

Continuous positive airway pressure (CPAP) therapy has been considered the reference standard in the treatment of OSA. However, despite the potential success of CPAP,[7,8] patient compliance represents a clear problem,[9,10] causing patients to seek surgical treatment. However, even with the wide acceptance of sleep apnea surgery within the surgical specialties of oral and maxillofacial surgery and otolaryngology, many sleep physicians remain skeptical of the efficacy of OSA surgery. Publications have been critical of surgery regarding its outcome.[11,12] However, I believe that the conclusions of these reports have been flawed and unrealistic in the realm of patient care. For example, Elshaug et al[12] proposed that "all future surgical audits report objective cure rates with success based on apnea-hypopnea index (AHI) outcomes of $<$ or $=$ 5 and/or $<$ or $=$ 10." However, nasal CPAP, the reference standard therapy, has established an acceptable compliance rate of 4 hours per night for 70% of the nights. This represents only approximately 50% of ideal use.[13] Therefore, nasal CPAP incompletely eliminates the sleep-related breathing disorder and clearly does not satisfy the criteria recommended for surgery by Eishaug et al.[12] Also, one needs to realize that OSA is similar to chronic illnesses, such as diabetes or hypertension, because the total elimination of these diseases is impossible. Therefore, the goal of any treatment modality should be to "improve" or "control" the symptoms and the risk of OSA by reducing the severity. Sleep apnea surgery clearly satisfies that goal. The commonly accepted criteria for surgical success, which achieves a 50% reduction in the respiratory disturbance index (RDI) and fewer than 20 events per hour, is actually along the same line of logic as the establishment of the CPAP compliance criteria.

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0278-2391/10/xx0x-0$36.00/0

doi:10.1016/j.joms.2010.09.014

To Phase or Not to Phase

In examining the outcomes of sleep apnea surgery, one of the glaring problems has been the predictability of surgery. The success rate of uvulopalatopharyngoplasty (UPPP) has been reported to be approximately 40%.[14] However, the success rate of any type of sleep apnea surgery will be influenced by a variety of factors such as the OSA severity, body mass index (BMI), and airway anatomy. To improve the predictability of surgical success, many preoperative assessments have been advocated to evaluate the airway, including cephalometric analysis, fiberoptic nasopharyngoscopy with or without Mueller's maneuver, computed tomography, magnetic resonance imaging, fluoroscopy, and sleep endoscopy. Additionally, a phased surgical protocol has been used by many surgeons with the intent of minimizing the extent of surgery performed in any one phase, minimizing the risk of unnecessary surgery. Such a phased protocol begins with the "less-invasive" surgery such as UPPP, nasal surgery, genioglossus advancement, hyoid advancement, and radiofrequency, with MMA only offered as the last resort.[15,16] When I first started treating patients with OSA, the phased protocol was strictly followed, because it sounded conservative, and the patients preferred the "less-invasive" procedures to control their problem. After years of practice, I have realized that the adherence to any "protocol" in sleep apnea surgery will be inadequate and flawed, because it often results in unnecessary surgical procedures. One should realize that the phase protocol was established more than 20 years ago. A tremendous amount of knowledge has been acquired since then. Patients with severe OSA, minimal pharyngeal soft tissue redundancy, an absence of tonsillar tissues, and significant maxillomandibular deficiency will have a low response rate to "less-invasive" surgical procedures. In these patients, the only procedure that will achieve a sufficient success rate is MMA. Therefore, proper patient counseling with a clear explanation of the risks, benefits, and expected outcomes are absolutely essential for each patient according to the individual sets of data.

MMA and Upper Airway

OSA is characterized by upper airway obstruction from repetitive upper airway narrowing and collapse during sleep. Many patients with OSA have been found to have diminished upper airway dimensions associated with maxillomandibular abnormalities (Fig 1).[17-20] Imaging studies using computed tomography and magnetic resonance imaging have shown that the upper airway is significantly smaller in patients with OSA, and the obstruction often occurs at multiple regions, including the velopharyngeal airway and hypopharyngeal airway during the different stages of sleep.[21-23] These findings explain the frequent lack of efficacy with soft tissue surgery such as UPPP in treating OSA in many patients. These findings also help explain why MMA represents a more appropriate surgical option for patients with OSA. Extensive reports have demonstrated that the advance-

