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Effects of different surgical procedures on the pharyngeal space with mandibular prognathism

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We investigated how different surgical procedures affect pharyngeal airway changes through a comparative analysis of skeletal mandibular prognathism patients treated by sagittal split ramus osteotomy surgery (SSRO) with and without Le Fort I osteotomy surgery. Twenty patients who were diagnosed as having skeletal mandibular prognathism were divided into two groups : 10 patients who underwent mandibular setback surgery using SSRO (SSRO group) and 10 who underwent two-jaw surgery using Le Fort I osteotomy and SSRO surgery (Two-jaw group). To compare the jaw relationship, the position of the hyoid bone and pharyngeal airway morphology were examined in each group using lateral cephalometric radiographs that were taken before surgery (T0) and after more than one year and six months post-surgery (T1). The surgical changes between T0 to T1 were calculated and statistically compared for the two groups. The result, tongue position did not appear to change significantly between the two groups. The palatal pharyngeal space increased significantly in the Two-jaw group, while there was no significant difference in the SSRO group. The superior posterior and middle pharyngeal space decreased significantly in the SSRO group, while there was no significant difference in the Two-jaw group. All changes showed significant difference between the two groups. In contrast, the epiglottic pharyngeal space decreased in both groups. The ratio was bigger in the SSRO group than in the Two-jaw group. We concluded that the surgical method influences the pharyngeal airway space for patients treated only with SSRO and for those who recieved two-jaw surgery. (J Osaka Dent Univ 2015 ; 49 : 143–148)

Key words : Pharyngeal space ; Orthodontic treatment ; Skeletal mandibular prognathism

INTRODUCTION

Mandibular prognathism is among the most common types of jaw deformity and the degree of deformity and the severity level varies greatly from case to case. Surgical procedures to correct mandibular prognathism are generally determined based on the degree of mandibular protrusion and maxillary retrusion. Treatment options include the one jaw approach by mandibular sagittal split ramus osteotomy alone or the two jaw approach by a combination of mandibular setback and maxillary advancement with Le Fort I osteotomy. Pre- and postoperative changes in facial esthetics and occlusion, and postoperative skeletal stability have been investigated extensively.[1, 2] Influences of these procedures on the upper respiratory tract have also been widely studied.[3–6] However, few reports have addressed long-term changes in the pharyngeal airway space of patients treated by these procedures. The purpose of this study was to investigate how different surgical procedures affect pharyngeal airway changes through a comparative analysis of skeletal mandibular prognathism patients who were treated by the one jaw and two jaw approaches. Pre- and postoperative measurements of the dentofacial skeleton, pharyngeal airway space and areas that affect pharyngeal airway space were used as the parameters for measurements and comparison.

Table 1 Comparison of measurements at T0 and T1 for each group

	SSRO group			Two-jaw group		
	T0	T1	t-test	T0	T1	t-test
∠SNA (°)	78.2 ± 3.0	78.3 ± 2.8	NS	76.4 ± 2.8	79.3 ± 3.8	*
∠SNB (°)	85.1 ± 3.1	77.6 ± 3.8	*	83.1 ± 5.1	76.8 ± 4.8	*
∠ANB (°)	−6.2 ± 2.2	0.5 ± 1.8	*	−6.8 ± 3.2	2.2 ± 2.3	*
∠MP (°)	31.2 ± 4.5	33.5 ± 4.7	*	30.8 ± 8.5	31.7 ± 7.7	*
∠OPT-SN (°)	98.8 ± 7.5	99.0 ± 7.2	NS	98.5 ± 8.5	99.0 ± 8.2	NS
∠HSN (°)	88.2 ± 2.8	91.0 ± 4.2	*	89.1 ± 6.8	90.4 ± 6.2	NS
∠SP (°)	56.8 ± 6.0	53.2 ± 7.3	*	57.1 ± 6.0	52.3 ± 7.1	*
S-H (mm)	117.1 ± 8.7	119.2 ± 7.8	NS	118.0 ± 7.7	119.1 ± 7.4	*
C3-H (mm)	39.1 ± 5.5	38.8 ± 7.2	NS	39.4 ± 3.5	38.9 ± 3.2	NS
D1 (mm)	16.8 ± 3.5	11.8 ± 3.8	*	18.8 ± 4.5	14.8 ± 2.8	*
PPS (mm)	25.5 ± 4.3	25.7 ± 3.8	NS	24.2 ± 3.5	28.4 ± 2.1	*
SPPS (mm)	14.8 ± 2.8	12.1 ± 1.8	*	13.1 ± 2.2	13.3 ± 2.9	NS
MPS (mm)	13.3 ± 2.1	10.8 ± 3.7	*	13.2 ± 2.5	13.3 ± 2.7	NS
IPS (mm)	17.2 ± 4.9	13.1 ± 4.2	*	16.6 ± 3.8	14.2 ± 3.2	*
EPS (mm)	17.1 ± 3.8	13.2 ± 4.5	*	17.7 ± 2.8	16.1 ± 4.0	*

