Original Article

A Retrospective Comparative Study of Mandibular Stability and the Anteroposterior Dimension of the Airway between the Surgery-early and the Conventional Orthognathic Surgery after Bilateral Sagittal Split Ramus Osteotomy Setback

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Abstract

The purpose of this study was to compare the skeletal and upper airway stability at 6 months post-surgical treatment between the surgery-early approach and the conventional orthognathic surgery in patients with skeletal Class III malocclusion who underwent one-jaw bilateral sagittal split ramus osteotomy setback surgery. Thirty-five patients were included and allocated into two groups based on pre-surgical orthodontic treatment: surgery-early group (n = 15) and conventional orthognathic surgery (n = 20). Lateral cephalometric radiographs were taken before surgery (T0), immediately after surgery (T1), and 6 months after surgery (T2). Independent t-test and Mann-Whitney U test were used to analyze the data between the two groups. Paired *t*-tests and Wilcoxon signed-rank tests were used to analyze the data in each group. At 6 months after surgery (T1-T2), forward, upward, and counterclockwise rotational movements of the mandible in both groups were observed with no statistically significant difference. Changes in upper airway dimensions, when compared between the pre-post surgical phase (T2-T0) revealed that the surgery-early group showed a statistically significant decrease ($p<0.05$) in the oropharynx, while the conventional orthognathic surgery group showed statistically significant decrease ($p<0.05$) in the oropharynx and hypopharynx. A comparison between the two groups at 6 months post-surgical treatment revealed no statistically significant difference. Dental movement in both groups had no statistically significant difference in either the vertical or anteroposterior movement. Compared with the conventional orthognathic surgery group, the surgery-early group showed an equal amount of mandibular movement and upper airway change at 6 months post-surgical treatment.

Keywords: Class III orthognathic surgery, Surgery-early, Upper airway

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Introduction

In the past several years, it has been established that conventional orthognathic surgery (COS) with pre-surgical orthodontic treatment is an appropriate treatment in patients with severe skeletal discrepancies.[1] However, the pre-surgical orthodontic phase contains leveling and aligning, and decompensation of the anterior teeth that worsen facial aesthetics with time during a period of about 15–24 months, especially among patients with skeletal Class III malocclusion where the lower lip protrudes according to the alignment of the lower teeth.[2]

The surgery-first/early approach (SEA) is a therapeutic strategy that consists of orthognathic surgery followed by post-surgical orthodontics without pre-surgical orthodontic treatment or minimal pre-surgical orthodontic treatment.[3] The surgery-first/early approach increases patient satisfaction with immediate profile improvement after surgery and shortens the total treatment time due to regional acceleratory phenomena, which include accelerated bone turnover and decreased regional mineral density resulting in faster tooth movement. Furthermore, the direction of post-surgical orthodontic treatment coincides with the natural direction of spontaneous dental compensation and muscular force.[4] Even though the surgery-first/early approach has many advantages, stable occlusion is not found immediately after surgery. More tooth movement is needed to settle the occlusion, unlike conventional orthognathic surgery. Therefore, surgical relapse due to occlusal instability is found to be greater in this group.[5]

The mandible, tongue and pharyngeal walls are closely related by their soft tissue attachments. Mandibular setback surgery can reduce pharyngeal airway volume and may lead to obstructive sleep apnea.[6,7]

Several studies have concluded that the surgery-first/early approach is a clinically acceptable and helpful approach; however, postoperative mandibular stability from post-surgical orthodontic treatment remains unclear, and none of the studies has compared post-surgical changes in the upper airway between patients in the COS and the SEA groups.

Our study aimed to assess the skeletal and upper airway stability 6 months after mandibular setback and compare the results between the COS group and the SEA group in skeletal Class III patients.

Materials and methods

Study subjects and power analysis

This retrospective study was conducted on patients with skeletal Class III who underwent surgery at the Prince of Songkla University between January 2014 and August 2020. Approval from the ethics committee was received from Prince of Songkla University(EC6303-009). The sample size was calculated using the G*Power 3.1 statistical program based on a significance level of 0.05 and a power of 80%. Power analysis showed that 19 patients were required for each group.

Inclusion criteria

- Class III patients who underwent one-jaw surgery with bilateral sagittal split ramus osteotomy (BSSRO) setback with non-extraction.
- Patients had three sets of good quality radiographs.
- The SEA group had minimal presurgical orthodontics not longer than 6 months.

