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Effect of Anterior Displacement of the Chin on Pharyngeal Airway Morphology in Skeletal Class III Malocclusion Patients Treated with Orthognathic Surgery

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Abstract

Purpose：The present study aimed to evaluate the effect of anterior displacement of the chin by genioplasty on pharyngeal airway morphology in patients with skeletal class III malocclusion treated with orthognathic surgery.
Subjects and Methods：Subjects were 21 patients who underwent orthognathic surgery involving surgical displacement of the upper and lower jaw following a diagnosis of skeletal class III malocclusion. Patients were sorted into a group that underwent surgery with genioplasty（with-GE group；n＝9）and a group that underwent surgery without genioplasty（without-GE group；n＝12）. Lateral cephalometric radiographs were taken 1 month and 1 year after surgery for the two-dimensional evaluation of the upper airway diameter and the position of the hyoid bone before and after surgery.
Results：A significant increase in the diameter of the superior region of the upper airway was observed at 1 month after surgery in both the with- and without-GE groups；this outcome correlated with the amount of maxillary displacement. The amount of change and rate of change in the diameters of the superior, middle, and inferior regions of the upper airway were compared between both groups；however, no significant differences were observed. Conversely, the diameters of the middle and inferior regions of the upper airway decreased significantly despite genioplasty. The hyoid bone was displaced downward and forward in the with-GE group and forward in the without-GE group through surgery.
Conclusions：When surgical displacement of the upper and lower jaw was performed for patients with skeletal class III malocclusion, no clear increase in the upper airway diameter was observed, despite anterior displacement of the chin by genioplasty.

Key words： skeletal class III malocclusion, orthognathic surgery, pharyngeal airway space, genioplasty

Introduction

Skeletal class III malocclusion is often treated using a combination of preoperative corrective treatment and orthognathic surgery[1]. Orthognathic surgery includes surgery of the mandible alone, which is intended to posteriorly displace the mandible and is mainly represented by sagittal split ramus osteotomy, and surgical displacement of the upper and lower jaw combined with maxillary osteotomy. Patients who undergo these surgeries occasionally show marked changes in the postoperative pharyngeal airway space（PAS）due to the effects of displacement of bone fragments on maxillofacial mor-

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phology and pharyngeal airway morphology[2)–4)]. Because a mainly posterior displacement of the mandible is necessary after orthognathic surgery in patients with skeletal class III malocclusion, these patients are reported to be susceptible to developing obstructive sleep apnea syndrome, due to the decrease in PAS resulting from surgery[5)–7)]. In fact, past reports have described a clear decrease in PAS after surgery involving posterior displacement of the mandible alone[7)8)]. Accordingly, as a measure to control this decrease in PAS, some reports have recommended surgical displacement of the upper and lower jaw with simultaneous anterior displacement of the maxilla instead of surgery involving posterior displacement of the mandible alone to reduce the amount of absolute posterior displacement of the mandible[9)–12)].

Genioplasty is a surgical technique commonly performed together with surgical displacement of the upper and lower jaw, allowing chin bone fragments to be moved forward or backward depending on the patient[13)]. According to Kim et al., the chin is one of the most important anatomical structures of the lower third of the face, and plays a role in the aesthetics of facial appearance, in terms of the harmony of both the frontal and lateral views, the latter of which features the “esthetic line” (a line connecting the tip of the nose to the tip of the chin)[14)]. In particular, patients with skeletal class III malocclusion have a long lower facial height and the esthetic issue of chin protrusion. Genioplasty is therefore often used in correcting lower facial height. Meanwhile, in addition to the esthetics purposes, anterior displacement of the chin is considered to increase PAS by pulling the geniohyoid and genioglossus muscles forward[15)–18)].

The above suggests that anterior displacement of the chin by genioplasty using the esthetic line as a reference is also occasionally performed in orthognathic surgery for patients with skeletal class III malocclusion in addition to surgical displacement of the upper and lower jaw. Accordingly, this anterior displacement of the chin may have other substantive benefits in addition to improving esthetics, such as increasing PAS. However, few reports to date have described findings related to changes in PAS resulting from anterior displacement of the chin in patients with skeletal class III malocclusion[19)20)].

