

Three-dimensional CBCT Based Evaluation of the Maxillary Sinus by Facial Index: Retrospective Study

Jeong-Hyun Lee

Dental College, Dan-kook University

Won-Jeong Han

Dental College, Dan-kook University

Jong-Tae Park (✉ jongta2@dankook.ac.kr)

Dental College, Dan-kook University

Research Article

Keywords: maxillary sinus, 3D, Facial index, mesoprosopic, leptoprosopic, hyperleptoprosopic

Posted Date: June 23rd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-627502/v1>

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Abstract

The maxillary sinus growth is initiated 3 months after birth, and it grows lateral and inferior until the pneumatization of the alveolar bone occurs. Maxillary sinus size is determined around the age of 18 years. The facial skeleton has recently been determined as affecting the maxillary sinus, prompting additional studies on changes in the size of the maxillary sinus. This study aimed to determine the size of the maxillary sinus using a 3D program after categorizing South Korean adults according to their FI classification.

Upon categorizing the subjects based on their FI classification, they were grouped into the mesoprosopic, leptoprosopic, and hyperleptoprosopic types, with no subjects fitting the euryprosopic type. In this study, the maxillary sinus size varied based on the shape of the face when classified by FI. The maxillary sinus tended to be wider in those with mesoprosopic type, and tended to be higher in the hyperleptoprosopic type, suggesting a need for clinicians to focus to the shape of the face during clinical treatments.

Introduction

The maxillary sinus is the largest sinus, and has a pyramidal shape with four walls: the facial, infratemporal, orbital, and nasal surfaces[1]. Its growth is initiated 3 months after birth, and it grows lateral and inferior until the pneumatization of the alveolar bone occurs[2]. Maxillary sinus size is determined around the age of 18 years[3–4].

Since the maxillary sinus is located close to the teeth, research into inflammatory diseases such as dental infections and also into maxillary sinus floor augmentation during implant surgeries is being conducted in the dentistry field[5–7]. Studies are also being conducted on maxillary sinus diseases in the fields of otolaryngology and plastic surgery, highlighting the importance of the maxillary sinus[5]. The facial skeleton has recently been determined as affecting the maxillary sinus, prompting additional studies on changes in the size of the maxillary sinus[4,8]. However, most studies have been conducted on children, suggesting a need for research on adults.

The facial skeleton is fully developed by adulthood, with the shape varying between individuals and races. To determine this variation, we divided them into euryprosopic, mesoprosopic, leptoprosopic, and hyperleptoprosopic types based on their facial index (FI) classification[9]. However, most studies have compared maxillary sinus sizes based on growth, and no research that we know of has analyzed the relationship between maxillary sinus and FI classification. It was therefore necessary to study this undetermined relationship. Most studies have also not measured maxillary sinus size in three dimensions, instead measuring it in 2D, which may be less accurate. It was therefore necessary to use a 3D program for measurements in this study.

This study aimed to determine the size of the maxillary sinus using a 3D program after categorizing South Korean adults according to their FI classification. It was also designed to help prevent clinical

surgery complications by observing the relationship between maxillary sinus size and FI classification, including suggesting standard values.

Materials And Methods

2.1 Research subjects

This study analyzed cone-beam computed tomography (CBCT) data of 60 (male 30, female 30) patients aged 20–29 years with malocclusion, no lost teeth, and no asymmetry or systemic diseases who visited the Department of Orthodontics at Dankook University Dental Hospital after being referred from the Department of Oral and Maxillofacial Radiology. The required sample size was calculated using the G*Power 3.1 program, which determined the sufficiency of the data set.

The radiographic imaging data used in this study were obtained using retrospective analysis. This study was approved by the IRB of Dankook University Dental Hospital (approval no. DUDH IRB 2015-12-022), and the requirement to obtain informed consents from the patients was waived.

2.2 Methods

2.2.1 3D image creation

The CBCT data of the study subjects were collected using a scanner and presented in DICOM format. Computed tomography scanning was performed using a 0.39-mm slice increment, 0.39-mm slice thickness, and 512-pixel × 512-pixel matrix. The 3D Mimics program was used to extract DICOM data, which provided 3D images of the maxillary sinuses of the patients.

