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Original article

Linear and three-dimensional volumetric analysis of maxillary sinus in Saudi Arabian population: A cone-beam computed tomography study

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ABSTRACT

Background: *The maxillary sinus presents as an important anatomical structure and understanding its radiographic anatomy is crucial for surgical procedures such as dental implant placement and extractions. Measuring the linear and volumetric dimensions of the maxillary sinus is essential for accurate treatment planning and a favorable outcome. Forensic odontology requires population-specific data for victim identification. There is therefore some need to develop a multicentric, multiethnic data registry.* ***Purpose:*** *The present study evaluates and compares the dimensions of maxillary sinuses and their relationship with individual height in the Saudi Arabian population, using cone-beam computed tomography (CBCT).* ***Methods:*** *The study subjected CBCT scans of 30 individuals to linear and volumetric analysis. The measurements were taken by two observers and mean dimensions were used for the analysis. Linear and volumetric dimensions were measured for the total sample and male (n=11) and female (n=19) categories.* ***Results:*** *Differences between linear and volumetric dimensions were statistically nonsignificant for males, females, and the overall sample. Correlations between left- and right-sinus dimensions were significant within females and the overall group. There was weak association between individual height and maxillary sinus dimensions.* ***Conclusion:*** *There is no significant variation between right and left maxillary sinus dimensions among the Saudi Arabian population. A negative correlation was observed between overall height and left maxillary sinus volume in both genders, and with right sinus volume in females only.*

Keywords: *cone-beam computed tomography; linear dimension; maxillary sinus; medicine; volumetric analysis*
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INTRODUCTION

The maxillary sinuses, located above the maxillary posterior teeth, are an important anatomical structure in the field of dentistry due to their proximity to the dental tissue. Maxillary sinuses play an important role in dental management and implant surgery in the maxillary arch. Pneumatization of the sinus influences implant placement in the first molar region.[1,2] Furthermore, pathological sinus conditions such as chronic sinusitis, antroliths, and cysts can mimic dental problems and need to be included in differential diagnosis. Thus, the inclusion of the maxillary sinus for evaluation in routine radiographic imaging is an integral part of dental diagnosis and treatment planning. Cone-beam computed tomography (CBCT) is the best option among common imaging modalities, as it allows for three-dimensional visualization of the structure, either entirely or partially, without the superimposition of other structures as seen in two-dimensional imaging.[3]

Various methods have been used in the literature to measure maxillary sinus volume, including cadavers, stereology, conventional two-dimensional radiography, computed tomography, and magnetic resonance imaging.[1] Presurgical assessment of CBCT images has become a vital tool for diagnosis and surgical planning and preparation, including maxillary sinus floor elevation.[2]

Variation in sinus volumes has been observed in different populations, which may affect implant planning

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and outcomes.[3] The nasal cavity's capacity to augment its form, mainly in cases of inferior breadth, is most likely due to the adjacent maxillary sinuses serving as accommodation zones. However, much remains to be explained about how nose and sinus morphology interact with one another and with overall craniofacial shape, particularly in varied populations with varying respiratory needs.[4] A study conducted in Malaysia concluded that maxillary sinus dimensions are characteristic of the Malaysian population and can be used to distinguish between Malaysian and other populations.[5] A study conducted on an Indonesian population concluded that maxillary sinus dimensions are greater in males than in females and can be used for disaster victim identification.[6] Sinus dimensions hold the key to success in maxillary implant placement. The extent of the procedure and the cost associated with it depend solely on the dimensions of the maxillary sinus. Current forensic odontology requires the development of data related to dimensions of the facial skeleton and its structures with specificity to a population group. The literature shows a correlation between the depth of the maxillary sinus and femur head diameter, establishing a positive relationship between individual height and sinus pneumatization.[7] Based on this background, the present study was designed to evaluate and compare the dimensions of maxillary sinuses through CBCT, and their relationship with the height of individuals in a Saudi Arabian population.

