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Original Article

A CINERADIOGRAPHIC STUDY OF DEGLUTITIVE TONGUE MOVEMENT IN PATIENTS WITH ANTERIOR OPEN BITE

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Abstract

The purpose of this study was to use cineradiographic images to investigate tongue movement during deglutition in anterior open bite patients with tongue thrust. Each subject had semi-spherical lead markers attached to the tip and dorsal surface of the tongue and was asked to swallow 5 ml of diluted liquid barium. Tongue movement during deglutition was recorded in the mid-sagittal plane with an X-ray VTR system. The deglutition process was divided into 6 stages to analyze the movements of the tip and dorsal surface of the tongue in each stage. In open bite patients, both the tip and dorsum of the tongue were positioned anteriorly and inferiorly at rest and during the buildup of negative intraoral pressure. The dorsum of the tongue tended to move and be positioned anteriorly as the tongue tip protruded and pushed the maxillary and mandibular anterior teeth. The tongue tip traveled a significantly smaller distance from the stage of tongue rest position to that of most retruded tongue tip position and a significantly larger distance from the stage of most retruded tongue tip position to that of tongue tip fixation in open bite patients than in controls.

Key words: Tongue movement—Tongue thrust—Open bite—Deglutition—Cineradiographic study

INTRODUCTION

The tongue, an organ that occupies a large portion of the oral cavity and that performs complex movements, plays major roles in respiration, mastication, deglutition and speech. In particular, deglutition, which is closely associated with the size and range of motion of the tongue, has important effects on the growth and development of the jaws and dentition and the maintenance of occlusion[1,6,9,10,11,13,14].

Enoki *et al.*[1] reported on morphological and functional abnormalities of the tongue. The latter is seen in many orthodontic patients with malocclusions. The characteristics of deglutitive tongue movement observed in anterior open bite patients with tongue thrust include tongue tip protrusion between the maxillary and mandibular anterior teeth[2,5], slow vertical movement of the tongue dorsum and its inadequate contact with the palate[2,3], and irregular tongue movements[9]. However,

it is difficult to evaluate complex movements of the tongue during deglutition by morphologic analysis using conventional cephalograms or dental models.

Many cineradiographic studies have been conducted since Rushmen and Hendron[13] analyzed tongue movement during deglutition with cineradiography in 1955. Nishimura[7] divided the deglutition process into 10 stages for a detailed quantitative analysis of tongue movement during normal deglutition in 1977. For investigating the relationship between malocclusion and the pattern of tongue movement, Takimoto *et al.*[15] reported on the pattern of tongue movement during deglutition in open bite patients. More recently, Fujiki *et al.*[2] have investigated nasopharyngeal obstruction in relation to tongue movement in anterior open bite patients. However, these studies mainly concentrated on the movements of the tip of the tongue, and more data are needed to analyze as deglutition of the entire tongue. Then, it is necessary to investigate the malposition and the abnormal movements of the tongue in studies of oral function.

The purpose of this study was to quantify the movements of the tip and dorsum of the tongue during deglutition by using cineradiographic images in the mid-sagittal plane in anterior open bite patients with tongue thrust; this type of case is often encountered in clinical practice.

MATERIALS AND METHODS

1. Subjects

The study include 13 anterior open bite patients with tongue thrust (4 males, 9 females, mean age 14.5) and 9 non-thrust controls with adequate anterior coupling (3 males, 6 females, mean age 13.8); all were selected from previously untreated patients visiting the Orthodontic Department of the Tokyo Dental College Chiba Hospital. The diagnosis of tongue thrust was based on tongue tip protrusion into the space between the maxillary and mandibular anterior teeth during the pronunciation of /s/ and /t/ sounds (Fig. 1). Table 1 outlines the cephalometric analysis for each group.

