Subtypes of Maxillomandibular Advancement Surgery for Patients With Obstructive Sleep Apnea

Won-June Lee, MSD, Dong-Hyun Hwang, MSD,* Stanley Yung-Chuan Liu, MD, DDS,† and Su-Jung Kim, PhD‡*

Abstract: Maxillomandibular advancement (MMA) surgery, which is the most effective treatment modality for patients with moderate-to-severe obstructive sleep apnea with apparent skeletal discrepancies, has been modified in conjunction with segmental osteotomies, counterclockwise rotation of maxillomandibular complex, and other adjunctive procedures. However, any single type of MMA could not treat or cure all the patients with obstructive sleep apnea showing different dentofacial and pharyngeal patterns. We aimed to suggest critical decision factors for the selective application of MMA subtypes, categorized as straight MMA with genioplasty, rotational MMA, segmental MMA, and segmental-rotational MMA, in the surgical treatment objective process: anteroposterior position of maxilla, upper lip projection, overjet, lower incisor inclination as sagittal factors, and upper incisor exposure and occlusal plane angle as vertical factors. This case series deserves a clinical basis on the way of case-by-case application of the optimal MMA subtype based on the successful treatment outcomes with short-term stability.

Key Words: Critical decision factor, maxillomandibular advancement surgery, MMA subtype, surgical treatment objective

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Maxillomandibular advancement (MMA) surgery is known to be the most effective treatment modality for patients with moderate-to-severe obstructive sleep apnea (OSA) with apparent skeletal discrepancy such as mandibular and/or maxillary retrusion.[1,2] It enlarges the pharyngeal space transversely as well as anteroposteriorly and shortens the upper airway length to increase pharyngeal patency during inhalation as an osseopharyngeal reconstruction procedure.[3–7] Traditional straight MMA, which comprises LeFort I osteotomies and bilateral sagittal split osteotomies, was specifically designed as single splint technique by Riley et al[8–10] to allow greater advancement for maximum soft tissue tension. Although it has represented 65% to 100% of success rate with extensive advancement of maxilla (7.3–9.2 mm) and mandible (10.2–12.5 mm), it does not necessarily resolve the OSA signs and symptoms completely at the expense of facial appearance.[8] Accordingly, recent surgical interventions for patients with OSA include several modified designs to maximize airway opening at a specific level and to improve facial esthetics at the same time.[8,11,12]

A rotational MMA, focusing on the maximum counterclockwise (CCW) rotation of maxillomandibular complex (MMC) based on the traditional MMA technique, has been applied to achieve greater chin advancement than maxillary advancement in patients with steep mandibular and occlusal planes and low-hyoid-related airway obstruction.[13–16] A segmental MMA, combined with anterior segmental osteotomies (ASOs), has been preferred for Asian patients with already protrusive maxilla and lips,[17] or for patients with severe OSA with normal skeletal pattern.[18] Maxillary ASO allows retropalatal airway enlargement by greater pulling forward of pharyngeal tissues attached to the posterior maxilla with maintaining or improving facial profile by setting back of anterior maxilla.[18,19] Mandibular ASO enhances retroglossal airway enlargement by greater mandibular advancement as long as subapical segmental block to be pulled back does not contain the genial tubercles.[20] Segmental MMA involving 2-piece or 3-piece osteotomies is favorable for respiratory improvement by expanding nasal cavity and maxillary width when the constricted maxillary arch is a risk factor for OSA. Segmental MMA allows surgery-first approach through the surgical correction of proclined or extruded lower incisors and surgical dental arch coordination.[11] Advancing genioplasty and genial tubercle advancement surgery are beneficial adjunctive procedures for the patients in whom limited advancement or rotation of MMC is possible.[10,12,21] Considering that lower ASO and genioplasty could not be performed at the same time, strategic application is needed in terms of greater advancement of genioglossus muscles and tongue base.[18]

To determine optimal surgical designs for each patient with OSA with different dentofacial and pharyngeal patterns, individualized surgical treatment objectives (STOs) including airway prediction are required.[12] No single type of MMA technique could treat all the patients with OSA successfully. We aimed to categorize 4 subtypes of MMA for the selective application based on the critical consideration factors: traditional straight MMA with or without genioplasty, rotational MMA with MMC rotation, segmental MMA with ASO, and segmental-rotational MMA as a mixed type. Anteroposterior position of maxilla, upper lip projection, overjet, lower incisor inclination, upper incisor exposure, and occlusal plane angle are proposed as minimum decision factors, which are sorted out from the factors considered in a routine STO process (Table 1). This case series highlights the process of selective application of each subtype of MMA modification based on the successful treatment outcomes with short-term stability.

