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Effects of mandibular setback surgery on the sleep architecture and respiratory function (Clinical observations)

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Abstract

Cephalometric analyses and full channel laboratory-based polysomnography (PSG) were performed to clarify the relationship between mandibular setback surgery and the respiratory function at sleep and the sleep architecture. Thirty-nine Japanese adults (male, n = 13; female, n = 26) with skeletal Class III malocclusion who were treated with mandibular setback surgery were examined. All patients underwent lateral cephalography and full PSG before and at more than 6 months after advanced surgery. All radiographs were traced and the measurements were statistically analyzed. The anteroposterior airway width tended to decrease at all sites after mandibular setback, but no significant difference was observed. Among the full PSG data, the 5% oxygen desaturation index (ODI), wake time, and lighter stages of sleep (Stage N1, N2) were statistically significant parameter ($P < .05$).

It was suggested that mandibular setback surgery tended to result in a worse respiratory function at sleep and worse sleep architecture, even if the patient did not develop obstructive sleep apnea syndrome (OSAS).

KEYWORDS
mandibular setback surgery, obstructive sleep apnea syndrome (OSAS), pharyngeal airway space, quality of sleep, respiratory function

1 | INTRODUCTION

Orthodontic surgery is widely used to correct various facial and jaw discrepancies in which the position, aesthetics, and functional capabilities of the jaws and teeth are not in harmony. In particular, mandibular setback has been used to treat skeletal ClassIII malocclusion. Surgical skeletal movements change the positions of the jaws and soft tissues to achieve an appropriate maxillomandibular relationship and aesthetics. However, they may also cause changes in the pharyngeal airway morphology through the pushing and stretching of soft tissues.[1]

The issue of pharyngeal airway morphology is important in orthognathic surgery patients with skeletal ClassIII malocclusion, since the constriction might be a predisposing factor for obstructive sleep apnea syndrome (OSAS).[2] OSAS is a common disorder characterized by repetitive upper airway collapse during sleep. It has long been recognized that craniofacial skeletal restriction, such as narrow crania base, smaller maxilla and mandibular retrognathia are all likely to encroach on upper airway soft tissues and result in a smaller airway space.[3] Guilleminault et al[4] first reported the development of OSAS in two patients who had previously undergone mandibular setback surgery. Since then, the attention given to this subject has been growing. Although there have been few studies using full channel laboratory-based polysomnography (full PSG) to assess the respiratory function at sleep, the sleep architecture and OSAS. The aim of the present study was to evaluate the effects of mandibular setback surgery on sleep using cephalometric analyses and full PSG during sleep.

2 | MATERIALS AND METHODS

This prospective study included 39 patients (male, n = 13; female, n = 26) who had skeletal ClassIII malocclusion and who were treated with only mandibular setback surgery (1 jaw) at Kurume University, Dental and Oral Medical Center, during the period from 2008-2016. All subjects underwent a bilateral sagittal split osteotomy, while rigid fixation using screws was also performed. Patients with craniofacial anomalies, syndromes, and systemic diseases were excluded. The mean age of the patients at surgery was 22.14 ± 5.37 years (range: 17-37 years), and the mean body mass index was 20.80 ± 2.90 (range: 15.21-24.21; Table 1).

The protocol of this study has been carried out in accordance with Declaration of Helsinki and approved by the Ethics Committee of Kurume University (Ethics Committee: 16229). Informed consent was obtained from all patients.

2.1 | Cephalometric radiography

All the patients underwent lateral cephalography before and at more than 6 months after surgery. All cephalometric radiographs were obtained under the following conditions: in the sitting position, with the orbital-auricular plane (FH-plane) held horizontal, in centric occlusion, with the tongue in a relaxed position, and with the patient holding their breath at the end of the expiratory phase.

The cephalometric landmarks and measurements used in study are shown in Figure 1.

