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Craniofacial parameters and their interrelationships: a comprehensive CBCT analysis of cranial, nasal, mandibular, and maxillary dimensions with sinus measurements

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Objectives: The objective of this study was to examine the relationship between cranial width, nasal width, antegonial width (mandibular width), maxillary width, maxillary ratio, compared with the volume measurements of the maxillary and frontal sinuses.
Methods: One hundred and thirty-six CBCT images were selected, analysed, and divided into four groups as young female, young male, old female and old male subjects. Two-dimensional measurements were performed on DICOM format images obtained from the CBCT scans. Frontal and maxillary sinus volumes were assessed utilising the Mimics® software program (Materialise NV, Technologielaan, Leuven, Belgium). Data analysis was performed using IBM SPSS 25.0 software (IBM Corp., Armonk, NY, USA).
Results: The analysis revealed a significant positive correlation between maxillary sinus volumes (R MS VOL, L MS VOL) and the maxillary ratio (MxR-MxL/AgR-AgL) in both genders ($p < 0.05$). Furthermore, significant differences were found in R MSH, R MSD, L MSH, EurR-EurL, LnR-LnL, MxR-MxL, and AgR-AgL measurements ($p < 0.05$).
Conclusions: The findings of the study revealed a positive correlation between maxillary sinus volumes and maxillary ratio measurements, underscoring the multifactorial interactions in craniofacial development. Moreover, gender was identified as a significant factor influencing craniofacial measurements, as males presented higher values compared to females, while age-related differences were minimal and lacked statistical significance.
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Introduction

The paranasal sinuses, including the sphenoidal, ethmoid, maxillary and frontal sinuses, play essential physiological roles of warming inhaled air, facilitating nasal drainage, contributing to sound resonance, and participating in the development of the midface.[1,2]

As the most voluminous of the paranasal sinuses, the maxillary sinus starts to form during the tenth week of the prenatal period and attains its full size between the ages of 14 and 18 years.[3] Changes in sinus volume may result from congenital or acquired causes.[4–7] Tooth extraction and infection of the maxillary teeth may affect the maxillary sinus and cause changes in the craniofacial region.[8] Furthermore, studies have shown a relationship between different skeletal models and the volume of the maxillary sinus.[9,10]

The frontal sinus is also linked to remodelling of the nasomaxillary complex. The frontal sinus first becomes visible on radiographs around the age of 7 years and reaches its full size by the age of 20 years. The morphology of the frontal sinus can only be altered through surgical intervention that modifies the airway.[1,11,12] Studies have revealed that, similar to the maxillary sinus, the volume of the frontal sinus is influenced by the surrounding skeletal structures.[9,13]

The development of the maxilla is similarly associated with the development of the nasomaxillary complex.[14,15] The peak period of maxillary growth begins at approximately 9 years of age in females and 11 years in males, with completion occurring at age 13 in females and between 14 and 17 years in males.[16]

Maxillary transverse deficiency is a common problem in orthodontics.[17] Past studies have shown that maxillary expansion for the treatment of a maxillary transverse deficiency leads to an increase in maxillary sinus width.[18] Of the studies describing the connection between craniofacial structures and the paranasal sinuses, research exploring the link between mandibular length and the frontal sinus is particularly notable.[9,19] Additional studies have identified a positive relationship between the length of the mandibular body and the gonial angle with the size of the frontal sinus, thereby indicating that frontal sinus dimensions may influence the ultimate size of the mandible.[9,19] The majority of the published studies that have evaluated sinus dimensions have utilised two-dimensional imaging techniques, specifically in the form of lateral and postero-anterior cephalometric radiographs.[20–22] Three-dimensional evaluations eliminate the problems inherent with two-dimensional methods that involve the overlapping of images and scaling distortions. Greater accuracy in examining the maxillofacial region is achieved through the use of cone beam computed tomography (CBCT)[23–26] which has the additional advantage of delivering reduced radiation exposure.[27,28]

The development of the craniofacial structures should be considered as a complex process in which different components interact with each other. The main aim of the present study was to investigate the relationships between the volumes of the maxillary and frontal sinuses and the widths of the maxilla, mandible, nasal cavity and cranium using CBCT imaging, whilst taking into account studies that emphasise the interactive development of craniofacial region. Although changes in maxillary sinus dimensions due to maxillary enlargement have been examined with respect to gender and age, no studies have examined the relationships between the maxillary sinus and the cranial base, nasal, maxillary and mandibular widths and maxillary ratio in three dimensions.[8,18,29] In addition, many studies have examined frontal sinus measurements on different populations, but no study has evaluated the relationship of the sinuses with cranial structures in three dimensions.[4,30,31] The present literature review revealed no study that had previously examined the relationship between maxillary and frontal sinus volumes and the maxillary ratio (MxR-MxL/AgR-AgL).[4,8,10,20,31,32] Therefore, the present study aimed to contribute to the existing literature by assessing frontal and maxillary sinus relationships with surrounding structures.