Mean ± SD, NS : Not significant, $*p < 0.01$, $n = 10$ for each group.

MATERIALS AND METHODS

Subjects

We selected 20 female patients who had been diagnosed with skeletal mandibular prognathism and who had received orthognathic surgery at Osaka Dental University. Ten had achieved a mandibular setback of over 10 mm with sagittal split ramus osteotomy (SSRO group). Ten other patients had achieved a mandibular setback and maxillary advancement of over 10 mm in total by surgery using Le Fort I osteotomy and SSRO surgery (Two-jaw group). Both groups were followed up for at least one year and six months after the surgery. The data for this study was acquired from the cephalograms taken immediately before surgery (T0) and after more than one year and six months post-surgery (T1). The mean age of the patients at T0 was 21 years and 3 months (SSRO group) and 21 years and 8 months (Two-jaw group). The mean mandibular setback was 11.2 mm for the SSRO group. For the Two-jaw group the mean mandibular setback was 7.1 mm and the mean maxillary advancement was 4.5 mm. The Committee of Medical Ethics, Osaka Dental University approved the protocol of this study (No. 110801).

Table 2 Comparison of the differences from T0 to T1 between two groups

	SSRO group	Two-jaw group	t-test
∠SNA (°)	0.1 ± 0.3	2.9 ± 1.3	*
∠SNB (°)	−7.3 ± 1.3	−6.2 ± 2.5	*
∠ANB (°)	5.8 ± 1.2	7.4 ± 2.1	*
∠MP (°)	2.0 ± 2.3	−0.4 ± 3.1	*
∠OPT-SN (°)	0.9 ± 1.1	0.4 ± 2.4	NS
∠HSN (°)	3.3 ± 2.8	2.4 ± 2.4	*
∠SP (°)	−4.5 ± 2.3	−7.4 ± 2.5	NS
S-H (mm)	2.5 ± 3.3	2.7 ± 2.1	NS
C3-H (mm)	−1.8 ± 1.3	−1.2 ± 2.1	NS
D1 (mm)	−5.1 ± 3.8	−5.0 ± 2.9	NS
PPS (mm)	0.2 ± 0.8	3.8 ± 1.1	*
SPPS (mm)	−2.5 ± 2.7	1.3 ± 1.1	*
MPS (mm)	−2.5 ± 1.8	0.2 ± 2.2	*
IPS (mm)	−3.9 ± 4.2	−2.8 ± 2.6	*
EPS (mm)	−3.8 ± 2.1	−1.3 ± 1.7	*

$*p < 0.01$, $n = 10$ for each group.