The present study evaluated the effect of genioplasty on the postoperative pharyngeal airway by comparing postoperative morphology changes in the pharyngeal airway and the position of the hyoid bone over time on lateral cephalometric radiographs of patients with skeletal class III malocclusion who had undergone surgical displacement of the upper and lower jaw with and without anterior displacement of the chin by genioplasty.

Subjects and Methods

Subjects were 21 Japanese patients who underwent surgical displacement of the upper and lower jaw for skeletal class III malocclusion chosen from among 189 Japanese patients who underwent orthognathic surgery under general anesthesia following a diagnosis of jaw deformity in the Department of Oral and Maxillofacial Surgery at Fukuoka University Hospital between January 2013 and December 2016. Patients who exhibited marked facial asymmetry or maxillofacial deformities such as cleft lip or palate were excluded. The 21 patients were sorted into one group that underwent surgery with genioplasty (with–GE group) and a group that underwent surgery without genioplasty (without–GE group). The need for genioplasty was determined depending on whether a hypothetical esthetic line connecting the tip of the chin to the tip of the nose after surgical displacement of the upper and lower jaw is located to posterior to the upper and lower lips in a preoperative simulation using lateral cephalometric radiography. If the chin was located to posterior to the upper and lower lips after surgery, we located the chin anteriorly by the genioplasty.

Surgical method and technique

All patients underwent a surgical procedure that involved anterior displacement of the maxilla by Le Fort I osteotomy and posterior displacement of the mandible by bilateral sagittal split ramus osteotomy (short lingual osteotomy). Genioplasty involved peeling the periosteum back as far as the submental border in addition to making a horizontal vestibular incision in the area between the left and right canines. The bone was cut in the shape of a mountain and moved forward while preserving the lingual periosteum.

To fix the bone fragment in place, a titanium or absorbent plate was used. The same surgeon (T.K.) performed all surgeries.

Imaging examination and acquisition times

The data used in the study were obtained from lateral cephalometric radiographs taken at 3 time points：before surgery（T0）；1 month after surgery（T1）；and 1 year after surgery（T2）. Lateral cephalometric radiographs were taken with the Frankfort plane parallel to the ground and in a state of dental occlusion, with the head fixed in place by a cephalostat. While taking the radiographs, subjects were instructed not to swallow or perform any breathing motions.

Image analysis

Lateral cephalometric analysis was used for all image analyses. This method involved finding the actual measured value for the amount of bone fragment displacement by the superposition method, using the anterior limit of the maxillary alveolar base（point A）as the maxillary reference, the anterior limit of the mandibular alveolar base（point B）as the mandibular reference, and the most protruding point of the mental protuberance of the mandible（Pog point）as the chin reference. Mean horizontal maxillary change, horizontal mandibular change, and horizontal chin change were calculated where anterior displacement was positive and posterior displacement was negative. The resulting numeric values were compared between with– and without –GE groups.

Reference points and reference planes for measurement of upper airway diameter and position of the hyoid bone were set in accordance with a report by Sakai et al.[21]（Figure 1）. The measurement software used was WinCeph（Rise Corporation, Miyagi, Japan）and the following items were examined.