The first null hypothesis stated that an increase in maxillary and frontal sinus volumes would be associated with a corresponding increase in craniofacial parameter values. Secondly, it was further anticipated that maxillary and frontal sinus volumes, as well as craniofacial measurements, would be greater in males than females. Additionally, the measured parameters were expected to exhibit higher values in the younger group than in the older age group.

Materials and methods

A total of 1130 CBCT images of individuals aged between 20 and 60 years, acquired using the Planmeca Promax 3D Mid (Planmeca OY, Helsinki, Finland), were examined from the archives of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry. The exclusion criteria were a history of orthodontic treatment or orthognathic surgery, the presence of severe craniofacial deformities, significant alveolar resorption associated with tooth loss, pathological findings in the maxillary and frontal sinuses, or CBCT images of diagnostic quality unsuitable for examination. Of the 1130 CBCT images reviewed, 994 images were excluded based on the exclusion criteria, and so 136 patients were finally assessed by the study. The study population was divided into four groups identified as young male, young female, old male, and old female subjects. Participants aged 20–40 years were categorised as young, while those aged 41–60 years were classified as old. The gender of the participants was determined based on the biological gender statements recorded in retrospectively evaluated clinical records or questionnaire forms.

CBCT data were measured in the three spatial planes (sagittal, coronal, and axial) using 0.2 mm^3 isotropic

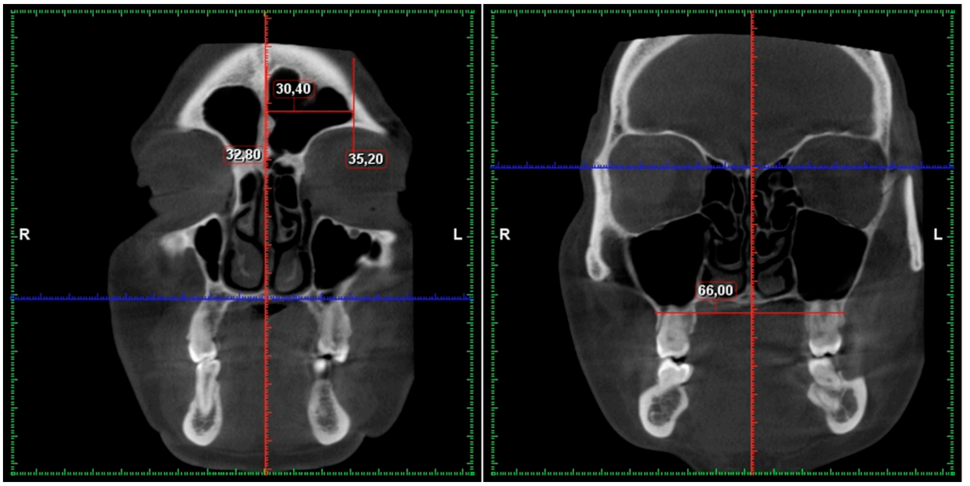

Figure 1. Two-dimensional measurements taken manually.

voxels and a slice thickness of 0.2 mm. The two-dimensional measurements, including cranial width (EurR-EurL), nasal width (LnR-LnL), antegonial width (mandibular width) (AgR-AgL), maxillary width (MxR-MxL), maxillary ratio (MxR-MxL/AgR-AgL), right and left maxillary sinus width (R MSW, L MSW), height (R MSH, L MSH), and depth (R MSD, L MSD), and right and left frontal sinus height (R FSH, L FSW), width (R FSW, L FSW), and depth (R FSD, L FSD), were taken from images captured in Digital Imaging and Communications in Medicine (DICOM) format. The layer with the greatest width was identified, and a tangent line was drawn to the widest boundaries to measure the perpendicular distance between the two tangents (Figure 1). (A list of abbreviations is located at the end of the text).

