HHS Public Access
Author manuscript
J Oral Maxillofac Surg. Author manuscript; available in PMC 2016 April 01.

Published in final edited form as:
J Oral Maxillofac Surg. 2015 April ; 73(4): 694–700. doi:10.1016/j.joms.2014.10.018.

Skeletal Stability of Patients Undergoing Maxillomandibular Advancement for Treatment of Obstructive Sleep Apnea

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Abstract

Purpose—To determine long-term stability of maxillomandibular advancement (MMA) in patients with obstructive sleep apnea (OSA).

Materials and Methods—This was a retrospective cohort study of patients who underwent MMA and genial tubercle advancement (GTA) for treatment of OSA. Patients were included who were over 19 years of age, had a confirmatory polysomnogram, underwent a LeFort I osteotomy, bilateral sagittal split osteotomies and GTA, had adequate radiographic documentation and at least 11 months follow-up. Exclusion criteria included previous history of orthognathic or other maxillofacial surgery. Predictor variables were presence of OSA treated by MMA, pre and postoperative orthodontia or no orthodontia, length of follow-up and magnitude of advancement. Outcome variable was stability of MMA judged by clinical examination and cephalometric measurements. Standardized lateral cephalometric measurements were done at T0, preoperative; T1 immediate postoperative; T2, latest follow-up >11 months. Differences in cephalometric measurements were calculated between time points T1-T0 and T2-T1 for the overall group and for patients who had orthodontia (Group 1) and those who did not (Group 2). A correlation analysis using length of follow-up and magnitude of advancement as predictor variables of stability were completed. For all analyses, $P < .05$ was considered statistically significant.

Results—During the 9 year study period 120 patients with OSA were evaluated and 112 had operative treatment; twenty-five patients specifically had MMA and GTA, met inclusion criteria and formed the study sample. Mean and range of maxillary and mandibular advancements (T1-T0) were 9.48 mm (range, 1.6–15.2) and 10.85 mm (range, 6.3–15.8) respectively. At T2-T1, no

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occlusal changes occurred. Changes in the subgroup analyses included a decrease in SNA and ANB and an increase in MnPl-SN in Group 1 and a decrease in ANB in Group 2. The only significant mean difference in cephalometric measurements between the groups was in Co-Gn. There was no correlation between length of follow-up (mean 27.84 months) and changes in cephalometric measurements.

Conclusion—Results of this study indicate that while there were changes in SNA and ANB between T1 and T2 suggesting maxillary relapse, the mean difference was ≤1 degree and no patients developed a malocclusion; therefore we considered the changes clinically insignificant. Advancement of the maxillomandibular complex 10 mm for treatment OSA remains stable at a mean followup period greater than 2 years and preoperative orthodontic treatment does not appear to influence skeletal stability.

Introduction

Obstructive sleep apnea (OSA) is characterized by repeated narrowing or collapse of the upper airway during sleep.[1,2] It results in a continuum of changes in upper airway resistance, reduced blood oxygen levels, fragmentation of sleep, snoring, daytime fatigue, and hypersomnia which often lead to occupational disability and behavioral changes. Furthermore, there are clear correlations between OSA and long term cardiovascular and pulmonary complications.[3]

The gold standard, first-line treatment for OSA is continuous positive airway pressure (CPAP) which pneumatically stents open the upper airway, preventing collapse during sleep. If patients are able to wear the mask effectively and tolerate the therapy for at least six hours of a sleep episode, there is a high level evidence for its efficacy in preventing airway collapse and relieving symptoms. However, more than 50% of patients are intolerant and reject the therapy within the first few months after initiation.[4,5]

