Objective and Subjective Outcomes Following Maxillomandibular Advancement Surgery for Treatment of Patients With Extremely Severe Obstructive Sleep Apnea (Apnea-Hypopnea Index >100)

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Purpose: It is important for patients and treating clinicians to know whether maxillomandibular advancement (MMA) surgery is effective when treating patients with obstructive sleep apnea syndrome (OSAS) and an extremely high apnea-hypopnea index (AHI) score. The purpose of this study was to evaluate objective and subjective treatment outcomes after MMA surgery for the treatment of OSAS in patients with a preoperative AHI score higher than 100.

Patients and Methods: This retrospective study included all patients who underwent MMA surgery for OSAS by members of the Department of Oral and Maxillofacial Surgery, QEII Health Science Centre (Halifax, Nova Scotia, Canada) from November 1996 through February 2014. Objective data were available in the form of polysomnographs (PSGs) obtained before and a minimum of 6 months after surgery. Patients completed a self-administered questionnaire before and after surgery regarding snoring, witnessed apneas, continuous positive airway pressure (CPAP) use, daytime somnolence, and overall satisfaction.

Results: Two hundred sixty-five patients had MMA surgery, of which 13 had pre- and postoperative PSGs. PSGs showed a mean preoperative AHI score of 117.9 and a mean postsurgical AHI score of 16.1 ($P < .001$). Pre- and postoperative questionnaires were available for 9 patients. After surgery, 7 patients denied having any daytime sleepiness and 2 patients reported minimal daytime sleepiness. The mean preoperative Epworth Sleepiness Scale score was 12.9 (standard deviation [SD], 5.5), whereas the postoperative mean score was 5.0 (SD, 4.1; $P = .004$). Before surgery, all 9 patients reported loud snoring and 8 reported witnessed apneas. After surgery, 2 patients reported minimal snoring and only 1 patient continued to have witnessed apneas. Six patients used CPAP preoperatively and only 1 patient continued to use CPAP after surgery.

Conclusions: The results of this study suggest that MMA surgery for treatment of extremely severe OSA can be a highly successful 1-stage surgery, which eliminates the use of CPAP, improves subjective outcomes, and considerably decreases the AHI score.

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Obstructive sleep apnea (OSA) is a common sleep disorder affecting approximately 2% of women and 4% of men 30 to 60 years old.[1] Several investigators believe there is a meaningful disparity between the estimated prevalence of OSA and daytime sleepiness and the number of patients whose condition is

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diagnosed and treated. Young et al[2] reported that 93% of women and 82% of men 30 to 60 years old with moderate to severe OSA are undiagnosed. Kapur et al[3] concluded that disparities (especially in women and those with a lower body mass index [BMI]) exist between current recognition rates of OSA syndrome (OSAS) and the estimated prevalence of symptoms reported across the United States. Punjabi[4] believed that despite the pathogenesis and clinical consequences of OSA being well understood, most of those affected remain underdiagnosed. The major health and social consequences of OSA and the recent appreciation that it is a relatively common condition that frequently remains undiagnosed make it an important public health issue.

Data from longitudinal studies have linked severe OSA to hypertension, diabetes, cardiovascular events, strokes, and death, which makes this chronic condition a serious public health concern.[5-8] Patients have reported a negative impact on quality of life and often complain of extreme daytime sleepiness and loud snoring.[9] Excessive daytime sleepiness has been correlated with an increased rate of workplace and motor vehicle accidents.[10] A decrease in neurocognitive functioning contributes to poor memory, difficulty concentrating, stress, and moodiness.[11] Owing to the multiple problems resulting from this sleep disorder, it is important to properly manage OSA on a long-term basis.