The three-dimensional measurements, including frontal sinus volume (FS VOL), right maxillary sinus volume (R MS VOL), and left maxillary sinus volume (L MS VOL), were determined using Mimics® software (Materialise NV, Technologielaan, Leuven, Belgium). The Hounsfield Unit (HU) values were adjusted to a minimum of -1024 HU and a maximum of -302 HU for three-dimensional (3D) visualisation of the frontal and maxillary sinuses (Figure 2). Subsequently, the desired area of interest was separated in the masking stage and adjustments were made by removing unnecessary soft tissue coverage using the mask editing section, following which the calculation function was applied to generate the correct volumes (Figure 3). All images were analysed by a single observer, and three weeks after the initial measurements, the same observer re-measured all parameters to determine intra-observer reliability, which showed excellent consistency with an intraclass correlation coefficient greater than 0.90.

The present retrospective study obtained ethical approval from the Biruni University Ethics Committee under Decision Number 2023/79-41.

Statistical analysis

G-Power analysis (Heireich Heine Universitat, Dusseldorf, Germany) was conducted to determine the sample size. The assumption of a normal distribution was tested using the Shapiro-Wilk test, along with descriptive statistics (number, percentage, mean, standard deviation, median, minimum, and maximum). The ANOVA test was used to compare three or more independent groups with a normal distribution, while the Kruskal-Wallis test was applied when the normality assumption was not met. Post hoc Bonferroni and adjusted Bonferroni tests were conducted to identify the specific group(s) responsible for the observed differences. The Independent Samples T-test was used to compare two independent groups with a normal distribution, while the Mann-Whitney U test was applied when the data did not follow a normal distribution. A Pearson correlation was used to examine the relationships between continuous measurements against a normal distribution, while a Spearman correlation was applied when a normal distribution was not present. All analyses were

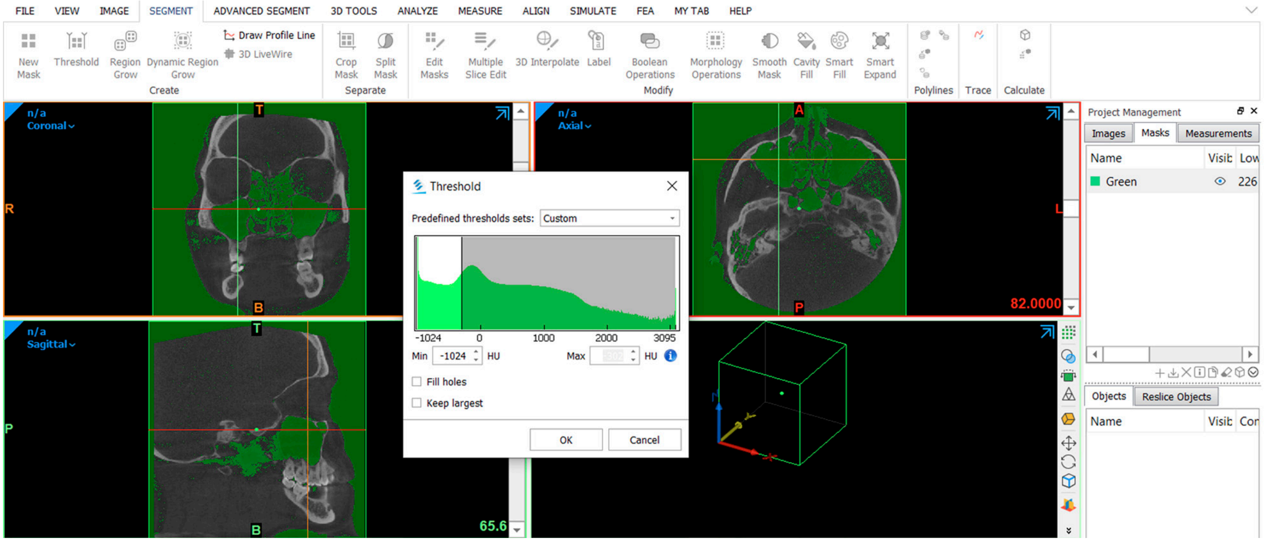

Figure 2. Hounsfield (HU) values were set to a minimum of -1024 HU and a maximum of -302 HU to visualise the frontal and maxillary sinuses.

performed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA).

Results

According to the G-Power analysis, the effect size was calculated as 0.243, and therefore 130 samples were required. However for contingency, the total sample size was 136, consisting of 68 female and 68 male individuals. No statistically significant difference was found between the initial and subsequent measurements of all parameters, and so the initial measurements were used throughout the research.