The exclusion criteria included patients who underwent two-jaw surgery or genioplasty only.

The patients were subsequently allocated into two groups. The SEA group was patients who obtained initial leveling and aligning for less than 6 months (n = 15; 4 males and 11 females; mean age 27.9 ± 3.6 years). The COS group was patients who obtained complete presurgical orthodontic treatments (n = 20; 6 males and 14 females; mean age 24.9 ± 4.9 years).

Changes in the mandibular position and upper airway dimensions were retrospectively examined by measuring the lateral cephalometric radiographs (GXDP-700™, Gendex, PA, USA) at three time points: before surgery (T0), 4–6 weeks after surgery (T1), and at 6 months after surgery (T2). Dolphin Imaging software (Dolphin Imaging and Management Solutions, Chatsworth, California, USA) was used to digitize and analyze the data by one examiner who was blinded to the groups of patients.

Landmarks and reference planes

The landmarks and reference planes are shown in Figure 1 and 2. The measurements were divided into three groups: (1) skeletal measurements: horizontal measurements, vertical measurements, and angular measurements (Fig. 1); (2) dental movements (Fig. 1); and (3) upper airway measurements (Fig. 2).

The horizontal reference plane was defined as the line that passes through the sella (S) and oriented 7 degrees inferior to the sella-nasion plane (SN7 plane). The line perpendicular to the SN7 plane through the S point was taken as the vertical reference plane (SN7 perp plane).

Pogonion (Pog) was selected to measure the mandibular position while the dental landmarks were mesial cusp tip of the upper and lower first molars. The distances between the SN7 perp plane and SN7 plane to the Pog and cusp tip were defined as horizontal measurements and vertical measurements, respectively. Rotational changes of the mandible were measured from the angle between the SN plane and the GoMe plane. Measurements of the upper airway were subdivided into three regions: nasopharynx; oropharynx; and hypopharynx. The nasopharynx was defined as the distance between the perpendicular line from the posterior nasal spine (PNS) to the upper posterior pharyngeal wall (UPW). The oropharynx was defined as the distance between the perpendicular line from the tip of the uvula (U) to the middle posterior pharyngeal wall (MPW), and the hypopharynx was defined as the distance between the perpendicular line from the vallecula (V) to the lower posterior pharyngeal wall (LPW).

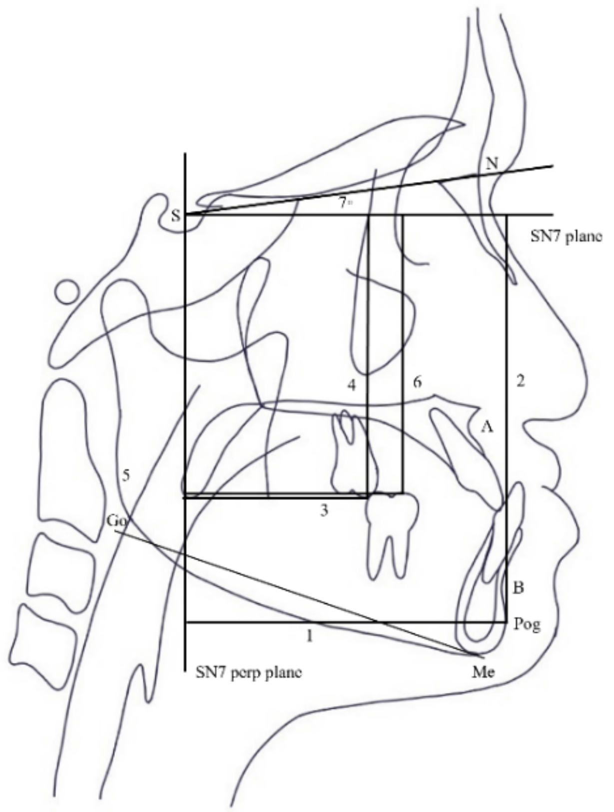

Figure 1 *Landmarks and reference planes for skeletal and dental measurements. Landmarks: S, sella; N, nasion; A, subnasale; B, supramentale; Pog, pogonion; Go, gonion; Me, menton; U6, upper molar; L6, lower molar. Reference planes: SN7 plane; perpendicular line of S to SN7 plane (SN7 perp plane). Skeletal and dental measurements (mm): 1. SN7 perp plane to Pog; 2. SN7 plane to Pog; 3. SN7 perp plane to U6; 4. SN7 plane to U6; 5. SN7 perp plane to L6; 6. SN7 plane to L6.*