To evaluate the pharyngeal airway morphology, a method based on the cervical spine in which no morphological changes due to orthognathic surgery were observed was used.[5]

The line passing through the lowest point of the third cervical vertebra and the lowest of the fourth cervical vertebra is provided as the reference line. Then we draw a perpendicular line from the first cervical vertebra to the reference line, and the point of intersection of the line and anterior pharyngeal wall define APW1. The point of intersection of the line and back wall is PPW1. Similarly, from the lowest point of the anterior tubercle of the first cervical vertebra, the lowest point of the second cervical superior articular surface, the lowest point of the vertebral body of the second cervical vertebra, the lowest point of the vertebral body of the third cervical vertebra to the reference line. The perpendicular line was drawn, and the intersections with the anterior wall of the pharynx were designated

APW2 to APW5, and the intersections with the posterior wall of the pharynx were PPW2 to PPW5. Five lines were set to evaluate the anteroposterior airway width (APW1-PPW1, APW2-PPW2, APW3-PPW3, APW4-PPW4, and APW5-PPW5).

A single operator performed all measurements (Figure 2).

2.2 | Full PSG

Overnight full PSG was performed before and after surgery in the sleep laboratory of Kurume University Hospital. PSG included electroencephalography (EEG), electromyography (EMG), electrooculography (EOG), electrocardiography (ECG), and examination of airflow using an oronasal thermistor, along with the measurement of chest and abdominal wall movements, oxygen saturation using a pulse oxymeter, snoring sounds using a tracheal microphone, and body position. The data were scored according to standard criteria. To evaluate respiratory disorder and sleep architecture, the following 12 indices were examined: wakefulness (Stage W), non-rapid eye movement sleep (Stage N1-N3), rapid eye movement sleep (Stage R), average number of arousals per hour of sleep (arousal index, ArI), apnea index (AI), hypopnea index (HI), apnea-hypopnea index (AHI), mean percutaneous oxygen saturation (mean SPO_2), lowest oxygen saturation (lowest SPO_2), and 3, 4, 5% oxygen desaturation index (3, 4, 5%ODI). Sleep efficiency is evaluated by the appearance rate of each sleep stage.

2.3 | Statistical analysis

The preoperative and postoperative cephalometric measurements and full PSG data were compared using the Wilcoxon test. The correlation between the amount of mandibular setback and anteroposterior airway width, full PSG data were assessed with Spearman's p test. A p-value of less than.05 was considered to indicate statistical significance. All statistical analyses were performed using Ekuseru-Toukei 2015 (Social Survey Research Information Co., Ltd).

3 | RESULTS

3.1 | Patients

Patients had a mean age of 22.14 ± 5.37 preoperatively. The preoperative body mass index (BMI) was 20.80 ± 2.90, while postoperatively it was 20.93 ± 2.85. No significant differences were observed perioperatively (P = .999). Table 2 presents the results before surgery and those after surgery.
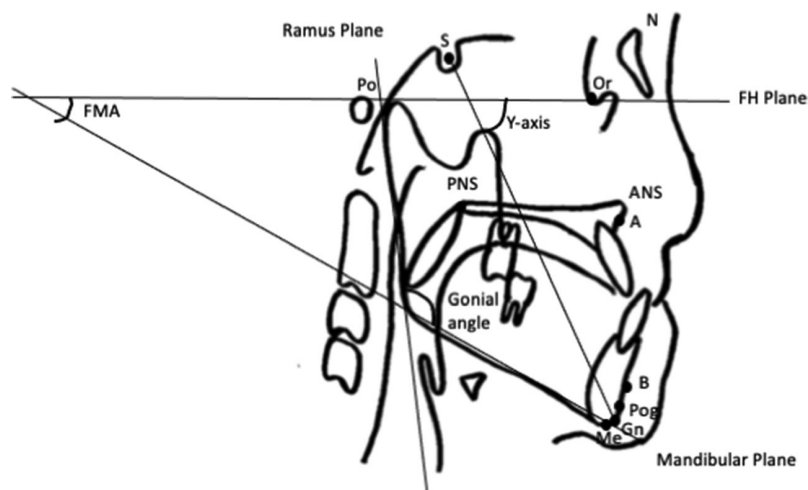
3.2 | The changes of airway space

The anteroposterior airway width tended to decrease at all sites after mandibular setback, but no significant difference was observed (Table 3).