General findings

The two-dimensional measurements are presented in millimeters (mm), while three-dimensional measurements are reported in cubic millimeters (mm^3). The analyses revealed statistically significant

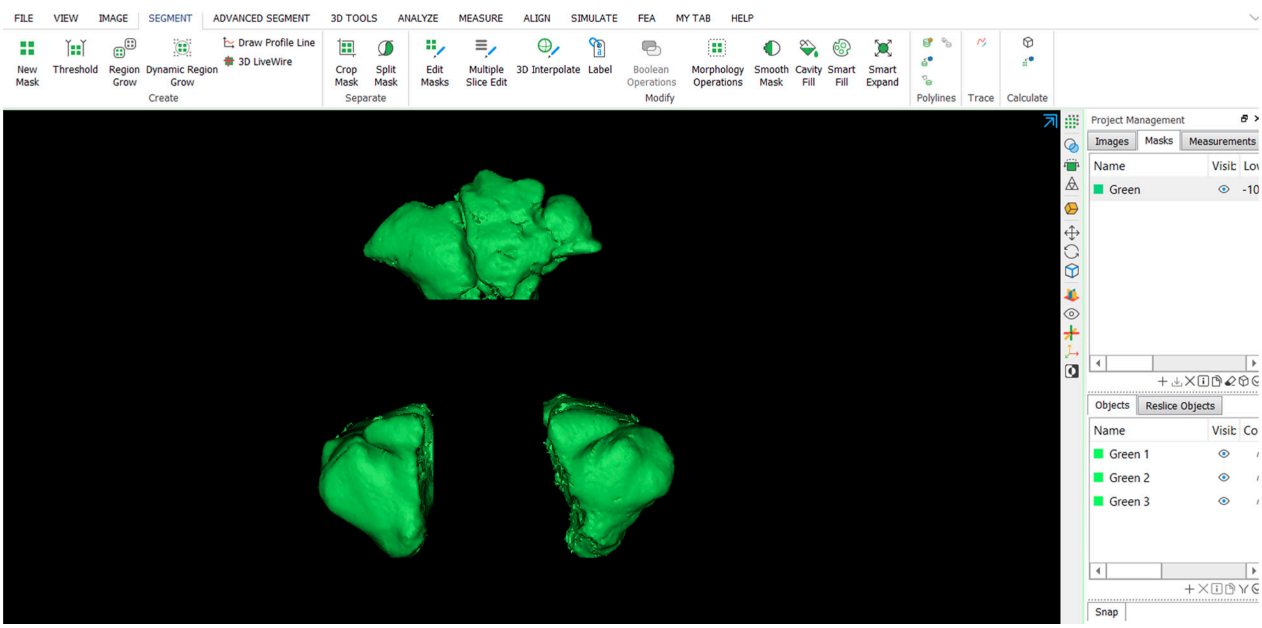

Figure 3. Obtaining the volumes of the final sinuses in 3D after mask editing.

Table I. Distribution and comparison of measurements by gender

	Mean.±S.D.(M.) (mm mm³)			
	Female	Male	Test statistics	p
R MSH	31.86 ± 4.64 (31.8)	34.54 ± 3.89 (35.3)	-3.646	<0.001*
R MSW	26.47 ± 4.37 (26.6)	26.82 ± 4.2 (27.6)	-0.442†	0.659
R MSD	34.65 ± 5.05 (35.2)	36.11 ± 3.47 (36.6)	-2.042†	0.041*
L MSH	32.03 ± 4.38 (32.6)	35.16 ± 4.18 (35.4)	-4.250	<0.001*
L MSW	26.21 ± 4.05 (26)	26.53 ± 4.25 (26)	-0.442	0.659
L MSD	35.4 ± 3.37 (35.6)	36.08 ± 3.35 (36.1)	-1.189	0.236
R FSH	20.31 ± 6.12 (21.4)	19.71 ± 6.07 (20.6)	0.577	0.565
R FSW	21.77 ± 7.5 (22.05)	20.88 ± 8.17 (20.6)	0.663	0.509
R FSD	13.76 ± 4.42 (13.6)	13.72 ± 4.8 (12.9)	-0.209†	0.834
L FSH	19.84 ± 6.18 (21.05)	19.59 ± 4.88 (19.7)	-0.860†	0.390
L FSW	21.13 ± 8.60 (21.4)	22.38 ± 7.54 (22)	-0.902	0.369
L FSD	13.43 ± 4.39 (12.6)	14.47 ± 4.58 (14)	-1.355	0.178
EurR-EurL	139.05 ± 6.32 (138.8)	144.26 ± 6.31 (144.8)	-4.811	<0.001*
LnR-LnL	30.46 ± 2.19 (30.8)	34.47 ± 2.81 (34.7)	-7.493†	<0.001*
MxR-MxL	58.72 ± 3.33 (59)	60.59 ± 7.6 (61)	-4.078†	<0.001*
AgR-AgL	84.25 ± 3.97 (84.6)	86.81 ± 4.27 (86.4)	-3.615	<0.001*
R MS VOL	13520.4 ± 4254.22 (13322.5)	14006.1 ± 4383.01 (13687)	-1.010†	0.313
L MS VOL	13784.07 ± 4424.32 (13681)	16496.85 ± 15181.67 (14703.5)	-1.663†	0.096
FS VOL	4713.82 ± 2439.45 (4580)	5149.53 ± 2995.65 (4627.5)	-0.627†	0.531
MxR-MxL/AgR-AgL	69.77 ± 4.02 (69.8)	69.87 ± 8.71 (70.98)	-1.486†	0.137

