

CT-Based Morphometric Analysis Of Maxillary Sinus For Gender Identification: A Perspective Study Of North Karnataka Region

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KEY WORDS:	Abstract
Maxillary dimensions, maxillary volume, maxillary anthropometry	<p>AIM: To evaluate the efficacy of maxillary sinus dimensions and volume measured by computed tomography (CT) of paranasal sinuses in gender determination of North Karnataka region.</p> <p>MATERIALS AND METHODS: A transverse study design was used from the records of patients who attended the Department of Radiology at KLE’s Dr. Prabhakar Kore Hospital & Medical Research Centre, Belagavi. The study included a total of 150 patients who were referred for a computed tomography (CT) scan of the paranasal sinuses. Measurements for medial-lateral (ML), superoinferior (SI), anteroposterior (AP) dimensions, and the volumes of both right and left maxillary sinuses were recorded using the ITK SNAP DICOM viewer.</p> <p>RESULTS The collection of participants demonstrated an evident male predominance over female in the region. The average ages of the male and female participants were 45.39 years and 33.43 years respectively. The analysis of maxillary sinus volume exhibited a significant difference of males having higher volume measurement than females on the right side. The difference of means between the genders on the left side were not significant, however, there was substantial recognition that males had greater sinus volume than females when examining the means of volumes on both sides. Females and males did not differ significantly by sex in the means of the measurements in linear dimensions; anteroposterior, mediolateral, superoinferior on both sides.</p> <p>CONCLUSION The current study ascertained the existence of sex-based differences in maxillary sinus volumes, specifically in total sinus volume, where males had larger volumes. Despite a lack of measurable linear differences by sex, volume proved to be a better differentiator for sex than linear measurements. As the accuracy and quality of imaging can greatly assist in clinical and forensic medicine evaluations, it may be beneficial to use CT scans for gender discrimination because of the detail provided in sinus shape assessment.</p>

Abbreviations

CT -Computed Tomography
MS- Maxillary sinus
ML- Mediolateral
AP-Anteroposterior
SI-Superoinferior

INTRODUCTION

The recognition of human features from skeletal remains is essential in forensic science, notably in the situations of mass catastrophes, crimes, accidents, and autopsies. These cases often involve the decomposition or destruction of soft tissues, and in such scenarios, the skeleton serves as the foundation for identifying a person. As much as the identification is important medically and legally, it is equally of sociocultural and humanitarian importance in relation to giving meaning to people and assisting in legal matters [1,3].

The scientific analysis of the proportions and measurements of the human body, known as anthropometry, was used in distinguishing people by examining their soft tissues and bones for a very long time. It is a supportive form of identification that can only be cross-checked if other forms of primary identification such as fingerprints, DNA, or dental records that are most often obliterated or inconclusive. Among anthropometric techniques, the first and most important is the determining sex of an individual because of its great impact on narrowing the list of possible names to be considered [8]. The pelvis and skull are the skeletal parts which provide sexual dimorphism in humans and therefore are the most reliable bones to determine biological sex. But when these bones are fragmented or partly destroyed, other more robust elements such as the maxillary sinus are relied upon.

The maxillary sinus, which is housed in the maxillary bone, has always been known for its strength and insensitivity to outwards damage such as extreme mechanical impact or fire. The anatomical architecture of the sinus is chronic in nature and lies preserved even in skeletal remains that are extremely badly compromised, thus making the maxillary sinus a good candidate for forensic analysis. Moreover, research has found that the width and the height of the maxillary sinus differ significantly in males and females which makes it a useful indicator for estimating sex identity [2,8].

The development of Computed Tomography (CT) has enabled imaging in forensics to reach a new level by offering high quality, complex 3-D images of body parts. Unlike traditional x-ray photos, CT images permit exact assessment of the anteroposterior (AP), mediolateral (ML), and superoinferior (SI) intersections, in addition to volumetric measurement of the maxillary sinus [9]. Such parameters may be relied upon for sex determination through craniofacial bones, particularly when used in conjunction with certain devices. In spite of the various foreign studies affirming the importance of the maxillary sinus in discrimination of sexes, there is still a lack of particular attention from scientists in the Indian subcontinent, especially in certain local populations. Bearing in mind the possible impact of ethnic, genetic and environmental craniofacial factors, region-specific data is essential for forensic accuracy [11].

Therefore, the present study was undertaken to assess the dimensions and volume of the maxillary sinus using CT imaging in individuals from the North Karnataka region. Our aim was to evaluate its effectiveness as a reliable marker for sex determination, thereby contributing valuable data to forensic anthropology in the Indian context.

METHOD

The aim of this study was to assess the potential of using maxillary sinus (MS) measurements of length, height, width, and volume obtained through Computed Tomography (CT) of the paranasal sinuses (PNS) for sex estimation in North Karnataka region.