2.2.2 Measurement items

All measurements were evaluated by calculating the mean value following the measurements made by Lee and Park. They were measured according to the FI classification, as follows:

- N: starting point of the nose.
- Gn: lowest point of the lower chin border on the midline.
- Zy: most-lateral point of the zygomatic arch.
- FH (facial height): distance between N and Gn.
- FW (facial width): distance between the Zy points.

The formula for FI was as follows (Table 1):

$$FI = \frac{FH}{FW} \times 100$$

Table 1
lists the number of subjects
classified by FI.

Facial type	N
Mesoprosopic	4
Leptoprosopic	14
Hyperleptoprosopic	42

The measured items for the maxillary sinus were as follows (Fig. 1), (Fig. 2):

- IOF: distance between the infraorbital foramen from one side to the other.
- RMA-LMA: distance between the left and right maxillary sinuses.
- Width: corona-view width.
- Length: Sagittal-view width.
- Height: maxillary sinus height.

2.2.3 Statistics

The measurement items were analyzed using SPSS software (version 23.0, IBM Corporation, Armonk, NY, USA). Since the sample was small, a one-way ANOVA test was conducted to detect significance after testing for normality. Post-hoc analysis was performed on the 95% confidence interval to determine the mean differences between maxillary sinus sizes based on FI classifications. Linear regression analysis was also performed to determine the effect of FI classification on maxillary sinus size. A p-value of < 0.05 was considered significant in all test results.

Results

Upon categorizing the subjects based on their FI classification, they were grouped into the mesoprosopic, leptoprosopic, and hyperleptoprosopic types, with no subjects fitting the euryprosopic type. Table 2 lists the results of comparing maxillary sinus sizes according to FI classifications.

Table 2
Comparison of maxillary sinus size according to FI classification

Measurements	Mesoprosopic (N = 4)	Leptoprosopic (N = 14)	Hyperleptoprosopic (N = 42)	P-value
RMA-LMA	94.79(3.13)	89.85(6.66)	88.96(8.42)	> 0.05
IOF	50.24(2.83)	54.47(5.42)	51.17(4.00)	< 0.05*
Lwidth	30.05(1.28)	27.34(1.96)	28.37(1.87)	< 0.05*
LLength	40.94(2.37)	38.58(3.51)	40.13(4.00)	> 0.05*
LHeight	44.74(1.23)	43.22(2.88)	49.17(4.05)	< 0.001**
Rwidth	31.05(1.91)	29.93(1.76)	27.46(4.47)	< 0.05*
RLength	41.29(1.10)	38.63(3.33)	39.94(4.32)	> 0.05
RHeight	46.02(1.36)	44.43(1.48)	47.49(2.66)	< 0.001*
Data are mean(standard-deviation values)				
P-value were obtained by One-Way ANOVA				
*p < 0.05, **p < 0.001				

RMA-LMA decreased in the following order: mesoprosopic > leptoprosopic > hyperleptoprosopic. IOF decreased in the following order: leptoprosopic > hyperleptoprosopic > mesoprosopic ($p < 0.05$). The width decreased in the following order: mesoprosopic > hyperleptoprosopic > leptoprosopic ($p < 0.05$) on the left, and mesoprosopic > leptoprosopic > hyperleptoprosopic ($p < 0.05$) on the right. The length decreased in the following order on both sides: mesoprosopic > hyperleptoprosopic > leptoprosopic. The height decreased in the in the following order on both sides: hyperleptoprosopic > mesoprosopic > leptoprosopic ($p < 0.001$).

Simple linear regression analysis was performed to determine whether the FI classification affected the maxillary sinus size (Table 3). The regression model was considered suitable since $F = 4.799$ ($p < 0.05$), and the explanatory power was 43% with $R^2 = 0.429$. β was -0.112 for RMA-LMA and -0.206 for IOF, and these parameters were not affected by FI classification ($p > 0.05$). On the left, β was -0.189 , 0.119 , and 0.645 for the width, length, and height, respectively, which were all affected by FI classification ($p < 0.001$); the corresponding values on the right were -0.100 , 0.078 , and 0.185 , and none of these values were affected by the FI classification ($p > 0.05$). $\beta(+)$ was shown in terms of the length on the left and the height on both sides, indicating changes based on the FI classification (Table. 3).