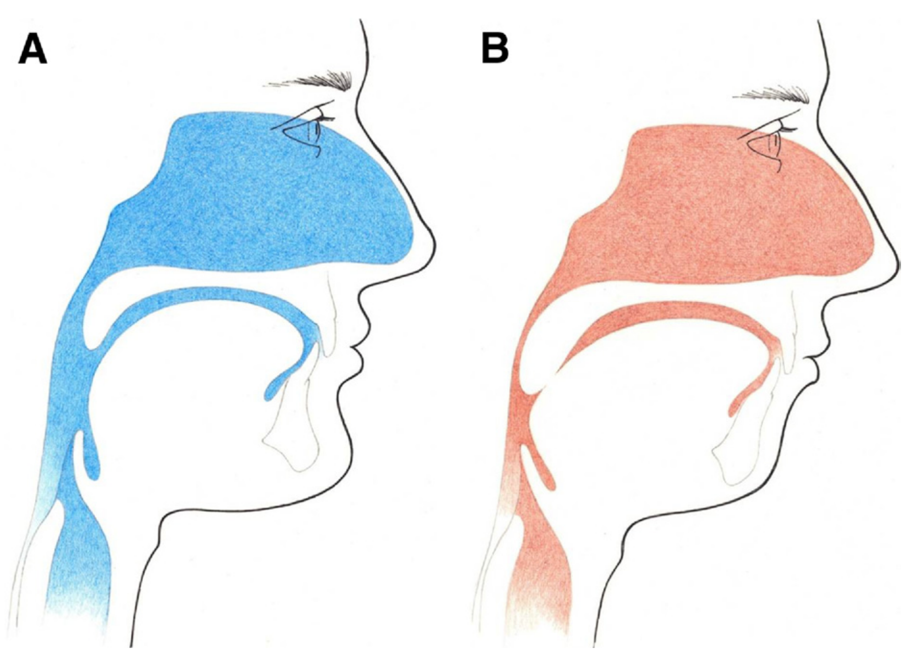

FIGURE 1. Comparison of facial skeletal and airway characteristics of normal and OSA subjects.

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ment of both the maxilla and the mandible expands the airway in the anteroposterior dimension as shown by cephalometric measurements (Fig 2).[24-28] Using 3-dimensional computed tomography scanning, Fairburn et al[29] demonstrated that the anteroposterior and lateral dimensions of the upper airway from the level of the hard palate to the hyoid bone were significantly enlarged in all patients after MMA. The lateral dimension was much more enhanced than the anteroposterior dimension in the retroglossal region. In addition to having a decreased airway dimension, patients with OSA can have abnormalities in airway dynamics, described as a "floppy airway" owing to increased collapsibility of the tongue and pharyngeal walls.[30,31] Using an inspiratory force meter to ensure the consistency of the inspiratory efforts, Li et al[28] showed that MMA expands the upper airway and reduces the collapsibility of the airway by comparing the fiberoptic airway findings pre- and postoperatively during Mueller's maneuver with controlled inspiration. Moreover, although the retrodisplacement of the tongue base was improved, it was the improvement of the lateral pharyngeal wall collapse that was the most striking (Figs 3, 4).

MMA has been shown to enlarge the pharyngeal and hypopharyngeal airway by physically expanding the facial skeletal framework. The study by Li et al[28] showed that the collapsibility of the lateral pharyngeal wall decreases with MMA. Because the lateral pharyngeal wall is the most dynamic of the upper airway, both the improvement in the anteroposterior dimensions and the decrease in the collapsibility of the upper airway explain the successful outcomes of MMA.[30,32,33]

MMA and Facial Esthetics

Although MMA has been primarily recommended for patients with OSA and significant maxillomandibular deficiency, it should also be advocated for the treatment of OSA in patients with relatively mild maxillofacial abnormalities. It appears that despite the alteration of facial esthetics after MMA, with many patients having a "prominent jaw," only a few patients believed their appearance was compromised.[34,35] The explanation was such that because most of the patients with OSA have been middle-age adults with some soft tissue sagging and facial aging, MMA "augmented" the skeletal support of the facial soft tissues, thereby reducing the soft tissue sagging and enhancing the facial esthetics. Approximately one half of the patients believed they appeared more youthful after the surgery. Additionally, various techniques used in facial reconstruction and esthetic surgery such as counterclockwise rotation of the maxillomandibular complex with alteration of the occlusal plane have been applied to limit the potential negative esthetic effect of maxillary advancement, as well as maximizing the mandibular advancement (Fig 5). Therefore, MMA should be considered as a treatment option for most patients with OSA.[34,35]