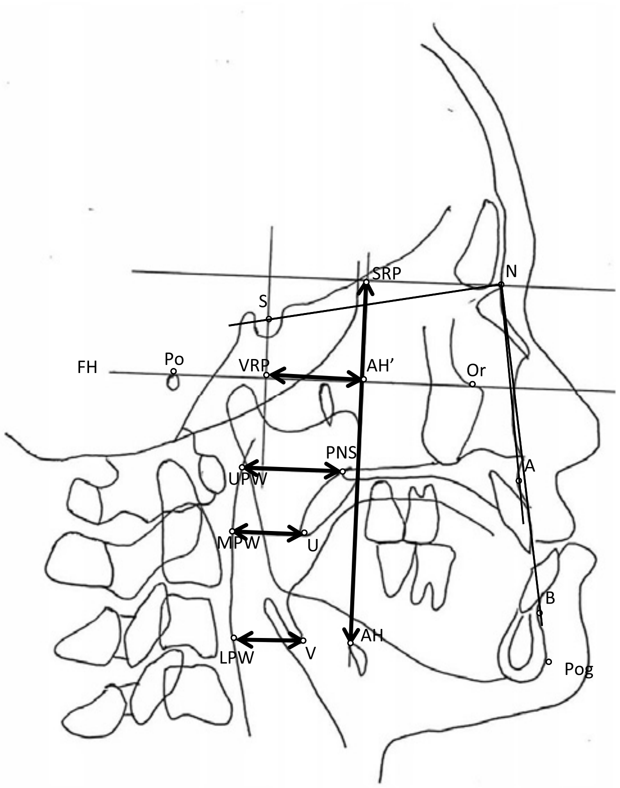

Figure 1 Landmarks and lines in study
A, A point（deepest anterior point in concavity of anterior maxilla）；B, B point（deepest anterior point in concavity of anterior mandible）；FH, Frankfort horizontal plane（a standard craniometric reference plane passing through the right and left porion and the left orbitale）；N, nasion（most anterior point of frontonasal suture）；Or, orbitale（lowermost point on the lower margin of the left orbit, located instrumentally on the skull or by palpation on the head）；PNS, posterior nasal spine（most posterior point of bony hard palate）；Po, porion（most lateral point in the roof of the bony external auditory meatus）；Pog, pogonion（most anterior point of bony chin）；S, sella（center of sella turcica）；U, inferior soft palate（most inferior point of soft palate）；V, vallecula epiglottis（intersection of epiglottis and base of the tongue）

Diameter of the superior region of the upper airway (PNS–UPW): Distance (mm) from PNS to the posterior pharyngeal wall (UPW) on a parallel line on the FH plane passing through PNS.

Diameter of the middle region of the upper airway (U–MPW): Distance (mm) from tip of the soft palate (U) to the posterior pharyngeal wall (MPW) on a parallel line on the FH plane passing through U.

Diameter of the inferior region of the upper airway (V–LPW): Distance (mm) from the epiglottal base (V) to the posterior pharyngeal wall (LPW) on a parallel line on the FH plane passing through V.

Horizontal distance of the hyoid bone (AH′–VRP): Distance (mm) from VRP (point of intersection between the FH plane and the perpendicular line passing through point S) to the point of intersection (AH′) with the perpendicular line drawn from the highest point of the hyoid bone (AH) on the FH plane.

Vertical distance of the hyoid bone (AH–SRP): Distance (mm) from AH to the point of intersection with the perpendicular line drawn from AH on a plane parallel to the FH plane passing through point N (SRP).

These measurement items were measured over time (T0, T1 and T2) and examined for any significant differences in each of the groups (with- and without-GE groups).

The amount of change in measured values for each of the five aforementioned measurement items was calculated from before surgery (T0) to each point after surgery (T1, T2) and compared between groups.

The rate of change in measured values for each measurement item was also calculated for 1 month after surgery (T1) and 1 year after surgery (T2), using the measured value before surgery (T0) as 100%, and compared between the two groups.

In addition, to determine how the amount of displacement of the upper and lower jaw and chin affected postoperative upper airway diameter in each subject, correlation coefficients were calculated for amounts of change from T0 to T1 and from T0 to T2. Each value was subject to statistical processing, with the correlation coefficient between the amount of change in upper airway diameter from T0 to T1 and horizontal displacement of the upper and lower jawbone and chin designated as R1, and the correlation coefficient between the amount of change in upper airway diameter from T0 to T2 and horizontal displacement of the upper and lower jawbone and chin designated as R2.

Statistics

Student's t-tests were used for statistical processing, with the level of statistical significance set at 5%. SPSS for Windows version 18.0 software (SPSS, Chicago, United States) was used for processing and analysis of data.

Research ethics

The protocol of this study was approved by Fukuoka University - Medical Ethics Review Board (approval number: 2017M056).

Results

Patient characteristics

The group that underwent surgery with genioplasty (with-GE group) included 9 patients, while the group that underwent surgery without genioplasty (without-GE group) included 12 patients (Table 1).

