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## Gender determination of maxillary sinus using CBCT

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### Abstract

**Aim:** This retrospective study aimed at assessing the reliability of morphometric measurements performed on the maxillary sinus for sex determination on cranio-facial and sinuses CBCT scans.

**Materials and Methods:** Bilateral maxillary sinus images (left and right) were acquired for 30 patients (15 females and 15 males) and different parameters (width, length, height, area, perimeter and volume) were measured and evaluated. Mean and standard deviation of both maxillary sinuses measurements were calculated and compared. The data was subjected to discriminative statistical analysis and analyzed using unpaired t-test.

**Results:** Comparison between male and female groups showed statistically insignificant differences on both the right and left sides with respect to the maxillary sinus length, height, area, volume and perimeter. However, the female group showed statistically significant lower values than males.

**Conclusion:** Maxillary sinus can be used as an aid in forensic anthropology for gender determination.

**Keywords:** Gender determination, maxillary sinus, CBCT, forensic anthropology

### 1. Introduction

Gender identification is a classic procedure in forensic medicine as sex assessment constitutes an important step in constructing a post-mortem profile [1]. Recently, judicial demand for gender identification has increased because of an increase in criminal cases involving young people, irregular immigration and modern crimes. Traditionally, radiology has been limited in its applications to forensic medicine in the field of identification. Visual inspection, anatomic measurement and precise measurement of bone dimensions often exceed radiologic contribution, particularly where identification of skeletal remains is required. The most helpful area of the body for comparison radiography is the cranium. Radiography is used in forensic pathology for the identification of humans especially in cases where the body is decomposed, fragmented or burned. The skull, pelvis and femora are the most useful for the radiological determination of gender [2]. It has thus become important to use denser bones that are often recovered intact, e.g. the maxillary sinus and thus alternate areas of the skeleton to be researched for sex estimation. It has been reported that zygomatic bones and maxillary sinus remains intact although the skull and other bones may be badly disfigured in victims who are incinerated [3].

Maxillary sinuses are air spaces, located in the maxillary bone and can be in various sizes and shapes. They appear at the end of the second embryonic month and reach their mature sizes at the age of about 20 years, when the permanent teeth fully develop. They tend to stabilize after the second decade of life and the radiographic images could provide adequate measurements of maxillary sinuses for use in morphometric forensic analysis that cannot be approached by other means [4].

Considering the complex structure of maxillary sinuses, magnetic resonance imaging (MRI) and computed tomography (CT) are the gold standard methods to depict the true anatomy of the Highmore's antrum. Nevertheless, their use is limited by high dose, cost, or restricted accessibility. These drawbacks were overcome with the introduction of cone-beam computed tomography (CBCT) [5].

Using CBCT technology, measurements of the maxillary sinus volume and the quantification of craniofacial structures are now available that reduce radiation dose compared with CT scans as well as reduced costs compared with MRI.

CBCT data sets allow the possibility of a realistic representation of the head of the patient and has expanded diagnostic possibilities,

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enabling three dimensional (3D) simulation of surgical procedures. In addition, since its introduction in 1998, CBCT technology has also been improved in terms of accuracy in identifying the boundaries of soft tissues and empty spaces (air) [6]. considering this parameters CBCT has been used in this present study for measuring maxillary sinus.

The aim of this study was to evaluate whether sexual dimorphism from the height, width and length measurements of the maxillary sinus could be determined using the CBCT imaging modality.

## Materials and methods

### Collection of samples

One hundred CBCT scans of bilateral maxillary sinuses were retrospectively retrieved from the database from CBCT center in Hyderabad. After initial screening for adaptability to the inclusion and exclusion criteria's finally 30 CBCT scans of bilateral maxillary sinuses (60 maxillary sinuses) with 15 male and 15 female subjects and age ranging from 20 to 70 years were selected.

### Inclusion criteria

- Only high quality reconstructed images of bilateral maxillary sinuses were selected
- Scans with inflamed lining of the sinus were included in the study.

### Exclusion criteria

- All low quality images with blurring or artifacts caused by metallic objects were excluded.
- Scans that were not covering the entire extent of the sinus were excluded.
- Scans with pathologically destructive maxillary sinus from tumor, trauma, cleft or any other disease within or in the vicinity of the sinus or previous surgery were excluded.

