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# Divulge the Enigma: Morphometric Analysis of Maxillary SinusesTo Determine Sexual Dimorphism: A Cone Beam Computed Tomography Study

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**ABSTRACT**: Skull radiography is a technique of skeletal analysis using radiographic images. Personal identification can be achieved through skull radiographic methods especially in situations of mass disasters. Sexual dimorphism refers to the systemic difference in the form, either in shape or size, between individuals of different sexes in the same species. Various studies have revealed that the shape and size of the maxillary sinus differ between males and females and among various populations. The purpose of this study is to evaluate the accuracy of different morphometric parameters of maxillary dimension of the skull in determining sexual dimorphism using Cone Beam Computed Tomography(CBCT) images.

**Methods:**

A retrospective study involving a total of 100 CBCT images of known age and gender, 50 females and 50 males between the age groups of 18- 80 years were retrieved from the archives of the Department of Oral Medicine and Radiology. Each of these images was evaluated using Planmeca Romexis Viewer version 5.1.0.4 to determine the morphological dimensions of the Maxillary sinus. The width, length and volume of each of the maxillary sinuses were measured on the axial section and the height of each sinus was measured in the coronal section. The dimensions for all were measured in millimetres and the volume in centimetre cube. The measurements were tabulated in Excel Data Spread sheet and were subjected for statistical analysis.

**Results:**

In this study the mean values for maxillary sinus height and volume were greater in males than females. The maxillary sinus length of males showed greater value in right side when compared to left, but was not statistically significant. The width of maxillary sinus did not show any significant change in its measurements between male and female groups. In gender identification, there was an overall accuracy of 62% and 59% when considering right and left maxillary sinus height respectively. For the length of right and left maxillary sinus, there was an overall accuracy of 54% and 52% in gender identification respectively. The right and left maxillary sinus volume showed an overall accuracy of 54% and 52% respectively

**Conclusion:**

The results of the present study suggest that the maxillary sinus dimensions using CBCT is a promising tool in determining gender in situations like mass disasters. The comparison of available ante mortem radiographs is also considered to be important in such situations. These can be implemented in the field of forensic science for identification process.

**KEYWORDS:**Anthropology, Cone Beam Computed Tomography, Forensic, Maxillary sinus, Mandible, Sexual Dimorphism.

## I. INTRODUCTION

Forensic odontology, a branch of forensic science, is a well-developed discipline that plays an important role in the identification of the mutilated and decomposed corpses[1]. It is defined by Keiser-Neilson as “that branch of forensic dentistry that in the interest of justice deals with the proper handling and examination of dental evidence and the proper evaluation and presentation of dental findings[2].

As the Holy Scripture says, ‘Hate evil, love good and maintain justice in courts’, our judicial system seeks the forensic odontologists to investigate and interpret the dental evidences at the crime scene. Radiographic images have been used in the conventional dental identification by means of comparison of maxillofacial skeletal landmarks in ante mortem and post-mortem records[3].

The skull, femora and pelvis are the most reliable structures in the body for radiographic

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determination of the gender, among which skull is most commonly used in comparison radiology[4]. It is therefore important to identify those bones in skull that remain intact such as themaxilla and mandible. Hence dimensions of maxillary sinus can be used in forensic odontology for gender determination[5].

Maxillary sinuses are two pyramid shaped structures located in the maxillary bone and can be of various size and shapes. It is the largest paranasal sinus and is the first to develop. It varies greatly in size, shape and position in different individuals[6]. Therefore, it can be used for gender determination. Radiographic assessment of maxillary sinus, its length, width, height and volume is useful for supporting gender determination in forensic medicine. Cone Beam Computed Tomography (CBCT) is a new advanced imaging modality and has variety of applications in dentistry. This uses a cone shaped x-ray beam and has an additional advantage of lower radiation exposure and cost when compared to Computed Tomography (CT). This imaging modality shows higher precision in the diagnosis and examination of anatomical structures of the cranium[7]. Considering the present scenario, there is a limited literature using CBCT for assessing maxillary, which is used in this study as a tool in gender determination and personal identification.