Inclusion Criteria

1. Patients aged 18 years or older.
2. Presence of intact permanent dentition.
3. Undergoing CT scan of the PNS for clinical indications unrelated to sinus pathology.

Exclusion Criteria

1. Patients below 18 years of age.
2. CT scans showing congenital craniofacial anomalies or abnormal midfacial development.
3. CT scans with evidence of pathological sinus conditions such as cysts, tumors, polyps, or mucosal thickening.
4. History of facial trauma or previous sinus surgery.

Imaging and Data Collection

Standard procedures were followed when performing CT scans of the paranasal sinuses. The images were reconstructed to both axial and coronal planes for detailed anatomical evaluation. RadiAnt DICOM Viewer, and ITK-SNAP software were used for the analysis.

The following measurements for the right and left maxillary sinuses were taken:

- Anteroposterior (AP) Dimension: Longest distance between the anterior most point and the posterior most point of the sinus cavity was measured on axially reconstructed images.
- Superoinferior (SI) Dimension (Height): Distance between the highest point of the sinus roof, and lowest point of the sinus floor on coronal reconstructed images was measured as the vertical distance.
- Mediolateral (ML) Dimension (Width): Measured on axial sections as the maximum perpendicular distance from the medial wall of the sinus to the outermost point of the lateral wall.
- Maxillary Sinus Volume: Volumetric assessment was performed by using the Paint on Slices tool in ITK-SNAP. The boundaries of the sinuses were manually selected on every axial and coronal slice while the software calculated the total volume in cm^3 .

For cases with bilateral asymmetry as a default, each side was analyzed separately.

Ethics Approval

The approval for this study was granted by the institutional ethics committee (iec). The research was carried out in accordance with the ethical guidelines outlined in the declaration of helsinki and its subsequent updates.

All participants were given detailed information about the purpose and goals of the study. Consent was obtained from all participants. Patient information was kept private and anonymous throughout the entire study process.

Statistical Analysis

In the initial analysis, descriptive analysis was performed on all continuous variables. The calculations of sinus measurements, including means, standard deviations, ranges, and medians, were performed for both male and female patients.

Comparative Analysis: Student's Unpaired t-Test

In establishing whether the differences between males and females concerning maxillary sinus dimensions and volumes had statistical significance, the student's unpaired t-test was utilized. This particular test is used to determine whether two independent samples (males and females in this instance) have statistically significant different averages and if these differences are not likely due to random chance.

- Null Hypothesis (H_0): No significant difference exists in male and female sinus dimensions and volumes.
- Alternative Hypothesis (H_1): A significant difference exists between the two groups.

Results less than .05 ($p < .05$) in this t-test would be deemed statically significant, thus considerable evidence to deny the null hypothesis would be accepted. For example, a notable p value concerning the right maxillary sinus volume means there is an anatomical difference based on gender.

Analysis of Variance (ANOVA)

In situations where the comparisons needed to be done across more than two groups (e.g., other age groups or some other stratified variable), One-Way ANOVA was used. This procedure was used to test the hypothesis that the means of several populations were equal irrespective of them being treated as distinct.

Correlation Analysis

In the evaluation of correlation between different sinus parameters (e.g., volume versus dimensions, or left versus right sinus measurements), Pearson correlation coefficient (r) was calculated. This r value helps derive the strength and the nature of linear relationships among four continuous variables:

- $r = +1$ indicates a perfect positive correlation.
- $r = -1$ indicates a perfect negative correlation.
- $r = 0$ indicates no correlation.

Statistical significance at $p < 0.05$ suggests correlation wherein changes in one variable slowly but surely would also bring about changes in another.

Regression Analysis

Linear regression analysis was performed to analyze if maxillary sinus volume, or any individual dimension, predicted gender. This model provided insight on how sinus measurements could serve as a predictive model in sex determination.

- The coefficient of determination (R^2) defined the proportion of variance in gender that would be accounted for by the model.
- A higher R^2 value would mean greater predictive capability.

Significance Threshold

All tests of statistical significance were considered significant at a p-value of < 0.05 (5%). This level of significance defines 95% confidence level indicating that there is 5% of probability that any of the differences or correlations that are being observed are due to random variation.

RESULTS

A total of 150 participants were recruited for this study, all of whom underwent CT-PNS for one or more clinical indications. The gender distribution was biased toward male. Out of the 150 participants, 90 were male (60%) and 60 were female (40%), as shown in Figure 1.