*$p<0.05$.

†, Mann–Whitney *U* test.

S.D., Standart Deviation.

differences between genders in the mean values of the variables RMSH, R MSD, L MSH, EurR-EurL, LnR-LnL, MxR-MxL, and AgR-AgL (p<0.05). The mean values of the variables were found to be higher in males compared to females (Table I).

Statistically significant differences were found between the groups in the measurements of R MSH, R MSD, L MSH, EurR-EurL, LnR-LnL, MxR-MxL, AgR-AgL, R MS VOL, and MxR-MxL/AgR-AgL ($p<0.05$) (Table II).

The findings revealing the relationship between the frontal sinus and craniofacial parameters are shown in Table III and Figure 4, while the relationship between the right and left maxillary sinuses and craniofacial parameters is shown in Table IV, Figure 5 and 6.

Discussion

The first null hypothesis of the present study was partially accepted because a positive correlation was found between the volumes of the maxillary and frontal sinuses and certain craniofacial parameters. The second hypothesis was also partially accepted. Specifically, in the male group, several parameters were found to be significantly greater. The third hypothesis was rejected, as no statistically significant differences were observed in the measured parameters across the age groups.

Traditional two-dimensional radiographic imaging techniques have limitations, related to magnification errors, image distortion, and the superimposition of adjacent anatomical structures. However, CBCT scans overcome these shortcomings by providing

Table II. Distribution and comparison of measurements according to age and gender