## II. MATERIALS AND METHODS

The present study was conducted in the Department of Oral Medicine and Radiology after required approval from Institutional ethical committee. The study sample comprised of 100 images [50 females and 50 males], whose gender was known and was above 17 years of age.

INCLUSION CRITERIA
1. Age range from 18-80 years
2. Images with no pathologies.

EXCLUSION CRITERIA
1. Images with facial deformities, head and neck trauma or pathologies.
2. Images lacking desired quality.

CBCT SCANS

Selected CBCT images were obtained using Planmeca Promax 3D Plus CBCT machine. These patients underwent CBCT examination of head and neck for medical reasons other than pathologies involving maxillary sinuses. The scans were made with a matrix of 20.00 x 10.02cm FOV, 90 KV, 10mA and exposure time of 13 to 14 seconds. The images were viewed using Planmeca Romexis Viewer.

**MEASUREMENTS**

**The maximum height** of the maxillary sinus is measured in coronal view as the longest distance from the lowest point of the inferior wall of maxillary sinus to the highest point of the superior wall of maxillary sinus [Figure 1].

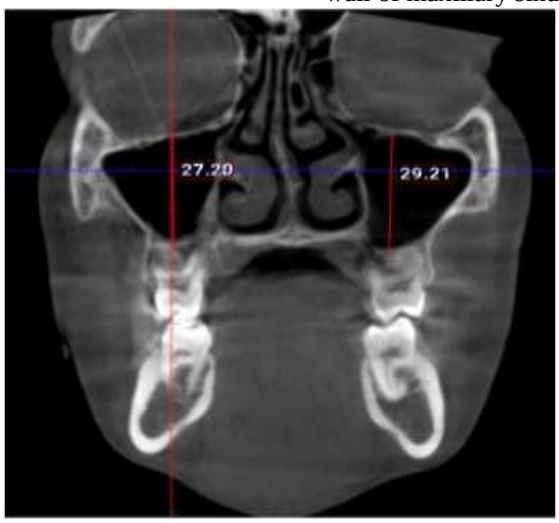


**FIGURE 1**

**The maximum width** of the maxillary sinus was measured in axial view as the longest distance perpendicular from the most prominent point of the medial wall of maxillary sinus to the most prominent point of the lateral wall of maxillary sinus [Figure 2].

**The maximum length** of the maxillary sinus was measured in axial view as the longest distance from the most anterior point of the anterior wall of

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maxillary sinus to the most posterior point of the posterior wall of maxillary sinus [Figure 2].

**The volume of maxillary sinus** was measured in axial view by marking the external outline of the sinus in 2mm thickness axial section. This was done by using the free region grow tool in the Romexis software thereby assessing the regional volume of the right and left maxillary sinus [Figure 3].