MATERIALS AND METHODS

The study was conducted after obtaining institutional ethical approval from Batterjee Medical College, Jeddah (Approval no. RES-2023-0004). The data used retrospectively scanned CBCT data pertaining to individuals enrolled for orthodontic treatment. We extracted 44 (equal males and females) scans from the college's CBCT machine (Durr Dental, Vista Vox-3D w/Ceph, Germany, with field-of-view size 108.5 mm), according to a sample-size calculation based on the prevalence of maxillary sinus pathology secondary to odontogenic infections in the Saudi Arabian population. Since the data suggest a prevalence in the range of 15 to 20%,[8] the sample size was calculated using the following formula for known population proportion (p),[9] at a 95-per-cent confidence interval with margin of error (d) at ± 15%:

$$n = \frac{z^2\, p(1-p)}{d^2}$$

$$n = \frac{(1.96)^2\, 0.2(1-0.2)}{0.15^2}$$

$$n = 27.31$$

where n = sample size; z = z score (1.96); p = population proportion (0.069); and d = margin of error (0.15). The formula provided a minimum sample size of 27 patients to be included in the study.

Clinical case records of the selected 44 individuals were reviewed as per the inclusion and exclusion criteria. Individuals with systemic diseases, smoking habits, oral breathing, extracted maxillary posterior teeth, or height less than 153 cm (5 feet) were excluded from the study. Out of 22 male case records, 8 individuals were smokers and 3 had a history of asthma. Meanwhile, the height of 3 female participants was less than 153 cm. These were all excluded from the study. Thus, the study group comprised 30 members with 11 males and 19 females. Age criteria included only persons aged 21–30 years. The age range of selected candidates was between 24 and 28 years and the range of height was between 158.4 and 176.7 cm. The height of the participants was extracted from the clinical data registry of the Orthodontic Division, Batterjee Medical College, Jeddah, Saudi Arabia. Finally, the two investigators recorded the linear dimensions of both the sinuses from selected scans. The mean dimensions were calculated and used for statistical analysis.

The depth (anteroposterior), height (craniocaudal), and width (mediolateral) of sinuses were recorded using the following method.[10] The anteroposterior dimension was measured on the sagittal image and was defined as the longest distance from the most anterior point to the most posterior point. The height was measured on the coronal image and was defined as the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof. The width was measured on the coronal image and was defined as the longest distance perpendicular from the medial wall of the maxillary sinus to the outermost point of the lateral wall (Figure 1). Volumes of both maxillary sinuses were calculated using the following formula[10]: (height) x (width) x (depth) x (0.52), wherein the maximum dimensions were used.

The obtained data were tabulated, aggregated, and arranged in an Excel sheet. Student's t-test and Pearson's r, Spearman's rho, and analysis of variance (ANOVA) tests were conducted using IBM SPSS Statistics software for Windows (version 27.0.1; IBM Inc. NY, USA). Pearson correlation was used to detect the relationship between right and left maxillary sinus volumes, and Spearman correlation was used to measure monotonicity in sinus volume. Student's t-test was used to compare the linear dimensions of right and left maxillary sinuses. ANOVA was applied to determine significance for volumetric dimensions for the male, female and total groups. A p-value of <0.05 was regarded as indicating statistical significance.

RESULTS

Differences between participants were statistically insignificant. The overall height of males was higher than that of females but the difference was statistically insignificant (Table 1). Comparison of linear and volumetric measurements of both the sinuses among males and females and the overall group showed no statistical significance (Tables 2 and 3). Correlations of linear volumes of left and right sinuses were statistically significant among females

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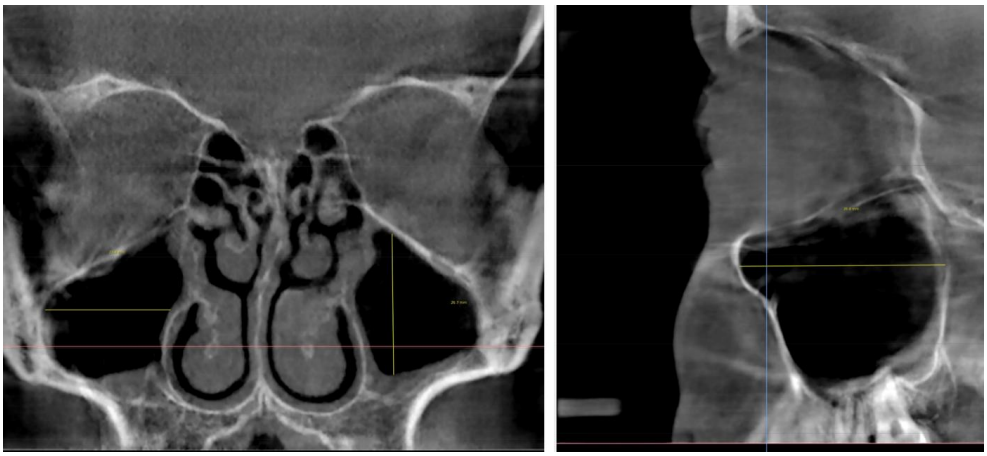

