Original Article

Deglutitive tongue movement after correction of mandibular protrusion
A pilot study

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ABSTRACT

Objective: To investigate any change in deglutitive tongue movement following the correction of malocclusion by orthognathic surgery.

Materials and Methods: The subjects were nine patients with mandibular protrusion. A control group consisted of 10 individuals with a similar age range and normal occlusion. Swallowing events before and after mandibular setback via sagittal split ramus osteotomy were recorded by cineradiography, and the tongue movement was analyzed. Time and linear measurements were compared before and after surgical treatment by the Wilcoxon signed rank test; control and test subjects were compared with the Mann-Whitney *U*-test.

Results: Tongue-palate contact and the tongue-tip position changed after orthognathic surgery and became similar to those of the controls. Movements of the anterior and middorsal regions of the tongue did not change after orthognathic surgery and remained different from those of the controls.

Conclusion: Our findings suggest that tongue-palate contact and tongue-tip position during deglutition adapted to the corrected oral and maxillofacial morphology, but the anterior and middorsal regions of the tongue during deglutition may have been affected by pharyngeal constrictors rather than by the oral and maxillofacial morphology. (*Angle Orthod.* 2013;83:591–596.)

KEY WORDS: Deglutition; Orthognathic surgery; Mandibular protrusion; Cineradiography

INTRODUCTION

Deglutitive tongue movement is important for bolus propulsion.[1–4] This movement is affected by insertion of an oral appliance[5–7] and expansion of the maxillary dental arch.[8] We suggested previously that sensory input from the tongue affects neurophysiological control of deglutitive tongue movement.[9] Therefore, the sensory receptors in the tongue may recognize the intraoral structure, and this sensory input may modulate tongue movement during deglutition.

Severe malocclusions are treated by a combination of surgery and orthodontics. Although surgical-orthodontic treatment improves the oral and maxillofacial morphology dramatically, there is no information available on changes in tongue function during deglutition following surgical-orthodontic treatment. We suggested previously that the patients with malocclusions, such as anterior open bite, had a deglutitive tongue movement that compensated for or adapted to their abnormal oral and maxillofacial morphology.[10,11] Hence, when the morphology is corrected by surgical-orthodontic treatment, deglutitive

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Accepted: November 2012. Submitted: June 2012.
Published Online: January 4, 2013

tongue movement may also change to adapt to the new morphology. On the other hand, there is a report of prolonged dysphagia after surgical-orthodontic treatment, although the cause is unknown.[12] If deglutitive tongue movement was not able to adapt to the new oral and maxillofacial morphology, difficulty in swallowing might occur.

Previous studies have shown that there was an immediate change in tongue-palate contact and tongue-tip position during deglutition after blocking sensory input from the lingual nerve.[9] It is suggested that if there is a change in the sensory input from the tongue, there is an immediate change in the movement of the tongue. Furthermore, it is known that there is an immediate change in tongue movement after the use of a tongue crib.[13] Therefore, we sought to determine whether the tongue would immediately recognize the morphologic change after surgery and alter its movement.

The purpose of the present study was to investigate any changes in deglutitive tongue movement following correction of mandibular protrusion by surgical-orthodontic treatment. We focused on the immediate change in the movement of the tongue after the surgery. Deglutitive tongue movement was analyzed by cineradiography before and after surgical treatment.

MATERIALS AND METHODS

Control subjects were selected from undergraduate dental students who had volunteered to participate, understood the purpose of this study, and met the following criteria:

- No previous orthodontic treatment,
- No complex medical history or craniofacial anomalies,
- Skeletal Class I and Angle Class I,
- Average mandibular plane angle,
- Overjet and overbite in the range of 0.5–4.5 mm,
- Arch length discrepancy less than 4 mm in both jaws, and
- No temporomandibular joint disorders.

Control subjects were 10 patients ages 23 and 24 years with overbites ranging from 0.8 to 4.2 mm (mean 2.3 mm) and overjet ranging from 1.6 to 4.0 mm (mean, 3.0 mm).

