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Morphological changes in the pharyngeal airway space following orthodontic treatment of skeletal open bite

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We examined changes in the pharyngeal airway space of skeletal open bite patients receiving orthodontic treatment. To compare jaw relationships, the position of the hyoid bone and pharyngeal airway space were examined for each case using sets of three lateral cephalometric radiographs that were taken before treatment (A1), after treatment (A2) and for control (N). Craniofacial skeletal measurements revealed no significant differences in ∠SNA between Groups A1 to A2. Although ∠SNB and the ∠MP showed a slight increase between Groups A1 and A2, the difference was not significant.

Measurements of the cervical vertebrae, tongue and velum revealed that HSN and S-H were significantly greater in Group A1 than in Group N. Both HSN and S-H increased significantly between Groups A1 to A2. C3-H in Group A1 was significantly less than in Group N, and showed a significant decrease between Groups A1 and A2. ∠SP was significantly less in Groups A1 and A2 than in Group N. No significant difference was seen between the measurements of Groups A1 and A2. The values for D1 in Groups A1 and A2 were significantly greater than for Group N. There were significant differences between Groups A1 and A2.

Measurements of the superior posterior pharyngeal airway space, SPPS, and the middle pharyngeal airway space, MPS, in Group A1 were significantly less than in Group N, indicating a narrowing of the pharyngeal airway width. SPPS and MPS in Group A2 were significantly decreased compared with Group A1, indicating a narrowing after treatment. There were no significant differences in the palatal pharyngeal space, PPS, and the epiglottic pharyngeal space, EPS, in Groups A1 and A2, respectively.

These results suggest that the pharyngeal airway space decreased after orthodontic treatment of skeletal open bite caused by posterior inclination of the soft palate. (J Osaka Dent Univ 2015 ; 49 : 137–142)

Key words : Pharyngeal airway ; Orthodontic treatment ; Skeletal open bite

INTRODUCTION

It has been reported that oral parafunctional habits such as tongue thrusting and mouth breathing are frequently found in orthodontic patients.[1] Correlation between malocclusion, in particular open bite, and oral parafunctional habits has been investigated extensively.[2, 3] Oral parafunctional habits are known to affect not only over-occlusion, but also dentofacial morphology.[4–6]

Patients with strong physiological swelling of the pharyngeal tonsils exhibit pharyngeal airway narrowing.[7] Narrowing of the pharyngeal airway space often causes mouth breathing due to nasal breathing impairment and a low position of the tongue, leading to adenoid facies.[8–10] Patients with adenoid facies often have the common features of labial slanting of the anterior maxilla, maxillary dental arch narrowing with open bite, bradyauxesis of the mandible and excessive lower anterior facial height. They often develop severe malocclusion. It has been reported that retruded mandibular position due to bradyauxesis causes a decrease in oral cavity volume and backward displacement of the tongue and tongue root, and may result in pharyngeal airway space narrowing which induces sleep apnea syndrome.[11] Thus, dentofacial features and pharyngeal airway space are closely correlated both morphologically, and functionally and are regarded as important factors in orthodontia.[12–14]

We investigated the correlation between maxillofacial complex and pharyngeal airway morphologies before and after orthodontic treatment for skeletal open bite. Standardized cephalograms, which are widely employed in orthodontics, were used for this analysis.

MATERIALS AND METHODS

Subjects

For this study we selected 10 female patients exhibiting skeletal open bite associated with the retrusion of the mandible (Group A). from patients undergoing treatment at the Orthodontic Clinic of Osaka Dental University. The control consisted of 10 females having individual normal occlusion without any history of orthodontic treatment (Group N). We used standardized cephalograms taken before treatment (Group A1) and at the end of dynamic treatment (Group A2). The mean age and overbite for Group A1 was 23 years 8 months and −3.3 mm, respectively. Standardized cephalograms were also taken of control patients. The mean age of the controls was 23 years 6 months. The Committee of Medical Ethics, Osaka Dental University, approved the protocol of this study (No.110801).