2. Method of imaging

An X-ray VTR system for the head and neck region (Toshiba Corporation, Ultimax, Tokyo, Japan) owned by the Tokyo Dental College was used in the study. Each patient was asked to sit on a dental chair, and semi-spherical lead markers were fixed on the tip and dorsal surface of the tongue with surgical superglue. The marker on the tip of the tongue was set at the most anterior point when the tongue was consciously protruded and the marker on the dorsum of the tongue was set at the central point on the dorsal surface of the left and right lingual groove at the mandibular first molars. Five ml of diluted liquid barium (Fushimi

Fig. 1 Open bite patient with tongue thrust

Table 1 Cephalometric analysis of the subjects

	SNA (degree)	SNB (degree)	Mandibular plane angle (degree)	Over bite (mm)	Over jet (mm)
Open bite	81.3	78.1	36.5	−4	0.9
Control	83.2	79	31.8	1.6	2.8

Pharmaceutical Corporation, Barytgensol, Kagawa, Japan) was swallowed to clearly delineate oral structures, followed by imaging of tongue movement in the mid-sagittal plane during swallowing of 5 ml of drinking water. A 1 cm × 1 cm lead ribbon was placed on the anterior border of the left external auditory meatus for calibration during analysis. The imaging conditions were established so that the tube voltage and current were automatically adjusted to 65–95 kVp and 0.4–0.6 mA, respectively.

3. Method and items of analysis

The obtained images were recorded with a Hi8 video recorder (Sony Corporation, CVD-1000, Tokyo, Japan) and entered into a computer with a video image processor and an image processing software program. The process of deglutition was divided into 6 stages. Images for each stage were traced on cellophane paper. Tongue tip and tongue dorsum points were digitized using a coordinate transformation system (NEC Corporation, N-BASIC86, Tokyo, Japan). Each coordinate was then transformed to one with the lower border of the mandible as the X-axis and a line perpendicular to the lower border of the mandible passing through the edge of the mandibular central incisor as the Y-axis. The movements of the tongue tip and tongue dorsum points were traced with a plotter (Roland Corporation, DCP301, Osaka, Japan). From the tracings thus obtained, scatters of these points in each stage were compared between open bite patients and controls using 90% confidence ellipses. In addition, the distance of tongue tip movement in each

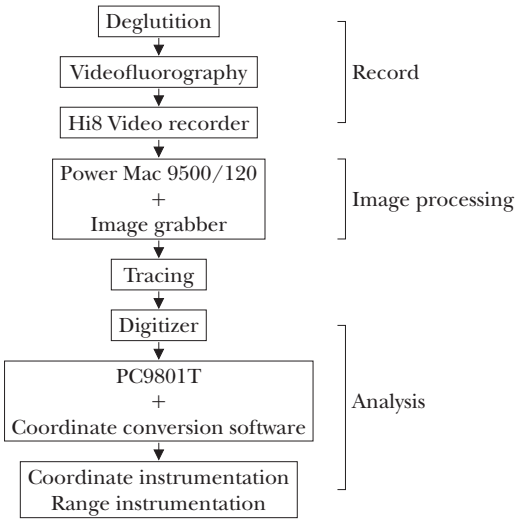

Fig. 2 Block diagram of the analysis method

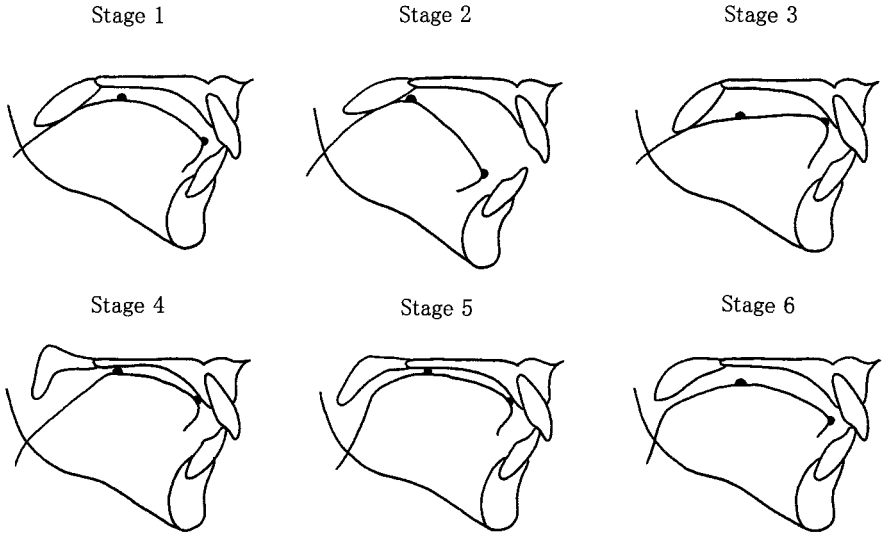

Fig. 3 Schema of deglutition

stage was compared between the two groups. A block diagram of the analysis is depicted in Fig. 2.