Experimental subjects were nine patients with Class III molar relationships and mandibular protrusion who had finished presurgical orthodontics. They were between 18 and 28 years of age. Results of cephalometric analysis are indicated in Table 1. No subjects had difficulty in swallowing, although all subjects complained of difficulty in chewing. They received sagittal split ramus osteotomy to set back the mandible. These subjects were recorded during swallowing events using cineradiography before surgical treatment and within 2–4 months (average $\pm$ standard deviation $= 8 \pm 2$ weeks) after surgical treatment. After surgical treatment, no subject had pain or paresthesia in the mouth, although a few subjects had paresthesia around the chin. Ethical approval for the study was granted by the Ethics Committee of Okayama University Graduate School of Medicine and Dentistry, and all subjects gave informed consent.

For the cineradiographic recording, a lead marker was fixed on the tongue tip,[14] and barium liquid (Fushimi Pharmaceutical Co Ltd, 100 wt/vol%, Barytgensol, Kagawa, Japan) was applied to the nasal part of the pharynx of each subject. Each subject was seated on a chair, lateral to the face of the image intensifier, with the head stabilized by a cephalostat attached to the chair. Each subject was asked to swallow 10 mL of liquid barium diluted 10% (wt/vol) with water with the head in the natural position (with Frankfort horizontal plane parallel to the floor). Cineradiographic recordings were obtained at 70–85 kV with a 9-inch image intensifier (Shimadzu Corporation, DIGITEX2400UX, Kyoto, Japan), and lateral images of the entire mouth and pharynx were obtained with appropriate collimation.

Cineradiographic images were recorded on 35-mm film (Fuji Film, MI-CF, Tokyo, Japan) at 30 or 60 frames per second. These swallowing events were recorded three times both before and after surgical treatment.

The cineradiographic images were analyzed in slow motion and by single-frame analysis by use of the playback capability of Cineangio-projector (ELK, CAP35B, Aichi, Japan). The time points used in this study during deglutition have been described elsewhere.[9–11] By modification of oral transit time and pharyngeal transit time,[15] we measured the times between each time point and the times from each time point to nasopharyngeal closure.

Cineradiographic images were traced, standard reference points and planes were established, and the linear measurements were analyzed at several time points (Figure 1, Table 1).[9–11] Because deglutitive tongue movement was highly variable among different individuals,[6] the data recorded three times in each subject were averaged.

Tracings and measurements were performed by one investigator. To determine intraexaminer error in tracing and measurements, one frame of cineradiographic images was traced and measured twice during deglutition in each subject on two separate occasions at least 1 month apart. The method error was determined by Dahlberg's formula: $ME = \sqrt{\Sigma d^2/2n}$,

Table 1. Cephalometric Variables Pre- and Postsurgery

	Presurgery		Postsurgery	
Cephalometric Variables	Mean	SD[a]	Mean	SD[a]
Facial angle	90.9	8.6	86.5	2.3
MP-SN[a]	33.2	9.1	28.9	6.3
Overjet	−4.0	3.3	3.3	1.8
Overbite	−3.5	3.3	1.7	1.3

[a] MP-SN indicates mandibular plane angle; SD, standard deviation.

where n is the number of subjects and d is the difference between two measurements of a pair. The method error did not exceed 0.1 mm.

The data of time and linear measurements were compared before and after surgical treatment by the Wilcoxon signed ranks test. Furthermore, statistical comparison between the surgery subjects and the control subjects was performed with the Mann-Whitney *U*-test, and a *P* value less than .05 was considered statistically significant. These analyses were carried out with statistical analysis software (Statview, version 5.0.1, SAS Institute, Cary, NC).