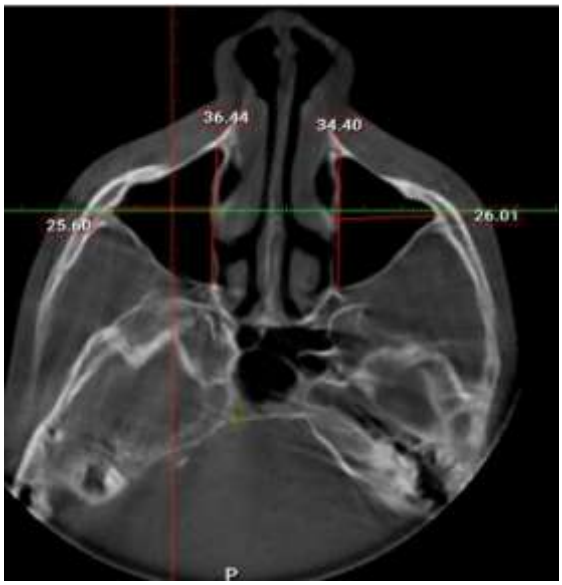


**FIGURE 2**

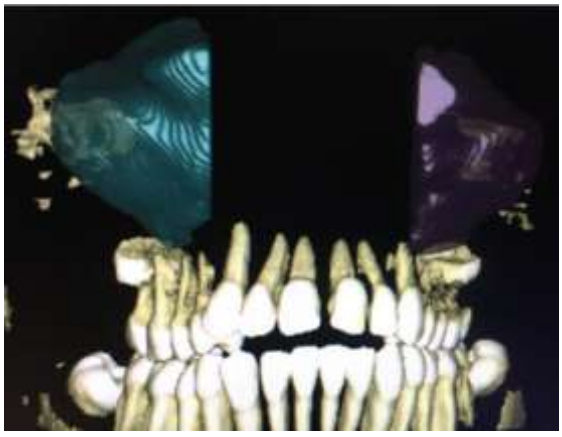

**FIGURE 3**

## III. STATISTICAL ANALYSIS

The measurements were tabulated separately for both the genders and were evaluated statistically.

Independent sample T- test was used to compare the morphometric differences between the genders. Classify test was used to predict the accuracy of gender determination. In the analysis significance level is taken to be 0.05. The statistical analysis was performed by using the statistical package SPSS software (version 22.0.0.0).

## IV. RESULTS

This study was conducted to investigate whether the morphometric dimensions of maxillary sinus could be used for determination of gender using Cone Beam Computed Tomography images in Central Kerala Population.

Independent T test was used to compare the maximum height, width and length of the maxillary sinus on right and left side between males and females.

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**Table 4: Independent Sample test to compare height, width and length of maxillary sinus**

| | | Gender (n) | Mean ± SD | T test | p value |
|---|---|---|---|---|---|
| Maxillary sinus height – Coronal View | Right | Male (50) | 34.003 ± 5.420 | 3.311 | 0.001 |
| | | Female (50) | 30.635 ± 4.726 | | |
| | Left | Male (50) | 32.598 ±5.264 | 2.871 | 0.005 |
| | | Female (50) | 29.780 ± 4.522 | | |
| Maxillary sinus width – Axial View | Right | Male (50) | 26.828 ± 4.965 | 0.652 | 0.516 |
| | | Female (50) | 26.224 ± 4.282 | | |
| | Left | Male (50) | 26.937 ± 5.210 | 0.437 | 0.663 |
| | | Female (50) | 26.533 ± 3.938 | | |
| Maxillary sinus length – Axial View | Right | Male (50) | 38.993 ± 5.680 | 1.312 | 0.193 |
| | | Female (50) | 37.809 ± 2.913 | | |
| | Left | Male (50) | 38.227 ± 4.850 | 0.25 | 0.803 |
| | | Female (50) | 38.034 ± 2.484 | | |
| Maxillary sinus Volume – Axial View | Right | Male (50) | 13.526 ± 5.419 | 1.666 | 0.049 |
| | | Female (50) | 12.207 ± 4.222 | | |
| | Left | Male (50) | 13.496 ± 4.921 | 1.549 | 0.062 |

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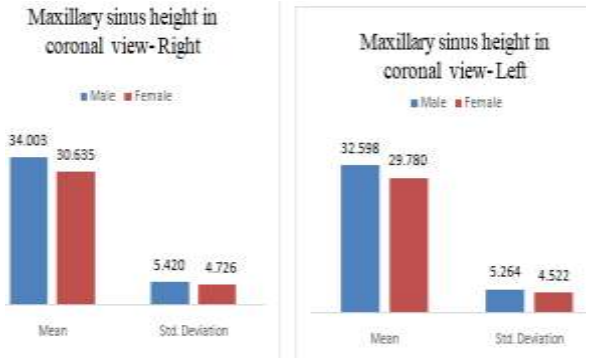
| | | | | | |
|---|---|---|---|---|---|
| | | Female (50) | 12.127 ± 3.858 | | |

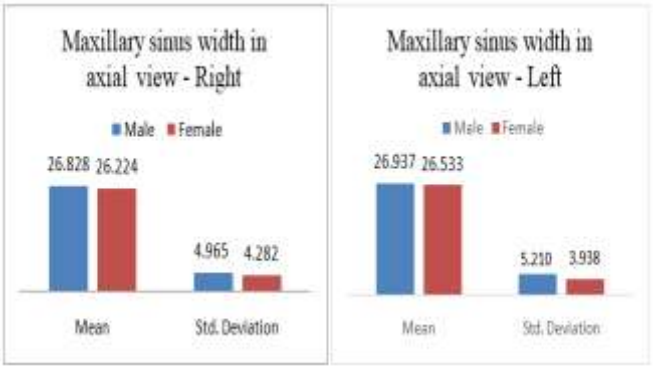
**Distribution of morphometric parameters of maxillary sinus for gender determination**