From the *Kyung Hee University Graduate School, Seoul, Republic of Korea; †Division of Sleep Surgery, Department of Otolaryngology Head and Neck Surgery, Stanford University Medical Center, Stanford, CA; and ‡Department of Orthodontics, Kyung Hee University School of Dentistry, Seoul, Republic of Korea.
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Address correspondence and reprint requests to Su-Jung Kim, Department of Orthodontics, Kyung Hee University School of Dentistry, 1 Hoegi-Dong, Dongdaemoon-Ku, Seoul 130-701, Republic of Korea; E-mail: ksj113@khu.ac.kr
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TABLE 1. Outcome Measures Assessing the Skeletal and Dentofacial Improvements on Lateral Cephalometric Images

STO Steps	Cephalometric Parameters	Norm	Patient 1		Patient 2		Patient 3	
			Initial	Final	Initial	Final	Initial	Final
I. Dentomaxillary relation	UI-MxOP (°)	55	59.5	53.5	54.5	54.5	54.0	54.5
	UI-PP (°)	115	101.0	112.0	115.0	115.0	107.0	109.0
	LI-MnOP (°)	66	45.0	59.0	64.0	66.0	56.0	63.0
	IMPA (°)*	90	116.0	100.5	94.0	91.0	93.0	90.0
II. Intermaxillary relation	Overjet (mm)*	3	8.0	3.0	4.5	3.0	10.0	3.0
	Overbite (mm)	3	8.0	2.5	0.5	2.5	6.5	2.5
	AB-MxOP (°)	86	99.0	86.0	93.0	89.0	97.0	88.0
III. Positioning MMC								
	Vertical							
	UI exposure (mm)*	4	4.0	1.5	5.5	2.5	6.0	3.0
	Anteroposterior							
	N perp-A point (mm)*	1	5.0	2.5	−3.0	1.0	2.5	2.5
	Upper lip angle (°)*	16	18.0	16.0	6.0	16.0	16.0	16.0
	N perp-Pog (mm)	−3	−18.0	−7.0	−13.0	−1.0	−24.0	−12.0
	Inclination							
	MxOP-TVL (°)*	99	103.0	101.0	101.0	97.0	110.0	105.0
	FH-AB (°)	83	63.0	77.0	68.0	82.0	58.0	72.0
IV. Soft tissue prediction	Upper lip (Sn′-UL, mm)	5	6.0	5.0	2.0	6.0	6.0	5.0
	Lower lip (Sn′-LL, mm)	3	−2.0	1.5	1.0	4.0	−5.0	−1.0
	Chin (Sn′-Pog′, mm)	−3	−26.0	−12.0	−16.0	−3.5	−32.0	−18.0
	Airway							
	Retropalatal (mm)	17	2.0	9.0	8.5	18.0	4.0	9.0
	Retroglossal (mm)	14	7.0	12.0	6.0	16.0	5.0	8.0
V. Balance verification	N-ANS:ANS-Me	1:1	1:1.2	1:1.2	1:1.5	1:1.2	1:1.5	1:1.3
	Sn′-stms:stmi-Me′	1:1.8	1:1.7	1:1.7	1:2.1	1:1.9	1:1.9	1:1.7
	FH-A′B′	86	63.0	81.0	77.0	85.0	58.0	75.0