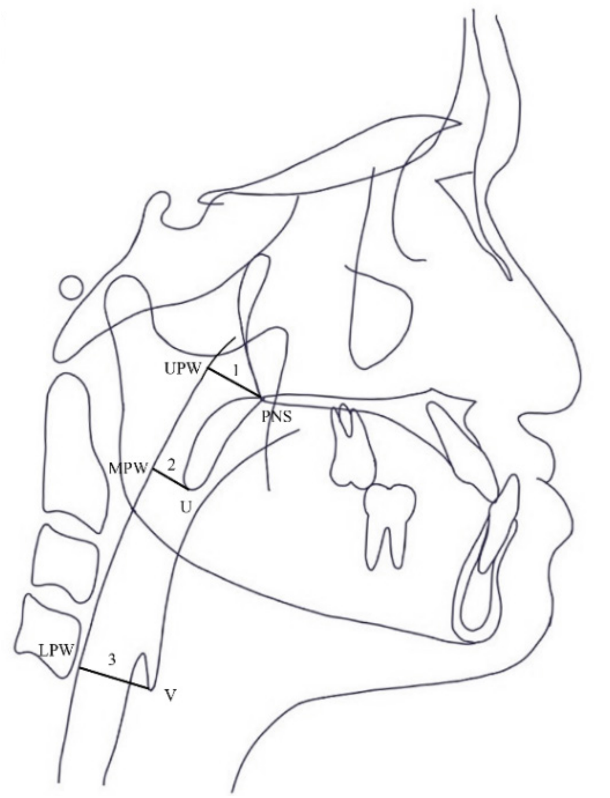

Figure 2 *Landmarks and reference planes for upper airway measurements. Landmarks: PNS, posterior nasal spine; U, uvula; V, vallecula; UPW, upper posterior pharyngeal wall; MPW, middle posterior pharyngeal wall; LPW, lower posterior pharyngeal wall. Upper airway measurements (mm): 1. PNS-UPW; 2. U-MPW; 3. V-LPW.*

Statistical analysis

Statistical analyses were performed using SPSS software, version 26 (IBM Corp., Armonk, NY, USA). Assessing the assumption of normality was accomplished by Shapiro-Wilk test. Postoperative movement of the mandible, dental, and anteroposterior changes of the upper airway in each group were analyzed using a paired t-test/Wilcoxon sign rank test, while changes between the SEA and the COS groups were determined using the independent sample *t*-test/Mann-Whitney U test. For all tests, two-sided *P* values <0.05 were considered significant.

All cephalometric measurements were repeated on ten randomly selected radiographs after a 1-month interval. The intra-observer reliability was high according to the correlation coefficients that were between 0.7916 and 0.8885.

Results

Comparison of demographic data between the SEA and the COS groups at the initial examination (T0)

No significant difference was observed in the skeletal measurements (SNA, SNB, ANB, Sn-GoMe), upper airway measurements (nasopharynx, oropharynx, hypopharynx), or overjet between the two groups (Table 1). However, overbite and interincisal angle were larger in the SEA group ($p<0.05$).

Comparison of surgical changes (T0-T1) and post-operative changes (T1-T2) in skeletal measurements

No significant difference was observed in mandibular setback distance between the SEA group (6.68 ± 3.46 mm) and the COS group (6.09 ± 3.93 mm). Rotational movement changed by 1.95 ± 2.55° in the SEA group and 1.23 ± 1.79° in the COS group with clockwise direction (Table 2). However, there was significant difference ($p<0.05$) between the groups in the vertical movement immediately after surgery. In the SEA group, downward movement (0.50 ± 1.89 mm) was observed, while upward direction (1.04 ± 2.79 mm) was observed in the COS group.