Other treatments for OSA aimed at enlarging the upper airway while decreasing airway collapsibility include mandibular positioning devices and surgical reduction of the pharyngeal soft tissues.[6,7] Maxillomandibular advancement surgery (MMA), often in conjunction with genial tubercle advancement, has been shown to be an effective surgical alternative for the treatment of obstructive sleep apnea (OSA). Despite the fact that there is no direct manipulation of pharyngeal tissue, MMA is believed to improve OSA because the skeletal movements favorably alter upper airway shape.[7] The effectiveness of MMA for the treatment of OSA has been confirmed in short and long term follow-up studies employing both objective (polysomnograms) and subjective data (patient questionnaires).[8–10] Evaluation of skeletal stability of MMA is important because the amount of skeletal advancement (and therefore its stability) has been considered to be a significant predictor of success in the surgical treatment of OSA.[9,11–15]

Maxillofacial surgical procedures used for MMA are the same as those used to correct malocclusions and facial esthetics in patients with dentofacial deformities (DFD). While the operations are technically the same, there are considerable differences between OSA and DFD patient cohorts. Patients with OSA are generally older and have more medical comorbidities than those with DFD and their occlusions may be normal. MMA for OSA usually entails moving the facial skeleton forward to a cephalometrically “telegnathic” position while DFD treatment is aimed at positioning the facial skeleton to a cephalometric and/or esthetic “normal” position. The magnitude of skeletal movements is generally greater in the treatment of OSA than DFD. A primary goal of orthognathic surgery for DFD is to correct the accompanying malocclusion. In the case of OSA patients, the occlusion is often not altered by the operation. The long-term stability of skeletal movements for treatment of DFD has been studied; however, there are few publications evaluating skeletal stability of maxillary and mandibular advancement for OSA.[9,16–18] In addition, there are even fewer studies analyzing the effect on skeletal stability, if any, of orthodontic correction of dental occlusion in conjunction with MMA.

The objective of this study is to assess, via clinical and cephalometric analyses, the long term skeletal and occlusal stability of MMA for treatment of OSA. We hypothesize that MMA advancement of the magnitude usually carried out for OSA will result in a skeletally stable result.

Materials and methods

Patients

This was a retrospective cohort study of all adult patients with OSA who underwent MMA in the Department of Oral and Maxillofacial Surgery at Massachusetts General Hospital (Boston, MA) from 2003 to 2012. Inclusion criteria were 1) diagnosis of OSA via polysomnogram, 2) maxillomandibular advancement having been completed via Le Fort I and bilateral mandibular sagittal split osteotomies, 3) adequate radiographic and clinical documentation, and 4) postsurgical follow-up of at least 11 months. Exclusion criteria were 1) previous orthognathic surgery and 2) other previous maxillofacial surgery. Predictor variables were presence of OSA treated by MMA, pre and postoperative orthodontia or no orthodontia, length of follow-up and magnitude of advancement. The outcome variable was stability of MMA, defined as no patient reported or clinically observed changes in occlusion and no significant changes in cephalometric measurements between immediate postoperative images and long term images. Patients were divided into 2 groups: Group 1 preoperative and postoperative orthodontia and Group 2 no orthodontic treatment. This study was approved by the Partners Institutional Review Board (Protocol #2013P001140).

Image acquisition

Standardized commercial digital lateral cephalograms were obtained by use of Planmeca Dimax 2 Ceph (Planmecam Helsinki, Finland). The X-ray setting were 62 to 66 peak kilovolts (based on gender and race), 9 to 12mA (based on gender and race), and source-sensor distance of 50 to 60cm (1.13 × magnification).

Image analysis

Images from three different time points were used in the analyses. Preoperative (T0), lateral cephalograms were obtained within 8 weeks before surgery. Immediate postoperative (T1) images were acquired within 10 days of the operation and long term follow-up (T2) lateral cephalograms occurred at least 11 months following the operation. The digital images were imported into the image-analyzing software program Dolphin (version 10.0 Premium; Dolphin Imaging & Management Solutions, Chatsworth, CA).