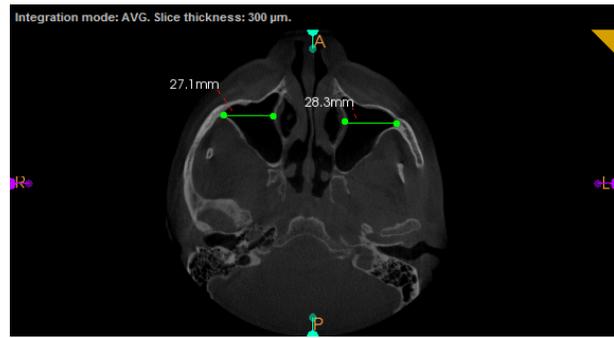
All the scans were made using a CS9300 3Dunit, with field of view of 17cm×13.5cm, voxel size – 90µm, X-ray pulse time of 30 ms, kVp – 60 to 90 kV (max), mA – 2 to 15 Ma, exposure time of 10.8 s. Images were reconstructed using a high spatial frequency reconstruction algorithm.

### Measurements

Two independent observers (both experienced radiologists) blind to the details of age and sex of the subjects, used the Digital Image Communication in Medicine (DICOM) compatible CS 3D Imaging software (version 3.2.9, copyright Carestream Health Inc.) to analyze the reconstructed image sections. All the CBCT images obtained in the DICOM format were transferred to a separate workstation and the measurements done in a quiet windowless room with dimmed lighting.

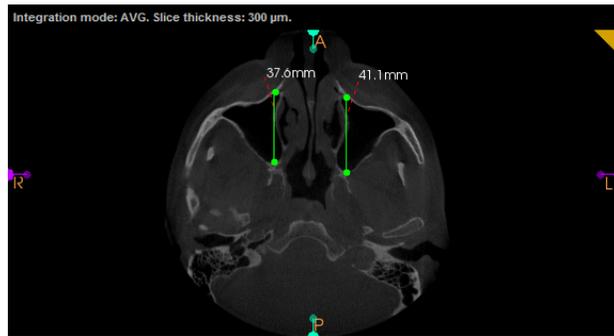
Observers were allowed to use two – fold magnification and modify screen brightness as well as scroll through the axial, sagittal and coronal sections with slice thickness standardized at 300 µm. The three straight distances (height, width, and depth), were taken on the axial and coronal cross sections, where the longest distances could be measured. The width and depth distances measured on axial section while the height distances measured on coronal cross section.

- The width was defined as the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the lateral process of the maxillary sinus in the axial view (Fig. 1).



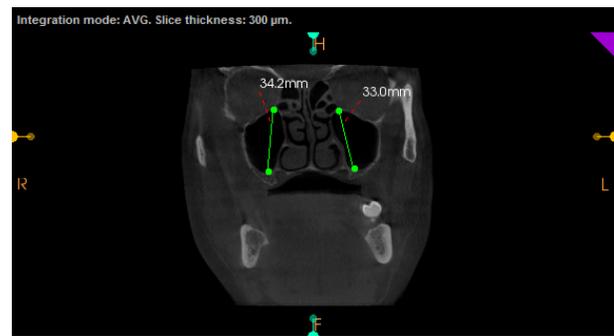
**Fig 1:** Width of the maxillary sinus on axial view.

- The depth was defined as the longest distance from the most anterior point to the most posterior point of the medial wall in the axial view (Fig. 2).



**Fig 2:** Length of the maxillary sinus on axial view.

- The height was measured away from the inner surface of the anterior border of maxillary sinus and was defined as the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof in the coronal view (Fig. 3).