**Graph 3: Maxillary sinus height in coronal view**

In the present study the mean of maxillary sinus height in males were **34.003 ± 5.420mm** and in females **30.635 ± 4.726mm** for **right** side, **32.598 ±5.264mm** in males and **29.780±4.522mm** in females for the **left** side.

Therefore, the maxillary sinus height is greater in males in the present study and was found as significant parameter for assessing gender with a p value of **<0.05.**




**Graph 4: Maxillary sinus width in axial view**

In the present study the mean of maxillary sinus width in males were **26.828 ± 4.965mm** and for females **26.224 ± 4.282mm** the **right** side, **26.937 ± 5.210mm** for males and **26.533 ± 3.938mm** for females the **left** side.

Therefore, the maxillary sinus width does not show statistically significant difference between males and females (p value of >**0.05).**

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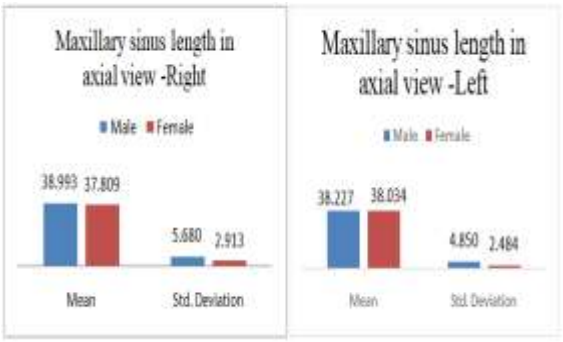
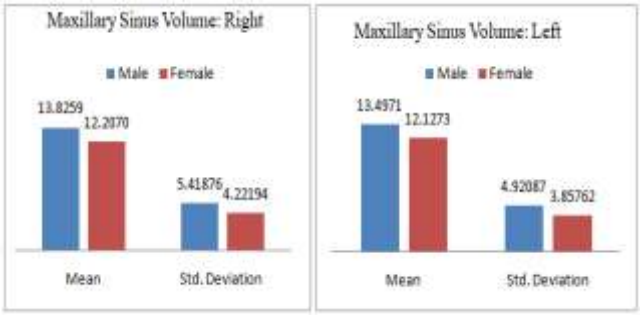



**Graph 5: Maxillary sinus length in axial view**

The mean of maxillary sinus length in males were **38.993 ± 5.680 mm** and for females **37.809 ± 2.913 mm** on the **right** side, **38.227 ± 4.850 mm** for males and **38.034 ± 2.484 mm** for females on the **left** side. Therefore, the maxillary sinus length in right side of males was greater than the females but it does not show statistically significant difference (p value of **>0.05).**




**Graph 6: Maxillary sinus volume in axial section**

The mean of maxillary sinus volume in males were **13.826 ± 5.418 cm$^3$** and for females **12.2070 ± 4.221 cm$^3$** the **right** side, **13.497 ± 4.920 cm$^3$** for males and **12.127 ± 3.857 cm$^3$** for females the **left** side. Therefore, the maxillary sinus volume right side of males was greater than the females with statistically significant difference (p value of **<0.05**).

## V. DISCUSSION

The skull is the most reliable part of skeleton next to the pelvis for gender determination but it is not reliable until after puberty. The uniqueness and inter-individual variation in size, shape, symmetry, permanence of anatomical landmarks of skull provides scientific information in forensic anthropology[8]. The nasal cavity is surrounded by four paired air-filled spaces, the paranasal sinuses (maxillary, frontal, sphenoid and ethmoid). The maxillary sinus can exhibit morphological variation hence they are useful tools for gender dimorphism[9]. The study used CBCT scans in order to overcome the disadvantages of the two dimensional imaging modalities and to accurately locate the anatomical landmarks for the morphometric analysis to determine sexual dimorphism.