	Mean.±S.D.(M.) (mm mm^3)					
	Old Female	Young Female	Old male	Young male	Test statistics	*p*
R MSH	30.54 ± 4.5 (30.6)	33.19 ± 4.46 (33.2)	34.28 ± 3.33 (34.6)	34.8 ± 4.41 (35.6)	6.922	<0.001*
R MSW	25.51 ± 4.69 (25.4)	27.43 ± 3.86 (27.2)	26.03 ± 4.22 (26.4)	27.61 ± 4.1 (28.2)	5.236†	0.155
R MSD	34.87 ± 3.28 (35.4)	34.42 ± 6.4 (35.2)	35.4 ± 3.64 (35.4)	36.81 ± 3.19 (37.3)	8.098†	0.044*
L MSH	31.01 ± 4.21 (31.5)	33.06 ± 4.38 (32.9)	35.34 ± 3.62 (35.6)	34.98 ± 4.73 (35.2)	19.217†	<0.001*
L MSW	25.3 ± 4.26 (25)	27.13 ± 3.66 (27.1)	26.51 ± 4.12 (25.6)	26.55 ± 4.45 (26.8)	3.534†	0.316
L MSD	35.29 ± 3.51 (35.6)	35.51 ± 3.28 (36.4)	36.1 ± 3.09 (35.8)	36.07 ± 3.63 (36.3)	0.489	0.690
R FSH	18.84 ± 6.5 (18.6)	21.79 ± 5.4 (22.8)	19.79 ± 5.63 (20.6)	19.62 ± 6.56 (20.1)	5.251†	0.154
R FSW	20.6 ± 8.4 (21.2)	22.94 ± 6.38 (23.4)	21.27 ± 8.03 (20.9)	20.49 ± 8.41 (20)	0.705	0.550
R FSD	12.99 ± 4.52 (13.2)	14.56 ± 4.24 (14.4)	14.38 ± 5.62 (13.3)	13.05 ± 3.78 (12.7)	1.125	0.342
L FSH	18.09 ± 6.41 (19.6)	21.58 ± 5.5 (21.9)	19.34 ± 5.23 (19.9)	19.84 ± 4.56 (19)	2.380	0.073
L FSW	19.9 ± 8.44 (19.65)	22.36 ± 8.71 (22.2)	21.84 ± 8.21 (20.8)	22.92 ± 6.89 (22.6)	0.896	0.445
L FSD	12.4 ± 4.45 (12.1)	14.45 ± 4.15 (13.9)	14.72 ± 5.33 (13.8)	14.22 ± 3.74 (14)	1.894	0.134
EurR-EurL	139.84 ± 6.49 (139.2)	138.26 ± 6.13 (138.4)	145.42 ± 6.48 (146.4)	143.09 ± 6 (142.7)	8.940	<0.001*
LnR-LnL	30.31 ± 2.2 (30.7)	30.61 ± 2.2 (30.8)	34.08 ± 2.36 (34)	34.87 ± 3.19 (35.2)	29.396	<0.001*
MxR-MxL	58.3 ± 3.01 (58.8)	59.14 ± 3.61 (59)	60.55 ± 3.38 (60.6)	60.63 ± 10.28 (62)	20.234†	<0.001*
AgR-AgL	85.26 ± 3.55 (85.6)	83.24 ± 4.15(83.1)	86.21 ± 4.63 (86.25)	87.41 ± 3.84 (86.6)	14.327†	0.002*
R MS VOL	12208.5 ± 3388.08 (12269)	14832.29 ± 4660.44 (14185.5)	13345.24 ± 4452.49 (13485.5)	14666.97 ± 4275.41 (13935)	7.868†	0.049*
L MS VOL	13018.71 ± 3979.72 (12716.5)	14549.44 ± 4764.15 (14843.5)	17930.15 ± 21135.2 (14460.5)	15063.56 ± 4125.58 (15646.5)	5.288†	0.152
FS VOL	4243 ± 2277.36 (3878.5)	5184.65 ± 2537.53 (4874.5)	4869.88 ± 2754.26 (4014)	5429.18 ± 3236.15 (5036.5)	3.203†	0.361
MxR-MxL/AgR-AgL	68.41 ± 3.12 (68.23)	71.13 ± 4.39 (70.72)	70.35 ± 4.14 (69.66)	69.4 ± 11.68 (72.01)	11.113	0.011*

*p<0.05.

†Kruskal–Wallis test.

S.D., Standart Deviation.

Table III. Relationships between frontal sinus volume measurements and craniofacial measurements in female and male groups

		FemaleFS VOL (mm^3)	MaleFS VOL (mm^3)
EurR-EurL	r	0.111	-0.045
	p	0.369	0.717
LnR-LnL	r	0.206	0.254
	p	0.092	0.037*
MxR-MxL	r	0.304	0.001
	p	0.012*	0.991
AgR-AgL	r	0.113	0.036
	p	0.357	0.773
MxR-MxL/ AgR-AgL	r	0.272	-0.089
	p	0.025*	0.470

*$p<0.05$.

**Pearson Correlation.

three-dimensional information about craniofacial structures and, further, enabling cross-sectional imaging in the axial, sagittal, and coronal planes. By eliminating the issue of superimposition of adjacent structures, CBCT offers a more reliable and accurate visualisation as reported in previous studies.[33–35]

While earlier studies evaluated frontal sinus dimensions from various perspectives across different populations, none assessed the three-dimensional relationship with the cranial structures addressed in the present study.[4,30,31] Büyük et al. investigated the relationship between cranial parameters (mandibular width, maxillary width, nasal width, and cranial width) and frontal sinus structure using postero-anterior radiographic images, thereby identifying a significant correlation between the variables.[30]

A three-dimensional analysis of the frontal sinus in a Korean population revealed a significant relationship between frontal sinus dimensions and cranial width.[4] The study identified a similar relationship between frontal sinus volume and cranial width in a male group. In contrast, no significant correlation was observed between frontal sinus volume and cranial width in the female group. Additionally, the present measurements revealed a positive correlation between frontal sinus volume and both maxillary width and the maxillary ratio (MxR-MxL/AgR-AgL) in the female group.

