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Comparison of the maxillary sinus size of adult Korean individuals with different skeletal patterns using cone-beam computed tomography

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Abstract

Objectives: This study aimed to examine the relationship between the maxillary sinus size and different skeletal patterns in adult Korean individuals using cone-beam computed tomography (CBCT).

Materials and Methods: We enrolled 56 adult Korean individuals (mean age, 26.04 ± 6.58 years; 21 males, 35 females) and classified them into three antero-posterior skeletal patterns (skeletal Class I, Class II, and Class III) according to the A point-nasion-B point angle (ANB) —Class I (-1° ≤ ANB < 4°), Class II (ANB ≥ 4°), and Class III (ANB < -1°)—and three vertical skeletal patterns (hypodivergent, normodivergent, and hyperdivergent) according to the mandibular plane angle (MP) —hypodivergent (MP ≤ 23°), normodivergent (23° < MP < 30°), and hyperdivergent (MP ≥ 30°) as measured through CBCT images. The maxillary sinus width and depth were measured using a measurement template and automated processing with reference to the methods reported in previous studies. Differences in the size of the maxillary sinus (maxillary sinus width and depth) among the different skeletal patterns (three anteroposterior skeletal patterns and three vertical skeletal patterns) were statistically analyzed using one-way analysis of variance with the post-hoc Tukey test.

Results: There were no statistically significant differences in the maxillary sinus width and depth among the anteroposterior skeletal patterns. However, a statistically significant difference ($P < 0.05$) in the maxillary sinus width was observed among the vertical skeletal patterns. In the vertical skeletal patterns, the mean maxillary sinus width increased as follows: normodivergent, hypodivergent, and hyperdivergent.

Conclusions: Our results indicate that the vertical skeletal patterns of adult Korean individuals might be associated with the maxillary sinus width.

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Introduction

There are four types of paranasal sinuses in humans: maxillary, frontal, sphenoid, and ethmoid sinus. The maxillary sinus, which is the largest paranasal sinus, comprises most of the maxilla. The development of the maxillary sinus begins in the third month of fetal life and continues until the age of 18 years[1,2]. Owing to the anatomical features of the maxillary sinus (i.e., close to the permanent tooth root in the maxilla), some researchers have reported that the maxillary sinus and thickness of the cortical bone around the maxillary sinus might affect orthodontic treatment[3-5]. Therefore, evaluation of the maxillary sinus size and position is crucial for orthodontic diagnosis and treatment.

Lateral cephalometric radiography has been used as a traditional and effective tool for orthodontic diagnosis and the evaluation of orthodontic treatment. In particular, the classification of skeletal patterns using anatomical landmarks on lateral cephalometric radiography is an important factor for orthodontic diagnosis and treatment decisions. Generally, skeletal patterns are classified into anteroposterior and vertical skeletal patterns[6].

Some studies have evaluated and compared the size of the maxillary sinus in anteroposterior skeletal patterns (i.e., skeletal Class I, Class II, and Class III malocclusions)[7-10]. Although, the size of the maxillary sinus has been evaluated through two-dimensional (2D) analysis using lateral cephalometric radiography, 2D analysis for the measurements and evaluation of craniofacial region has some limitations, such as image distortion, magnification differences, and super imposition of craniofacial structures[11].

Three-dimensional analysis using cone-beam computed tomography (CBCT) has recently become a popular strategy for orthodontic diagnosis and treatment[12,13]. It provides a more detailed evaluation of the craniofacial structure than cephalometric assessments.

Okşayan et al.[14] reported that the maxillary sinus length and width, as evaluated through CBCT, of patients with high-angle vertical growth (hyperdivergent) pattern was statistically lower than that of patients with low-angle vertical growth (hypodivergent) pattern. Kumar et al.[15] reported statistically significant differences in the maxillary sinus volume, as assessed using CBCT, between patients with horizontal growth (hypodivergent) pattern and average growth (normodivergent) pattern[15]. Syverson et al.[16] reported that skeletal Class II patients with a high angle (hyperdivergent) had larger maxillary sinus than skeletal Class II patients with a low (hypodivergent) or normal angle (normodivergent), and the difference was statistically significant. However, in patients with skeletal Class I malocclusion, there were no statistically significant differences in the maxillary sinus size among the different vertical skeletal patterns[16,17]. Asantogrol et al.[18] also reported no statistical differences among different sagittal skeletal positions of the maxillary groups regarding the maxillary sinus dimensions and volume. Thus, the evaluation of the maxillary sinus size using CBCT among the different vertical skeletal patterns remains controversial. Moreover, few studies have reported the relationship between the size of the maxillary sinus and anteroposterior skeletal patterns that are assessed using CBCT.