Patients with OSA experience repeated complete and partial blockages of the upper airway during sleep, known as apneas and hypopneas, respectively. An obstructive apnea is defined as the absence of breathing for at least 10 seconds despite an effort to breathe. The definition of hypopnea is a 30% decrease in thoracoabdominal movement or airflow lasting at least 10 seconds compared with baseline, with at least 4% of oxygen desaturation.[12] The severity of OSA is measured using the apnea-hypopnea index (AHI), which assesses the total number of apneas and hypopneas per hour of sleep. OSAS is defined as an AHI score of at least 5 in addition to excessive daytime sleepiness as reported by the patient. A special task force of the American Academy of Sleep Medicine developed a standard system for rating the severity of OSAS. A diagnosis of mild OSA requires an AHI score of 5 to 15, an AHI score of 16 to 30 indicates moderate OSA, and an AHI score higher than 30 indicates severe OSA.[13]

There are currently no adequate prospective studies that have validated severity criteria for sleepiness. The data to justify a severity index based on event frequency are derived from the Wisconsin Sleep Cohort data, which show an increased risk of hypertension that becomes substantial at an AHI score of approximately 30.[7] Currently, there are no data available to indicate an appropriate distinction between mild and moderate degrees of obstructive breathing events during sleep. The recommended level of 15 reflects the consensus opinion of the task force. Additional research is required to characterize changing risk profiles with changing frequency of hypopneas and apneas.[13]

There is a deficiency of studies that specifically address whether a higher AHI score, which represents increasing severity, means an increased health risk to the patient. Dziewas et al[14] found that patients with stroke recurrence had a higher mean AHI score compared with patients with first stroke. Punjabi et al[15] found that an increasing AHI score was associated with worsening insulin resistance independent of obesity.

In light of sparse evidence looking at the correlation of the AHI to the health risk to the patient, it is reasonable to make the assumption that an extremely high AHI score most likely carries an increased risk to the patient.

Continuous positive airway pressure (CPAP) is considered the gold standard nonsurgical treatment for sleep apnea.[16] Studies have shown that effective treatment with CPAP can decrease mood symptoms and daytime sleepiness. Unfortunately, many patients express dissatisfaction with CPAP and become noncompliant with treatment. When CPAP was recommended for at least 4 hours throughout the night, 29 to 83% of patients with OSA were found to be nonadherent to treatment.[17] The device must be worn every night to achieve maximum results.[18] The device is cumbersome and there are many problems associated with CPAP usage, such as air leakage around the mask, skin irritation if the device is not fitted properly, and the feeling of claustrophobia.[17,18] Many patients explore surgical treatment options to eliminate the need for CPAP.

Maxillomandibular advancement (MMA) surgery is an effective surgical technique for treatment of moderate to severe OSA.[16,19-24] MMA surgery increases the dimensions of the pharyngeal airway (Fig 1) and decreases the potential for airway collapse during sleep.[22] Maxillary surgery is achieved through a Le Fort I osteotomy. Advancement of the maxilla causes advancement of the soft palate and the palatoglossus muscle, which contributes to improvement of the pharyngeal airway.[25] Mandibular advancement is achieved using a bilateral sagittal split osteotomy, which advances the anterior belly of the digastric, mylohyoid, geniohyoid, and genioglossus muscles. These muscles help to pull the tongue forward and away from the pharynx. In addition, a genioplasty designed to preserve and advance the suprahyoid muscles can be performed in patients with anterior mandibular deficiency.[26]

FIGURE 1. Lateral cephalometric radiographs visualizing changes in the pharyngeal airway before and after maxillomandibular advancement and chin surgery. *Arrows* indicate the retroglossal region. *Left,* Preoperative image. *Right,* Postoperative image.

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There are no studies that have examined the success of MMA surgery in relation to the severity of the AHI. It is important for patients and treating clinicians to know whether this surgery is still effective when treating patients who have an extremely high AHI score. To look at this question, an AHI score of at least 100 events was arbitrarily chosen to designate such a population.

The purpose of this study was to evaluate objective outcomes by comparing AHI values from polysomnograms (PSGs) before and after surgery with subjective outcomes (data collected from pre- and postoperative questionnaires) after MMA surgery for treatment of OSAS in patients with an AHI score higher than 100.

