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Research

Influences of lymphoid tissues on facial pattern

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ABSTRACT

Background: The aim of this study was to investigate the specific contribution of enlarged tonsils or adenoids to craniofacial growth in children.
Methods: A total of 50 Japanese children (25 boys, 25 girls) at cervical vertebral maturation stage 2 or 3 were quantitatively evaluated regarding their level of obstruction by adenoidal and tonsillar tissues. We calculated the ratios of the cross-sectional areas of the adenoidal or tonsillar tissues to that of the pharyngeal airway using lateral cephalometric radiographs. The correlations between these ratios and several cephalometric variables were then examined using regression analysis.
Results: Children with a high ratio of cross-sectional area of adenoidal tissue to nasopharyngeal airway area had an increased mandibular plane (MP) angle and decreased articulare-gonion line, upper incisor–Frankfort horizontal plane line, and lower incisor–MP line dental measurements. In contrast, children with a high ratio of cross-sectional area of tonsillar tissue to oropharyngeal airway area had an increased MP angle and a decreased upper incisor–Frankfort horizontal plane line measurement.
Conclusion(s): The results suggest that postpharyngeal lymphoid tissues might have partly specific, but partly indiscernible, effects on craniofacial growth. This finding must be considered when making an orthodontic diagnosis in patients at cervical vertebral maturation stage 2 or 3.

1. Introduction

It has been suggested that etiologic factors affecting facial form (e.g., malocclusion) consist of two groups: an extrinsic, or general, group and an intrinsic, or local, group [1]. Of the extrinsic (general) factors, it has been noted that enlarged tonsils and adenoids can affect the tongue position, which can then induce abnormal pressure in the oral cavity and craniofacial skeletal bone, resulting in alteration of the facial form.

With regard to the effects of lymphoid tissues (specifically adenoidal tissue), Linder-Aronson [2] established a relationship between the presence of large adenoidal tissue and the following features: increased anterior facial height, steeper mandibular plane (MP) angle, and a retrognathic mandible compared with those in healthy controls. Other investigators have noted similar characteristics. For example, in a study in children with enlarged adenoids, the MP angle was increased, and the tongue occupied a more downward and forward position in the oral cavity [3].

However, previous findings of the relationship between enlarged adenoidal or tonsillar tissues and facial form are conflicting. Behlfelt and coworkers [4], in a study comparing children with and without enlarged tonsils, found that those with enlarged tonsils had more retrognathic and posteriorly inclined mandibles, increased anterior total height and decreased facial height, and increased MP angles compared with those in children without enlarged tonsils. Conversely, Trotman and colleagues [5] reported that an increase in the size of the tonsils was associated with a decrease in the lower anterior facial height and the MP angle. Baroni and coworkers [6] noted that subjects with tonsillar hypertrophy showed increased length of the mandibular ramus, more horizontal growth direction, increased length of the mandibular body, a more anterior mandibular position, and a decreased sagittal discrepancy between the maxilla and the mandible compared with those in subjects with adenoidal hypertrophy or a control group.

Some studies have reported that different sites of obstruction of the upper airway, as a result of enlarged lymphoid tissues, are associated with different types of malocclusion [2–6]. However, the contribution of (enlarged) adenoids or tonsils to the facial form remains unknown. We therefore investigated the specific contribution of enlarged tonsils or adenoids to craniofacial growth in children.

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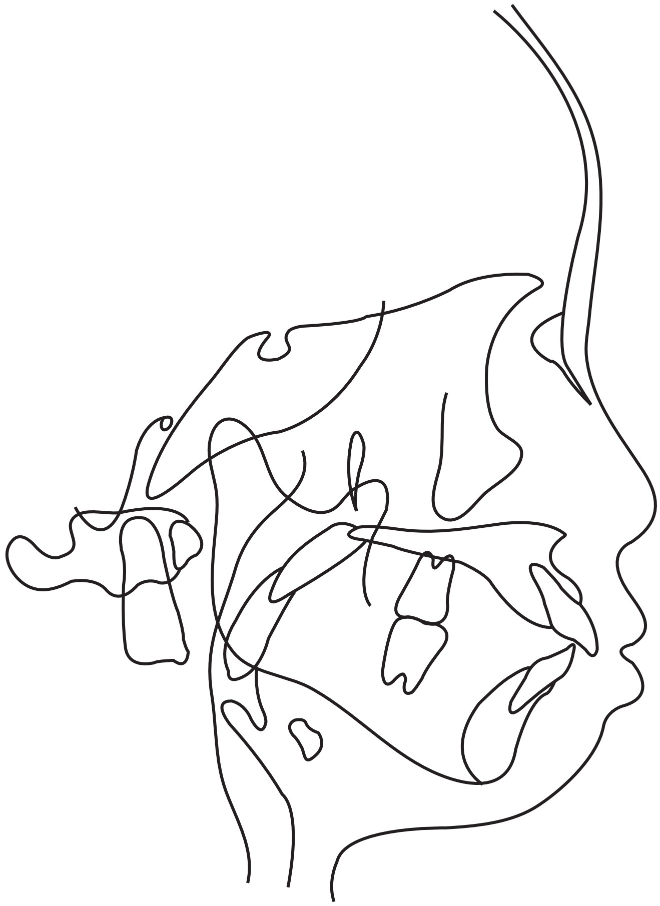