Methods

We analyzed the cephalograms at T0 and T1 in the two groups. The reference points and planes used in assessing the craniofacial skeleton, pharyngeal airway morphology and hyoid position were defined based on the reports by Kouno *et al.*[6] and Mochida *et al.*,[7] and the following cephalometric measurements of the craniofacial skeleton were performed (Fig. 1) :

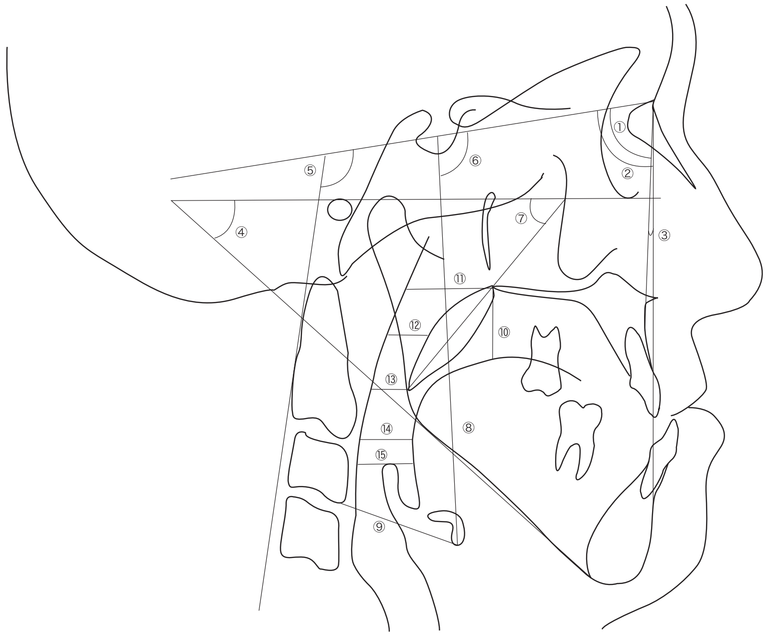

Fig. 1 Measurements on the lateral cephalogram.
①∠SNA (°), ②∠SNB (°), ③∠ANB (°), ④∠MP (°), ⑤∠OPT-SN (°), ⑥∠HSN (°), ⑦∠SP (°), ⑧S-H (mm), ⑨C3-H (mm), ⑩D1 (mm), ⑪PPS (mm), ⑫SPPS (mm), ⑬MPS (mm), ⑭IPS (mm), ⑮EPS (mm).

∠SNA, ∠SNB, ∠ANB, and mandibular plane angle (∠MP). The following measurements of angles and distances that may affect the pharyngeal airway were performed, ∠OPT-SN : Angle formed by the SN plane and the line through the most superior point and the most inferior point of the posterior part of the cervical vertebra, ∠HSN : Angle formed by the SN plane and the line through S and the most inferior point (H) of the hyoid bone, ∠SP : Angle formed by the FH plane and the line through PNS and the most inferior point of the velum (PSP), S-H : Shortest distance from S to the He, C3-H : Distance from the most inferior point of the anterior part of the 3rd cervical vertebra to H, D1 : Distance from PNS projected on the line perpendicular to the FH plane to the dorsum of the tongue, Palatal pharyngeal space (PPS) : Distance between the posterior wall of the pharynx and PNS on the line parallel to the FH plane through PNS, Superior posterior pharyngeal space (SPPS) : Distance between the posterior wall of the pharynx and the velum on a line parallel to the FH plane through PNS and the midpoint between PNS and PSP, Middle pharyngeal space (MPS) : Distance between the posterior wall of the pharynx and PSP on a line parallel to the FH plane through the PSP, Inferior pharyngeal space (IPS) : Distance between the posterior wall of the pharynx and the tongue on a line parallel to the FH plane through the most inferior point of the anterior part of the second cervical vertebra, Epiglottic pharyngeal space (EPS) : Distance between the posterior wall of the pharynx and the tongue on the line parallel to the FH plane through the epiglottis. Measurements for both groups at T0 and T1 were analyzed and compared, and the statistical significance of the differences was determined using the t-test. In addition, the changes between T0 and T1 for the two groups were analyzed and compared, and the statistical significance was determined using the unpaired *t*-test.