Cephalometric parameters were maxillary relationship to cranial base (SNA), mandibular relationship to cranial base (SNB and Mn Pl to SN), maxillomandibular relationship (ANB), maxillary length (ANS-PNS and Co-ANS), mandibular length (Co-Gn), and dental relationship (overbite and overjet) (Table 1). A reference line of 40 mm was used to calibrate the measurements of each image. The amount of planned maxillomandibular advancement was confirmed measuring the difference of A points, upper incisor tips and lower incisor tips on superimposition of the T0 and T1 cephalometric tracing images. Lower incisor tip was used instead of B point to calculate mandibular advancement due to the skeletal changes resulting from GTA.

Statistical analysis

Data were entered into a database during the course of study (Statistical Package for Social Sciences software version 13.0, SPSS Chicago). Bivariate statistics were computed to compare changes in variables at immediate postoperative (T1) and long term follow-up (T2) time points. Parametric methods were used to evaluate the changes of cephalometric measurements at long term follow-up (paired t-test). A clinical tolerable margin was verified within the interval by an equivalency test evaluating the evidence that mean difference is different from 0. The patients were divided into two groups for the subgroup analysis based on whether they underwent orthodontic treatment in conjunction with MMA. Group 1 patients had pre-surgical and post-surgical orthodontic treatment and Group 2 patients did not have orthodontia. Changes of cephalometric parameters within each group were evaluated via paired t-test while student t-test was used to evaluate changes between the two groups. The correlation between length of follow-up and amount of skeletal advancement with change of cephalometric variables between T1 and T2 were analyzed by Pearson's correlation. For all analysis, $p < .05$ was considered statistically significant.

The study could detect a difference in paired means over time that is at least 58% of its standard deviation (i.e. Cohen's d>0.58) with an 80% power at a 5% significance level paired samples t-test for the whole sample analysis.

Electronic health records for all 25 patients were reviewed to identify documentation of patient reported changes in occlusion and/or notation of occlusal changes found on clinical examination between T1 and T2.

Results

A total of 120 patients were evaluated for OSA and 112 underwent surgical treatment between 2003 and 2012. Twenty-five (8 females and 17 males) of these patients (22%) specifically underwent MMA with GTA. The age range was between 19 and 59 years (mean 38.24 ± 13.57).

The reproducibility of the measurements was validated by retracing the cephalometric landmarks of all study subjects at T1 and T2 by the same investigator. The systematic error was assessed using a paired *t* test at the 10% level as recommended by Houston.[19] There was no statistically significant difference between initial and retracing cephalometric landmarks at T1 and T2.

The maxillary advancements measured at upper incisor tip and A point were an average of 9.26 ± 3.06 mm (range, 1.6–15.2) and 9.48 ± 3.02 mm (range, 3–14.8) respectively. The mean mandibular advancement calculated at lower incisor tip was 10.85 ± 2.36mm (range, 6.3–15.8). Twenty two patients had genial tubercle advancement and three patients underwent extended genioplasty.

Maxillary rigid fixation was achieved with miniplates while the mandible was fixed with bicortical screws (20 patients) and/or miniplates (5 patients). Eleven patients underwent preoperative and postoperative orthodontic treatment (Group 1) and fourteen patients had no preoperative orthodontic treatment (Group 2). The mean follow-up period was 27.84 ± 19.96 months (range, 11–85 months). Hardware removal between T1 and T2 was performed on 6 patients. No patient had bone grafts during maxillomandibular advancement surgery. A repeat LeFort I osteotomy with rigid internal fixation and application recombinant BMP-2 on bovine absorbable collagen sponge was completed on a patient who sustained direct trauma to upper jaw on at least two separate occasions after hardware removal and developed a malocclusion secondary to maxillary fracture through the osteotomy.

At T1-T0, all cephalometric measurements except overbite (p=0.86) changed significantly in the directions expected for the planned procedures in a whole sample analysis (n = 25) (Table 2). During subgroup evaluation (Table 3), in Group 1, at T1-T0, there were no significant changes in ANS-PNS (p=0.28) and overbite (p=0.26). In Group 2 there were no significant mean changes in MnPl-SN (p=0.14), ANS-PNS (p=0.07) and overjet (p=0.22).