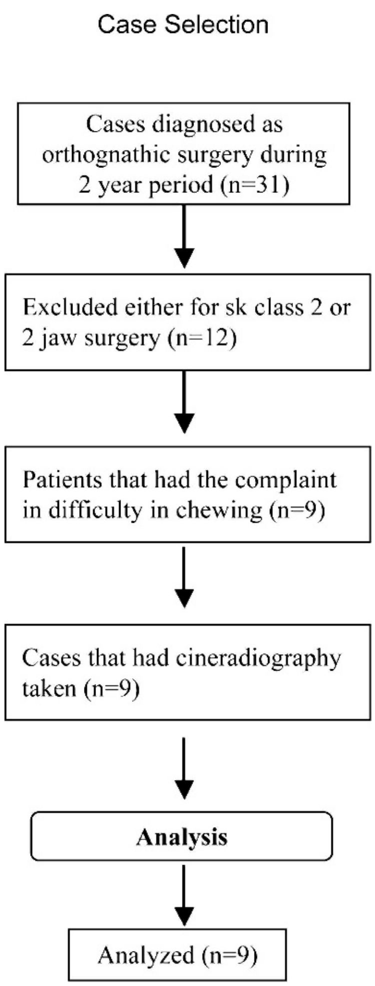

Figure 1. Chart describing how the cases were selected.

RESULTS

The intervals between successive measurements were not significantly different among those determined before and after orthognathic surgery and those of the controls (Table 2A). Before orthognathic surgery, the latencies from time points 3 and 5 to nasopharyngeal closure were significantly smaller than those of the controls (Table 2B). After surgical treatment, the latencies from time points 2 and 5 to nasopharyngeal closure were significantly smaller than those of the controls (Table 2B). The time from each time point to nasopharyngeal closure was not significantly different among the surgical patients between before and after orthognathic surgery (Table 2B).

The data of linear measurements at each time point are indicated in Table 3. Findings were as follows:

(1) Contact between the tongue and palate before orthognathic surgery was significantly smaller than that of the controls at time points 2, 3, and 4, and contact after orthognathic surgery was different from that of controls at point 3.
(2) The anterior region of the dorsal tongue before and after orthognathic surgery was significantly larger than that of the controls at time points 2 and 3.
(3) The middorsal region of the tongue before and after orthognathic surgery was significantly larger than that of the controls at time point 3.
(4) Before orthognathic surgery, the tongue tip was significantly larger than after orthognathic surgery and vs that of controls at time points 2, 3, and 4. In addition, the tongue tip after orthognathic surgery was significantly smaller than before surgery at all points (Wilcoxon signed ranks test).

DISCUSSION

We reported previously that patients with anterior open bite had tongue-tip protrusion, slow movement of the posterior region of the dorsal tongue, and early closure of the nasopharynx during deglutition.[10] These previous findings[10] were similar to the results found in the present subjects before orthognathic surgery. The

Table 2. Measurements of Deglutition over Time

Time Points	Before Surgery (Mean ± SD) (ms)	After Surgery (Mean ± SD) (ms)	Differences (Mean ± SD) (ms)	Controls (Mean ± SD) (ms)
(A) Time between seven time points				
1 to 2	138.3 ± 104.3	147.6 ± 73.8	9.3 ± 14.0	143.0 ± 105.6
2 to 3	114.9 ± 73.7	79.7 ± 36.5	−35.2 ± 4.9	80.2 ± 30.8
3 to 4	93.6 ± 27.8	119.2 ± 41.4	25.6 ± 43.0	109.9 ± 68.9
4 to 5	104.4 ± 63.9	77.5 ± 44.6	−26.9 ± 55.2	65.7 ± 29.7
5 to 6	141.9 ± 68.9	152.3 ± 67.9	10.3 ± 24.0	176.7 ± 47.0
6 to 7	263.9 ± 119.3	272.6 ± 84.5	8.7 ± 65.5	286.3 ± 67.9
(B) Time from each time point to nasopharyngeal closure				
1	173.2 ± 143.9	190.7 ± 76.8	17.4 ± 151.5	246 ± 65.5
2	35.0 ± 62.9	43.1 ± 22.2*	8.1 ± 53.2	103.0 ± 117.1
3	−80.0 ± 120.8*	−36.6 ± 41.9	43.4 ± 94.1	22.9 ± 116.9
4	−173.5 ± 139.4	−155.8 ± 78.4	17.8 ± 89.2	−87.0 ± 68.5
5	−278.0 ± 180.1*	233.3 ± 101.2*	44.7 ± 102.0	−152.6 ± 65.5
6	−419.9 ± 184.5	−385.6 ± 116.1	34.3 ± 98.5	329.4 ± 71.1
7	−683.8 ± 164.3	−658.1 ± 82.4	25.6 ± 116.2	−615.7 ± 73.2