Fig. 1. Tracing of cephalometric radiographs including not only the skeletal structure but also adenoidal and tonsillar tissues.

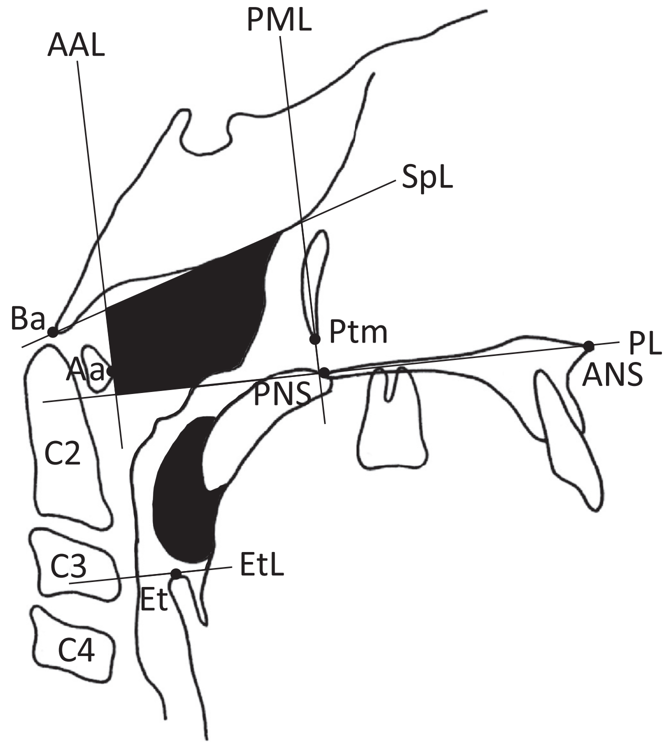

Fig. 2. Landmarks of the nasopharynx, oropharynx, and hypopharynx. Aa, anterior medial point of the atlas; AAL, anterior atlas line (line perpendicular to the palatal line registered on the anterior medial point of the atlas); ANS, anterior nasal spine; Ba, basion; C2, second cervical vertebra; C3, third cervical vertebra; C4, fourth cervical vertebra; Et, epiglottis; EtL, epiglottis line (line parallel to the palatal line registered on the most superior point of the epiglottis); PL, palatal line (line from the anterior nasal spine to the posterior nasal spine); PML, pterygomaxillary line (line perpendicular to the palatal line registered on the pterygomaxillon); PNS, posterior nasal spine; Ptm, pterygomaxillon; SPL, sphenoid line (line tangential to the lower border of the sphenoid registered on the basion).

2. Methods and materials

The study sample consisted of 50 Japanese children—25 boys (mean $\pm$ SD age, 9.75 $\pm$ 1.49 years) and 25 girls (mean $\pm$ SD age, 9.92 $\pm$ 1.15 years)—at cervical vertebral maturation stage (CVMS) 2 or 3 [7]. They were randomly selected from among patients with no history of adenoidal or tonsillar surgery who visited the Tokyo Medical and Dental University Dental Hospital (Tokyo, Japan) between 2001 and 2011 for orthodontic treatment. For the quantitative evaluation of the morphology of the adenoidal and tonsillar tissues, we calculated the ratios of their cross-sectional areas to that of the pharyngeal airway on lateral cephalometric radiographs. The radiographs were obtained under standardized conditions: the intercuspal mandibular position with the subject's Frankfort horizontal plane parallel to the floor. To identify the adenoidal and tonsillar tissues on regular cephalometric radiographs, we traced not only the skeletal structure but also the adenoidal and tonsillar tissues on each lateral cephalometric radiograph used in this research (Fig. 1).