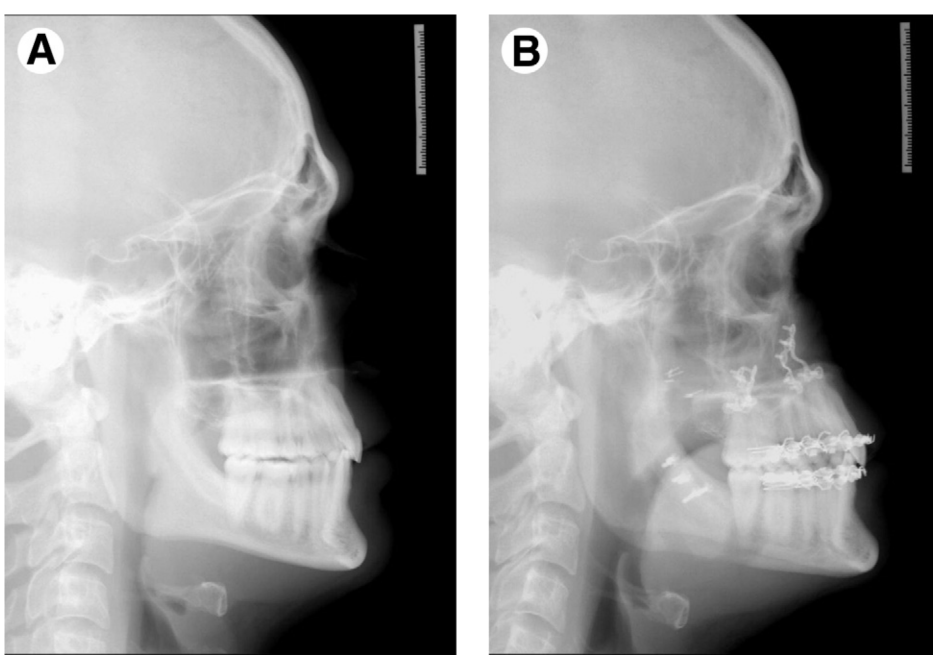

FIGURE 2. MMA. *Left,* Preoperative. *Right,* Postoperative.

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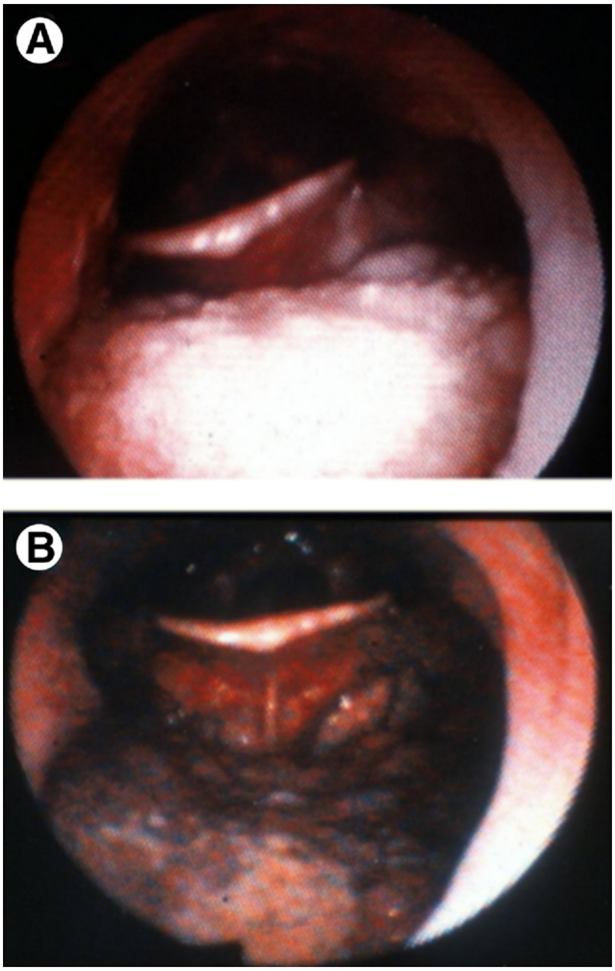

FIGURE 3. Fiberoptic airway evaluation. *Left,* Preoperative view of obstructed hypopharyngeal airway. *Right,* Postoperative view of less-obstructed hypopharyngeal airway.