Patients and Methods

PATIENTS

This retrospective study was conducted as a chart review of all patients who underwent MMA surgery for OSAS in the Department of Oral and Maxillofacial Surgery at the QEII Health Sciences Centre (Halifax, Nova Scotia, Canada) from 1996 through 2014. Approval for this study was granted from the Capital Health institutional review board. To be included in this study, patients had to complete an overnight in-laboratory (level 1) preoperative PSG to confirm the presence and severity of OSA. Patients selected to be in the study were those with a preoperative AHI score higher than 100. There were no age restrictions. All patients previously underwent a trial of CPAP and could not tolerate the treatment; however, several were still using CPAP before MMA surgery to marginally manage OSA symptoms. During this period, 265 patients had MMA surgery for OSA. At the time of surgery, the mean patient age was 38.6 years (standard deviation [SD], 8.4 yr; Table 1). Fourteen patients had a preoperative AHI score higher than 100. One patient was excluded from the study because the PSG after MMA was not available, which left a study sample of 13 patients (Table 2).

Table 1. PATIENT DEMOGRAPHICS

Patient Number	Age (yr)	Gender	Treatment Adjunct	History of UPPP
1	38	M	Orthodontics	No
2	44	M	Arch bars	No
3	26	M	Arch bars	No
4	43	M	Orthodontics	No
5	35	M	Arch bars	No
6	28	M	Orthodontics	No
7	30	M	Orthodontics	No
8	41	F	Arch bars	No
9	56	M	Orthodontics	Yes
10	33	F	Arch bars	No
11	49	M	Orthodontics	Yes
12	35	M	Arch bars	No
13	34	M	Orthodontics	No

Abbreviation: UPPP, uvulopalatopharyngoplasty.

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Table 2. PRE- AND POSTOPERATIVE AHI AND ESS SCORES FOR PATIENTS WHO COMPLETED THE PRE- AND POSTOPERATIVE QUESTIONNAIRES

	AHI		ESS		BMI	
Patient Number	Before Surgery	After Surgery	Before Surgery	After Surgery	Before Surgery	After Surgery
1	107.3	1.4	—	—	42.9	38.8
2	133.0	38.6	—	—	—	37.9
3	114.4	5.8	—	—	41.4	39.4
4	119.8	1.9	—	—	21.4	—
5	117.8	95.4	15	3	—	—
6	113.2	5.8	12	7	—	31.5
7	122.7	11.5	8	8	—	—
8	123.1	4.5	21	3	61.3	53.9
9	128.3	24.4	8	3	34.2	29.0
10	129.0	3.1	7	2	34.0	35.6
11	106.9	2.9	8	1	39.8	—
12	113.3	13.2	18	14	43.4	42.4
13	103.6	1.3	19	4	31.2	27.3
Average	117.9	16.1	12.9	5.0	38.8	37.3
SD	9.2	26.2	5.5	4.1	10.9	8.0

Note: $P < .001$ for AHI; $P = .004$ for ESS. Available pre- and postoperative BMI values are listed.
Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; ESS, Epworth Sleepiness Scale; SD, standard deviation.

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METHODS

The Delaire architectural and structural craniofacial cephalometric analysis was used in all cases to plan surgical movements.[27] The maxilla and mandible were advanced using Le Fort I and bilateral sagittal split osteotomy procedures. When anterior mandibular deficiency was diagnosed, an advancement genioplasty was performed.

The primary outcome variable was in the form of objective data: AHI values were gathered from PSGs interpreted by board-certified sleep medicine physicians before and a minimum of 6 months after surgery in the same laboratory. Objective data were analyzed using a paired-samples *t* test.

Secondary outcome variables were in the form of subjective data, namely patient responses regarding the presence of snoring, witnessed apneas, use of CPAP, and overall satisfaction with treatment. Subjective data were obtained from pre- and postoperative questionnaires completed before and a minimum of 6 months after surgery. Questionnaires were designed using yes-versus-no binary variable questions (eg, Has anyone ever told you that you stop breathing during sleep? Do you snore during sleep?). To determine overall satisfaction, the questionnaire asked whether the benefit obtained from MMA surgery was worthwhile and whether the patient would recommend this surgery to others. The Epworth Sleepiness Scale (ESS), also included in the questionnaires, was used to measure daytime sleepiness.[28] Subjective data were reported based on patient responses, and a paired-samples *t* test was used to analyze ESS values.