**Fig 3:** Height of the maxillary sinus on coronal view.

### Data analysis

All data were transferred on Microsoft Excel 2007 software and subjected to descriptive analysis where comparison between gender groups was done with the help of unpaired t test with a p value less than 0.05 taken as significant level. A discriminate functional analysis was then performed to assess whether the measurements of the maxillary sinuses could be used for sex determination. Multiple logistic regressions were performed to generate an equation that could reliably classify the observations according to sex. The Receiver Operating Curve (ROC) analysis was then used to determine the fit of the regression model as well as to identify the optimum cut off criteria for the equations. Data analysis was done using the

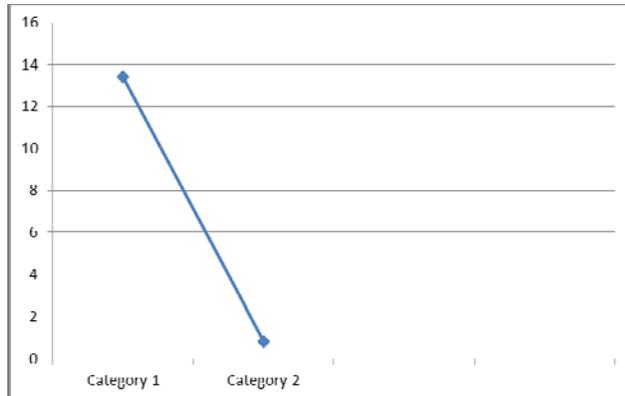
software, SPSS version 15.

The Multiple Logistics Regression proposed the following equation for sex determination from measurements of the:-

Right maxillary sinus:  $\text{sex} = 2082.963 + (32.392 \text{ right width}) + (7.335 \text{ right length}) + (43.331 \text{ right height})$ .

Left maxillary sinus:  $\text{sex} = 68.961 + (1.272 \text{ left width}) + (0.0214 \text{ left length}) + (0.935 \text{ left height})$ .

The ROC analysis proposed the optimum cut off criterion of 13.4606 for the right sinus and 0.8446 for the left sinus respectively. Subjects with values higher than the cut off criterion were classified as males and those with lower values than the cut off criterion were classified as females. The chosen cut off criteria were corresponding with the highest Youden Index.



X-axis – gender, y-axis-cut off value.

Category 1 = male (above cut off value i.e., 13.5)

Category 2 = female (above 0.8)

### Discussion

Identification of gender from remains of human skeletons is an important forensic procedure. It has been reported that the gender can be determined with an accuracy of 100% if entire skeleton is available. A total of 98% accuracy can be achieved from both the pelvis and the skull [7]. It has been reported in previous studies that the maxillary sinuses are significantly larger in males than in females.

In the present study also, comparison between male and female groups showed that the female group had statistically significant lower values for both the right and left maxillary sinuses as regards the width, length and height dimensions.

The current study was designed to determine the reliability and accuracy of MS dimensions measurement as a method for gender identification using CBCT on 30 patients (15 males and 15 females). After birth, the MS continues to pneumatize into the developing alveolar ridge as the permanent teeth erupt. At the age of 20, with the completion of the eruption of the third molars, the pneumatization of the sinus ends. It has been reported that genetic diseases, post infections and environmental factors can affect the sizes of MS. Considering this factor the patients with disease conditions were excluded from the study.

A study by Tambawala SS *et al.*, for comparison between male and female groups demonstrated that the female group had statistically significant lower values for both the left and right MS in context to the length, height and width dimensions [8].

A discriminating analysis performed by Azhar A *et al.*, on MS measurements showed that the left MS width was the best discriminate parameter (with an overall accuracy of 61.3%)

[9]. The results obtained in our study were in agreement with Azhar A *et al.*, study as left MS width was the best discriminative parameter with an overall accuracy of 60%.

Teke HY *et al.*, estimated the mean value for the maximum width of MS and obtained almost similar results as that of our study in relation to the width of MS [10].

A study by Sharma SK *et al.*, conducted a study on similar population as in our study and showed that 68.9% of females and 65.16% of males were sexed correctly and the overall percentage for sexing MS correctly was 67.03%. The prediction accuracy in our study is comparatively greater than this study [11].

The limitations of this study included the small sample size owing to the stringent inclusive and exclusive criteria of the study. This also emphasizes the need to conduct these analysis on a larger population. The difference in the equations generated for different populations also suggests that this study could be done for different world populations to generate such identification equation for sex determination.

### Conclusion

Gender determination is an important step in identification in forensic medicine. Maxillary sinus dimensions measurements are valuable in studying sexual dimorphism. They tend to stabilize after second decade of life and the radiographic images could provide adequate measurements for maxillary sinuses that cannot be approached by other means. Hence, morphometric analysis of maxillary sinuse can assist in gender determination. However, this is a preliminary study further studies on large sample size is desirable.

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