Table 1 1 Patient characteristic

	With-GE	Without-GE	P-value
Number of subjects	9 (2 males, 7 females)	12 (1 male, 11 females)	NS
Age (year)	23.2±6.1	23.1±6.5	NS
SNA (degrees)	81.9±3.0	80.3±3.1	NS
SNB (degrees)	79.1±2.5	80.0±3.5	NS

Abbreviations: NS, no significant difference; SNA, sella-nasion-A point angle; SNB, sella-nasion-B point angle; P-vaule, probability-value
Values are the mean±standard deviation for continuous variables

Horizontal displacement of the upper and lower jawbone and chin as a result of surgery

Mean horizontal anterior displacement of the maxilla and mean horizontal posterior displacement of the mandible were calculated, and the resulting numeric values were then compared between the with- and without-GE groups. No significant differences were observed in those subjects. The amount of horizontal anterior displacement of the chin was 4.4±1.7 mm (Table 2).

Pre- to postoperative change in upper airway diameter and position of the hyoid bone

The results are summarized in Table 2. From T0 to T1, the diameter of the superior region of the upper airway (PNS-UPW) significantly increased, while the diameters of the middle region (U-MPW) and inferior region (V-LPW) significantly decreased in the with-GE group. Meanwhile, in the without-GE group, the diameter of the superior region (PNS-UPW) significantly increased from both T0 to T1 and from T0 to T2, whereas no decreased was observed in the diameters of the middle region (U-MPW) and inferior region (V-LPW).

The horizontal position (AH′-VRP) and vertical position (AH-SRP) of the hyoid bone both significantly increased between T0 and T2 in the with-GE group. This means that the hyoid bone moved both downward and forward. No increase in horizontal position of the hyoid bone (AH'-VRP) was observed in the without-GE group ; a significant increase was only observed in the vertical position of the hyoid bone (AH-SRP) between T0 and T2 (Table 3).

Amount of change and rate of change

The amount of change and rate of change in upper airway diameter and vertical and horizontal distances of the hyoid bone were compared between the two groups from T0 to T1 and from T0 to T2, but no significant differences were observed in any items (Tables 4, 5).

Association between horizontal displacement of the upper and lower jawbone and chin and amount of change in upper airway diameter

Based on R1, a significant positive correlation was observed between the amount of horizontal displacement of the maxilla and the amount of change in the diameter of the superior region of the upper airway from T0 to T1 in both the with-GE and without-GE groups. A sig-

Table 2 Horizontal change in each surgery

Type of surgery	Horizontal change (mean±SD) (mm)		
	Maxilla	Mandible	Chin
With-GE	4.0±0.8	−4.4±1.7	4.4±1.7
Without-GE	3.3±0.8	−3.7±1.2	
P-value	NS	NS	

Abbreviations : SD, standard deviation ; GE, genioplasty ; NS, no significant difference

Table 3 Cephalometric linear measurements at each treatment stage (T0, T1, T2)

	Type of surgery	Mean±SD (mm)			Significance	
		T0	T1	T2	T0-T1	T0-T2
PNS-UPW	With-GE	24.1±4.0	26.7±3.5	26.3±3.2	*	NS
	Without-GE	24.1±4.9	27.6±4.9	26.9±4.7	*	*
U-MPW	With-GE	14.8±5.1	12.4±4.7	13.3±3.6	*	NS
	Without-GE	12.7±3.5	11.6±3.7	12.5±3.3	NS	NS
V-LPW	With-GE	18.1±3.6	15.6±2.5	17.0±3.8	*	NS
	Without-GE	17.8±3.9	15.1±3.0	17.5±3.4	NS	NS
AH'-VRP	With-GE	9.6±6.0	9.2±7.8	10.2±5.5	NS	*
	Without-GE	7.5±10.7	7.5±7.8	8.8±8.7	NS	NS
AH-SRP	With-GE	114.3±8.8	117.5±8.0	119.0±7.9	NS	*
	Without-GE	113.4±6.2	117.0±7.0	119.1±6.8	NS	*

Abbreviations : T0, before surgery ; T1, 1 month after surgery ; T2, 1 year after surgery
* : P-value<0.05, NS : no significant difference

nificant positive correlation was also observed between the amount of horizontal displacement of the mandible and the amount of change in the diameter of the inferior region of the upper airway from T0 to T1 in the without−GE group. Based on R2, a significant positive correlation was observed between the amount of horizontal displacement of the maxilla and the amount of change in diameter of the superior region of the upper airway from T0 to T2 in the with−GE group.