* Significant difference compared to the control ($P < .05$).

subjects in both the previous and present studies had anterior open bite, but the former subjects were either Class I or Class II with excessive overjet and the latter were Class III with negative overjet. Hence, the position of the tongue tip, the dorsal tongue movement, and the time of nasopharyngeal closure during deglutition in the patients with anterior open bite might be the same, regardless of overjet.

Before orthognathic surgery in the present study, contact between the tongue and palate was smaller and the tongue tip was positioned more anteriorly than in control subjects[10] when the dorsal tongue lost contact with the soft palate, the bolus head passed across the posterior/inferior margin of the ramus of the mandible, and the bolus head passed through the opening of the esophagus. These results support the findings of other investigators, ie, that patients with mandibular prognathism have small tongue-palate contact and tongue-tip protrusion during deglutition.[16] In addition, open bite was observed in the present cases, which often resulted in incompetent lip closure and also prevented normal deglutition. After surgical treatment, the contact between tongue and palate and the tongue-tip position were similar to those of the

Table 3. Linear Measurements During Deglutition[a]

Time Point	Before Surgery (Mean ± SD) (%)	After Surgery (Mean ± SD) (%)	Differences (Mean ± SD) (%)	Controls (Mean ± SD) (%)
Point 2				
(a) Contact of tongue and palate	6.4 ± 7.7**	12.1 ± 6.5	5.7 ± 0.1	20.5 ± 8.9
(b) Anterior region of dorsal tongue	75.5 ± 14.2**	72.1 ± 13.8*	−3.4 ± 0.1	50.0 ± 17.2
(c) Middorsal region of tongue	66.6 ± 17.3	75.8 ± 8.8	9.2 ± 0.2	63.3 ± 15.5
(d) Posterior region of dorsal tongue	27.9 ± 5.5	27.9 ± 4.5	0.1 ± 0	31.2 ± 5.6
(e) Tongue tip	106.3 ± 4.1***,****	93.2 ± 2.6	−13.1 ± 0.1	91.9 ± 4.5
Point 3				
(a) Contact of tongue and palate	19.6 ± 10.3*	21.8 ± 7.0*	2.2 ± 10.5	35.1 ± 12.6
(b) Anterior region of dorsal tongue	51.3 ± 9.2**	52.2 ± 11.6**	0.9 ± 14.2	25.3 ± 15.5
(c) Middorsal region of tongue	80.5 ± 11.1**	75.6 ± 9.1*	−4.9 ± 11.4	57.0 ± 21.1
(d) Posterior region of dorsal tongue	32.7 ± 5.5	32.1 ± 5.1	−0.6 ± 1.8	34.1 ± 2.6
(e) Tongue tip	106.6 ± 4.4***,****	93.0 ± 2.6	−13.6 ± 4.9	92.6 ± 4.5
Point 4				
(a) Contact of tongue and palate	45.7 ± 25.2*	59.5 ± 22.6	13.8 ± 28.9	71.3 ± 13.5
(b) Anterior region of dorsal tongue	15.5 ± 15.5	9.9 ± 12.6	−5.6 ± 14.8	4.2 ± 6.5
(c) Middorsal region of tongue	59.6 ± 27.9	43.2 ± 19.2	−16.4 ± 23.5	36.9 ± 21.1
(d) Posterior region of dorsal tongue	33.5 ± 4.8	34.8 ± 5.1	1.3 ± 2.6	34.7 ± 4.5
(e) Tongue tip	106.2 ± 5.4***,****	93.0 ± 2.7	−13.2 ± 5.1	94.0 ± 2.9

[a] SD indicates standard deviation.