Table 3
Effect of FI classification on maxillary sinus size

Measurements	B	SE	β	t(p)	f(p)	R2
Constant	3.208	1.600		2.005*	4.799	.429
RMA-LMA	-.015	.016	-.112	-.934		
IOF	-.016	.019	-.206	-.836		
Lwidth	-.059	.056	-.189	-1.054		
LLength	.019	.039	.119	.484		
LHeight	.088	.025	.645	3.506**		
Rwidth	-.015	.029	-.100	-.522		
RLength	-.012	.037	-.078	-.321		
RHeight	.007	.035	.029	.185		
P-value were obtained by Simple linear regression						
*p < 0.05, **p < 0.001						

Discussion

The maxillary sinus, which is the largest of the four sinuses, occupies up a large region of the face [10], and has therefore been the focus of studies in various clinical fields [1–13]. Until now, most studies have been clinical case studies based on sex, but studies have been conducted recently on the growth of the maxillary sinus [2,8,11–13]. According to a study by Jun [4], the maxillary sinus grows until adolescence and the twenties in females and males, respectively. Studies of adults are therefore important considering the lack of literature focusing on this population. While most clinical treatments are performed on adult patients, there have yet to be studies comparing size of the maxillary sinus according to the facial skeletons of adults.

The development and anatomy of the facial skeleton depends on several factors, such as sex, race, socioeconomic status, nutrition, and genetics [9]. These factors are essential for planning orthodontic and other various treatments, and are helpful in predicting potential changes [14]. In particular, facial-skeletal measurements can identify racial differences, and are also useful in the anthropology and forensic science fields [15]. Until now, Angle's classification has been used for facial skeletal measurements; however, that classification analyzes the relationship between the molars, which may not accurately classify the facial skeleton [9]. A study by Endo [16] indicated that there was no significant difference between sexes in the maxillary sinus size based on Angle's classification, but there were size differences according to measurements of the tooth face shape. Despite the need to analyzed the maxillary sinus size according to FI classification, no studies have yet been conducted on this topic.

This study classified 60 subjects based on the FI. They comprised 4 mesoprosopic, 14 leptoprosopic, 42 hyperleptoprosopic, and no euryprosopic subjects. The maxillary sinus size was therefore only compared in subjects of mesoprosopic, leptoprosopic, and hyperleptoprosopic types.

About 6.7% of subjects were of the mesoprosopic type. Upon comparing maxillary sinus size, these subjects had the largest RMA-LMA, width, and length. In a study by Jahanshahi[17], which also compared skull size according to FI classification, the distances between the cheekbones, nose width, and mouth width were larger in mesoprosopic than leptoprosopic subjects. Therefore, as for maxillary sinus size, the RMA-LMA, width, and length values of the mesoprosopic type, the midface size of this type was expected to be the largest.

About 70% of the 60 subjects were of the leptoprosopic type. Upon comparing maxillary sinus sizes, these subjects had the largest IOF. Kassab [18] reported that the interpupillary distance, canine arc distance, and incisal width of the central incisor were larger in the leptoprosopic than the mesoprosopic type. Sinavarat[19] reported that there was a strong correlation between the interpupillary distance and canine arc distance. Therefore, considering the maxillary sinus size, the IOF of the leptoprosopic type, which causes a narrow face, was expected to be the largest among the three types.

About 23.3% of the 60 subjects belonged to the hyperleptoprosopic type. Upon comparing maxillary sinus sizes, these subjects had the largest height. Malim [20] reported that the hyperleptoprosopic type had a larger lower part of the face than the leptoprosopic type. The subject with the longest face in the hyperleptoprosopic type was therefore expected to have the largest facial height among the three types.

This study also aimed to determine the association between the facial skeleton and the maxillary sinus. Regression analysis indicated that the FI classification did not affect maxillary sinus size. In addition, the length on the left and the height on both sides were β , indicating that there were differences according to the FI classification. The study by Uchida [21] and Hong [2] indicated that the length and height were correlated with changes maxillary sinus volume. Moore [22] similarly reported that changes in maxillary sinus volume based on age and sex were similar to the changes associated with body growth, such as the height and the development of the wrist bones. It therefore seems possible that the maxillary sinus size changes with the size of the facial skeleton.