At T2-T1, only the mean SNA (p=0.012) and ANB (p=0.001) decreased significantly and the other mean cephalometric variables did not change significantly (Table 2). Subgroup evaluation (Table 3) revealed that in Group 1, at T2-T1, significant decreases (though <1 degree) were found in SNA (p=0.02) and ANB (p=0.01) with a significant increase in MnPl-SN (p=0.01). In Group 2, the only signficant change was a decrease (again, <1 degree) in ANB (p=0.04).

There was no relationship between the duration of follow-up and changes in cephalometric parameters. However, the correlation between the change of SNB between T2-T1 and the amount of maxillary advancement was statistically significant and the change of MnPl-SN between T2-T1 correlated significantly with the amount of both maxillary and mandibular advancement (Table 4).

There were no patient reported changes in occlusion nor documentation of occlusal changes noted on clinical examination between T1 and T2. The single patient who sustained trauma postoperatively requiring a repeat LeFort I osteotomy was noted to have the same occlusion after the repeat LeFort I as was present after the initial LeFort I.

Discussion

MMA is currently considered to be the most effective craniofacial surgical technique for the treatment of OSA in adults.[13] BMI, age, severity of OSA, airway space, amount of skeletal advancement and relapse of MMA have been reported as clinical factors predictive of surgical success of OSA.[9,11–15]

The magnitude of maxillomandibular advancement recommended in OSA treatment is generally greater than in DFD. Riley et al reported that patients with better outcomes (RDI 0–10) have a significantly greater mandibular advancement (12.2 mm ± 2) and the authors recommended at least 10 mm of advancement.[20] Holty et al found, in a meta-analysis, that the amount of maxillary advancement played a more significant role in outcomes. OSA subjects achieving surgical success had a mean maxillary advancement of 9.5 mm compared with 7.9 mm for those without success ($p= 0.029$) while mandibular advancements of over 11mm were still associated with unsuccessful surgical outcomes.[13] However others have noted no association between the degree of maxillary advancement and reduction in AHI after mean overall mandibular advancement of 10.66 mm ± 2.82, and mean maxillary advancement of 5.24 mm ± 1.8[14]. The magnitude of skeletal movements completed in this study were comparable with the above studies: the mean amount of the maxillary advancement measured at upper incisor tip and A point were 9.26 ± 3.06 mm (range, 1.6–15.2) and 9.48 ± 3.02 mm (range, 3–14.8) respectively and the mean mandibular advancement calculated at lower incisor tip was 10.85 ± 2.36 mm (range, 6.3–15.8). The broad range of maxillary and mandibular movements noted in this study can be explained by the fact that departmental protocols for treatment of OSA evolved during the time frame of the study with smaller movements (e.g., upper incisor tip advancement = 1.6mm) being completed early in the study period. Larger advancements of both the maxilla and mandible became standard as evidence supporting the role of larger maxillary advancement in addition to the mandible became available.

Unlike treatment of DFD, which usually includes orthodontia as part of the surgical treatment, only 44% of the patients (Group 1) undergoing treatment in this study had orthodontia. In a previous surgical stability study by Smatt et al., 44.44% of OSA patients underwent MMA (n = 18) without modification of occlusion. However there was no analysis of the role changes in occlusion played in skeletal stability.[14] In this study, subgroup evaluations of cephalometric changes along with clinical examination indicated that there was no difference in skeletal stability when comparing patients who had orthodontia with those that did not.

At T1-T0 the only variable that did not change significantly in the whole group analysis was overbite. Though occlusion changed in only 44% of the patients, the significant change in ANB in the whole group analysis is a reflection of the change in B point in all patients as a result of GTA (Table 2). The variables that did not change significantly in the subgroup analysis in Group 1 were overbite and ANS-PNS while in Group 2 MnPl-SN, ANS-PNS and overjet did not show significant changes. The greater number of changes in Group 1 is not unexpected given that these patients were treatment planned for occlusal changes. The data suggests that patients treatment planned for occlusal changes had greater counter-clockwise rotation of the mandible postoperatively than patients not having perioperative orthodontia.