AB-MxOP, AB (A point–B point) plane angle to maxillary occlusal plane; FH-AB, angle formed by the lines between Frankfort horizontal line and AB plane; FH-A′B′, angle formed by the lines between Frankfort horizontal line and soft tissue AB plane; IMPA, lower incisor mandibular plane angle; LI-MnOP, lower incisor inclination to mandibular occlusal plane; MMC, maxillomandibular complex; MxOP-TVL, angle formed by the lines between maxillary occlusal plane and true vertical line; N-ANS:ANS-Me, the linear ratio between nasion and anterior nasal spine (ANS) to ANS–menton; N perp-A point, perpendicular distance between A point and nasion perpendicular line; N perp-Pog, perpendicular distance between pogonion and nasion perpendicular line; Sn′-LL, linear measurement between subnasale perpendicular line and the lower lip mucocutaneous junction; Sn′-Pog′, linear measurement between subnasale perpendicular line and soft tissue pogonion; Sn′-stms:stmi-Me′, the linear ratio between subnasale and superior stomion to inferior stomion to soft tissue menton; Sn′-UL, linear measurement between subnasale perpendicular line and the upper lip mucocutaneous junction; STO, surgical treatment objective; U1 exposure, upper incisor exposure; U1-MxOP, upper incisor inclination to maxillary occlusal plane; U1-PP, upper incisor inclination to palatal plane; upper lip angle, angle formed by the lines between subnasale perpendicular line and subnasale–stomion line.

*Critical consideration factors that are considered for the decision of maxillomandibular advancement subtypes.

CLINICAL REPORTS

Patient 1: Segmental Maxillomandibular Advancement

A 27.9-year-old man with severe OSA and snoring was referred from a sleep center. He complained about poor life quality by excessive daytime sleepiness from frequent sleep fragmentation and low level of O_2 saturation. He had an apnea–hypopnea index (AHI) of 49.5, supine AHI of 81.1, respiratory disturbance index (RDI) of 58.3, and the lowest oxygen saturation ($LSaO_2$) of 87%. He was obese with a body mass index (BMI) of 25.3 kg/m^2 and had excessive fat deposition around the submental area with thick neck circumference. He showed convex profile with protrusive upper lip and severely retruded chin (Fig. 1). Class I molar and canine relationships and deep overbite by extruded upper and lower incisors existed as a consequence of dental compensation. Lateral cephalometric analysis (Table 1) represented skeletal class II with protruded maxilla and retruded short mandible with slightly steep occlusal plane, uprighted upper incisors, and proclined lower incisors. Upper incisor exposure was acceptable relative to the long philtrum. Entire upper airway was severely obstructed associated with thick and long soft palate and posteriorly displaced hyoid.

FIGURE 1. Initial (A) and final (B) photographs of patient 1 showing the face and occlusion.

TABLE 2. Summary of 3-Dimensional Volumetric, Cross-Sectional, and Increment Measurements From Cone Beam Computed Tomography Images

	Patient 1			Patient 2			Patient 3		
CBCT Measurement	Initial	Final	Increment (%)	Initial	Final	Increment (%)	Initial	Final	Increment (%)
Total airway volume (mm^3)	9,776.4	17,208.2	76.0	13,285.8	18,798.0	41.1	12573.4	20,674.8	64.4
Minimum cross-sectional area (mm^2)	121.7	188.6	55.0	180.2	277.1	53.8	108.0	201.2	86.3
Retropalatal area (mm^2)	272.4	422.4	55.1	398.0	617.1	55.1	438.2	665.3	51.8
Retroglossal area (mm^2)	201.4	446.6	121.7	337.7	467.0	38.3	318.1	422.7	32.9

CBCT, cone beam computed tomography.

Segmental MMA with bimaxillary ASO was chosen based on protruded maxilla and upper lip, insufficient overjet by proclined lower incisors, and deep overbite by extruded lower incisors (Fig. 4A). After presurgical orthodontic flattening of maxillary occlusal plane, anterior maxilla was retracted when posterior maxilla was protracted and moved downward at the posterior nasal spine (PNS) level to maintain the occlusal plane angle. Along with mesial movement of the fulcrum at upper molar area by ASO, autorotation of mandibular proximal segment occurred. Secondary advancing genioplasty was performed at 6 months after MMA surgery to make up for insufficient mandibular advancement and incomplete improvement of OSA symptoms. As a final result, posterior maxilla was protracted by 4 mm at PNS and anterior maxilla was retracted by 2.5 mm at A point. Mandible was advanced by 5 mm at B point and by 11 mm at chin point (Table 1). Retropalatal airway width was increased by 7 mm (175% of PNS change) with forward displacement of soft palate, and retroglossal airway width by 5 mm (45% of chin point change) with upward displacement of hyoid and tongue base. Facial profile was improved by increased chin projection and throat length, supposedly in relation to weight loss as well (Fig. 1). Cone beam computed tomography (CBCT) analysis showed the increment of total airway volume by 76.0%, minimum cross-sectional area by 55.0%, retropalatal area by 55.1%, and retroglossal area by 121.7% (Fig. 5A–B; Table 2). Obstructive sleep apnea symptoms almost disappeared except for intermittent mild snoring with the posttreatment AHI of 14.0, supine AHI of 19.9, apnea index of 1.5, and LSaO$_2$ of 90.0% (Table 3).