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Patient Considerations in MMA

As was previously stated, it has been a general concept that surgery is indicated only when other conservative therapies have failed or have not been tolerated or for patients with underlying physical abnormalities responsible for the OSA. Most surgeons and sleep specialists consider MMA as "the procedure of last resort or salvage therapy" and have only recommended this surgical option when other "less-invasive" procedures have been ineffective in sufficiently improving the OSA. Clearly, this "staged" or "phased" surgical concept has been the most accepted practice. However, sufficient evidence has shown that MMA should be considered as the first and only surgical option for some patients. The chronic and progressive development of local neuropathy secondary to microtrauma, vibratory disease, and gastric reflux should always be considered when performing surgery, as well as the most significant comorbidity, abdominal obesity with abnormal adipocyte activity, because these issues might preclude a successful surgical outcome. In all, patients with moderate or severe OSA without significant pharyngeal tissue redundancy, patients with significant maxillomandibular deficiency, young patients who require long-term OSA resolution, and patients who desire the most effective single-stage surgery should consider MMA as their first option.

Outcomes of MMA

DEFINING SURGICAL SUCCESS BY POLYSOMNOGRAPHY AND QUALITY OF LIFE

The reported success rate of MMA in treating OSA has been 57% to 100%.[16,24,25,36-39] Hendler et al[16]

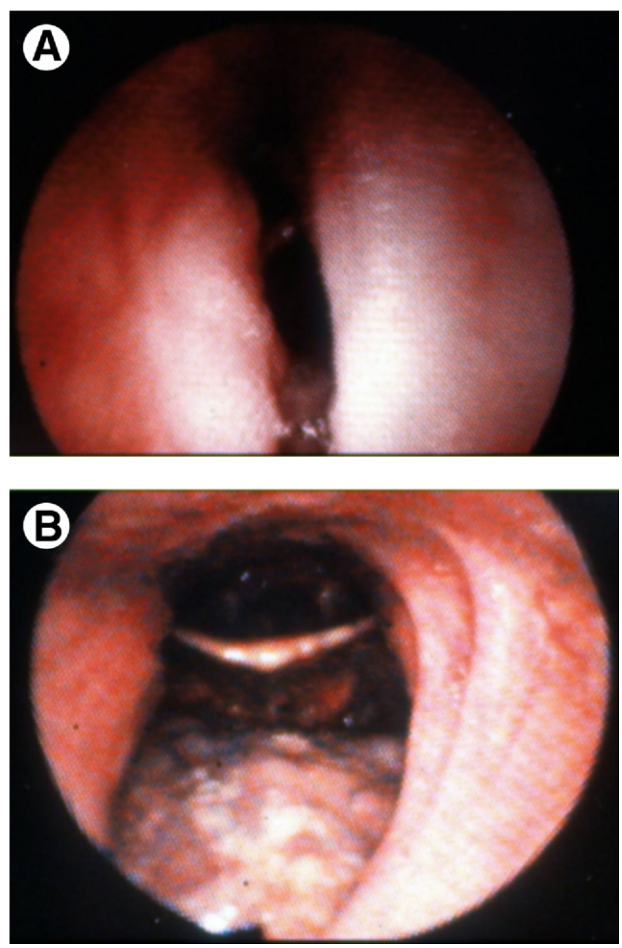

FIGURE 4. Fiberoptic airway evaluation. *Left,* Preoperative view showing severe lateral pharyngeal wall collapse during Mueller's maneuver. *Right,* Postoperative view demonstrating improvement in lateral pharyngeal wall collapse during Mueller's maneuver.