At T2-T1 the mean SNA and ANB decrease in the whole sample analysis was less than 1 degree and may reflect remodeling in the A point as there were no changes in dental parameters such as overbite and overjet (Table 2). The variables that changed significantly in the subgroup analysis in Group 1 were a decrease in SNA and ANB of less than 1 degree and an increase in MnPl-SN of 1 degree. In Group 2, ANB alone decreased, again by less than 1 degree. The changes in SNA and ANB may once again reflect skeletal remodeling at A point. As previously noted, the MnPl-SN decreased significantly in Group 1 at T1-T0. The significant increase in this measure at T2-T1 likely represents a clockwise rotation of the mandible, possibly as a consequence of postoperative orthodontia.

Authors of previous studies on long term clinical outcomes of MMA for OSA reported no statistical changes in SNA and SNB at 48.6 months of mean follow-up in 16 patients[21] and stable A point and B point in horizontal (sagittal) plane and ANS, PNS in vertical plane in 19 patient after greater than 12 months[22] while others showed an average of 7% of mandibular skeletal relapse in patients with a successful OSA outcome and recurrence of OSA in a single patient with skeletal relapse of 25% of an initial MMA of 6 mm without rigid fixation[9,20]. In the present study, there was no correlation between duration of follow-up and changes in cephalometric parameters (Table 4). While there was a correlation between the amount of maxillary advancement and changes in SNB (Table 4), the changes in SNB were overall not significant (Table 2). The change in MnPl-SN at T2-T1 was found to correlate with amount of both maxillary and mandibular advancement (Table 4). These changes are suggestive of some skeletal relapse; however, there was no change in occlusion on clinical examination.

In this study, a change in cephalometric measurement of 1° or less was statistically significant however this change appears to be clinically insignificant. This should be regarded in the same light as standards established by Proffit et al who considered changes of < 2 mm within the range of method error and clinically insignificant[23].

As this is a retrospective study with focused inclusion and exclusion criteria, there is a small number of total subjects (n=25). This represents the greatest weakness of this study and limits the ability to compare changes in outcomes between Group 1 and Group 2 in the subgroup analysis. Additionally, different cephalometric parameters that rely on linear measurements instead of angular measurements may have been used to demonstrate skeletal stability. The study is a baseline analysis of maxillofacial surgical outcomes in a cohort of OSA patients treated at one major academic medical center. Future plans include prospective collection of data on all patients undergoing MMA for OSA as well as analysis of outcomes of MMA with regards to OSA improvement based on multiple variables, including polysomnograms and quality of life measures.

Results of this study indicate that even though there were significant cephalometric changes between T1 and T2 suggesting maxillary relapse, the mean difference was ≤1 degree and no patients developed a malocclusion. Large advancement of the maxillomandibular complex for treatment OSA remains stable at mean follow-up greater than 2 years and preoperative orthodontic treatment does not appear to influence skeletal stability.

Acknowledgement

This work was conducted with support from Harvard Catalyst | The Harvard Clinical and Translational Science Center (National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health Award 1UL1 TR001102-01) and financial contributions from Harvard University and its affiliated academic health care centers and the MGH Department of Oral & Maxillofacial Surgery Education and Research Fund.

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Table 1

Cephalometric variables studied

Maxillary relation to cranial base	
SNA	Angle formed by sella (S), nasion (N) and A point (A)
Mandibular relation to cranial base	
SNB	Angle formed by sella (S), nasion (N) and B point (B)
MnPl-SN	Angle formed by mandibular plane (Gn-Go) to a line from sella to nasion (SN)
Maxillomandibular relation	
ANB	Angle formed by nasion (N), A and B point
Maxillary length	
ANS-PNS	Distance between anterior nasal spine (ANS) and posterior nasal spine (PNS)
Co-ANS	Distance between condylion (Co) and anterior nasal spine (ANS)
Mandibular length	
Co-Gn	Distance between condylion (Co) and gnathion (Gn)
Dental relationship	
Overbite	Vertical distance between upper and lower incisal tip
Overjet	Horizontal distance between upper and lower incisal tip