Studies examining frontal sinus volume and linear dimensions by gender have found that frontal sinus sizes are greater in male compared to female subjects.[4,31] Consistent with the findings of the present study, frontal sinus volume measurements were found to be higher in the male group compared with the female group.

Frontal sinuses begin their formation around the age of 3 and typically finish developing by the age of 20 years.[36] McLaughlin et al. examined the development and growth of the frontal sinuses, as well as their response to mechanical stresses, such as mastication. It was suggested that the frontal sinuses may continue to expand until the age of 40 years, after which they tended to decrease in size with aging.[37] In a study by Park et al., individuals were divided into four groups: young female, young male, older female, and older male groups. The age range for the young group was set between 20 and 40 years, while the age range for the older group was between 40 and 80 years.[31] Based on the previous studies, individuals under the age of 20 were excluded from the present study. Individuals aged between 20 and 40 years were categorised as young, while those aged between 40 and 60 years were classified as older adults. Based on the radiographic analysis, significant resorption was observed in the maxillary and mandibular bases due to multiple tooth losses in both the maxillary and mandibular arches. Consequently, individuals aged over the age of 60 were excluded from the study.

Park et al. defined their study group as individuals aged between 20 and 80 years. It was observed that a decrease in frontal sinus volume accompanied advancing age and attributed this finding to progressive atrophic changes in the sinus structure over time.[31] In the present study, comparisons across different age groups for both genders revealed no

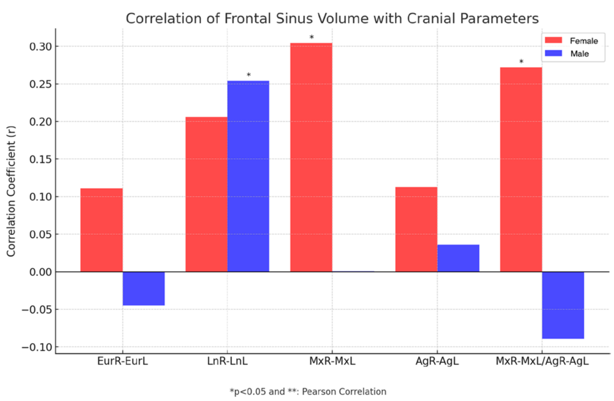

Figure 4. Correlation between the frontal sinus volume a cranial parameters.

Table IV. Relationships between maxillary sinus volume measurements and craniofacial measurements in female and male groups

		FemaleR MS VOL (mm^3)	FemaleL MS VOL (mm^3)	MaleR MS VOL (mm^3)	MaleL MS VOL (mm^3)
EurR-EurL	r	-0.022	0.004	-0.070	0.082
	p	0.859	0.973	0.571	0.506
LnR-LnL	r	-0.182	-0.195	-0.099	-0.206
	p	0.137	0.111	0.421	0.093
MxR-MxL	r	0.472	0.464	0.116	0.141
	p	<0.001*	<0.001*	0.348	0.250
AgR-AgL	r	-0.070**	-0.006**	-0.225	-0.162
	p	0.570	0.962	0.065	0.186
MxR-MxL/AgR-AgL	r	0.582	0.496	0.312	0.272
	p	<0.001*	<0.001*	0.012*	0.025*

*p<0.05.

**Pearson Correlation.

significant changes in frontal sinus volume. However, limiting the present study to the 20–60 age range may have restricted the ability to adequately assess potential atrophic changes in sinus structures that might occur in older age groups.

The present study noted that nasal width was found to be greater in the male group compared to the female group, which emphasised a significant difference in nasal width between the genders. However, Büyük et al., observed no statistically significant difference in nasal width between the genders.[30] This difference may have been due to the current measurement method and the use of a three-dimensional analysis, which effectively eliminated the issue of structural overlap, thereby providing a clearer image. When parameters were analysed by grouping them according to gender and age, no significant age-related differences were found.

Although there are literature studies evaluating changes in maxillary sinus measurements according to gender and age due to different treatment methods, there are no three-dimensional studies that relate the maxillary sinus to the cranial base, nasal, maxillary and mandibular widths and the maxillary ratio.[8,18,29,38] Additionally, the current literature search did not reveal any study which examined the relationship between maxillary and frontal sinus volumes and maxillary ratio (MxR-MxL/AgR-AgL).[4,8,10,20,31,32] The present study aimed to address this gap and make a significant contribution to the existing body of knowledge. A positive correlation was identified between maxillary sinus volume and the maxillary ratio measurement (MxR-MxL/AgR-AgL) within each gender group. However, no statistically significant relationship was found between frontal sinus volume and the maxillary ratio measurement.