TABLE 1 Patients'data

	Men	Female	Total
Cases (n)	13	26	39
Age (years)	20.15 ± 3.00	23.15 ± 5.98	22.14 ± 5.37
BMI (Pre-OP)	22.34 ± 2.66	20.02 ± 2.70	20.80 ± 2.90
BMI (Post-OP)	22.91 ± 2.79	19.95 ± 2.32	20.93 ± 2.85
Mandibular setback (mm)	5.31 ± 1.05	5.19 ± 2.18	5.23 ± 1.88

Abbreviation: BMI, body mass index.

FIGURE 1 Cephalometric landmarks of hard and soft tissues

TABLE 2 Results of a cephalometric analysis

	Pre-OP		Post-OP		Wilcoxon test (P < .05)
	Mean	SD	Mean	SD	
SNA (*)	77.01	4.37	77.01	4.37	
SNB (*)	82.76	4.51	80.18	3.64	P > .05
ANB (*)	−5.74	3.29	−2.99	3.26	P > .05
FMA (*)	30.94	6.43	32.47	7.66	P = .79
Go-angle (*)	124.68	7.85	123.77	7.51	P = .13
Y-axis (*)	68.38	8.82	68.85	4.42	P = .07

3.3 | The respiratory function at sleep and the sleep architecture

ArI, AI, HI and AHI tended to increase but there was no significant difference between the preoperative and postoperative values. Regarding oxygenation and desaturation, 5% ODI was the only statistically significant parameter (P < .05; Table 4).

Stage N3 of deep sleep decreased and stage N1/N2 of light sleep increased after surgery; thus, stage N3 of deep sleep shifted to lighter stage of N1/N2 sleep. These results suggest that the mandibular setback operation affects the sleep architecture and reduce the sleep quality (Table 5).

3.4 | Correlation between the amount of mandibular setback and anteroposterior airway width and PSG data

There was a significant relationship between the amount of mandibular setback and the change in APW2-PPW2, AI, and HI (P < .05). However, the correlation coefficients of these values were −0.34, 0.04, and −0.32 respectively, which shows that the amount of mandibular setback had little effect on AI and HI (Table 6).

4 | DISCUSSION

As the mandible, base of the tongue and pharyngeal wall are directly connected to each other by muscles and ligaments, mandibular setback surgery causes the posterior movement of the tongue and a reduction of the airway space.[6] Thus, mandibular setback surgery influences the surrounding organs in various ways.

In this study it was suggested that mandibular setback surgery tended to reduce the anteroposterior airway width and cause a worsening of the sleep architecture, even if the patient did not develop OSAS. The amount of mandibular setback had a little effect on the anteroposterior airway width and respiratory events. Kitahara et al[7] reported that the pharyngeal airway morphology and position of the hyoid bone, which change after mandibular setback surgery, can adapt to postsurgical dentoskeletal morphology or relapse during the long retention period. In addition, ClassIII patients showed significantly larger anteroposterior airway width in comparison to control subjects and exhibited significant posterior changes in most parameters of the anteroposterior airway width immediately after mandibular setback surgery. Hasebe et al[8] reported that almost all of the patients who had undergone mandibular setback surgery adapted to the new environment in respiratory function during sleep, but patients with more than 12 mm of mandibular setback may develop OSA after surgery, because it is difficult for the surrounding tissues to adapt to the new environment. In general BMI remained a risk factor associated with high AHI.[9] Because of that we planned two jaw surgery for patients requiring more than 10-mm mandibular setback, and almost all of the subjects were within the standard in this study, any patient can develop OSAS after surgery.