We followed the method reported by Handelman and Osborne [8] to calculate the cross-sectional areas of the adenoidal tissues and the nasopharynx. The palatal line, sphenoid line, anterior atlas line, and pterygomaxillary line represent four corners of a trapezoid that defines the nasopharyngeal (Np) area, as shown in Figure 2. The Np area can be subdivided into the Np airway area and the adenoidal pharyngeal wall (Ad) area (Fig. 3A). The Np and Ad areas were measured using WinCeph version 9 software (Rise Corp., Tokyo, Japan). The Ad area/Np area ratios were then automatically calculated in each of the samples.

Because no specific method for the quantitative evaluation of the tonsillar tissues and the oropharynx has been described, we measured the oropharyngeal (Op) area and tonsillar tissue (Tn) area

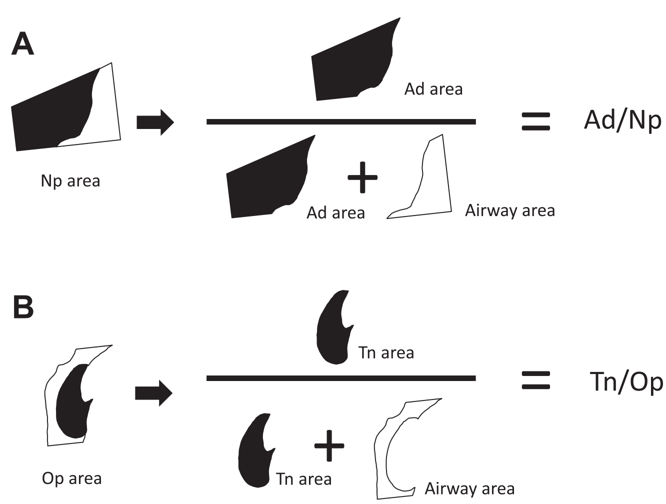

Fig. 3. Definitions of the adenoidal (Ad) area to the nasopharyngeal (Np) area ratio (***A***) and the tonsillar (Tn) area to the oropharyngeal (Op) area ratio (***B***). Ad, cross-sectional areas of the adenoidal tissues; Ad/Np, Ad area/Np area ratio; Airway, cross-sectional areas of the airway; Np, cross-sectional areas of the nasopharynx; Op, cross-sectional areas of oropharynx; Tn, cross-sectional areas of tonsillar tissues; Tn/Op, Tn area/Op area ratio.

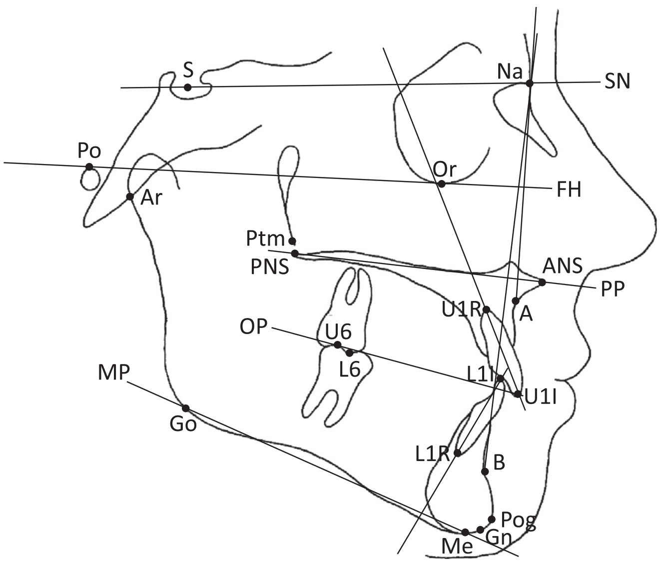

Fig. 4. Reference points and lines. A, point A; ANS, anterior nasal spine; Ar, articulare; B, point B; FH, Frankfort horizontal; Gn, gnathion; Go, gonion; L1I, incisal edge of the mandibular central incisor; L1R, root apex of the mandibular central incisor; L6, midpoint of the occlusal surface of the mandibular first molar; Me, menton; MP, mandibular plane; N, nasion; Or, orbitale; PNS, posterior nasal spine; Po, porion; Pog, pogonion; PP, palatal plane; Ptm, pterygomaxillary fissure; S, sella; SN, sella-nasion plane; U1I, incisal edge of the maxillary central incisor; U1R, root apex of the maxillary central incisor; U6, midpoint of the occlusal surface of the maxillary first molar.