Therefore, the present study aimed to examine the relationship between maxillary sinus size and different anteroposterior and vertical skeletal patterns in adult Korean individuals using CBCT.

Materials and methods

Participants

A total of 56 adult Korean individuals (mean age, 26.04 ± 6.58 years; 21 males, 35 females) who visited the Department of Orthodontics, Pusan National University Dental Hospital were enrolled. All individuals had no congenital craniofacial disorders, such as cleft lip or palate, or systemic diseases. They were classified according to their A point-nasion-B point angle (ANB; parameter of antero-posterior skeletal patterns) — Class I ($-1° \leq ANB < 4°$), Class II ($ANB \geq 4°$), and Class III ($ANB < -1°$) — and mandibular plane angle (MP; parameter of vertical skeletal patterns) — hypodivergent ($MP \leq 23°$), normodivergent ($23° < MP < 30°$), and hyperdivergent ($MP \geq 30°$) as measured through CBCT images[19-22] (Table 1). Written informed consent was obtained from all the participants. All procedures were performed in accordance with the guidelines of the Declaration of Helsinki. This study was approved by the Ethics Committees of Kanagawa Dental University (approval number: 841) and Pusan National University Dental Hospital (approval number: IRB PNUDH-2019-025).

CBCT images and measurements

The CBCT images of all individuals were obtained using Zenith 3D (Vatech Co., Seoul, Korea). The scan-

Table 1 Skeletal classification of Participants

Skeletal classification		Number of individuals
Antero-posterior skeletal patterns	Skeletal Class I	25
	Skeletal Class II	21
	Skeletal Class III	10
Vertical skeletal patterns	Hypodivergent	14
	Normodivergent	29
	Hyperdivergent	13

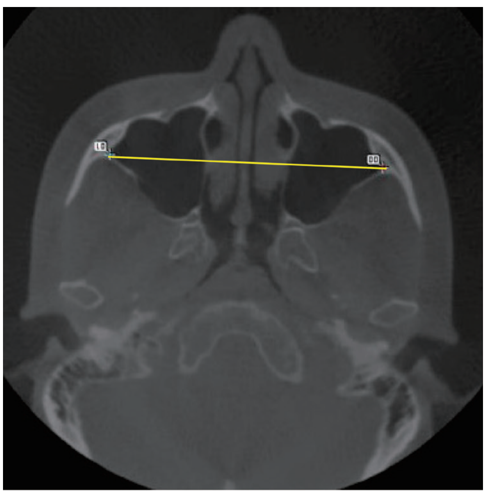

Figure 1-a. Measurement template of the maxillary sinus width using axial cone-beam computed tomography. The landmark point 00 is defined as the most protruding outwards point on the left side of the maxillary sinus, and landmark point 01 is defined as the most protruding outwards point on the right side of the maxillary sinus. The yellow line shows the distance from point 00 to point 01 and represents the maxillary sinus width as measured by the automatic measurement program.

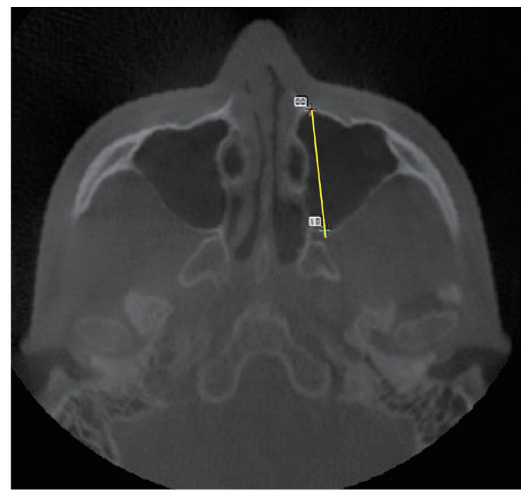

Figure 1-b. Measurement template of the maxillary sinus depth using axial cone-beam computed tomography. Landmark point 00 is defined as the most anterior point on the medial wall on the left side of the maxillary sinus, and landmark point 01 is defined as the most posterior point on the medial wall on the left side of the maxillary sinus. The yellow line shows the distance from point 00 to point 01 and represents the maxillary sinus depth as measured by the automatic measurement program.

ning conditions were set at 90 kV and 10 mA, with a voxel size of 0.3 mm and scanning time of 24 s. The patients were seated comfortably in a chair with a natural head position. They were then asked to bite but not move or sallow during the scanning. The CBCT images were stored in the Digital Imaging and Communications in Medicine format.