No other associations were observed between the horizontal displacement of the upper and lower jawbone and chin and the amount of change in upper airway diameter (Table 6).

Discussion

Many published reports have investigated the decrease in PAS that occurs as a result of surgical posterior displacement of the mandible for skeletal class III malocclusion, and the use of surgical displacement of the upper and lower jaw combined with surgical anterior displacement of the maxilla has been reported to be effective for preventing a decrease in PAS[3)−5)]. We hypothesized that surgical displacement of the upper and lower jaw combined with anterior displacement of the chin by genioplasty would contribute to an increase in PAS in patients with skeletal class III malocclusion who are susceptible to a marked decrease in postoperative PAS. Accordingly, we evaluated PAS before and after

Table 4 Comparison of differences in cephalometric variables between T0 and T1 and between T0 and T2 for types of surgery

	Type of surgery	Change in Mean±SD (T0 to T1) (mm)	Significance	Change in Mean±SD (T0 to T2) (mm)	Significance
PNS−UPW	With−GE	2.6±1.2	NS	2.2±3.5	NS
	Without−GE	3.5±2.6		2.8±2.2	
U−MPW	With−GE	−2.5±2.4	NS	−1.5±3.1	NS
	Without−GE	−1.0±1.8		−0.2±2.3	
V−LPW	With−GE	−2.5±2.4	NS	−1.1±2.7	NS
	Without−GE	−2.6±3.4		−0.2±2.6	
AH'−VRP	With−GE	−0.5±6.1	NS	0.1±4.6	NS
	Without−GE	0.6±5.6		1.3±4.4	
AH−SRP	With−GE	3.2±5.4	NS	4.7±4.5	NS
	Without−GE	3.7±4.3		5.8±5.1	

Note : Negative values indicate movement in the opposite direction
Abbreviations : NS, no significant difference ; : SD, standard deviation ; T0, before surgery ; T1, 1 month after surgery ; T2, 1 year after surgery

Table 5 Comparison of the rate of change in cephalometric variables between T0 and T1 and between T0 and T2 for type of surgery at the treatment stage

Variable	Type of surgery	Rate of change in Mean±SD (T0 to T1) (%)	Significance	Rate of change in Mean±SD (T0 to T2) (%)	Significance
PNS−UPW	With−GE	111.5±6.3	NS	110.6±15.9	NS
	Without−GE	115.1±10.7		112.3±10.1	
U−MPW	With−GE	84.1±14.4	NS	92.1±14.2	NS
	Without−GE	91.3±12.4		100.6±16.8	
V−LPW	With−GE	87.3±12.3	NS	94.4±15.6	NS
	Without−GE	87.3±17.6		100.6±16.9	
AH'−VRP	With−GE	125.5±121.0	NS	221.8±286.8	NS
	Without−GE	102.2±135.9		156.5±138.2	
AH−SRP	With−GE	103.0±4.7	NS	104.3±4.0	NS
	Without−GE	103.2±3.8		105.2±4.7	

Abbreviations : NS, no significant difference ; : SD, standard deviation ; T0, before surgery ; T1, 1 month after surgery ; T2, 1 year after surgery

surgery based on lateral cephalometric radiographs. Twenty‒one patients with skeletal class III malocclusion who underwent orthognathic surgery with surgical displacement of the upper and lower jaw were divided into a group that underwent surgery with genioplasty（n＝9）and a group that underwent surgery without genioplasty（n＝12）. As the result, significant increase in diameter of the superior region of the upper airway was observed 1 month after surgery in both groups. The diameter of the superior region of the upper airway increased with greater anterior displacement of the maxilla, but no association was observed with anterior displacement of the chin. Examination of the pre‒ and postoperative positions of the hyoid bone revealed that the bone had moved downward and forward in both groups.

It is considerd that the position of the hyoid bone changes by proportionately increasing the tractive force on the infrahyoid muscles because the tension of suprahyoid muscles, i.e., the mylohyoid muscle, anterior belly of the digastric muscle, and geniohyoid muscle, attached to the mandible, is relaxed when the mandible is surgically displaced posteriorly[26].