* $P < .05$, ** $P < .01$, *** $P < .001$ (significant differences, surgical vs control subjects); **** significant difference within surgical patients, before vs after surgical treatment ($P < .05$).

controls[10] at the times of the dorsal tongue's loss of contact with the soft palate and the bolus head's passing through the esophageal opening. Earlier, the contact between tongue and palate and tongue-tip position during deglutition were shown to be modulated by sensory input from the tongue.[9] Correction of open bite created an anterior lip seal that may have resulted in negative intraoral pressure and led to changes in tongue-tip position and deglutition patterns. Therefore, in the present study, the sensory receptors in the tongue might have recognized the change in oral and maxillofacial morphology caused by the orthognathic surgery, and this sensory input might have modulated the tongue-palate contact and the tongue-tip position. Both of these adaptations occurred within a short period after surgical treatment.

In the present study, the anterior and middorsal regions of the tongue did not change position after orthognathic surgery, and these regions were smaller than those of the controls[10] at the times of the dorsal tongue's loss of contact with the soft palate and the bolus head's passing across the posterior/inferior margin of the ramus of the mandible. These results suggest that dorsal tongue movement during deglutition before and after orthognathic surgery is slower than bolus transport. In normal swallowing, bolus propulsion is aided by pharyngeal constrictors, while the movement of the dorsal tongue is the main propulsive force for bolus transport.[1,2,4] The pharyngeal constrictor muscles are connected with the lingual muscles.[17] Therefore, before orthognathic surgery, pharyngeal constrictors might compensate for the slow movement of the anterior and middorsal regions of the tongue to provide the proper propulsive force on the bolus. The compensatory function of pharyngeal constrictors before orthognathic surgery might have remained within 2–4 months after orthognathic surgery. The pharyngeal constrictor muscle is involved not only in bolus propulsion but also in nasopharyngeal closure during deglutition.[18] Before and after orthognathic surgery, the present patients showed early nasopharyngeal closure during deglutition. Taken together, the early closure of the nasopharynx in these patients might have occurred by adduction of the pharyngeal constrictor muscle, which exerts a propulsive force on the bolus. It was suggested that the movements of the anterior and middorsal regions of the tongue and the time of nasopharyngeal closure during deglutition were modulated by the coordination with pharyngeal constrictors and could not adapt to the corrected oral and maxillofacial morphology within 2–4 months after orthognathic surgery.

During normal swallowing, the tongue tip and sides are in contact with the alveolar ridge, and the center portion of the tongue sequentially elevates from front to back.[19,20] When the bolus head, propelled by the tongue movement, passes across the posterior or inferior margin of the ramus of the mandible, the pharyngeal swallow is activated.[21] In the present study, time point 3 was the beginning of the pharyngeal swallow. We suggested previously that dorsal tongue movement compensated for the abnormal oral and maxillofacial morphology to propel the bolus between time points 3 and 4 during deglutition and that deglutitive tongue position at time point 4 had no relationship to oral and maxillofacial morphology.[11] At time point 4 in the present study, dorsal tongue position was not different between patients, either before or after orthognathic surgery, and controls, except for tongue-palate contact. Therefore, it is suggested that deglutitive tongue movement after the involuntary phase is not affected by maxillofacial morphology.

Deglutitive tongue movement adapts to changes in bolus volume.[22] Furthermore, this movement is affected by the insertion of an oral appliance[5–7] and expansion of the maxillary dental arch.[8] Hence, we speculated that deglutitive tongue movement would change to adapt to the new oral and maxillofacial morphology after orthognathic surgery. However, dorsal tongue movement during deglutition did not change after orthognathic surgery, although the tongue tip changed. Because both the tongue tip and dorsal tongue are a part of the same tongue, a change in the movement of the anterior and middorsal regions of the tongue, with correction of the tongue-tip position, may occur long after orthognathic surgery. Further investigation over a longer period after orthognathic surgery is necessary to clarify the relationship between deglutitive tongue movement and oral and maxillofacial morphology.

CONCLUSIONS

- The tongue-palate contact and tongue-tip position during deglutition adapted to the corrected oral and maxillofacial morphology.
- The anterior and middorsal regions of the tongue may have been affected by pharyngeal constrictors during deglutition rather than by the oral and maxillofacial morphology.

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