Figure 1. Sagittal and coronal section obtained through CBCT for linear measurements of maxillary sinus.

Table 1. Demographics of the study sample

Variables	Number	Age in years	Height in cm
Males	11	26.64	168.32
Females	19	26.16	164.54
p-value		0.28	0.69
Inference		Insignificant	Insignificant

Table 2. Comparison of linear dimensions of right and left maxillary sinuses

Variables		Males	Females	Total
Height	Right sinus	27.28±2.81	25.12±4.38	25.91±3.97
	Left sinus	28.05±2.91	25.11±3.78	26.19±3.72
	p-value*	0.26	0.49	0.39
Width	Right sinus	21.34±2.3	22.25±2.49	21.92±2.42
	Left sinus	21.13±2.44	22.24±2.13	21.83±2.27
	p-value*	0.41	0.49	0.44
Depth	Right sinus	29.04±3.1	29.38±2.68	29.26±2.8
	Left sinus	30.09±3.57	29.86±2.84	29.94±3.07
	p-value*	0.23	0.29	0.18

*All p-values are insignificant

Table 3. Comparison of volumetric dimensions of right and left maxillary sinuses

Variables	Number	Right sinus volume	Left sinus volume	t-value	p-value	Inference
Males	11	8,882.94	9,407.59	−0.5344	0.29	
Females	19	8,689.85	8,788.13	−0.1242	0.45	Insignificant
Total	30	8,760.65	9,015.26	−0.4179	0.33	

Table 4. Correlation in volumetric dimensions of right and left sinuses

Variables	Number	Right-sinus volume	Left-sinus volume	Pearson's r	p-value	Inference
Males	11	8,882.94	9,407.59	0.5693	0.067	Insignificant
Females	19	8,689.85	8,788.13	0.798	0.00004	Significant
Total	30	8,760.65	9,015.26	0.7155	0.00001	Significant

Table 5. Correlation of individual height with volume of maxillary sinus

Variables	Males	Females
Right sinus	8.88	8.68
Individual height	168.32	164.54
Spearman's rho	0.16	−0.208
p-value	0.62	0.3
Left sinus	9.41	8.78
Individual height	168.32	164.54
Spearman's rho	−0.03	−0.09
p-value	0.92	0.6

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and the entire study population, whereas males exhibited nonsignificant correlation (Table 4). A negative correlation of overall height with the volume of left maxillary sinuses was observed among females and males, and with the volume of right maxillary sinuses among females only. Among males, the right sinus showed a positive correlation with height. In both cases, the correlation was weak as the values were near zero (Table 5). The maxillary sinuses evaluated in the study group were also examined for the presence of anatomical variations, sinus pathology, and septa. However, none of the CBCT images showed positive findings.

DISCUSSION

The maxillary sinuses are located in close proximity to the maxillary premolars and molars, and their pathologies should be included in diagnosis of dental problems in this region. The anteroposterior extent of sinuses encompasses the roots of maxillary cuspids anteriorly and up to the apices of the third molars/the maxillary tuberosity posteriorly. Therefore, it is important to evaluate maxillary sinuses during dental procedures such as extractions and dental implant placement. It is imperative to understand the importance of maxillary sinus dimensions for accurate planning of implant placement, avoiding inadvertent antral perforation and implant failure.[11,12]

Retrospective data collection allowed for fast analysis and prevented unwanted radiation exposure. Both the sinuses were examined and linear measurements were recorded for statistical analysis. The volume of the sinus was measured using the appropriate formula for obtaining the volume of a pyramid. We selected the third-decade group as the growth and development of the sinus are completed by the second decade, and with age the sinus dimensions decreased.[13,14]