RESULTS

Measurements of the dentofacial skeleton

Between T0 and T1, the SSRO group showed a significant decrease in ∠SNB and a significant increase in ∠ANB and ∠MP. In the Two-jaw group, ∠SNA, ∠ANB and ∠MP showed a significant increase, whereas ∠SNB showed a significant decrease.

When comparing the amount of changes between T0 and T1 for the two groups, the changes in ∠SNA and ∠ANB for the Two-jaw group were significantly greater than for the SSRO group and the changes in ∠SNB and ∠MP were significantly smaller for the Two-jaw group.

Measurement of the areas that affect the pharyngeal airway

Between T0 and T1, the SSRO group showed a significant increase in ∠HSN and a significant decrease in ∠SP and D1. In the Two-jaw group, the value S-H showed a significant increase, whereas ∠SP and D1 showed a significant decrease. When comparing the amount of changes between T0 and T1 for the two groups, the change in ∠HSN of the Two-jaw group was significantly smaller than that in the SSRO group.

Measurement of pharyngeal airway space

In the SSRO group, SPPS, MPS, IPS and EPS decreased significantly from T0 and T1. In the Two-jaw group, PPS increased significantly, whereas IPS and EPS showed a significant decrease. When comparing the amount of changes between T0 and T1 for the two groups, significant differences were observed in every parameter.

DISSCUSSION

Study method

When treating patients with skeletal mandibular prognathism, it is important to achieve occlusal and esthetic improvements while minimizing the impacts of mandibular setback on the morphology and function of the pharyngeal airway. We investigated how and where the morphology and function of the pharyngeal airway are affected by SSRO with mandibular setback alone, and by two-jaw surgery with a combination of mandibular setback and maxillary advancement. Included in this study were patients with severe skeletal mandibular prognathism requiring a relative positional bony change greater than 10 mm. A significant increase in ∠ANB was observed in both groups, indicating that surgery had produced a considerable improvement in the relative position of maxilla and mandible. It has been reported that the head position on the lateral cephalograms influences the pharyngeal airway.[8] After mandibular setback surgery, the cervical spine undergoes compensatory changes to secure pharyngeal airway space that has been narrowed. Kouno[6] investigated changes in the pharyngeal airway space in relation to the changes in the cervical spine at a natural head position. On the other hand, a report has suggested the need of evaluating pharyngeal airway measurements by excluding the pharyngeal airway changes caused by cervical spine movements.[4] In this study, conventional imaging was performed using the FH plane as reference, and the measurements at T0 and T1 were compared. Neither group showed any significant difference in ∠OPT-SN, indicating that the head position is unlikely to have a significant impact on the pharyngeal airway space.

Changes in pharyngeal airway morphology

Kawakami *et al.*[9] investigated the pharyngeal airway space after mandibular setback surgery and reported a decrease of 2.2 mm in IPS, which is a significant factor in this study, one year after the surgery. Achilleos *et al.*[4] reported a decrease in PPS and no change in EPS 3 years after the surgery. Both PPS and EPS are the significance factors in this study. Although slight differences are observed in the results due to different study protocols such as the postoperative follow-up period, the method of cephalograms and the amount of mandibular setback, there seems to be a basic consensus that pharyngeal airway space decreases with mandibular setback surgery.

In this study, a significant decrease in SPPS and MPS, which are in the posterior area of the soft palate, and IPS and EPS, which are in the lower area of the oropharyngeal airway, was confirmed in the SSRO group. For Le Fort I osteotomy, on the other hand, Kouno *et al.*[6] reported a significant increase in PPS and a significant decrease in IPS and EPS. Sakai *et al.*[10] also reported a decrease of EPS, a significant factor in this study, at follow-ups of over 2 years after surgery. Although the Two-jaw group in this study showed no significant increase in SPPS and MPS, there was a decrease in IPS and EPS and an increase of PPS. Based on the significant difference observed in the amount of change in every parameter, the postoperative pharyngeal airway space narrowing in the Two-jaw group seems less than that in the SSRO group, which is consistent with the findings of Kouno *et al.*