with a method comparable to that used for studying the Np and Ad areas [8]. The oropharynx is the area outlined by the inferior border of the nasopharynx, the posterior surface of the soft palate, the posteroinferior surface of the tongue, the epiglottis line, and the posterior pharyngeal wall (Fig. 2) [9]. The Op and Tn areas were measured using the same software as for the Np and Ad areas (Fig. 3B). The Tn area/Op area ratios were automatically calculated in each of the samples.

The correlations between these ratios and several cephalometric variables were then examined. Reference points and lines are shown in Figure 4. To facilitate interpretation, the cephalometric variables are presented as skeletal (Table 1) and dental (Table 2) parameters. We did not investigate the relationships between cephalometric variables and parameters concerned with mouth breathing, sleep apnea syndrome, or lip incompetence in this study.

The lateral cephalometric radiographs were traced and analyzed by a single investigator (H.S.Y.). Intraexaminer measurement reliability was evaluated by replicate analyses performed on 10 lateral cephalograms measured on two different days. On average, the random method errors for the linear and angular cephalometric measurements were 1.6 mm and 1.3°, respectively [10]. Method errors for area measurements using WinCeph version 9 averaged 1.64 mm^2.

Simple linear regression analyses were performed to determine correlations between both the Ad area/Np area ratios and the Tn area/Op area ratios and cephalometric variables, with the ratios as the independent variables and the cephalometric variables as the dependent variables. A paired Student's t test was used for comparing the cephalometric variables between the boys and the girls. The level of statistical significance was established at $P < 0.05$.

Table 1
Skeletal variables

Variable	Description
SNA, °	Angle between the anterior cranial base (SN) and the NA line
SNB,°	Angle between the anterior cranial base (SN) and the NB line
ANB,°	Difference between SNA and SNB
MP,°	Angle formed by the FH plane and the MP (MP; Go-Me)
FH, mm	Distance between N and Me when N and Me are projected on line perpendicular to FH plane
Ar-Go, mm	Distance between Ar and Go when Ar and Go are projected on line perpendicular to FH plane

ANB, point A, nasion, point B angle; Ar, articulare; FH, Frankfort horizontal; Go-Me, gonion-menton line; Me, menton; MP, mandibular plane; N, nasion; NA, nasion-point A line; NB, nasion-point B; SN, sella-nasion line; SNA, sella, nasion, point B angle; SNB, sella, nasion, point B angle.

Table 2
Dental variables

Variable	Description
OB, mm	The vertical overlapping of maxillary teeth over mandibular teeth
OJ, mm	The horizontal projection of maxillary teeth beyond the mandibular teeth
U1-FH, °	Angle formed by the FH plane and a line drawn through the long axis of U1
L1-MP, °	Angle formed by the MP (MP; Go-Me) and a line drawn through the axis of L1

FH, Frankfort horizontal; Go-Me, gonion-menton line; L1, mandibular central incisor; MP, mandibular plane; OB, over bite; OJ, over jet; U1, maxillary central incisor.

3. Results and discussion

Because there were no significant differences in the cephalometric variables between the boys and the girls (Table 3), the data from the two groups were combined and analyzed together. The Ad area/Np area ratio showed a significant positive correlation with the Tn area/Op area ratio (Fig. 5). Among the cephalometric variables investigated, there was a significant positive correlation between the Ad area/Np area ratio and the MP. The Ad area/Np area ratio also had a significant negative correlation with the articulare-gonion line (Ar-Go), upper incisor–Frankfort horizontal plane angle (U1-FH), and lower incisor–MP angle (L1-MP) measurements (Fig. 6). The Tn area/Op area ratio showed a significant positive correlation with the Ad area/Np area ratio and the MP. There was a significant negative correlation with U1-FH (Fig. 7).