The present study did not show statistically significant linear dimensions of right and left sinuses among the male, female, or overall groups (n=30). Previous studies conducted on the Turkish population did not find significant variation in the size of the sinus in either linear or volumetric analysis.[15] A similar study in the Sri Lankan population found no significant differences in linear dimensions. Nonetheless, the study concluded that using CBCT provided valuable knowledge of the anatomical dimensions of the maxillary sinus, which helped clinicians in treatment planning.[16] Kamburoğlu et al.[17] found no significant difference in linear dimensions, although the primary objective of their study was to evaluate changes in dimensions of periapical lesions and sinus mucosa thickness in maxillary sinuses before and after endodontic treatment.

Numerous CBCT-based studies have evaluated maxillary sinuses for parameters such as the presence of septa, periapical pathologies, dental implants, and antral pneumatization. One such study was conducted in the population of Al-Qassim, Saudi Arabia, and recommended the use of CBCT for understanding the relationship between posterior maxillary teeth and the maxillary sinus before diagnosis and treatment planning. This can help to exclude periapical pathologies and aid the selection of appropriate bone graft and sinus lift procedures.[18] Another study evaluated sinus septa in a Saudi subpopulation, reporting septa in 40% of the population.[19] The present study did not find any anatomical variations, sinus pathology or septa in the maxillary sinuses. Nonetheless, evaluation of septa in the maxillary sinus is critical to avoid complications during the sinus augmentation procedure.[20]

The present study features a small, population-specific sample size; nonetheless, it provides insight into the importance of assessing sinus anatomy and dimensions before planning certain dental procedures in the posterior maxilla. Furthermore, the significant correlation between volumes of maxillary sinuses among the female group and the total sample suggests that these parameters can be applied to gender determination in forensic sciences. Christoloukas et al.[21] reviewed the relationship between maxillary sinus measurements and anatomic variability by gender and suggested that these parameters can render a complementary method for human identification.

The present study set out to determine whether there is any relationship between overall individual height and the volume of the maxillary sinus. Although the scientific literature lacks studies in this area, previous anthropometric studies have suggested the relevance of ethnic data on craniometric indices such as facial and orbital index. As overall height is related to facial height and growth pattern, it is imperative to also establish its relation to maxillary sinus dimensions. As the maxillary sinus is the largest hollow in the facial skeleton, its ethnic and population-specific dimensions are of utmost importance in craniofacial syndromology.[22] The correlation between human height and sinus volume was found to be negatively insignificant. One previous study established a significant relationship between craniofacial height and maxillary sinus dimensions.[23] Based on this background, the present study set out to establish whether there is any relationship between individual height and sinus dimensions. However, the correlation was weak and did not confirm an association. The data are nonetheless relevant, showing that sinus dimensions can help to approximate the height of an individual, which is potentially useful in victim identification, especially in situations where only the skull is available as forensic evidence.

Previous studies comparing maxillary sinus dimensions among oral and nasal breathers suggest that the volume of the maxillary sinus is significantly greater in nasal breathers than in oral breathers.[24,25] The present study included only nasal breathers, which means that the data set presented can be used for baseline estimation of volumetric differences between nasal and oral breathers.

The current study presents several limitations that impact its generalizability. It exclusively focuses on a specific age group within the dentate population, restricting

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the applicability of its findings to other age demographics. Additionally, the study is limited to nasal breathers without any consideration of lifestyle habits. Habits such as smoking (cigarettes, pipes, or hookah) are known to significantly influence maxillary sinus morphology. Consequently, future research should investigate the role of these lifestyle factors to provide a more comprehensive understanding of their effects on sinus anatomy.

The present study included 30 participants and evaluated the linear and volumetric dimensions of 60 maxillary sinuses. There was no significant variation in either dimension, but a positive correlation was elicited in the female subgroup between left and right sinuses. Further research should be conducted with a larger sample size and inclusion of parameters such as the effect of dental pathoses on sinuses, pre- and post-implant volumetric changes, and post-extraction sinus pneumatization. The authors wish to suggest a multicentric, multi-population prospective study to evaluate and compare maxillary sinus dimensions in various populations. This would promote the collection of ethnic data for forensic purposes, as well as region-specific implant development.

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