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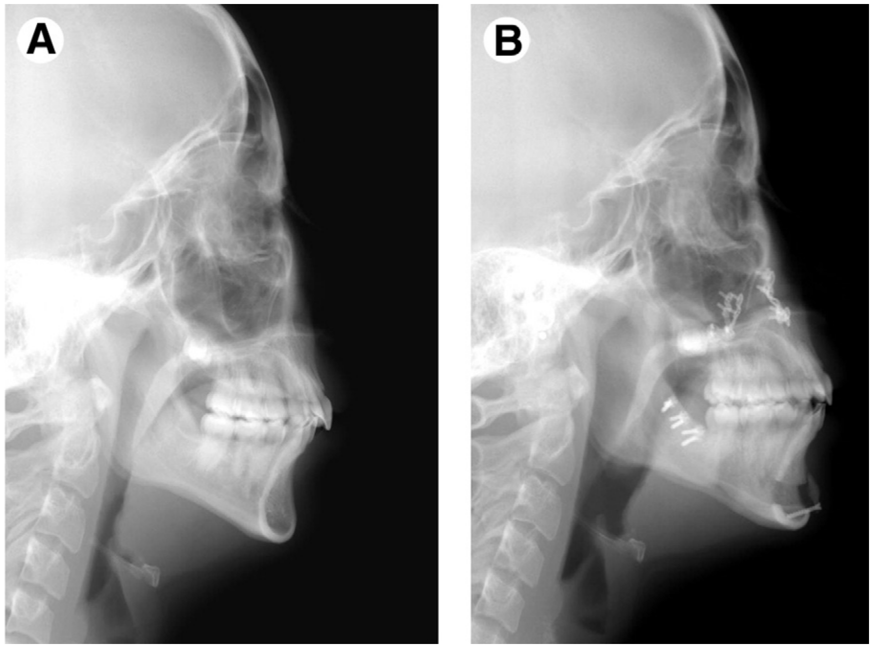

FIGURE 5. Cephalometric radiograph showing counterclockwise rotation with alteration of occlusal plane.

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reported on 7 patients, of whom 4 achieved successful results. The mean age was 47 years, and the mean BMI was 36.3 kg/m^2. The mean AHI improved from 90 to 16.5, with a corresponding improvement in the oxygen nadir from 64.9% to 88.2%. Bettega et al[38] reported on 20 treated patients, with 15 achieving success. The mean age was 45 years, and the mean BMI decreased from 26.9 kg/m^2 preoperatively to 25.4 kg/m^2 postoperatively. The mean AHI improved from 59 to 11, with a corresponding improvement in the oxygen nadir from 82% to 90%. Li et al[39] reported on 42 treated patients, with 37 achieving success. The mean age was 46 years, and the mean BMI was 32.1 kg/m^2. The mean RDI (including scoring of hypopnea with no or limited desaturation of $<$3%) improved from 58.7 to 10. The mean oxygen nadir improved from 76.3% to 87.3%. Prinsell[25] reported on 50 treated patients, of whom, all achieved success. The mean age was 42.7 years. The mean BMI decreased from 30.7 kg/m^2 preoperatively to 28.6 kg/m^2 postoperatively. The mean AHI improved from 59.2 to 4.7, with a corresponding improvement in the oxygen nadir from 72.7% to 88.6%. The largest published single-center data were from Li,[40] with 175 patients, of whom 166 achieved success. The mean RDI improved from 72.3 to 7.2, with a corresponding improvement in the oxygen nadir from 64% to 86.7%.

Few investigators have reported on the long-term results after MMA. Conradt et al[41] reported on 12 of 15 patients with continual successful results as determined by objective polysomnographic data after 2 years. Li et al[42] reported on 36 of 40 patients with continual success after a mean follow-up of 50.7 months. The preoperative RDI and long-term follow-up RDI was 71.2 and 7.6, respectively. The preoperative oxygen nadir and long-term follow-up oxygen nadir was 67.5% and 86.3%, respectively.