4. Classification of the deglutition process

The deglutition process was divided into 6 stages for analysis. Figure 3 shows a schematic drawing of typical tongue movement during deglutition in each stage.

1) Stage 1: tongue rest position
   All the oral structures including the tongue are at rest.
2) Stage 2: most retruded tongue tip position
   The tongue tip retracts as the bolus enters the oral cavity.
3) Stage 3: tongue tip fixation
   The tongue tip stops moving and becomes fixed.
4) Stage 4: most elevated soft palate position
   The soft palate rises to the highest level with the dorsal surface of the tongue mostly in contact with the palate.
5) Stage 5: most depressive soft palate position
   The soft palate descends to the lowest level.
6) Stage 6: tongue rest position after deglutition
   Deglutition is complete, and the tongue and other oral structures return to their rest positions.

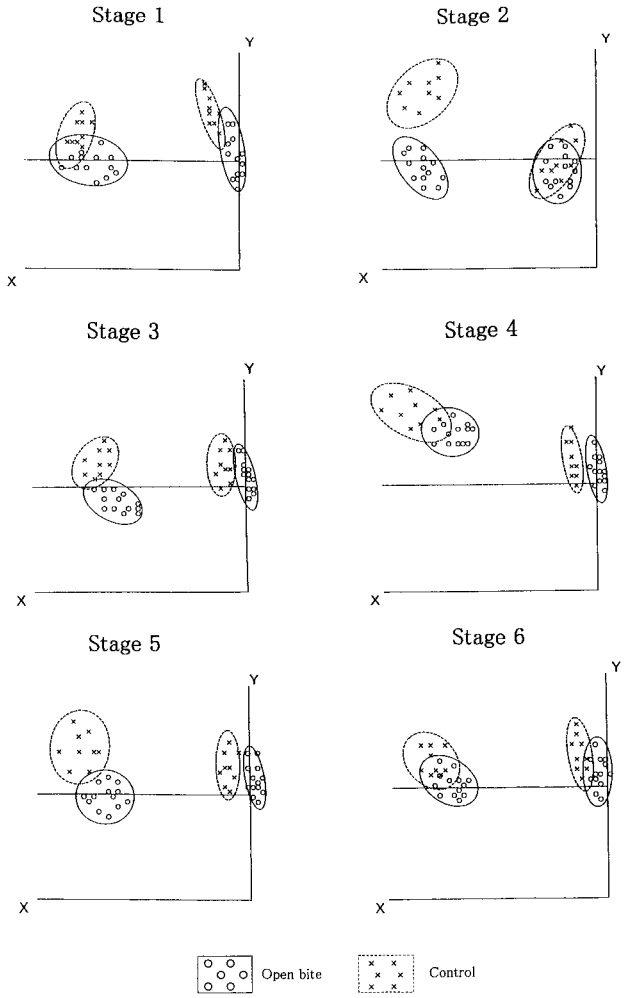

Fig. 4 90% confidence ellipses of the tongue tip and the dorsal surface of the tongue

RESULTS

1. Positional changes of the tip and dorsum of the tongue

Figure 4 shows 90% confidence ellipses for the tip and dorsum of the tongue at each stage for open bite patients and controls.

At Stage 1 with the tongue at rest, both the tip and dorsum of the tongue tended to be positioned more anteriorly and inferiorly in open bite patients than in controls. At Stage 2, the tongue tip moved posteriorly and inferiorly in both groups. The dorsum of the tongue was lifted high up towards the palate in controls, but minimally in open bite patients. At Stage 3, the tip of the tongue was located on the maxillary incisors and/or the palatal mucosa in controls; open bite patients exhibited tongue tip protrusion and associated anterior and inferior positioning of the tongue dorsum. At Stages 4 and 5, both the tip and dorsum of the tongue were positioned more anteriorly and inferiorly in open bite patients than in controls. At Stage 6, both the tip and dorsum of the tongue tended to be in more anterior and inferior positions in open bite patients than in controls as observed at Stage 1.

The confidence ellipses for tongue tip movement were elongated anteroposteriorly in many stages of deglutition with great variabilities vertically in both groups. The confidence ellipses for the dorsum of the tongue were elongated vertically or almost round in both groups. There was no marked difference in the size of the confidence ellipse between the groups.