No significant difference in mandibular movement was observed at 6 months post-surgery between the two groups. The mandible moved forward in both groups: 1.44 ± 1.71 mm and 0.72 ± 2.05 mm in the SEA and the COS groups, respectively. In the vertical direction, the mandible moved upward in both the SEA group (0.59 ± 2.30 mm) and the COS group (0.97 ± 1.50 mm). The average rotational change in the counterclockwise direction was 0.52 ± 2.36° in the SEA group and 0.39 ± 1.32° in the COS group.

Comparison of the postoperative changes (T2-T0) in upper airway measurements

The anteroposterior dimension decreased with no significant difference between the two groups at the oropharynx and hypopharynx, while the nasopharynx was barely maintained through the follow-up period (Table 3).

At 6 months after surgery, the changes at the oropharynx from T0 to T2 were decreased to 1.76 ± 2.03 mm in the SEA group and 0.93 ± 2.66 mm in the COS group with statistically significant differences in SEA group ($p<0.05$).

After surgery from T0 to T2, the hypopharynx were decreased to 1.59 ± 2.43 mm in the SEA group and 1.52 ± 2.75 mm in the COS group with statistically significant differences in both groups ($p<0.05$).

Comparison of post-surgical changes (T1-T2) in dental measurements

The upper molar showed extrusion in the SEA group (0.62 ± 1.69 mm) and the COS group (0.13 ± 1.29 mm), and mesialization in the SEA group (1.09 ± 2.86 mm) and the COS group (0.47 ± 1.69 mm) without statistically significant difference between the two groups (Table 4). The lower molar presented extrusion in the SEA group (0.89 ± 2.24 mm) and the COS group (1.04 ± 1.39 mm) and distalization in the SEA group (1.38 ± 2.38 mm) and the COS group (1.26 ± 1.70 mm). However, there was no significant movement of the lower molars between the groups during this period (Table 4).

Table 1 Comparison between the SEA and the COS groups at the initial examination (T0)

Variable	SEA group		COS group		*p*-value
	Mean	SD	Mean	SD	
SNA	84.53	2.98	82.31	3.65	0.064
SNB	86.96	4.46	85.56	3.16	0.294
ANB	−2.41	3.64	−3.23	3.63	0.512
SN-GoMe	36.17	5.41	36.04	4.40	0.939
Overjet	−3.10	2.78	−4.31	2.66	0.201
Overbite	1.53	1.63	0.50	1.12	0.034*
Interincisal angle	132.49	7.39	122.73	7.73	0.001*
Nasopharynx	24.47	3.40	24.57	3.21	0.973
Oropharynx	11.75	2.80	11.51	3.59	0.894
Hypopharynx	15.81	3.77	17.29	3.44	0.161

nasopharynx: distance between the perpendicular line from the posterior nasal spine (PNS) to the upper posterior pharyngeal wall (UPW). oropharynx: distance between the perpendicular line from the tip of the uvula (U) to the middle posterior pharyngeal wall (MPW).
hypopharynx: distance between the perpendicular line from the vallecula (V) to the lower posterior pharyngeal wall (LPW).
**significance at p-value <0.05 (independent sample t-test)*

Table 2 Measurement of mandibular movement

Variable		T0		T1		T2		T0-T1		*p*-value between gr.	T1-T2		*p*-value between gr.
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD	
SN7 perp -Pog (mm)	SEA	68.63	9.17	61.95	9.16	63.39	9.11	6.68	3.46	0.647	−1.44	1.71	0.550
	COS	69.6	8.59	63.58	7.70	64.30	7.69	6.09	3.93		−0.72	2.05	
SN7-Pog (mm)	SEA	103.7	8.06	104.28	7.85	103.69	7.62	−0.50	1.89	0.045*	0.59	2.30	0.278
	COS	103.8	8.92	102.84	8.38	101.86	8.21	1.04	2.79		0.97	1.50	
SN-GoMe (°)	SEA	36.17	5.41	38.13	4.53	37.61	5.66	−1.95	2.55	0.334	0.52	2.36	0.844
	COS	36.04	4.40	37.28	4.37	36.89	4.16	−1.23	1.79		0.39	1.32	

SN7 perp to Pog (+) backward movement of the mandible, (–) forward movement of the mandible.
SN7 to Pog (+) upward movement of the mandible, (–) downward movement of the mandible.
SN-GoMe (+) counterclockwise rotation of the mandible, (–) clockwise rotation of the mandible.
**significance at p-value <0.05 (independent sample t-test)*