To evaluate the size of the maxillary sinus, CBCT images were obtained using the method of Koga et al.[22]. The CBCT images were reoriented using two types of horizontal standard planes through each landmark point to prevent measurement errors caused by the compression of inclined CBCT images before measurements[22].

The maxillary sinus width, defined as the length between the most protruding outwards point on the left and right sides of the sinus, and depth, defined as the distance between the most anterior and posterior points on the medial wall on the left side of the maxillary sinus, were measure reported d using a measurement template and automated processing with reference to the methods in previous studies[22-24]. Experienced orthodontists created the measurement templates with some anatomical landmark points using CBCT images. Thereafter, the automatic measurement program detected the coordinates of the established markers on the measurement templates and measured the distance between those coordinates[22] (Figures 1-a and b).

Statistical analysis

All the statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM

Table 2 Measurement results of the maxillary sinus size based on antero-posterio and vertical skeletal patterns and ANOVA results

	Number of individuals	Mean(mm)	S.D.	Min(mm)	Max(mm)	ANOVA
The width in antero-posterior skeletal pattern						
Skeletal Class I	25	89.7	5.4	75.0	100.0	
Skeletal Class II	21	90.2	8.3	78.0	105.4	N.S.
Skeletal Class III	10	91.3	10.8	66.4	102.1	
The depth in antero-posterior skeletal pattern						
Skeletal Class I	25	40.7	3.0	32.1	46.7	
Skeletal Class II	21	40.8	3.4	34.0	47.2	N.S.
Skeletal Class III	10	40.5	4.9	28.8	46.1	
The width in vertical skeletal pattern						
Hypodivergent	14	87.9	8.4	66.4	100.7	
Normodivergent	29	92.6	6.8	82.2	105.4	0.04*
Hyperdivergent	13	87.3	7.0	75.0	96.1	
The depth in vertical skeletal pattern						
Hypodivergent	14	40.5	4.2	28.8	45.9	
Normodivergent	29	41.3	3.0	36.7	47.2	N.S.
Hyperdivergent	13	39.5	3.7	32.1	45.1	

S.D.: Standard deviation, Min: Minimum, Max: Maximum, ANOVA: Analysis of variance, N.S.: not significant,
*Statistical significance at the .05 level

Corporation, Armonk, NY, USA). The Shapiro–Wilk test and quantile-quantile (Q-Q) plots were used to confirm normality among the measurements. One-way analysis of variance (ANOVA) was performed with a post-hoc Tukey test to compare the size of the maxillary sinus among the different anteroposterior and vertical skeletal patterns. Statistical significance was defined as $P < 0.05$.

Results

Table 2 shows the size of the maxillary sinus (maxillary width and depth) and ANOVA for the different skeletal patterns. Statistically significant differences in the maxillary sinus width and depth were not observed among the anteroposterior skeletal patterns. However, we found a statistically significant difference in the maxillary sinus width among the vertical skeletal patterns. In the vertical skeletal patterns, the mean maxillary sinus width increased as follows: normodivergent, hypodivergent, and hyperdivergent. However, the post-hoc Tukey test revealed no statistically significant differences between the two vertical skeletal patterns.

Discussion

In orthodontic treatment, the maxillary sinus may restrict tooth movement and insertion of temporary anchorage devices[3-5]. Moreover, maxillary sinus size may be associated with facial development[9,18,25]. Therefore, a thorough understanding of the anatomical features of the maxillary sinus is essential.