Table 2

Cephalometric variables of whole sample analysis in preoperative (T0), immediate postoperative (T1) and long term follow-up period (T2); (n=25)

	T0 ± SD	T1 ± SD	T2 ± SD
SNA (degree)	79.66 ± 5.45	87.71 ± 5.83	87.22[¶] ± 6.00
SNB (degree)	74.16 ± 5.38	79.87 ± 5.23	79.93 ± 5.36
MnPl-SN (degree)	41.00 ± 7.50	38.27 ± 6.82	38.81 ± 7.01
ANB (degree)	5.47 ± 2.47	7.84 ± 2.30	7.29[¶] ± 2.47
ANS-PNS (mm)	51.61 ± 3.15	50.23 ± 3.62	50.92 ± 4.36
Co-ANS (mm)	87.94 ± 7.08	93.58 ± 8.17	93.20 ± 8.24
Co-Gn (mm)	117.16 ± 9.62	128.79 ± 8.72	128.92 ± 8.97
Overbite (mm)	1.40 ± 2.21	1.41[*] ± 1.59	1.85 ± 1.5
Overjet (mm)	4.88 ± 2.67	3.48 ± 1.24	3.57 ± 0.97

[*]-indicates **no** significant change from T0 value

[¶]-indicates significant change from T1 value ($p<0.05$)

Table 3

Changes (mean) of cephalometric variables in Group 1 and Group 2

	T1-T0 ± SD		**T2-T1 ± SD**	
	Group 1 (n=11)	**Group 2 (n=14)**	**Group 1 (n=11)**	**Group 2 (n=14)**
SNA (degree)	8.18 ± 3.09	8.97 ± 2.95	−0.74¶ ± 0.87	−0.31 ± 0.90
SNB (degree)	6.54 ± 1.96	5.59 ± 1.42	−0.17 ± 0.76	0.24 ± 0.80
MnPl-SN (degree)	−5.06 ± 2.53	−1.12* ± 2.67	1.02¶ ± 1.13	0.16 ± 2.56
ANB (degree)	1.65 ± 1.98	3.36 ± 2.35	−0.57¶ ± 0.59	−0.54¶ ± 0.88
ANS-PNS (mm)	−0.88* ± 2.45	−1.89* ± 3.56	0.36 ± 1.33	0.94 ± 2.60
Co-ANS (mm)	5.75 ± 3.77	6.37 ± 4.43	−0.85 ± 2.05	−0.01 ± 0.82
Co-Gn (mm)	12.91 ± 3.12	11.79 ± 5.57	−0.63 ± 1.46	0.72 ± 1.49
Overbite (mm)	0.69* ± 1.84	−0.64 ± 0.90	0.81 ± 1.60	0.15 ± 1.04
Overjet (mm)	−2.29 ± 2.25	−0.72* ± 1.47	0.18 ± 1.14	0.02 ± 0.78

*-indicates **no** significant change

¶-indicates significant change (p<0.05)

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Table 4

The correlations of follow-up period and amount of skeletal advancement with change of mean cephalometric parameters at T2-T1.

Cepahlometric Parameter	Duration of Follow up	Maxillary advancement		Mandibular advancement
		U1	A point	L1
SNA	0.36	0.15	0.20	0.25
SNB	0.99	0.03*	0.01*	0.22
MnPl-SN	0.85	0.02*	0.02*	0.02*
ANB	0.30	0.54	0.26	0.99
ANS-PNS	0.62	0.06	0.07	0.28
Co-ANS	0.15	0.74	0.74	0.64
Co-Gn	0.46	0.32	0.19	0.52
Overbite	0.76	0.99	0.91	0.42
Overjet	0.34	0.40	0.54	0.34

*-indicates *p* value: <0.05

U1: Maxillary advancement measured at upper incisor tip
A point: Maxillary advancement measured at A point
L1: Mandibular advancement measured at lower incisor tip