In this study, the maxillary sinus size varied based on the shape of the face when classified by FI. The maxillary sinus tended to be wider in those with mesoprosopic type, and tended to be higher in the hyperleptoprosopic type, suggesting a need for clinicians to focus to the shape of the face during clinical treatments. In addition, since the FI classification has revealed an association with the maxillary sinus size, this should be studied further. The results of this study should help to prevent complications during various clinical treatments, and provide valuable data for future research on maxillary sinus growth.

Declarations

Funding:

N/A

Conflicts of interest/Competing interests:

The authors declare that they have no conflict of interest

Ethics approval:

The study was conducted after IRB(Dankook University Dental Hospital, approval no. DUDH IRB 2015-12-022) had been approved. This study is a retrospective analysis of radiological imaging data which were obtained from the completed check-up processes. Thus, an application for waiver of consent was requested and was approved by the institutional review committee of Dankook University Dental Hospital.

Consent to participate:

N/A

Consent for publication:

N/A

Availability of data and material:

N/A

Code availability:

N/A

Related guidelines and regulations:

This study was conducted with the methods in accordance with relevant guidelines and regulations.

Authors' contributions:

- Jeong-Hyun Lee: development, data collection, data analysis, manuscript writing
- Won-Jeong Han : data collection, data analysis
- Jong-Tae Park : development, data collection, data analysis, manuscript editing

ACKNOWLEDGMENT:

This work was supported by a National Research Foundation of Korea Grant funded by the Korean Government (NRF 2016R1D1A1B01008853).

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Figures

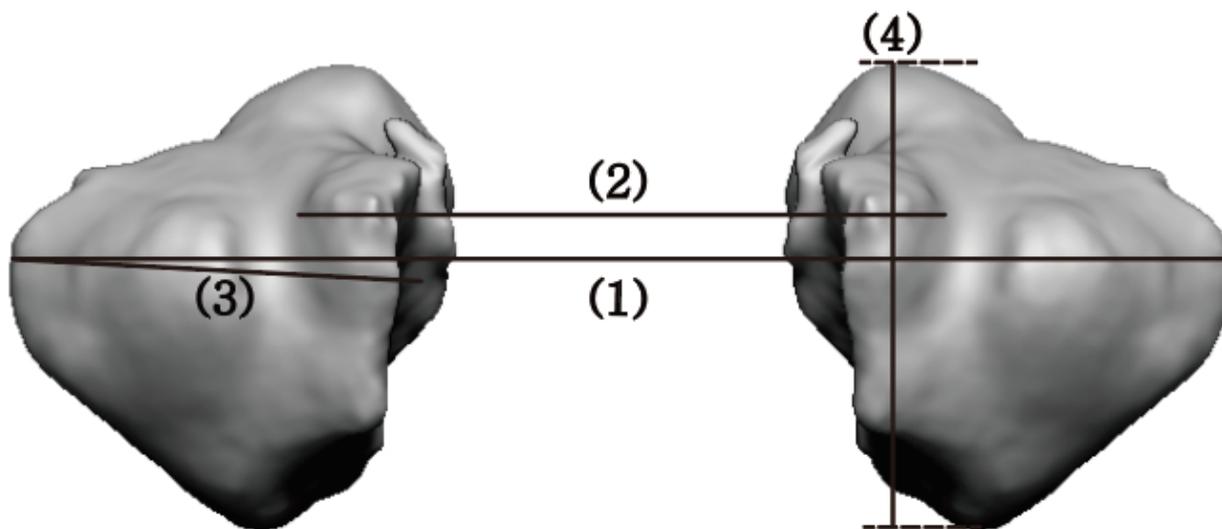


Figure 1

Coronal view. (1) IOF: The distance between the infraorbital foramen on one side to the other; (2) RMa-LMa: The distance between the left and right maxillary sinuses; (3) Width: The width from the corona view; (4) Height: The height of the maxillary sinus



Figure 2

Sagittal view. (5) Length: The width from the sagittal view