Changes of hyoid bone position

It has long been thought that it is extremely difficult to accurately capture the hyoid bone position because it easily changes with changes in the head/neck posture when cephalograms are expressed.[11, 12] It is believed that a substantial margin of error should be accepted when determining the position of hyoid bone or tongue on lateral cephalograms.[13, 14] Analyzing the hyoid bone position on lateral cephalograms by defining various measurement parameters is believed difficult due to the considerable variation and poor reproducibility of the measured values. With this in mind, Nagai *et al.*[15] investigated how the head position influences hyoid bone position and suggested parameters that can be used to determine hyoid bone position that are not affected by head position.

According to the report by Nagai *et al.,*[15] the hyoid bone position in this study was evaluated using S-H for vertical and ∠HSN and C3-H for horizontal measurements. Tongue movements resulting from positional changes in the hyoid bone have been reported as a potential cause of pharyngeal airway narrowing.[9, 10] Kawakami *et al.*[11] indicated that the hyoid bone is pressed inferiorly and the tongue is pushed posteriorly after SSRO, resulting in narrowing of the pharyngeal airway space. Kouno *et al.*[6] reported that although the hyoid bone after surgery in the SSRO group was posterior to its position in the Two-jaw group, there was no changes in its vertical relationship. They concluded that the pharyngeal airway space narrowing was caused by the tongue being compressed towards the pharyngeal airway. Sakai *et al.*[10] reported that the hyoid bone after SSRO was slightly posterior to its preoperative position. For the Le Fort I osteotomy, on the other hand, they reported that the postoperative hyoid bone was located close to the preoperative position. They suggested that adaptation of the upper respiratory tract to the new postoperative environment created by the soft palate and nasal cavity changes resulted from the maxillary advancement. In our study, although slight shifts in the hyoid bone toward the inferior-posterior direction were observed in both groups, the changes were not statistically significant. There was no significant difference of the changes between the SSRO group and the Two-jaw group.

From these observations, the difference in the amount of mandibular setback is thought to be a factor contributing to the positional changes in the hyoid bone. The parameters used in this study to measure the hyoid bone position and the soft palate inclination were D1 and ∠SP. Reports have indicated that changes in the soft palate morphology after mandibular setback surgery lead to a decrease in oral cavity volume and compression of the soft palate by the tongue being pressed in a posterior direction. This pushes up the posterior region of the soft palate, leading to a narrowing of the pharyngeal airway, which is located in the posterior of the soft palate.[16–18]

In contrast, it has been reported that maxillary advancement leads to an increase in oropharyngeal airway space as a result of the anterior shift of the soft plate. Based on the findings of this study such as the significant decreases in D1, ∠SP, SPPS and MPS in the SSRO group, we think that the tongue, which was upthrusted by the decrease in the oral cavity volume, pushed up the posterior area of the soft palate and resulted in a decrease in the oropharyngeal airway space. In the Two-jaw group there was a decrease in the D1 and ∠SP, no significant change in SPPS or MPS, and a significant increase in PPS. Therefore, an anterior shift of the soft palate caused by the maxillary advancement partially contributed to the prevention of oropharyngeal airway narrowing.

Skeletal relapse after correction of mandibular prognathism

Reports have investigated how the amount of mandibular setback causes skeletal relapse after surgical correction of mandibular prognathisum.[2, 19–23] No investigation of skeletal relapse was performed in this study. However, the subjects in this study all had severe mandibular prognathism requiring mandibular setback of over 10 mm, and the amount of change in the pharyngeal airway space was greater in the SSRO group than in the Two-jaw group. Therefore, reduced pharyngeal airway space may impact postoperative skeletal stability. To maintain long-term stability, it is necessary to train the perioral muscles and tongue to facilitate their adaptation to the new environment.

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