To our knowledge, this is the first study that selected a sample based on the CVMS for evaluating possible relationships between adenoidal and tonsillar morphology and cephalometric variables in growing children. The use of a reliable biological indicator of skeletal maturity is highly recommended for a wide variety of research and clinical applications because there are wide interindividual variations with regard to skeletal maturity, even among subjects of similar chronological age. Use of the CVMS enables the categorization of subjects for biologically appropriate matching [7]. Hence, we selected the study participants based on CVMS.

Subtenly and Baker [11] described the growth changes of adenoidal tissue in the mid-sagittal plane relative to the configurative changes in the Np cavity. Their study indicated that the

Table 3
Comparison of cephalometric variables between male and female subjects

Variable	Boys (n = 25)	Girls (n = 25)	P
SNA, °	80.9 ± 3.4	81.4 ± 3.4	0.60
SNB, °	76.5 ± 3.1	77.9 ± 3.9	0.17
ANB, °	4.4 ± 2.6	3.5 ± 3.5	0.33
MP, °	28.3 ± 6.0	28.9 ± 4.3	0.66
OB, mm	3.1 ± 2.0	1.9 ± 2.9	0.11
OJ, mm	4.5 ± 4.6	3.7 ± 3.9	0.52

ANB, point A, nasion, point B angle; MP, mandibular plane; OB, over bite; OJ, over jet; SNA, sella, nasion, point B angle; SNB, sella, nasion, point B angle.
Data are presented as mean ± SD.

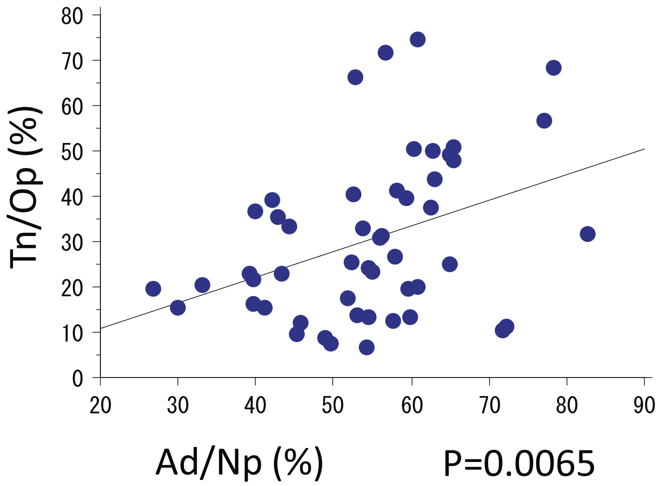

Fig. 5. Correlations between the adenoidal (Ad) area to nasopharyngeal (Np) area ratio and the tonsillar (Tn) to oropharyngeal (Op) area ratio.

adenoids followed Scammon's lymphatic cycle, becoming evident on radiography by 6 months to 1 year of age and attaining maximum bulk between the ages of 9 and 15 years. From the comparison between CVMS and chronological age, we can see that this range of ages is related to CVMS 2 or 3 [12]. Baccetti et al. [7] reported that the peak mandibular growth occurs, on average, 1 year after CVMS2 and during the year after CVMS3. Scammon's curve indicates that the peak in maxillary growth is slightly earlier than the peak in mandibular growth [13]. Because CVMS 2 and 3 compose the most active period regarding postpharyngeal lymphoid tissue growth and facial growth, we thought that it was the best age at which to investigate the relationship between postpharyngeal lymphoid tissue and facial form.

Most investigators have assessed differences in facial form or cephalometric variables between subjects with enlarged postpharyngeal lymphoid tissue and those with normal postpharyngeal lymphoid tissue [4,14]. In contrast, we evaluated the correlation between ratios of the cross-sectional areas of the adenoidal and tonsillar tissues of the same subject to that of the pharyngeal airway on the lateral cephalometric radiograph with cephalometric variables using regression analysis. To that end, we randomly selected the sample from growing subjects at CVMS 2 or 3.

It has been stated in the literature that adenoidal and tonsillar hypertrophy tend to coexist, and the adenoids and tonsils are almost invariably considered together in regard to adenotonsillectomy [15–17]. Correspondingly, our results showed that the Ad area/Np area ratio had a significant positive correlation with the Tn area/Op area ratio (Fig. 5), suggesting that subjects with higher Ad area/Np area ratios also have higher Tn area/Op area ratios. This relationship seems reasonable because adenoids and tonsils are histologically lymphoid tissues, both of which constitute Waldeyer's ring [18]. Although Stearns [19] reported no correlation between adenoid and tonsil weights, it seems that there might have been a methodologic bias because the adenoids and tonsils were removed by different techniques (curettage and dissection, respectively). Furthermore, there was no guarantee that they were completely removed.