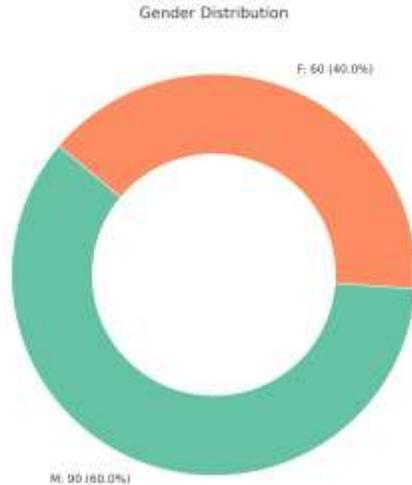


Figure 1: Gender-wise breakdown of study participants, illustrating the proportion of male and female patients included in the research study.

Participants aged 31 to 40 years were the highest in number (69 patients, 46.0%), with the next group (41 to 50 years) comprising 37 patients (24.7%). The rest of the participants (51 to 60 years) group contained 32 patients (21.3%) and 21 to 30 years group had the least number of participants (12 patients, 8.0%). No participants were reported in the 61 to 70 years age group (Figure 2).

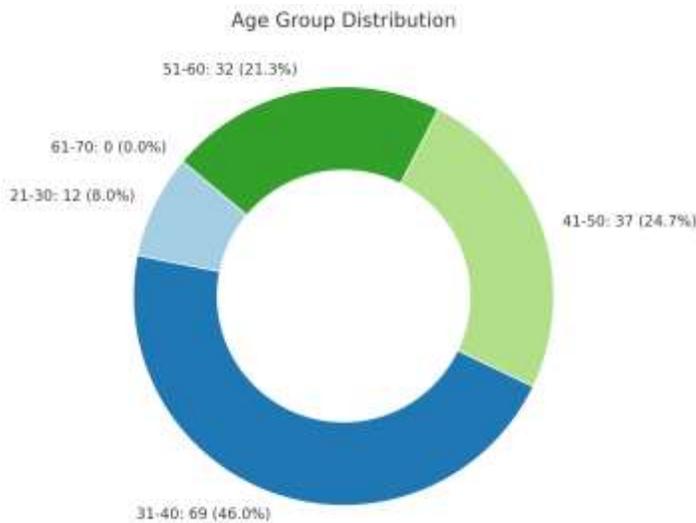


Figure 2: Distribution of patients across different age groups included in the present study.

Analysis of volumetric assessment of the maxillary sinuses showed notable differences between genders. The average right-sided volume among males was 15.04 cm³ compared to 7.52 cm³ in females, a difference which was statistically significant ($p < 0.05$). Males also had greater left-sided volume (13.50 cm³) than females (7.96 cm³), although this particular difference did not reach statistical significance. Males had a greater average sinus volume in comparison to females (14.27 cm³ vs. 7.74 cm³), suggesting sexual dimorphism in sinus volume (Figure 3).

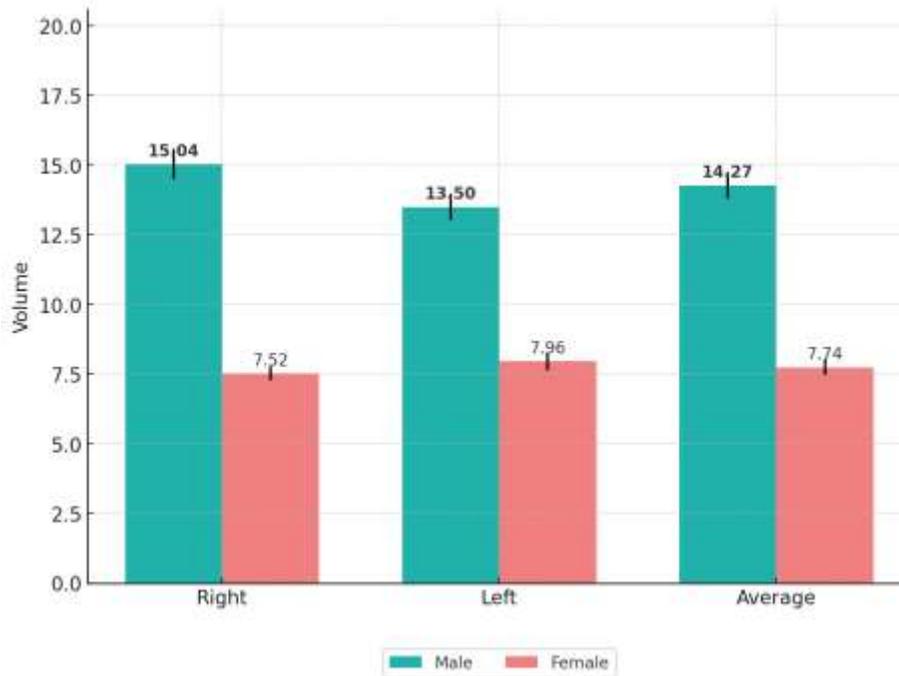


Figure 3: Comparative analysis of sinus volume measurements between male and female subjects, illustrating right and left side volumes as well as overall average volumes.