Several studies have evaluated the size of the maxillary sinus in patients with different skeletal patterns using lateral cephalometric radiography or CBCT[7-10,14-18]. Endo et al.[7] evaluated maxillary sinus sizes in patients with anteroposterior skeletal patterns (i.e., skeletal Class I, Class II, and Class III malocclusions) based on the A point-nasion-B point (ANA) angle. The results suggested that there were no statistically significant differences among the different antero-posterior skeletal patterns. Urabi et al.[8] reported that the mean length, height, and area of the maxillary sinus in patients showed no statistically significant differences among the different antero-posterior skeletal patterns. Conversely, Yassaei et al.[9] reported that the mean height and surface area of the maxillary sinus in patients with skeletal Class III malocclusion were significantly greater than those with skeletal Class I and Class II malocclusions. Albarakani et al.[10] reported that patients with skeletal Class II malocclusion had a more prominent sinus length and statistically significant increase in surface area than those with skeletal

Class I Class III malocclusions. These findings were obtained from evaluations using lateral cephalometric radiography and compared among the different anteroposterior skeletal patterns.

Some recent studies have evaluated the maxillary sinus morphology in patients with different skeletal patterns using CBCT but have reported diverse results [14-17]. Okşayan et al.[14] reported that the maxillary sinus length and width in patients with a high-angle vertical growth (hyperdivergent) pattern was significantly lower than that in patients with a low-angle vertical growth (hypodivergent) pattern, and although the maxillary sinus volume in patients with a horizontal growth (hypodivergent) pattern was significantly lower than that in patients with an average growth (normodivergent) pattern, there were no statistically significant differences in the maxillary sinus width and depth among different vertical skeletal patterns[15]. Moreover, Syverson et al.[16] reported that skeletal Class II patients with high angle (hyperdivergent) had larger maxillary sinus volume, height, and width compared with skeletal Class II patients with low (hypodivergent) and normal (normodivergent) angle, and the difference was statistically significant.

Whereas, other studies have reported different results when evaluating the maxillary sinus depth in skeletal Class I patients with different vertical skeletal patterns[16,17]. Results obtained from studies in the same population that were evaluated by the same research group suggest that the size of the maxillary sinus might be associated with anteroposterior skeletal patterns rather than vertical skeletal patterns[16,17].

In this study, we evaluated and compared the size of the maxillary sinus (width and depth) in adult Koreans with different anteroposterior and vertical skeletal patterns using CBCT. Our results showed no statistically significant differences in the maxillary sinus width and depth among the anteroposterior skeletal patterns. In terms of the comparison among anteroposterior skeletal patterns, our results agree with those of previous studies[7,8,18].

Our results also suggest that there is a statistically significant difference in the maxillary sinus width among the vertical skeletal patterns. Although the result was similar to that reported by Syverson et al.[16], unlike the results of the study, our findings showed that the mean width of the maxillary sinus in normodivergent individuals was larger than that in hyperdivergent individuals. The result agree with that of Okşayan et al.[14]. One possible explanation for this result is that maxillary sinus development in hyperdivergent might be inhibited during the growth stage, as patients with hyperdivergent often have mouth breathing[26-28]. Tikku et al.[26] reported that mouth breathers have smaller sinus volumes than normal breathers. Moreover, Cho et al.[27] reported that the maxillary sinus volume was significantly decreased in patients with chronic rhinosinusitis. Mouth breathing and/or nasal disease may be a key factor that affect the size of the maxillary sinus. As for other factors, we should also consider the measurement method using CBCT, age of the participants, race, sex, and laterality. Although the maxillary sinus depth was measured only on the left side in this study, some studies indicated that there were differences in morphology between the left and right sides of the maxillary sinus[14,18,29]. One cause of the difference in the results among various studies that evaluated the size and volume of the maxillary sinus by CBCT is that there are no studies that were evaluated using unified study designs and the mentioned factors.

The present study has some limitations. First, the sample size was small, and the number of participants with different skeletal patterns varied. Therefore, further studies with larger sample sizes are required, and the number of participants should be the same for each skeletal pattern. Second, the sex of the participants were not considered. It would be valuable to classify the participants according to sex, as it has been reported that sex might affect the size of the maxillary sinus[30]. Third, we did not evaluate maxillary sinus volume. Volumetric analysis using CBCT provide more detailed findings of the size of the maxillary sinus. Fourth, the difference between the left and right sides of the maxillary sinus depth was not evaluated. A more accurate evaluation of the anatomical features of the maxillary sinus in future studies to overcome these limitations may provide valuable information regarding the prediction of craniofacial growth patterns and tooth movement.

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Conflicts of Interest

The authors declare that they have no related conflicts of interest.

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