Clear evidence has shown objective improvement after MMA for the correction of OSA. Several studies have also examined the subjective improvements in daytime sleepiness and quality of life for patients undergoing this procedure. Dattilo and Drooger[27] compared the subjective findings using the Epworth Sleepiness Scale with objective findings using data from overnight polysomnograms for 15 patients who had undergone MMA for OSA. The preoperative average Epworth Sleepiness Scale score was 17.8 and the RDI was 69.4. The postoperative average Epworth Sleepiness Scale score had improved to 4.7 and the RDI to 10.6. Lye et al[43] investigated the quality of life for patients who had undergone MMA for OSA using the Functional Outcomes of Sleep Questionnaire. MMA was performed in 15 patients, with 13 patients achieving success. The 13 patients also reported a successful Functional Outcomes of Sleep Questionnaire change with a score of 18 or more. The measures of significant improvements in quality of life included general productivity, social outcome, activity level, vigilance, and intimacy and sex.

MMA and Meta-Analysis

An extensive review of the outcomes of MMA was published by Holty and Guilleminault.[44] A total of 627 patients from 22 unique patient populations were identified from 914 reports. The mean age was 44.4 ± 9.4 years, and 88% were men. The follow-up period was 5.3 months, and 67% had undergone previous sleep apnea surgery. The BMI decreased from 30.4 ± 5.5 kg/m^2 to 29.4 ± 5.3 kg/m^2 (P = .023). The AHI improved from 63.9 ± 26.7 to 9.5 ± 10.7 (P < .001), with a corresponding improvement in the oxygen nadir from 71.9% ± 14.8% to 87.7% ± 4.8% (P < .001). The surgical success rate was 86% ± 30.9%. Additional examination of the polysomnographic data showed that the apnea index had improved from 34.7 ± 26.7 to 1.6 ± 2.4 (P < .001). The improvement in rapid eye movement and stage III or IV sleep was also significant. Also, 56 patients from 3 studies reported a long-term success rate of 89% with a follow-up period of 43.7 ± 29.5 months. Individual data from 330 patients were evaluated further and showed an 84% success rate (AHI improved from 64.2 to 10.4 and oxygen nadir improved from 67% to 86.2%). Univariate and multivariate predictors of surgical success were younger age, lower preoperative AHI, lower BMI, and greater degree of maxillary advancement. The quality of life assessments showed that the Functional Outcomes of Sleep Questionnaire score improved from 14 to 19 (P < .001), with a 72% absolute reduction in depression/irritability. The systolic blood pressure improved from 139 to 124 mm Hg (P = .001).

MMA and Complications

To maximize airway expansion, a major advancement (12 to 15 mm at the mandibular osteotomy site) of the maxillomandibular complex is required to achieve highly successful results. Because patients with OSA are often much older and significantly overweight compared with typical patients who undergo orthognathic surgical procedures for dentofacial deformity, several factors must be considered when performing MMA for OSA.

MAXILLARY VASCULARITY

Aseptic necrosis of the maxilla is a feared, but fortunately, unusual consequence after maxillary osteotomy.[45] Aseptic necrosis of the maxilla is a potential concern when performing MMA for OSA because of the amount of advancement required. In large advancements, the soft tissue envelope of the maxilla will be "stretched" to its maximal physiologic limit. To maintain an optimal blood supply to the maxilla, attempts should be made to preserve the descending palatine vessels. However, these vessels could require ligation, because they might not always accommodate the extent of the advancement. The mucosal attachment of the maxilla can also be compromised during the advancement process. Therefore, the vascular integrity of the maxilla should be monitored throughout the case, with attention to preserving the soft tissue integrity.

SKELETAL FIXATION

Most patients with OSA are men and obese. A review of 21 morbidly obese patients undergoing OSA surgery showed that 4 of the 5 complicating events were related to the stability of the fixation.[24] These events could have been related to the patients' obesity in that the conventional fixation methods might be inadequate in this patient population owing to the increased tissue mass and consequent forces exerted on the plates and screws. Therefore, improved rigidity and fixation might be necessary.

OCCLUSION

Most patients with OSA require expedited treatment. Therefore, arch bars have been routinely used instead of orthodontics to establish occlusion. Although this method is usually adequate, significant malocclusion can occur owing to skeletal relapse from a large advancement, early functioning by uncooperative patients, or increased forces exerted on the fixation devices in obese patients. Despite diligent efforts, postoperative malocclusion might be unavoidable, and postoperative orthodontic therapy could be necessary and should be discussed preoperatively.