Methods

We analyzed the cephalograms of the three groups. The reference points and planes used in assessing the craniofacial skeleton, hyoid position and pharyngeal airway morphology were defined based on the reports by Mochida *et al.*[15] and Kouno *et al.*[16] The following cephalometric measurements of the craniofacial skeleton were performed (Fig. 1) : ∠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

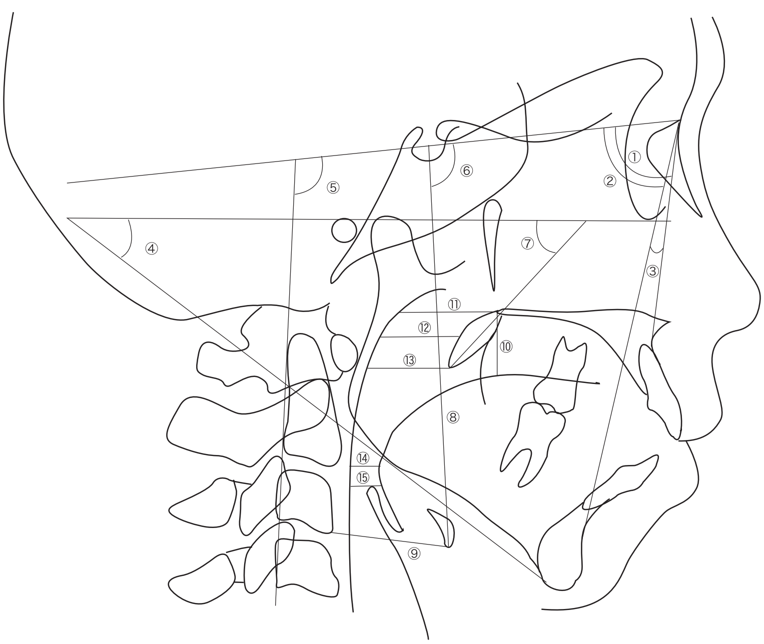

Fig. 1 Measurements on the lateral cephalogram.
①∠SNA (°), ②∠SNB (°), ③∠ANB (°), ④∠MP (°), ⑤∠OPT−SN (°), ⑥∠HSN (°), ⑦∠SP (°), ⑧S-H (mm), ⑨C3-H (mm), ⑩D1 (mm), ⑪PPS (mm), ⑫SPPS (mm), ⑬MPS (mm), ⑭IPS (mm), ⑮EPS (mm).

Table 1 Comparison of measurements among A1, A2, and N

	A1	A2	N	t-test (A1 and A2)	t-test (A1 and N)	t-test (A2 and N)
∠SNA (°)	82.4±3.4	82.2±2.8	82.6±4.4	NS	NS	NS
∠SNB (°)	77.8±4.1	78.2±1.8	79.8±2.8	NS	*	*
∠ANB (°)	4.8±2.3	3.9±3.1	2.8±1.1	NS	*	*
∠MP (°)	35.1±3.9	36.3±3.1	33.4±5.2	NS	*	*
∠OPT-SN (°)	98.1±3.9	102.2±6.5	101.1±2.1	NS	NS	NS
∠HSN (°)	86.5±4.2	88.2±3.8	84.1±3.7	*	*	*
∠SP (°)	50.2±1.1	48.3±2.2	52.1±3.2	NS	*	*
S-H (mm)	113.8±7.2	118.2±4.4	110.0±4.8	*	*	*
C3-H (mm)	36.8±1.2	34.4±3.1	40.2±4.4	*	*	*
D1 (mm)	9.2±3.8	7.8±3.4	6.8±3.3	*	*	*
PPS (mm)	27.5±2.2	26.2±3.1	28.8±4.8	NS	NS	NS
SPPS (mm)	14.8±3.8	13.1±2.8	16.2±3.9	*	*	*
MPS (mm)	11.8±4.2	10.1±3.9	14.2±4.8	*	*	*
IPS (mm)	12.1±1.2	12.0±2.3	12.8±2.1	NS	NS	NS
EPS (mm)	13.1±3.6	14.1±3.4	14.8±1.1	NS	NS	NS

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

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 Groups A1, A2 and N were analyzed and compared, and the statistical significance of the differences was determined using the *t*-test.