Sleeping time, sleep architecture, and arousal are the factors that affect the sense of sleep satisfaction. Because the sleeping time and deeper stage of sleep decrease with aging and stage N3 sleep almost disappears after 50 years of age, the possibility of developing sleep disorder can be expected to increase with age. In the present study, we recognized that the changes in the

TABLE 3   Anteroposterior airway width at Pre and Post-OP

| | Pre-OP | | Post-OP | | Wilcoxon' s test |
	Mean	SD	Mean	SD	(P < .05)
APW1-PPW1 (mm)	17.97	3.31	17.01	4.24	P > .05
APW2-PPW2 (mm)	15.16	3.90	12.90	3.70	P > .05
APW3-PPW3 (mm)	13.80	4.02	11.92	3.52	P > .05
APW4-PPW4 (mm)	13.50	3.20	11.89	3.33	P > .05
APW5-PPW5 (mm)	13.79	5.13	11.69	3.87	P > .05

TABLE 4   Changes in arousal, respiratory events, oxygenation and desaturation between Pre and Post-OP

| | Pre-OP | | Post-OP | | Wilcoxon's test |
	Mean	SD	Mean	SD	(P < .05)
Arousal					
Arl (events/h)	15.85	5.44	18.25	7.42	P = .10
Respiratory events					
AI (events/h)	0.82	0.69	0.87	0.99	P = .84
HI (events/h)	1.51	1.83	1.93	2.75	P = .99
AHI (events/h)	2.34	2.19	2.80	3.54	P = .08
Oxygenation and desaturatlon					
Mean SP0$_2$ (%)	97.26	0.93	97.31	0.76	P = .43
Lowest SP0$_2$ (%)	92.62	3.26	92.08	2.58	P = .20
3% ODI (%)	19.05	24.66	23.03	28.81	P = .06
4% ODI (%)	7.26	11.89	9.90	18.88	P = .22
5% ODI (%)	3.21	5.60	5.74	13.91	P = .006[*]

*P < .05, significant differences.

TABLE 5   Changes in **the sleep architecture between Pre and Post-OP**

| | Pre-OP | | Post-OP | | Wilcoxon' s test |
	Mean	SD	Mean	SD	(P < .05)
Stage W (%)	8.85	9.29	8.45	6.12	P = .01[*]
Stage Nl (%)	8.19	4.69	8.78	5.16	P = .002[*]
Stage N2 (%)	44.73	10.76	48.78	7.16	P = .002[*]
Stage N3 (%)	14.88	8.75	12.84	6.77	P = .89
Stage R (%)	22.94	5.39	20.93	5.60	P = .13

*P < .05, significant diff erences.

TABLE 6   Correlation between the amount of mandibular setback and anteroposterior airway width and PSG date

	P value	Correlation cofficients
APWl-PPWl	.74	
APW2-PPW2	.04[*]	−0.34
APW3-PPW3	.96	
APW4-PPW4	.39	
APW5-PPW5	.95	
AI	.005[*]	0.04
HI	.045[*]	−0.32
AHi	.10	
Ari	.07	
Lowes t SPO$_2$	.41	

*P < .05, significant differences.

anteroposterior airway width caused by mandibular setback surgery in young people affect the sleep architecture. According to Rama et al,[10] the oropharyngeal space is the most vulnerable part of in a patient with OSAS. We do not know whether there are long-term changes in the airway space that would affect sleep patterns; thus, a study investigating the long-term outcomes of mandibular setback is needed.