TABLE 3. Summary of Polysomnographic Records Among Patients Between Pretreatment and Posttreatment

	Patient1		Patient 2		Patient 3	
PSG	Initial	Final	Initial	Final	Initial	Final
BMI	24.4	22.1	24.45	23.84	18.8	22.2
Sleep efficiency (%)	86.0	90.0	94.0	99.3	87.7	98.8
AHI	49.5	14.0	22.6	3.4	77.5	5.0
RDI	58.3	18.9	25.8	7.5	81.3	8.3
Supine AHI	81.1	19.9	80.6	3.9	82.1	7.7
AI	41.9	1.5	20.2	2.1	66.1	1.0
HI	7.6	12.5	2.5	1.3	11.4	4.0
Lowest SaO$_2$ (%)	87.0	90.0	87.0	92.0	85.0	90.0

AHI, apnea–hypopnea index; AI, apnea index; BMI, body mass index; HI, hypopnea index; PSG, polysomnographic; RDI, respiratory disturbance index; SaO$_2$, oxygen saturation.

Patient 2: Rotational Maxillomandibular Advancement

A 24.1-year-old man with moderate OSA was referred from ENT department. He had a history of orthodontic treatment with 4 bicuspid extraction 10 years ago. He has suffered from severe snoring, mouth breathing, and excessive daytime sleepiness, with AHI of 22.6, supine AHI of 80.6, RDI of 25.8, LSaO$_2$ of 87%, and BMI of 24.4 kg/m^2. He showed a convex profile with obtuse throat angle caused by retruded chin (Fig. 2). He had incompetent retruded lips. Upper incisor exposure at smile was slightly excessive by 2 mm. Class I molar and canine relationships were observed with large overjet and shallow overbite. According to lateral cephalometric analysis (Table 1), he revealed skeletal class II with bimaxillary retrusion and hyperdivergent vertical pattern with steep occlusal and mandibular planes. Severe constriction of entire upper airway was found.

Counterclockwise rotational MMA surgery with advancing genioplasty was selected based on the retrusive maxilla and upper lip and steep occlusal plane (Fig. 4B). The whole maxilla was protracted by 4.5 mm at PNS and mandible was advanced by 8 mm at B point and 12 mm at chin point, along with flattened occlusal plane by 4° (Table 1). Retropalatal airway width was increased by 9.5 mm (211% of PNS change) in relation to forward displacement of soft palate by 7 mm (156% of PNS change), and retroglossal airway width by 10 mm (83% of chin point change) associated with forward displacement of hyoid and tongue base. Balanced facial profile with increased chin projection and decreased lower facial height was obtained (Fig. 2) with the increment of total airway volume by 41.1%, minimum cross-sectional area by 53.8%, retropalatal area by 55.1%, and retroglossal area by 38.3% from CBCT analysis (Fig. 5C–D; Table 2). Night symptoms completely disappeared with the great improvements of supine AHI from 80.6 to 3.9 and of LSaO$_2$ up to 92.0% (Table 3).