RESULTS

Craniofacial skeletal measurements revealed that ∠SNA showed no significant changes between Groups A1 and A2. Although ∠SNB and the ∠MP showed slight increase between Groups A1 and A2, the differences were not significant. Measurements of the cervical vertebrae, tongue and velum, HSN and S-H for Group A1 were significantly greater than for those of Group N, respectively. Both HSN and S-H increased significantly between Groups A1 and A2. C3-H in Group A1 was significantly less than in Group N, and there was a significant decrease between Groups A1 and A2. Although ∠SP was significantly less in both Groups A1 and A2 compared with Group N, there was no significant difference for this value between Groups A1 and A2. D1 for both Groups A1 and A2 were significantly greater than those of Group N, and there was a significant difference between Groups A1 and A2. SPPS and MPS, which respect pharyngeal airway space were significantly less in Group A1 than in Group N, indicating a narrowing of this space. SPPS and MPS for Group A2 were significantly decreased compared with these values for Group A1, indicating that treatment causes narrowing

(Table 1).

DISCUSSION

The tongue is a muscular structure indispensable for respiration, occlusion and swallowing that conforms to the morphology of the dental and alveolar arches. The balance of forces between the tongue and the lips influences the orientation of the anterior teeth. Poor force balance has been reported to adversely affect the axes of the maxillary and mandibular incisors, leading to crowding and/or an open bite. Tongue movements are affected by the width of the tongue space and the breathing pattern. For example, a wide tongue space, which is sufficient to keep the airway space clear and tongue movements unrestricted, contributes to establishment of nasal breathing with the mouth closed. In contrast, a narrow tongue space will cause tongue thrusting in an attempt to clear the airway, leading to an open bite in the anterior region, narrowing of the dental and alveolar arches and reduced activity of the masticatory muscles. An adverse effect on occlusion will result due to the increase in the posterior occlusal height and backward rotation of the mandible.[2,3]

In this study, the position of the dorsum of the tongue at rest was measured using a cephalogram taken at centric occlusal position. Though a report has stated that the head position impacts the position of the hyoid bone and the pharyngeal airway space,[17] Nakamura[18] reported that the impact of head position was negligible if the position change was within 5°.

In the present study, standardized cephalograms were obtained with the head securely stabilized and the reproducibility of the dorsum position was high. Therefore, it was unlikely that the head position and breathing had any significant impact on tongue position.

Based on the analysis of cephalgrams, D1, or the distance between the palate and dorsum of the tongue, measured for Groups A1 and A2 was compared with that for Group N. The distances D1 measured for Groups A1 and A2 were both significantly greater than for Group N. Between Groups A1 and A 2, however, this distance showed a significant decrease. During normal swallowing, the tongue moves upward pushes against the palate. In patients with tongue thrusting, however, the tongue does not move upward but is placed between the teeth during swallowing to create negative intraoral pressure.[19] As a result, patients with a skeletal open bite do not habitually move the tongue upward and therefore their tongue position is low even at rest.

Absence of significant difference in vertical position of dorsum of the tongue before and after treatment may indicate a decrease in intraoral volume resulting from orthodontic treatment involving tooth extraction. The muscular function of the tongue is improved through oral myofunctional therapy during orthodontic treatment. Despite a significant decrease in D1 between Groups A1 and A2, the value for Group A2 was significantly greater than for Group N. From these observations, it can be said that improvement in the muscular function of the tongue by myofunctional therapy does not directly produce a significant change in tongue position because of the decrease in intraoral volume.