Results

OBJECTIVE DATA

The preoperative PSGs yielded a mean AHI score of 117.9 (SD, 9.2). The postoperative sleep study was performed an average of 9.6 months after surgery, with a mean AHI score of 16.1 (SD, 26.2). The postoperative AHI score was lower than 6 for 8 patients, 6 to 15 for 2 patients, and higher than 15 for 3 patients (Table 2). Statistical analysis showed a statistically significant improvement in AHI score ($P < .001$) after MMA surgery.

SUBJECTIVE DATA

Nine patients completed the questionnaires before and after (mean, 21 months) surgery. Four patients could not be contacted and did not complete the pre- or postoperative questionnaire.

The mean ESS score decreased from 12.9 to 5 after surgery ($P = .004$). Eight of the 9 patients had a decrease in their ESS score, whereas 1 patient's score remained unchanged (Table 2). Preoperatively, all 9 patients reported loud snoring and 8 reported witnessed apneas. After surgery, 2 patients reported minimal snoring and only 1 patient continued to have witnessed apneas (Table 3). Excessive daytime sleepiness was initially a complaint for all 9 patients, and only 2

Table 3. PRE- AND POSTOPERATIVE SUBJECTIVE DATA FOR PATIENTS WHO COMPLETED THE PRE- AND POSTOPERATIVE QUESTIONNAIRES

	Snoring		Apneas		CPAP Use	
Patient Number	Before Surgery	After Surgery	Before Surgery	After Surgery	Before Surgery	After Surgery
5	Yes	No	Yes	No	Yes	No
6	Yes	Yes	No	No	No	No
7	Yes	No	Yes	No	No	No
8	Yes	No	Yes	No	Yes	No
9	Yes	No	Yes	No	Yes	No
10	Yes	No	Yes	No	Yes	No
11	Yes	No	Yes	No	Yes	No
12	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	No	Yes	No	No	No

Abbreviation: CPAP, continuous positive airway pressure.

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patients reported minimal daytime sleepiness postoperatively. Six of the 9 patients reported feeling tired or drowsy while driving; however, postoperatively, no patients reported drowsiness while driving. Six patients used CPAP preoperatively, and only 1 patient continued to use CPAP after surgery (Table 3).

Eight patients reported a favorable change after MMA surgery. However, all 9 patients considered the surgery a worthwhile experience, and 8 would recommend the surgery to others.

Discussion

MMA surgery is a safe and effective surgical treatment for OSA.[22,29] There are no previously published studies looking at outcomes of MMA surgery for patients based on the severity of OSA. This is important because the selection of treatment options is typically based on the severity of the problem. The AHI is the most important objective measurement used to determine severity.[30,31] Studies have found that MMA is an effective surgical treatment for moderate and severe OSA, especially when patients present with a retroposition maxillomandibular complex.[19,23,24] These studies have included patients with AHI scores higher than 15. However, there is a dramatic difference between a patient with an AHI score of 35 and a patient with an AHI score of 100, although the 2 scores are classified as severe. This range is much greater than the range used to differentiate mild from moderate OSA. It is important to know whether treatment options that are successful for patients with an AHI score of 35 are still useful when the AHI score is extreme (ie, >100).

The Delaire architectural and structural craniofacial cephalometric analysis was used for all patients to identify the anatomic abnormalities and plan the magnitude of movement for the maxilla, mandible, and chin. This analysis allows the surgeon to plan movements within the realm of normal facial balance for each patient.[27] In a study of 234 patients with sleep apnea, Vezina et al[32] found the Delaire analysis provided a better correlation between maxillomandibular retrusion and the AHI than did the Tweed analysis and recommended its use in the workup of sleep-disordered breathing.

In this study, the mean AHI score decreased by 101.8 events per hour. Six patients had a postoperative AHI score lower than 5, which represents a surgical cure.[22] Two other patients had a postoperative AHI score of 5.8, which is a level most sleep physicians would not treat if the patient does not have daytime sleepiness. All patients showed an improvement in the AHI score. Two patients maintained an AHI score higher than 30 after surgery. Previous research has defined surgical failure as an AHI score persistently higher than 30[24,33]; however, patient 2 had a greater than 50% decrease in AHI score from 133 to 38.6. Patient 5 represents the most important outlier, with a postoperative AHI score of 95.5. This patient's postoperative ESS score improved considerably from 15 to 3, and the patient denied having any daytime sleepiness. Review of cephalometric radiographs and clinical examination did not show an obvious reason why this patient did not show as dramatic an improvement in AHI score as the other patients. The increasing access to cone-beam computed tomography might help provide the reason for such a limited objective response to treatment. However, this patient reported the surgery was a worthwhile treatment and would recommend it to others.