A positive correlation was observed in the female group between maxillary sinus volumes and maxillary width measurements. Furthermore, a positive correlation was identified between maxillary sinus volumes and the maxillary ratio measurement (MxR-MxL/AgR-AgL) in both the male and female

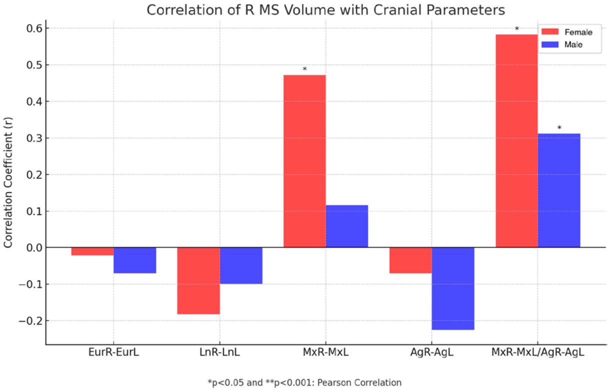

Figure 5. Correlation of right maxillary sinus volume with cranial parameters.

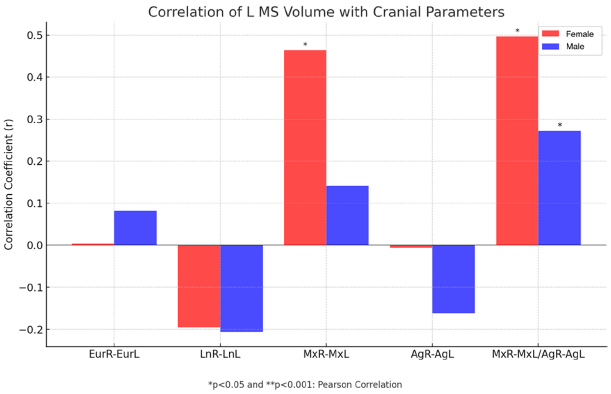

Figure 6. Correlation of left maxillary sinus volume with cranial parameters.

groups. Alqahtani et al. investigated the relationship between maxillary sinus volume and various skeletal patterns, reporting no statistically significant correlations.[29] In contrast, Yassaei et al. identified an association between the volumes of the maxillary and frontal sinuses and different skeletal patterns.[9] Based on these findings, sinus volumes may provide insights into both transverse and vertical growth.

In harmony with previous research, the current investigation found that maxillary sinus volumes did not exhibit a statistically significant change with age.[8]

While the literature includes studies indicating that maxillary sinus volume is greater in males compared to females, the present study found no significant relationship between maxillary sinus volume and gender.[27,39]

Conclusions

The present study was a comparative analysis of the width, height, and volume of the maxillary and frontal sinuses in relation to cranial, nasal, mandibular, and maxillary dimensions. The findings revealed that, while sinus dimensions were influenced by craniofacial structures, the interactions between the variables were intricate and multifaceted, underscoring the complexity of their relationships. Three-dimensional measurements obtained using CBCT offer a reliable framework for analysing the relationships. Clinically, these findings underscore the potential for personalised approaches in orthodontics, maxillofacial surgery, and otolaryngology, and emphasise the importance of incorporating sinus dimensions into treatment planning. Furthermore, the present study lays the foundation for future research in order to investigate the interactions across broader populations and age ranges, and paving the way for enhanced clinical outcomes in related disciplines.

Highlight Points

- The width, height, and volumes of the maxillary and frontal sinuses are directly related to cranial, nasal, mandibular, and maxillary dimensions, and these relationships have been analysed in a comparative manner.
- Three-dimensional measurements obtained via CBCT offer a reliable and detailed assessment of the relationships between craniofacial structures and the sinuses.
- The effect of gender on sinus and craniofacial structure measurements is more pronounced than that of age.
- It has been established that a relationship exists between sinus dimensions and craniofacial structures; however, this connection is complex and multifaceted.

Limitations

The present study had a narrow age range, which limited the ability to observe potential age-related changes. Additionally, the study was conducted on a single population, which restricted the generalisability of the findings to other ethnic groups. Environmental and genetic factors were also not considered. Future research should address these aspects, as incorporating them would contribute to more comprehensive and generalisable results.

Conflict of interest

The authors declare that there is no conflict of interest.

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