We performed cephalometry to evaluate the anteroposterior airway width in this study. Cephalometry performed by means of lateral teleradiography has been shown to be important for evaluating the upper airways in various fields because of the low cost
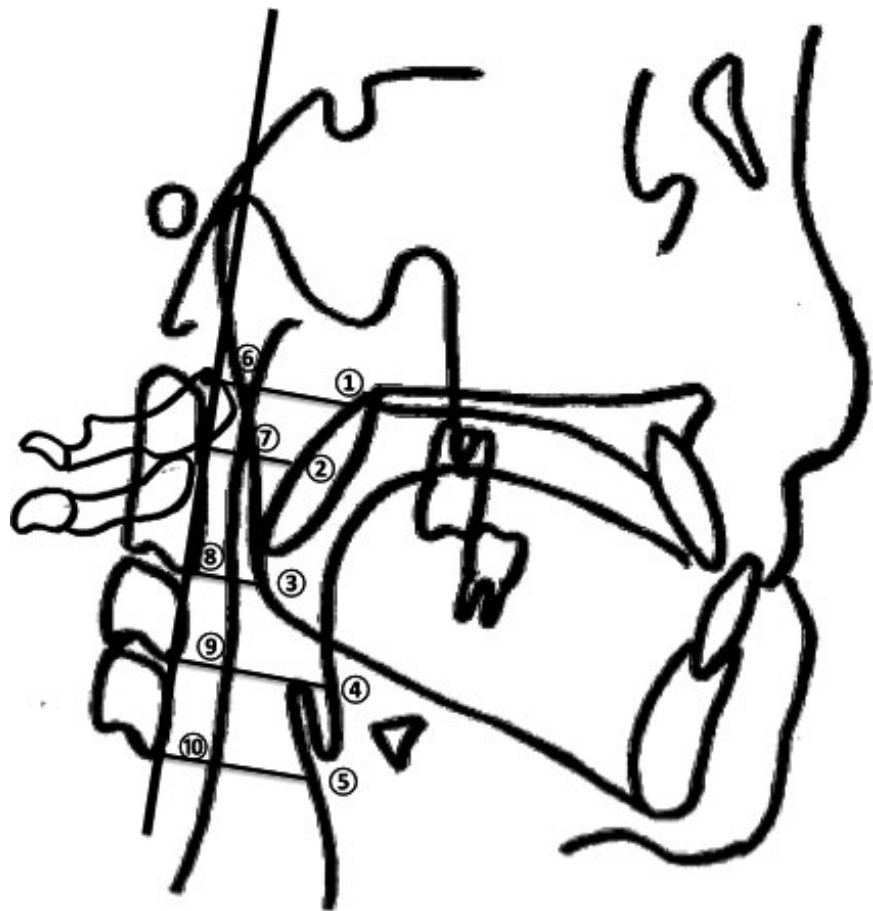
and easy accessibility of the technology. Furthermore, the results are highly reproducible and the dose of radiation to which the patient is exposed is low.[11,12] However, evaluation of the left-right diameter and the volume of the airway cannot be done by cephalometry. Okushi et al[13] reported that the left-right diameter of the velopharyngeal space was significantly increased after advancement of the maxilla and mandible, and the area of the space also increased

FIGURE 2 Landmarks for measurements of airway morphology. ①APW1. ②APW2. ③APW3. ④APW4. ⑤APW5. ⑥PPW1. ⑦PPW2. ⑧PPW3. ⑨PPW4. ⑩PPW5

significantly. Recently some studies have used computed tomography (CT) and fiber-optic pharyngoscope to evaluate the volume of the pharyngeal airway or three-dimensional morphologic changes in detail.[13-15] We would like to perform a similar study using these modalities in the future.

In the present study, OSAS was diagnosed based on polysomnography, preferably laboratory-based, full channel PSG, which is a gold standard for evaluating OSAS. It is known that sleep evaluations made with portable PSG devices are not as accurate as PSG data obtained a laboratory environment.[16] However, the performance of full PSG limited to institutions specializing in the treatment of sleep disorders and it is a relatively difficult examination to perform because the data must be analyzed by a laboratory technician and a sleep medicine-certified doctor. In this study, we were able to conduct detailed examinations to investigate sleep disorder by performing full-channel PSG in conjunction with our clinic sleep outpatient team.

5 | CONCLUSION

Mandibular setback surgery tended to result in a worse respiratory function at sleep and worse sleep architecture, even if the patient did not develop obstructive sleep apnea syndrome (OSAS). We need to know whether there are long-term changes in the airway space that would affect sleep patterns from now on.

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