2. Distance of tongue tip movement

The distance of tongue tip movement is shown for each group in Table 2.

Although the tongue tip moved a large distance from Stage 1 to Stage 2 in both groups, the open bite group exhibited a significantly smaller distance. In the open bite group, the distance of tongue tip movement from Stage 2 to Stage 3 was the greatest of all the stages of deglutition and significantly larger than that in the control group. In the subsequent stages from Stage 3 to the completion of deglutition, the position of the tongue tip remained almost unchanged in both groups with no significant difference in movement distance between the groups. The total distance of tongue tip movement was greater in the open bite group, although no significant difference was noted.

Table 2 Moving length of the tongue tip

Stage	Open bite	Control	Sig.
1–2	5.98	7.78	*
2–3	9.89	6.12	**
3–4	0.46	0.31	ns
4–5	0.22	0.41	ns
5–6	0.33	0.62	ns
1–6	16.88	14.5	ns

Sig.: Statistical significance
*: $p<0.05$, **: $p<0.01$, ns: not significant

DISCUSSION

Tongue thrust is the act of the tongue tip pressing against the lingual surfaces of the anterior teeth and protruding beyond the incisal edges[4]. Ozeki[9] defined tongue thrust as the tongue pushing against or protruding between the maxillary and mandibular anterior teeth during the pronunciation of /s/ and /t/ sounds and swallowing of 0.5 ml of water. In the present study, the similar criterion of tongue tip protrusion between the teeth during pronunciation of /s/ and /t/ sounds and swallowing of saliva was used for patient selection.

Nishimura[7] used the palatal and mandibular occlusal planes as references when measuring the height of the tongue dorsum and other points of interest. In the present study, the coordinates consisting of the mandibular plane as the X-axis and the line perpendicular to the mandibular plane passing through the incisal edge of the mandibular central incisor as the Y-axis were used as the reference coordinates. It would have been necessary to take mandibular movement into consideration if the palatal plane and the Frankfort Horizontal

had been used as reference planes. The use of the mandible as a reference allowed the analysis of tongue movement independent of mandibular movement.

In the present study, the tongue tip moved forward and downward as it protruded between the teeth from Stage 3 to Stage 5, which was associated with forward and downward movement of the tongue dorsum. These results support previous findings. It has been known that bolus entry causes the tongue tip to retract and the dorsum to rise at Stage 2. In this study, the dorsum of the tongue lifted and rubbed the barium bolus against the palate in controls, while the dorsum did not rise and only retracted in a wavy motion in the open bite group. This may be due to the presence of the maxillary incisors above the tip of the tongue, preventing the tongue tip from lifting and thus producing compensatory up and down movements of the tongue dorsum to improve swallowing efficiency.

Tongue thrust is known to affect maxillo-facial growth by increasing the downward component of the growth and opening the mandibular plane angle[8]. Ricketts[12] reported that tongue thrust puts the tongue in a forward and downward position, which, in turn, causes the mandible to be in a lower position than normal. A similar tendency was noted in this study; the mandibular plane angle of the open bite group was 4.7° larger than that of the control group, suggesting that tongue thrust with anterior tongue position may affect not only the teeth but also the maxillo-facial morphology.

In both groups, most of the tongue tip movement during deglutition occurred from Stage 1 through Stage 3. From Stage 1 to Stage 2, when the tongue tip moved down and back upon bolus entry, the open bite group showed a smaller distance of tongue tip movement than the control group. This may be due to a more anterior and inferior rest position of the tongue tip at Stage 1 in open bite patients than in controls, causing the tongue tip to move a smaller distance at Stage 1. From Stage 2 to Stage 3, the tongue tip normally presses against the alveolar ridge to build up negative pressure upon completion of bolus formation. During this period, the tongue tip moved a significantly greater distance in open bite patients. This may be attributed to tongue tip fixation between the maxillary and mandibular anterior teeth at Stage 3, the stage of tongue tip fixation, increasing the distance of subsequent tongue tip movement at Stage 3 in open bite patients.

When the overall deglutition process was compared between the two groups, the entire tongue was positioned anteriorly and inferiorly throughout the deglutition process in open bite patients. This may be related to the anterior and inferior position of the tongue at rest in these patients.

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