In the present study, the maxillary sinus height of right and left side for males were 34.003 ± 5.420mm and 32.598 ±5.264mm, and for females 30.635 ± 4.726mm and 29.780 ± 4.522mm with a significant p value of 0.001 and 0.005 respectively. Hence the height of maxillary sinus was greater in males than females.The maxillary sinus width of right and left side for males are 26.828 ± 4.965mm and 26.937 ± 5.210mm, when compared with the females 26.224 ± 4.282mm and 26.533 ± 3.938mm and did not showed statistical significance. The anteroposterior length of right and left maxillary sinuses for males are 38.993 ± 5.680mm and 38.227 ± 4.850mm and that for females are 37.809 ± 2.913mm and 38.034 ± 2.484mm respectively which showed no statistical significance with a p value of>0.05. The volume of maxillary sinus in males were 13.826±5.418cm$^3$and for females 12.207±4.221cm3 on the right side and

13.497±4.920cm3 for males and 12.127±3.857cm3 for females on the left side. The maxillary sinus volume was greater in males than females with a statistically significant value in right side compared to left.

Aretrospective study by Balaji Babu Bangi et alshowed statistically significant larger dimensions of the right and left maxillary sinuses in males when compared to females[10]. Studies by Anju Mathew et al, Uthman et al also showed similar results wherein the maxillary sinus dimensions were larger in males when compared to females[11,12]. Studies by Beom-Cho Jun et al[13], Kanthem R K et al[14], Luz J et al[15]showed that maxillary sinus volume is also an important parameter for gender determination.

## VI. LIMITATIONS

- The present study was done in a small sample size of Central Kerala Population which might affect the accuracy of gender prediction.
- Only individuals aged between 18-80years were selected due to the varying maxillary sinus dimensions in childhood.
- Only certain parameters in skull have been examined in our study due to the limited field of view available in our CBCT X- ray machine.
- The morphology and dimensions of maxillary sinus could be affected by the genetic, environmental and the growth patterns.

## VII. FUTURE PERSPECTIVE

- As sexual dimorphism is influenced by different factors such as the environmental, genetic and other growth factors, further studies involving a multidisciplinary approach could be beneficial.
- A large sample size is also recommended for overcoming the limitations to accurately predict the gender dimorphism.

## VIII. CONCLUSION

Obtaining post- mortem intra oral radiograph especially in cases of mass disasters will be a challenging procedure due to difficulty in placing and retaining radiographic films in the mouth due to rigor mortis affecting the mandibular muscles. CBCT provides an excellent method for imaging the maxillofacial region. The advantage of using this imaging modality is that the scans can be completed in a short time. In addition the processing software allows comparison of the available ante- mortem dental radiograph with the post mortem radiograph for dental identification. These advantages of dental radiograph using CBCT can be made applicable in the field of forensic science for gender determination.

Our study used the parameters of some specific dimensions of maxillary sinus for assessment of the gender variation. On assessment, there was a lack of literature review that assessed both the maxillary sinus in gender determination among the Central Kerala Population and hence this study can be marked as an initial attempt for gender determination using maxillary sinus in our population.

In this study, our aim was to evaluate the reliability and accuracy of different anatomic skull structures in determining sexual dimorphism using Cone Beam Computed Tomography in Central Kerala Population. Out of the four parameters which were assessed in our study, the maxillary sinus showed statistically significant results in predicting male and female. These parameters also had an accuracy of 55-75% in prediction gender. The results suggest that proper recording of the available ante-mortem dental radiograph data could be valuable in determining gender in the field of forensic science. Further studies with a large population sample are required to determine the strength of the results obtained from our study. However, we were able to conclude that the morphometric analysis of different anatomic skull structures using CBCT is a reliable method for gender determination and it can be implemented in the field of forensic dentistry.

As Herbert Leon MacDonnell wrote “physical evidence cannot be intimidated. It does not forget. It sits there and waits to be detected, preserved, evaluated and explained.” Thus the immortal human bones and their radiographs can speak for the mortal ones, wherein our study used CBCT to assess and concluded that the right and left dimensions of maxillary sinus is a promising tool in gender determination.

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