Patient 3: Segmental-Rotational Maxillomandibular Advancement

A 21-year-old man with severe OSA and snoring was referred from ENT department. He had a history of phase I surgeries such as uvulopalatal flap and tongue base reduction, but the subjective symptoms were still severe with AHI of 77.5, supine AHI of 82.1, RDI of 81.3, and LSaO$_2$ of 85%. He had normal BMI of 18.8 kg/m^2 with normal neck circumference. He represented severe skeletal discrepancy that was regarded as a strong etiologic factor of OSA. Convex profile with thick upper lip, severely retruded chin, and short throat length was observed (Fig. 3). Upper incisor exposure at smile was excessive by 3.5 mm. Class I molar and canine relationships were found with large overjet and deep overbite by dental compensation. Lateral cephalometric analysis (Table 1) represented skeletal class II with slightly protruded maxilla and severely diverged short mandible. The patient showed hyperdivergent

FIGURE 2. Initial (A) and final (B) photographs of patient 2 showing the face and occlusion.

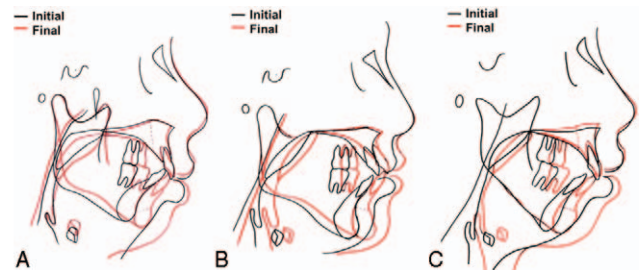

FIGURE 4. Superimposition between initial and final lateral cephalogram: (A) patient 1—segmental MMA; (B) patient 2—rotational MMA; (C) patient 3—segmental-rotational MMA. MMA, maxillomandibular advancement.

vertical pattern with steep occlusal and mandibular planes, short ramus, and resorbed condyles. Upper incisors were uprighted, and lower incisors were proclined and extruded with thin symphysis. Entire upper airway was severely constricted with downward position of hyoid.

Segmental-rotational MMA with advancing genioplasty was planned based on protruded maxilla and steep occlusal plane (Fig. 4C). The posterior maxilla was advanced by 5 mm at PNS maintaining sagittal position of anterior maxilla by maxillary ASO. At the same time, occlusal plane was flattened by CCW rotation of MMC reducing upper incisor exposure. The mandible was advanced by 6 mm at B point and 12 mm at chin point. Retropalatal airway width was increased by 5 mm (100% of PNS change) with forward displacement of soft palate. Retroglossal airway width was increased by 3 mm (25% of chin point change) associated with forward movement of hyoid. In spite of inadequate controls of occlusal plane and insufficient mandibular advancement due to anatomic limitations, soft tissue facial profile was acceptable (Fig. 3) and OSA signs and symptoms were cured based on posttreatment AHI of 5 and $LSaO_2$ of 90.0% (Table 3). According to CBCT analysis (Fig. 5E–F; Table 2), the increment ratios of total airway volume, minimum cross-sectional area, retropalatal area, and retroglossal area were 64.4%, 86.3%, 51.8%, and 32.9%, respectively.

DISCUSSION

All the presented patients were estimated as surgical success, which is defined as a posttreatment AHI $<$20 events/h and a reduction rate of AHI $>$50%, showing the reduction rates of AHI by 71.7% in patient 1, 85.0% in patient 2, and 93.5% in patient 3. Patients 2 and 3 could be judged as surgical cure based on posttreatment AHI $\leq$5 events/h, whereas patient 1 represented posttreatment AHI of 14 that may belong to mild level of OSA, although subjective symptoms completely disappeared. Patient's satisfaction beyond the figures might be explained by transition from apnea-dominant OSA type to hypopnea-dominant type with the increase of $LSaO_2$ from 87% to 90% (Table 3). Regarding postoperative dimensional changes of upper airway, total airway volumes from CBCT images were increased by 76.0% in patient 1 with segmental MMA, by 41.1% in patient 2 with rotational MMA, and by 64.4% in patient 3 with segmental-rotational MMA (Fig. 5; Table 2). According to the pharyngeal levels, the increment ratios in minimum cross-sectional area were 55.0% in patient 1, 53.8% in patient 2, and 86.3% in patient 3, and the ratios in retroglossal areas were 121.7% in patient 1, 38.3% in patient 2, and 32.9% in patient 3, while the retropalatal enlargements revealed similar ratios among 3 patients. The numerical discrepancy of increment ratio or AHI reduction could not support the previous studies[22] that had tried to compare the treatment efficacy among MMA techniques due to the lack of samples and of comparative criteria.