Table 3 Measurement of upper airway changes

Variable		T0		T1		T2		T2-T0		*p*-value intra gr.	*p*-value between gr.
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
PNS-UPW (mm)	SEA	24.47	3.40	24.27	3.42	24.45	3.96	−0.02	3.50	0.983	0.784
	COS	24.57	3.20	24.37	3.20	24.30	3.30	−0.27	1.91	0.527	
U-MPW (mm)	SEA	11.75	2.80	10.14	3.54	9.99	3.99	−1.76	2.03	0.007*	0.321
	COS	11.51	3.59	10.36	3.11	10.58	3.39	−0.93	2.66	0.159	
V-LPW (mm)	SEA	15.81	3.77	15.23	3.76	14.22	4.53	−1.59	2.43	0.026*	0.941
	COS	17.29	3.44	16.06	3.48	15.77	4.67	−1.52	2.75	0.026*	

T1-T0, T2-T0 (+) increased upper airway dimension, (–) decreased upper airway dimension.
**significance at p-value <0.05 (Wilcoxon signed-rank tests)*

Table 4 *Comparison of tooth movements at post-surgical evaluation (T1-T2)*

Variable		T1		T2		T1-T2		*p*-value	*p*-value
		Mean	SD	Mean	SD	Mean	SD	Intra gr.	between gr.
SN7-U6 (mm)	SEA	66.46	5.15	67.09	4.36	−0.62	1.69	0.162	0.537
	COS	66.12	4.94	66.34	5.04	−0.13	1.29	0.433	
SN7 perp-U6 (mm)	SEA	39.60	6.95	40.69	5.03	−1.09	2.86	0.201	0.714
	COS	43.09	5.08	43.52	3.39	−0.47	1.69	0.334	
SN7-L6 (mm)	SEA	68.07	5.42	68.37	5.59	−0.89	2.24	0.432	0.777
	COS	67.31	5.02	67.44	5.41	−1.04	1.39	0.506	
SN7 perp-L6 (mm)	SEA	40.43	7.09	40.49	7.16	−1.38	2.38	0.706	0.777
	COS	42.21	5.55	41.61	5.85	−1.26	1.70	0.191	

SN7-U6 (+) intrusion, (–) extrusion

SN7 perp-U6 (+) distalization, (–) mesialization

SN7-L6 (+) intrusion, (–) extrusion

SN7 perp-L6 (+) mesialization, (–) distalization

**significance at p-value <0.05*

Discussion

At the initial examination, all patients had a skeletal Class III relationship with a normal maxilla position and prognathic mandible with no difference in vertical growth to control the upper airway size.

The occlusion examinations revealed that the interincisal angle and overbite were greater in the SEA group. According to the compensatory mechanism in skeletal Class III patients, flaring of the upper incisors and lingual tipping of the lower incisors are generally observed. Therefore, in the SEA group that didn't receive a complete correction of these problems, the deep curve of Spee, flaring of the upper incisors, lingual tipping of the lower incisors, and increased overbite remained.

After surgical correction, mandibular displacement unavoidably occurs to some degree, and skeletal relapse occurs. Studies of skeletal relapse after mandibular setback for Class III patients have reported various results, including the amount of mandible setback (4.80 to 8.70 mm [mean = 6.49 mm]), forward movement (0.60 to 2.87 mm [mean = 1.49 mm]), and relapse rate (7.1% to 51.4% [mean = 22.6%]).[8] The results of this study revealed that the average amount of mandibular setback was 6.59 mm, which is close to a previous study, and the mandible moved forward with no significant difference between the groups during the post-surgical period. The average forward movement was 1.44 mm in the SEA group and 0.72 mm in the COS group, which was about 21% and 11.8% higher than the Ko *et al.*[9] study, which found a 14.3% forward movement in the SEA group and 15.7% in the COS group with no significant difference between the groups. However, the Kim *et al.*[10] study also found significant differences between the two groups and reported that the SEA group had greater relapse (3.14 mm) than the COS group (1.30 mm) due to counter-clockwise rotation of the mandible, which resulted in forward movement of Pog after correction of the occlusal interference in the SEA group.