A survey of the literature showed that subjects with enlarged adenoids had increased facial height and MP angle [2,3]. The findings of our study revealed a significant positive correlation between the Ad area/Np area ratio and the MP, whereas there was no correlation between that ratio and facial height (Fig. 6). Indeed, there was a significant negative correlation between the Ad area/Np area ratio and Ar-Go (Fig. 6). This can be interpreted to mean that subjects with higher Ad area/Np area ratios have a more significantly decreased posterior facial height than an increased anterior facial height. This development has been explained in the hypothesis that a change in breathing mode evokes a change in the muscular balance. Because of mouth breathing, the tongue position in the oral cavity is lowered, and the balance among the muscles is changed. This change in balance leads to a lower mandibular position,

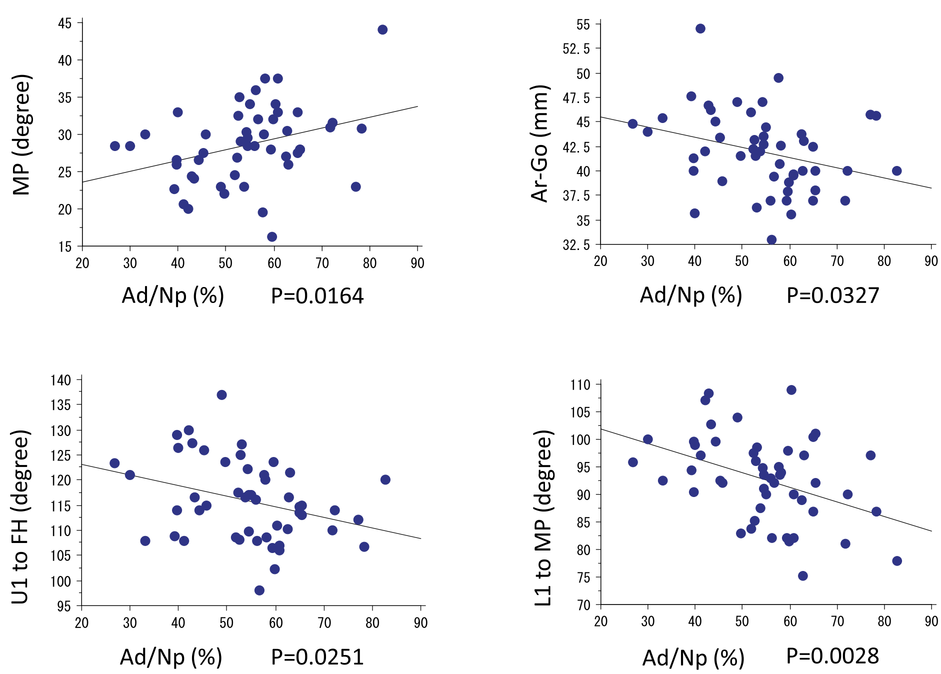

Fig. 6. Correlations between the adenoidal (Ad) area to nasopharyngeal (Np) area ratio and cephalometric variables. Ar-Go, articulare-gonion line; FH, Frankfort horizontal; L1, mandibular central incisor; MP, mandibular plane; U1, maxillary central incisor.

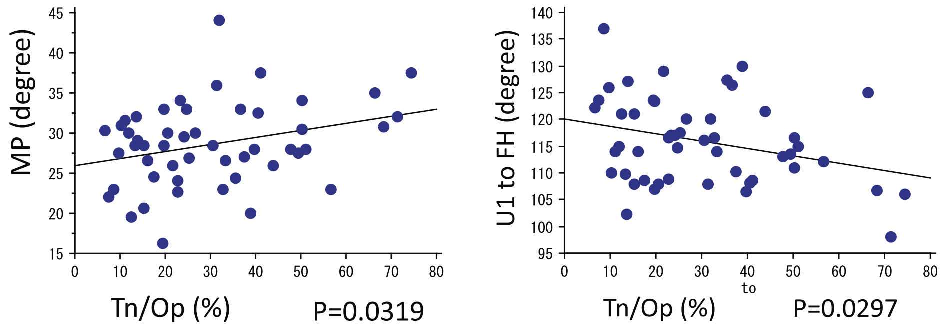

Fig. 7. Correlations between the tonsillar (Tn) area to the oropharyngeal (Op) area ratio and cephalometric variables. FH, Frankfort horizontal; MP, mandibular plane; U1, maxillary central incisor.

thereby causing a larger MP angle on lateral cephalometric radiography [3].