FIGURE 3. Initial (A) and final (B) photographs of patient 3 showing the face and occlusion.

There has been controversy on the therapeutic superiority among several MMA techniques. However, it might be pointless to inquire which MMA technique would be the best for patients with OSA, because there are plenty of other contributing factors such as degree of initial airway obstruction, main obstruction level, severity of neuromuscular dysfunction, pharyngeal soft tissue response to the skeletal movements, and so on. A meta-analysis found that it was impossible to calculate the difference in effect of the predictor variables between straight MMA and rotational MMA even though both procedures resulted in meaningful decrease in AHI and increase in $LSaO_2$.[23] Liao et al[18] highly appreciated a segmental MMA in terms of getting better esthetic and functional outcomes for Asian patients; however, they did not distinguish segmental-rotational MMA from nonrotational segmental MMA when reporting their outcome data. Not all the Asian patients with OSA fall under segmental MMA because individual patient has different skeletal, dentoalveolar, and pharyngeal soft tissue patterns surpassing racial difference. Rather than adhering to single specific surgical technique, selective application of optimal surgical modifications for each patient with OSA would be recommended to follow according to the decision criteria in the procedure of the individualized STO.

Minimum decision criteria for the selective application of MMA subtypes are suggested: anteroposterior position of maxilla, upper lip projection, overjet, lower incisor inclination, upper incisor exposure, and occlusal plane angle. Out of these, anteroposterior position of maxilla and upper lip projection deserve to be considered first. Unless a patient has protrusive maxilla and upper lip, straight MMA or rotational MMA could be taken into account according to the degree of maxillary retrusion, combined with advancing genioplasty if needed. Then, with normal range of incisor exposure and occlusal plane in addition, straight MMA would be selected. With excessive upper incisor exposure and steep occlusal plane, however, rotational MMA should be finally chosen. If a patient has protrusive maxilla and upper lip, on the contrary, segmental MMA with maxillary ASO would be considered. In patients with small overjet with lower incisor proclination simultaneously, bimaxillary ASOs should be the first option for the maximum mandibular advancement toward class I molar

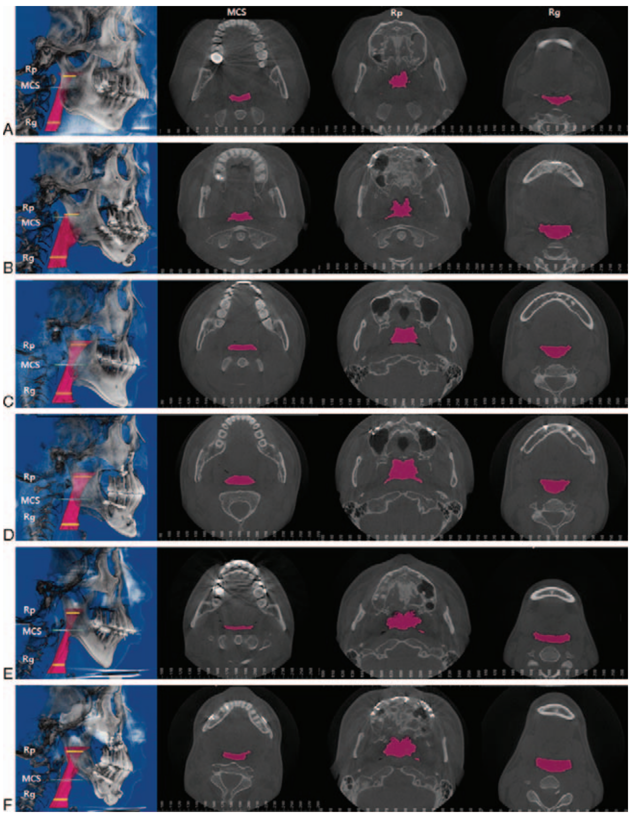

FIGURE 5. (A–F) Outcome measures assessing the dimensional improvements of upper airway on cone beam computed tomography images. Preoperative images of (A) patient 1, (C) patient 2, and (E) patient 3. Postoperative images of (B) patient 1, (D) patient 2, and (F) patient 3. The cross-sectional areas were measured: (second column) minimum cross-sectional (MCS) level; (third column) retropalatal (Rp) level; (fourth column) retroglossal (Rg) level.

relationship. Otherwise, MMA with maxillary ASO and advancing genioplasty might be beneficial for opening airway at the cost of molar relationship. Furthermore, if the patient has excessive upper incisor exposure and steep occlusal plane as well, segmental-rotational MMA would be required. In spite of some limitations to be applied to all types of patients with OSA, these critical decision factors could help the orthodontists to choose proper subtypes of MMA as a primary guideline.