Abnormal retrusion of the mandible due to bradyauxesis has been reported to cause a decrease in oral cavity volume, backward displacement of tongue as well as the tongue root, and narrowing of the pharyngeal airway space, thus serving as a trigger for sleep apnea syndrome.[11] In contrast, an anterior cross-bite and mandibular prognathism cause an increase in oral cavity volume and forward displacement of the tongue and the tongue root, resulting in an increase in the pharyngeal airway space. Changes in oral cavity volume and anteroposterior pharyngeal airway space after surgical orthodontic treatment have been investigated in many studies.[20,21] In this study, we analyzed the pharyngeal airway space by measuring SPPS and MPS.

The measured values for Group A1 were significantly less than those for Group N, which indicates a narrowing of the airway space. SPPS and MPS showed a significant decrease between Groups A1 and A2, indicating airway space narrowing after the treatment. Reports[8–10] have demonstrated the contribution of the hyoid bone position to pharyngeal airway space narrowing. Kawakami *et al.*[22] reported that the hyoid bone, which was displaced downward, tries to return to its original position, causaing the tongue to shift posteriorly and the pharyngeal airway space to narrow.

Wickwire[23] and Emata *et al.*[24] also reported that the hyoid bone, which is originally located in an inferior-posterior position, shifts inferiorly with orthodontic treatment and is further dislocated inferiorly due to physiological function acting to keep the airway clear. In this study, HSN and S-H measurements in Group A1 were significantly greater than in Group N, whereas C3-H in Group A1 was significantly less than in Group N. This suggests that the hyoid bone is located in an inferior-posterior position, and that changes between Groups A1 and A2, such as the significant increase in HSN and S-H and the significant decrease in CH-3, indicate that the hyoid bone shifted further inferiorly and posteriorly.

The position and morphology of the pharyngeal tonsils and the morphology of the pharyngeal airway are known to impact the morphology of the lower face and dental arches.[21, 25, 26] Changes in soft palate morphology have also been reported in patients with retruded mandibles.[27–29] Turnbull *et al.*[28] suggested that when the tongue is upthrusted due to a decrease in oral cavity volume and presses against the soft palate, the soft palate is inclined upward while being reduced in width, leading to stenosis of the pharyngeal airway located posterior to the soft palate. In this study, the SP angle, which indicates soft palate inclination, was significantly less in Group A1 than in Group N, suggesting that the soft palate may contribute to narrowing of the pharyngeal airway space. Although ∠SP in Group A2 was also significantly less than in Group N, changes between Groups A1 and A2 were not significant.

D1 showed a significant decrease between Groups A1 and A2, and the hyoid bone shifted in an inferior-posterior direction, indicating a posterior inclination of the soft palate resulting from the upward thrust of the tongue. In this study, narrowing of SPPS and MPS, which are located posterior to the soft palate, was observed at Group A1, and these values showed a significant decrease between Groups A1 and A2. These observations indicate the possibility that the posterior inclination of the soft palate contributes to airway space narrowing.

It has been reported that mandibular rotation occurs as a compensatory response to pharyngeal airway space narrowing after treatments.[20, 22] In this study, although no significant difference was observed in the mandibular plane between Groups A1 and A2, dilation was frequently observed. Based on these observations, narrowing of the pharyngeal airway space is thought to correlate with dilation of the mandibular plane.

Correction of skeletal open bite in adult patients often involves tooth extraction in an attempt to reduce the lower facial height and to increase the overbite by labial inclination of the anterior teeth. All of the patients in this study had received extractions to improve the occlusion. Despite successful correction of occlusion in every patient, there was inferior-posterior shift of the hyoid bone and partial stenosis of the pharyngeal airway. Generally, adult patients with skeletal open bite exhibit parafunction of the perioral muscles, including the tongue. Therefore, appropriate treatments, such as myofunctional therapy, are provided before, during and after orthodontic treatment to recover physiological functions. Treatments in this study were able to solve the problem of upward tongue thrust to some extent. However, decreases in the oral cavity volume due to tooth extraction increased functional factors that may contribute to the recurrence of malocclusion. We concluded that enhancement of myofunctional therapy for the acquisition of physiological function is indispensable for the long-term maintenance of treatment outcomes.

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