Previous reports have described posterior displacement of the hyoid bone[27)‒29], downward displacement of the hyoid bone[26], anterior displacement of the hyoid bone[30)31], and no displacement of the hyoid bone[8)32], all as a result of posterior displacement of the mandible. In the present study, however, no posterior displacement of the hyoid bone was observed that directly resulted in a decrease in postoperative PAS.

While the mandible moves backward as a result of surgery, a biological compensation mechanism was previously surmised to activate to anteriorly displace the anterior pharyngeal wall and secure the airways for respiration, since respiration is essential to maintain[26].

This compensatory mechanism may therefore have been activated in the present study, regardless of whether genioplasty was performed.

A review of published reports on the effect of genioplasty on postoperative PAS reveals that anterior displacement of the chin is considered to improve airway constriction by anteriorly displacing the hyoid bone and the base of the tongue when the geniohyoid muscle and genioglossus muscle attached to the mental tubercle are pulled forward[15)‒18]. On the other hand, Torres et al. reported seeing no effect of genioplasty on postoperative pharyngeal airway morphology in a comparison of pre‒ and postoperative standard head radiographs of 52 patients who underwent surgical anterior displacement of

Table 6 Pearson’s correlations

Correlation	Type of surgery	R1	R2
Horizontal maxillary change and PNS‒UPW change	With‒GE	0.739*	0.679*
	Without‒GE	0.737*	0.427
Horizontal mandibular change and PNS‒UPW change	With‒GE	0.235	0.340
	Without‒GE	0.176	0.323
Horizontal chin change and PNS‒UPW change	With‒GE	－0.332	－0.334
	Without‒GE		
Horizontal maxillary change and U‒MPW change	With‒GE	0.446	0.334
	Without‒GE	0.184	0.389
Horizontal mandibular change and U‒MPW change	With‒GE	0.304	0.191
	Without‒GE	0.470	0.449
Horizontal chin change and U‒MPW change	With‒GE	－0.13	－0.11
	Without‒GE		
Horizontal maxillary change and V‒LPW change	With‒GE	－0.01	0.058
	Without‒GE	0.257	0.200
Horizontal mandibular change and V‒LPW change	With‒GE	0.302	0.257
	Without‒GE	0.699*	0.400
Horizontal chin change and V‒LPW change	With‒GE	－0.618	－0.32
	Without‒GE		

Note：negative values indicate movement in the opposite direction
Abbreviations：R1, correlation between horizontal change of each jaw and change of each airway measurement observed from T0 to T1；R2, correlation between horizontal change of each jaw and change of each airway measurement from T0 to T2
*：P＜0.05

the upper and lower jawbone[13]. The present results support the conclusions of the latter paper. However, the osteotomy line used in our department is slightly below the tip of the mental tubercle and only part of the genioglossus muscle is attached to the bone fragment pulled out, which may have resulted in insufficient anterior traction of the hyoid bone and base of the tongue for patients in the present study.

Lateral cephalometric analysis using lateral cephalometric radiography, which we used to examine PAS in the present study, may not accurately reflect PAS, because morphological changes in the pharyngeal airway are analyzed as anteroposterior width, i.e., as a two-dimensional measured value. However, Fairburn[34] and Mehra et al.[35] reported that using lateral cephalometric radiography in the analysis of PAS does not pose any problems with accuracy and is in fact useful. Computed tomography (CT) as a method have recently become more mainstream in similar studies, and offer the advantage of allowing 3-dimensional calculation of airway space. However, exposure to radiation is a problem with CT when taking scans over time. According to the Japan Association of Radiological Technologists guidelines, the Diagnostic Reference Level (the target level for reduction) for lateral cephalometric radiography is 2.0 mGy and that for head CT scan is 85 mGy. Almost of patients with jaw deformity are relatively young and a low exposure dose is always desirable. When monitoring changes over time, as performed in our study, lateral cephalometric radiography is preferable to CT in terms of the exposure dose.

The present study did not show any effects of anterior displacement of the chin on upper airway diameter or position of the hyoid bone in genioplasty for skeletal class III malocclusion. Further research should evaluate a larger subject sample and create modified surgical technique for genioplasty.

Conflicts of interest

The authors declare no conflicts of interest.

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