An extensive evaluation of the left sinus showed that, in males, the anteroposterior (AP), mediolateral (ML), and superoinferior (SI) measurements were noticeably higher when compared to females (Table 1). In regard to males, the left AP measurement was 3.74 cm while in females, it was 3.19 cm; for ML, it was 2.26 cm versus 1.75 cm and for SI, it was 3.53 cm compared to 2.69 cm in females. For all of these comparisons, there was a high level of significance ($p < 0.001$).

Dimensions	Male		Female		Effect size	t-value	p-value
	Mean	Standard Deviation	Mean	Standard Deviation			
AP (cm)	3.74	0.04	3.19	0.03	16.2965	101.0187	<0.001
ML (cm)	2.26	0.04	1.75	0.03	15.7771	99.6443	<0.001
SI (cm)	3.53	0.04	2.69	0.05	18.6564	108.6063	<0.001

Table 1: Comparative analysis of left-side maxillary sinus dimensions between male and female subjects.

The same pattern was noticed for the right side as well. Males had higher measurements than females for AP, ML, and SI dimensions (Table 2). For the right AP measurement, males were at 3.69 cm while females were at 3.22 cm; for ML, it was 2.16 cm for males and 1.88 cm for females, and for SI, males were at 3.39 cm while females were at 2.62 cm. All of these differences had significance ($p < 0.001$).

Dimensions	Male		Female		Effect size	t-value	p-value
	Mean	Standard Deviation	Mean	Standard Deviation			
AP (cm)	3.69	0.04	3.22	0.04	11.666	69.6229	<0.001
ML (cm)	2.16	0.03	1.88	0.04	8.6681	50.1431	<0.001
SI (cm)	3.39	0.04	2.62	0.05	17.4193	98.3481	<0.001

Table 2: Comparative analysis of right-side maxillary sinus dimensions between male and female subjects.

The results have proven over and over again that males have larger maxillary sinus measurements than females, which is true for both sides of the sinuses.

DISCUSSION

This study was done to assess the feasibility of using maxillary sinus dimensions and volume measured by CT imaging as reliable correlates of gender within a South Indian population. The sample comprised CT scans of 150 patients, 60% of whom were males and 40% females. The largest age group was 31 – 40 years which indicates that majority of participants were adults and had fully formed maxillary sinuses which limits developmental or degenerative anatomical changes.

In volumetric analysis, the right maxillary sinus demonstrated a statistically significant difference in volume with males having a markedly greater volume than females. The left sinus volume was greater among males too, but this difference was not statistically significant. When the volumes of both sides were taken together, males had significantly more average sinus volume than females. These findings corroborated with other studies like Jha et al., where the author also noted that the sinus volumes for males is larger compared to females on both sides. On the other hand, we differ in the findings of Urooge et al. who investigated the gender differences in sinus volumes and reported no significant differences[7].

The measurements for anteroposterior (AP), mediolateral (ML), and superoinferior (SI) linear dimensions were considerably larger in males relative to females on both sides. This is in contrast with previous reports like that of Urooge A. et al. which stated that lesser linear measurements were taken at marked sexual dimorphism. Our results are, however, closer to those by Samhitha G. et al., which reported greater values in males than females for measures including maxillary width[4,7].

The difference in outcomes in various studies can be attributed to a combination of factors like sample size, ethnicity, geography, and even the accuracy of the software used for morphometric analysis[5]. The manual segmentation method utilized in this study with ITK-SNAP software was capable of generating detailed 3D volumetric reconstructions, which is likely to have contributed to increased sensitivity for detecting gender differences.

Furthermore, the statistical strength of our results particularly the high t-values and low p-values in volumetric and dimensional comparisons emphasizes the role of the maxillary sinus as a robust marker for sex estimation. Importantly, our study adds region-specific data to the limited pool of literature on South Indian populations, underscoring the value of localized anthropometric research for forensic and clinical applications[10].

CONCLUSION

Our analysis suggests that while some skeletal variations between males and females are not easily recognizable, there is a pronounced and constant difference in maxillary sinus volume, which is greater in males. The assessment of paranasal sinuses on CT scans provides reliable and reproducible evaluation of the sinus region, and so it is a useful estimate of the gender of an individual. Such measurements are particularly useful in forensic cases where the individual has to be identified by means other than his/her face. Moreover, they aid greatly in the surgical procedure by giving important anatomical details in the preoperative assessment. Thus, the study of maxillary sinuses by means of CT scans could assist in medicolegal examinations and in clinical practice for sex determination of a person, whether alive or deceased.

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