In the present study, the Ad area/Np area ratio had a significant negative correlation with the U1-FH and L1-MP measurements (Fig. 6), suggesting that subjects with higher ratios have more retroclined maxillary and mandibular incisors. Previous studies have reported that lingual tipping of mandibular incisors and crowding were associated with a temporal change in the mandibular position [20–22]. Linder-Aronson et al. [23] also reported that normalization of the incisor position after adenoidectomy was significantly associated with labial positioning of the incisors in both jaws. Because a significant correlation was found between the Ad area/Np area ratio and the MP, an extension of the craniocervical angle [24] may have occurred with hypertrophic adenoidal tissue. This extension would have induced the dorsally directed force on the incisors to retrocline the incisors of both jaws [24]. We did not measure the craniocervical angle in this study, however, so this assumption must be verified by further studies.

There was a significant positive correlation between the Tn area/Op area ratio and the MP, as was seen for the Ad area/Np area ratio (Fig. 7). This finding can be explained by the hypothesis that changing the breathing mode leads mechanistically to a lower mandibular position [3].

With regard to the correlation between the Tn area/Op area ratio and the incisal inclination, regression analysis indicated a significant negative correlation between the ratios and U1-FH (Fig. 7), suggesting that subjects with higher ratios have more lingually inclined maxillary incisors. In a previous study of dentition in children with enlarged tonsils, Behlfelt and coworkers [14] reported that, compared with control children, children with enlarged tonsils had not only more retroclined maxillary incisors but also retroclined mandibular incisors. Although our study did not show any significant correlation between the Tn area/Op area ratio and the inclination of mandibular incisors—for example, L1-MP and the Frankfort-mandibular incisor angle—the discrepancy may result from methodologic differences, including sample selection.

Three-dimensional (3D) imaging techniques such as cone beam computed tomography (CBCT) technology are currently available for assessing the upper airway space. Although CBCT has made it possible to acquire 3D image volumes of all structures in the maxillofacial complex, CBCT has a limited ability to identify and delineate all soft tissues because similar tissue types are defined by a similar range of density values. Therefore, the precise delineation of closely approximated soft tissues (e.g., distinguishing between adenoids and the pharyngeal wall) is often difficult [25]. Moreover, CBCT is not suitable for the typical orthodontic patient because radiation doses of CBCT are 3 to 44 times greater than comparable panoramic examination doses, depending on the CBCT device used [26–28].

There were several limitations in this study. First, we did not survey breathing mode and oral habits because the purpose was to evaluate exclusively the ratios of the adenoidal and tonsillar tissue areas to the pharyngeal airway area and their influence on the facial form. However, breathing mode and oral habits might affect the facial form. Second, although we used 2D lateral cephalometric radiography for the assessment of 3D pharyngeal airway and lymphoid tissues because it could be a good screening tool in adolescent orthodontic patients as well as a conventional evaluation tool for cephalometric analysis, it has limited accuracy in the assessment of pharyngeal airway and lymphoid tissues. Thus, one must exercise caution in interpreting the data.

In summary, there were some significant relationships between cephalometric variables and the ratios of the adenoidal and tonsillar tissue areas to the pharyngeal airway area in growing children. However, the independent effect of (the enlarged) adenoid and tonsillar tissues on cephalometric variables is obscure because of the significant developmental correlation of the two lymphoid tissues.

4. Conclusions

The findings of our study suggest that there are several specific craniofacial morphologic associations with the adenoids and tonsils. The facial form in subjects with high Ad area/Np area ratios may be characterized by a large MP angle, decreased posterior facial height, and more lingually inclined maxillary and mandibular incisors. With regard to the tonsils, subjects with high Tn area/Op area ratios may be characterized by a large MP angle and more lingually inclined maxillary incisors. Therefore, when making an orthodontic diagnosis using lateral cephalometric radiography in such patients, it is suggested that postpharyngeal lymphoid tissues be taken into consideration, with extra caution with regard to using a 2D evaluation method for 3D structures.

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