Segmental MMA has the advantage of greater maxillary and mandibular advancement in a patient with normal-to-protrusive anterior maxilla and upper lip with small overjet compensated by proclined lower incisors. Considering that the thing significantly correlated with the OSA improvement was the amount of maxillary advancement rather than of mandibular advancement,[4,22,24] and that the opening mechanism of airway by maxillary advancement depended on subsequent anterior displacement of soft palate,[2,4,19] the protraction amount of posterior maxilla would be more critical for the surgical success than that of anterior maxilla. In this context, segmental MMA was selected for the treatment of patient 1. In addition, extruded and proclined lower incisors could be surgically corrected in this patient without presurgical aggravating stage; however, the setback amount of anterior segment was not enough to upright the lower incisors due to moderate crowding. Inadequate correction of lower incisor inclination and the lack of presurgical decompensation of class I molars into class II relationship caused insufficient mandibular advancement even with ASO, which required additional advancing genioplasty at 6 months after MMA surgery. Accordingly, the greatest airway enlargement could be obtained at the retroglossal level at the end, and the result was stably maintained at 2 years after surgery.

Rotational MMA is frequently performed because one of the most common traits of patients with OSA is hyperdivergent skeletal pattern with steep occlusal plane affecting oropharyngeal and hypopharyngeal airway obstruction.[13–15] In spite of concerns on the stability regarding CCW rotation of MMC, autorotation of proximal segment, and upward forward displacement of hyoid, Wolford et al[25] have claimed substantial rotation of MMC for optimal esthetic and functional results representing stability of enlarged airway >34 months after surgery. Rotational MMA was applied to patient 2 because he had steep occlusal and mandibular plane with excessive upper incisor exposure at smile. Advancing genioplasty was combined due to the limited amount of CCW rotation by proclined upper incisors. Remarkable displacement of soft palate and hyoid may contribute to total airway enlargement with complete relief of OSA symptoms in addition to better facial appearance in this patient, which was maintained stably at 1 year after surgery. On the other hand, it is not easy to determine the CCW rotation of MMC in a patient with steep occlusal plane and insufficient incisor exposure together. In this patient, additional ASO could prevent reduction of incisor exposure allowing forward and downward movement of posterior maxillary segment to accomplish flattening occlusal plane for maximum rotational advancement of mandible.

Segmental-rotational MMA would be a good option to the patient with steep occlusal plane accompanied by protruded maxilla and insufficient upper incisor exposure. Patient 3 with highly severe OSA was treated by segmental-rotational MMA in consideration of steep occlusal and mandibular planes with severely diverged mandible and protruded thick upper lip. However, lower ASO could not be involved for the preferential correction of poor shape of chin and symphysis by genioplasty. Although 1-stage surgery was possible with this option, presurgical orthodontic period was too long and harsh for the patient to endure. Skeletal correction was not enough after surgery, but the OSA signs and symptoms were relieved with the greatest airway enlargement at the minimum cross-sectional area, supported by AHI reduction from 77.5 to 5 events/h. The point is that the concomitant control of occlusal plane and bone segments should be accurately performed by surgeon, and then strategic orthodontic treatment to keep the corrected occlusal plane and segmental position should be followed.

CONCLUSIONS

The authors suggested critical decision criteria to determine the optimal design of MMA to each patient with OSA with different skeletal and pharyngeal patterns. Despite the lack of statistical evidence based on large samples, this case series deserve a clinical basis for individualized surgical planning in terms of maximum airway enlargement with favorable facial appearance. Further study is needed to verify the utility of these criteria based on the feedback of long-term therapeutic effectiveness and on the search of therapeutic predictors of each MMA subtype.

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