Although the purpose of this study was not to look at all possible variables that could influence the outcome of surgery, pre- and postoperative BMI values

were included when available (Table 2). There were some interesting observations. Eight of 9 patients with available BMI values were obese before treatment. All but 1 remained obese after surgery. Changes in BMI after surgery were not important and did not appear to influence changes in AHI score. Not all patients need to be obese to have an AHI score higher than 100, as evidenced by patient 4 who had a healthy BMI of 21.4 kg/m^2 and a preoperative AHI score of 119.8. Surgery decreased this patient's AHI score to 1.9 events per hour.

Patients with severe OSA have extremely fragmented and non-restful sleep. They typically wake up in the morning feeling more tired than when they went to bed. The ESS was chosen as part of the questionnaire because it is considered the most accurate and widely used self-reporting assessment tool for daytime sleepiness.[24,31] The questionnaire results showed a meaningful mean improvement in daytime sleepiness. In the systematic review and meta-analysis performed by Caples et al,[34] it was determined that previous researchers had focused on analyzing AHI values before and after MMA surgery, whereas secondary measurements (ie, sleepiness and quality of life) were rarely measured. Daytime sleepiness and improvement in quality of life were major factors in this study in determining the success of MMA surgery in patients with OSA. After surgery, 13 patients reported ESS scores lower than 10, which is considered within the normal range.[24,33] No one scored higher after treatment and only 1 patient (patient 7) did not show an improvement (Table 2). However, this patient showed a major improvement in AHI score, considered the surgery worthwhile treatment, and would recommend it to others.

Because excessive daytime sleepiness has been correlated with an increased incidence of motor vehicle accidents, it is important for the questionnaire to ask patients whether they have had any experience falling asleep in potentially dangerous situations.[10] Six of the 9 patients reported feeling drowsy while driving. Postoperatively, these 6 patients reported major improvement in daytime sleepiness and none reported drowsiness while driving. This suggests that MMA surgery can improve a patient's ability to concentrate on driving and create a safer environment for all individuals operating motor vehicles.

Before deciding on surgery, patients are asked to undergo a trial of CPAP. In this study, 3 patients could not use CPAP and 6 patients wanted to eliminate the use of CPAP. Only 1 patient continued to use CPAP after surgery. This result is noteworthy for those patients considering MMA surgery as an alternative to CPAP. The considerable decrease in CPAP usage shows MMA surgery is an effective treatment option. The AHI score of patient 12 decreased from 113.3 to 13.2 and he continued using CPAP postoperatively because of daytime sleepiness. This patient reported that MMA surgery was worthwhile; however, he was the only one who would not recommend it to others.

There has been much discussion about the complications and adverse effects of MMA surgery. It has been suggested that when a major advancement is performed (>10 mm), dental complications can arise.[33,35] In this study, patients were clinically evaluated at a minimum of 6 months after surgery. All patients maintained the occlusion established at the time of surgery. This held true for those with orthodontic appliances and those with arch bars. None of the patients required root canal treatment postoperatively. Only 1 patient (patient 13) judged the change in facial appearance was unfavorable, but commented that family and friends found the change favorable. Researchers have found that patients with OSA typically display facial signs of aging and that, when the maxilla and mandible are advanced, soft tissues become more supported and the face appears rejuvenated.[19,32,36] Overall, patients in this study reported a favorable change in facial appearance.

In conclusion, this study shows that MMA surgery for treatment of extremely severe OSA (AHI score >100) can be a highly successful 1-stage surgery that eliminates the use of CPAP, improves subjective outcomes, and considerably decreases the AHI score. All patients were satisfied with the results and considered MMA surgery a worthwhile experience.

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