When we compared the changes in the vertical dimension immediately after surgery, the SEA group showed a downward movement, while the COS group moved upward. This possibly occurred from a remaining deeper curve of Spee and presented dental interference in the SEA group. Six months after surgery, both groups presented an upward movement with no significant difference in distance. This is contrary to the Kim *et al.*[10]

study that found an increase in upward movement of 2.69 mm in the SEA group more than 0.93 mm in the COS group.

Clockwise rotation of the mandible during surgery in this study occurred in both groups, but didn't present a significant difference. At 6 months post-surgery, the angular measurements decreased. Counterclockwise rotation of the mandible was found in this period, but without significant difference between the two groups. The Kim *et al.*[10] study found counterclockwise rotation, but the SEA group showed increased angular movement in the counterclockwise direction that was greater than the COS group. The rotational movement might contribute to the forward and upward movement of the mandible. This indicates that the horizontal position of the mandible is equally displaced in the vertical dimension; therefore, the movement in these two directions may have the effect on rotational movement.

Changes in the mandibular position during post-surgical orthodontic treatment can be due to muscular tone, the amount of mandibular setback, fixation technique, pre-surgical orthodontic treatment, and autorotation from a settling process of the upper and lower posterior teeth.[11] The results of this study exhibited upper first molar extrusion and mesialization, and lower first molar extrusion and distalization. All findings showed no significant difference between the SEA and the COS groups. It might be the result of using Class III elastic to correct open bite on the posterior teeth.[12] In addition, there was no significant difference of mandibular and tooth movement.

According to some studies, the mandibular setback can affect the upper airway.[6] Our findings confirm that upper airway changes need to be taken into account when planning surgical correction of dentofacial deformities. However, Park *et al.*[13] used cone-beam computed tomography which showed no significant changes of the nasopharyngeal or oropharyngeal airway in patients who underwent setback surgery. These results indicated lateral expansion of the soft tissue of the pharynx to preserve its volume. This present study showed that changes in the nasopharyngeal airway at 6 months post-surgery were not affected by mandibular setback surgery. These results are consistent with the studies by Engboonmeskul *et al.*[14]

At the 6-month post-surgical evaluation, the decrease in the anteroposterior dimension of oropharynx was founded in both groups in a ratio of 1:0.26–0.31 compared to the setback distance, but only the SEA group had a significant decrease compared with the initial examination. This agrees with the results of a study by Jeong *et al.*[15], which used CBCT superimposition to evaluate the three-dimensional morphologic changes in the upper airway space and found a decrease in the anteroposterior width of oropharyngeal region after 1-year mandibular setback surgery 14.2% and 18.0% in the CV1 and CV2 planes, respectively. However, recovery of the airway size was observed in some studies during the follow-up period.[16]

Together with the oropharynx, the hypopharynx significantly decreased in the anteroposterior dimension. A continued gradual decrease was shown in the hypopharynx and the size decreased in a ratio of 1:0.20–0.24 compared to the setback distance. This is in agreement with previous studies that found a continued reduction in the upper airway at the hypopharynx level for 2–6 years after surgery.[17,18] This occurs because this part of the upper airway is affected by the hyoid bone and muscles of the tongue that adjust to the new environment.

This study used a two-dimensional lateral cephalogram to analyze the pharyngeal airway space. The three-dimensional images might be a better method. However, they are more expensive and have a higher radiation dosage than lateral cephalogram. Riley and Powell[19] evaluated the reliability of CT scans and cephalograms in determining the posterior airway space and reported an acceptable result. Moreover, lateral cephalogram is widely used, less expensive, and simple for comparison with extensive normative data and with other studies.

Finally, no difference was observed between the SEA and the COS groups in the anteroposterior dimensions at all three levels of the upper airway, which is due to the similar amount of the mandibular setback.[20,21]

This study had some limitations. The small sample size possibly led to an increased type 2 error and affected the power of testing for statistical differences. The short observation period did not permit evaluation of the final complete occlusion. Further studies are needed to examine the treatment period to the end of complete orthodontic treatment to evaluate skeletal changes, especially upper airway changes.

Conclusions

At 6 months after surgery, Class III orthognathic surgery with or without presurgical orthodontic treatments showed no difference in the anteroposterior, vertical, or rotational change of the mandible, and the dimension of the upper airway. To achieve a good outcome of madibular setback surgery and prevent the occurrence of obstructive sleep apnea, careful and precise treatment plans about skeletal and soft tissue structures are needed.

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