FACIAL CHANGES

As previously stated, MMA for OSA can result in excessive maxillomandibular protrusion, potentially compromising the facial esthetics. This issue was investigated using a patient-administered questionnaire.[39] The patients who had undergone MMA for the management of OSA usually recognized changes in their facial appearance, with most patients perceiving the changes to be moderate. However, very few patients perceived the facial changes as unfavorable (ie, less attractive). Also, one half of the patients believed they were either more attractive or more youthful. Because most patients who undergo MMA for OSA are middle-age, the facial changes resulting from maxillomandibular protrusion appear to be more "forgiving" in this patient population owing to the presence of facial aging. MMA reconstitutes the skeletal support of the soft tissue, resulting in rejuvenation of the face. Although simultaneous mandibular advancement results in mandibular protrusion, as in the maxilla, improved soft tissue support of the lower face was also achieved. However, with any orthognathic surgical procedure, preoperative evaluation of the facial proportions and facial esthetics with cephalometric analysis should be performed before MMA for OSA. The possibility of unfavorable facial changes should be discussed with the patient preoperatively. In my experience, younger patients without signs of facial aging, patients with preexisting maxillomandibular protrusion, and nonobese or minimally obese patients with thinner facial soft tissues are at a greater risk of unfavorable facial changes. However, the various techniques used in facial reconstruction and esthetic surgery such as counterclockwise rotation of the maxillomandibular complex and alteration of the occlusal plane have been applied to MMA to limit the potential negative esthetic effect of maxillary advancement, as well as maximizing the mandibular advancement.

VELOPHARYNGEAL INSUFFICIENCY

It is well known that velopharyngeal insufficiency (VPI) is a potential risk after UPPP. The risk of VPI might be even greater in patients who undergo MMA after UPPP, because the forward movement of the maxilla increases the anteroposterior dimension of the velopharynx, thus further compromising the velopharyngeal closure. Li et al[26] found that despite the combined effect of UPPP and maxillary advancement on the velopharynx, the risk of VPI was low, in that fewer than 10% of the patients had very mild symptoms of VPI. The low incidence of VPI could also have resulted from the inherently narrowed pharyngeal airway and the increased collapsibility of the pharyngeal tissues and soft palate usually found in patients with OSA. The anatomic and physiologic characteristics that predispose these patients to the development of OSA might have provided some “protective effect” against the development of VPI after MMA. However, it must be emphasized that the risk of VPI is a potential complication in these patients. Therefore, preoperative consultation regarding the possibility VPI should be considered, especially for patients with an excessively foreshortened soft palate resulting from aggressive UPPP and when pre-existing VPI symptoms are present.

MY PERSPECTIVE

Sufficient published data support MMA as the most effective surgical treatment option available, and it could possibly be the definitive primary single-stage option for the treatment of OSA in selected patients. The procedure has been shown to have a therapeutic efficacy equal to that of CPAP. I had performed more than 600 MMAs for the treatment of OSA, with a success rate of 89% at the writing of the present report. This was in line with the published data and the results from the meta-analysis by Holty and Guilleminault.[44] Younger age and a lower BMI are predictors for greater surgical success, as long as sufficient advancement has been performed. Conversely, older age (>60 years), greater BMI (>33 kg/m^2), and limited advancement are negative predictors. Obese patients with white fat accumulation and abnormal adipocyte activity, or those with a long disease duration with a greater risk of permanent neurologic deficits in the pharyngeal airway might be poor candidates for surgery. However, that does not mean that patients with negative predictors cannot experience significant improvement. Additionally, despite some residual OSA on polysomnography, most patients have experienced a dramatic resolution of their symptoms. Nevertheless, despite these seemingly good outcomes, one must realize that not all patients will achieve a great outcome. I have witnessed a few patients with minimal improvement despite a very successful operation with 15-mm advancement. Thus, the complexity of OSA cannot be understated. Consequently, one must recognize that no surgeon should claim a 100% success rate. Furthermore, as with any surgical intervention, the major concern is the associated risk. Vigilance in airway management, proper surgical execution with adequate advancement and fixation techniques, and management of the soft tissue changes without compromising the esthetic results are essential to achieve an ideal and successful outcome.

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