Determination of sexual dimorphism of maxillary sinus using cone-beam computed tomography in a rural population of western Maharashtra – A retrospective, cross-sectional study

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ABSTRACT

Context: Radiography is used in forensics for the identification of humans, especially in cases where the body is decomposed, fragmented, or burned. In the skull bones, the zygomatic bone and maxilla including the maxillary sinus tend to remain intact even if the other bones are badly disfigured. Hence, the maxillary sinus has been considered by several authors for sex identification. The cone-beam computed tomography (CBCT) is a non-invasive, recently developed technology that has seen an exponential rise in the use for visualizing dental anatomy and pathologies. The present study chose the available CBCT records of patients who show maxillary sinus and used them for determining sexual dimorphism related to the maxillary sinus. Aims: To measure the maxillary sinuses using CBCT and determine the efficacy of these measurements for sex identification. Settings and Design: Observational, cross-sectional, retrospective study. Methods and Material: A total of 60 CBCT scans (30 males, 30 females) were selected from a rural setup, and the height, length, and width of the maxillary sinus with the highest dimension for each variable were measured and recorded. Statistical Analysis: The data were analyzed by using the paired t-test. The discriminant equations were derived for both the right and left maxillary sinus. Results: Statistically significant differences were observed between the males and females for height (right and left) and length (left) of the maxillary sinus. The accuracy rate for sex identification in the present study was found to be 71.3%. Conclusion: Maxillary sinus height can be used as a reliable radiographic marker in forensic odontology for sex identification.

Keywords: Cone-beam computed tomography, maxillary sinus dimensions, sex determination

Introduction

Individual identification is one of the most important priorities in conditions with mass casualties such as natural disasters, road accidents, air crashes, fires, and even in the investigation of criminal cases. Matching specific features detected on the cadaver with data recorded during the life of an individual is an important aspect in forensics for identification. These features can be assessed by fingerprint analysis, deoxyribonucleic acid matching, anthropological methods, radiological methods, and other techniques which facilitate age and sex identification.¹⁻³ Recently, the judicial
demand for sex identification has increased because of an
increase in criminal cases involving young people, irregular
immigration, and modern crimes. The estimation of sex from
the bones depends on their morphological and morphometric
features. The combination of both features usually gives
the most accurate results. The determination of sex can be
done through the skull, the pelvis, the long bones with
an epiphysis and a metaphysis in the skeletons, the mastoid
process, the foramen magnum, and the paranasal sinuses in
the skull. It has been reported that maxillary sinuses remain
intact despite the skull and other bones getting badly disfigured
in victims who are incinerated. Various radiographic imaging
techniques such as conventional radiography and computed
tomography (CT) have been used in forensic anthropology to
evaluate the paranasal sinuses’ dimensions for determining the
sex of an individual including measurements on dry skulls.
The cone-beam computed tomography (CBCT) is a relatively
new technology used primarily in a variety of maxillofacial
applications. In forensic contexts offering several advantages
for postmortem forensic imaging including good resolution for
skeletal imaging, relatively low cost, portability, metal artifact
reduction, and simplicity.

These findings created a surge in us for evaluating the maxillary
sinus dimensions on CBCT and to determine whether they
can be used as a parameter for sex identification. The aim and
objectives were to determine the size of the maxillary sinuses in
three dimensions—height, length, and width using a CBCT scan
and to evaluate if a significant difference can be found among
these variables in males and females.

Methods

The present study was designed as an observational,
cross-sectional, retrospective study. The study was conducted
after obtaining approval from the ethical institutional committee.
The study subject included CBCT scans available in the
department showing bilateral maxillary sinuses. A total of
60 scans (30 males, 30 females) that matched the inclusion criteria
of the study were included. The age group of 20–60 years was
included to avoid any age-related bias. Since the setup was in a
rural area, the included participants could be considered as rural
populations. Scans without any major imaging errors/distortions
in the maxillary sinus region were included in the study while
those showing maxillary sinus pathologies and scans of
dentulous patients were excluded. These CBCT images were
acquired with a standard resolution mode made of voxel size
of 0.3 mm using the Rainbow CT Scanner (made in Korea,
kVp 70–110, mA 7–10, 10–20 s) with a Field of view (FOV)
of 10 cm × 16 cm. An in-built Rainbow 3D viewer imaging
software was used to reconstruct the images and the following
measurements were performed.

The three longest straight distances (height, width, and length)
were measured for the right and left maxillary sinuses on the
axial and coronal sections as follows:

1. The width (mediolateral) of the maxillary sinus was measured
as the longest distance from the medial wall to the lateral wall
of the maxillary sinus in the axial view [Figure 1].
2. The length (anteroposterior) was measured as the longest
distance from the anterior wall to the posterior wall in the
axial view [Figure 2].
3. The height (superoinferior) was measured as the longest
dimension from the superior wall to the inferior wall (floor)
of maxillary sinus on coronal view [Figure 3].

The measurements were recorded as right sinus length (RSL),
left sinus length (LSL), right sinus width (RSW), left sinus
width (LSW), right sinus height (RSH), and left sinus
height (LSH). The data were recorded in an Excel sheet. All data
were first subjected to descriptive analysis by mean, standard
deviation, and percentage values. The sex-wise comparison was
done with the help of Student’s t-test with a P value less than
Results

The sample of 60 scans had a mean age of 34.43 years (SD ± 13.42) for males and 35.23 years (SD ± 15.96) for females. There was no statistically significant difference in the age distribution of males and females ($t = 0.21$, df = 58, $P = 0.834$). Table 1 shows the mean, standard deviation, and $P$ value of all predictor variables for males and females. According to the Student’s $t$-test, there was a statistically significant difference between males and females in the RSH, LSH, and LSL. Such statistically significant difference could not be found in the width and RSL of the maxillary sinus for males and females.

Based on the discriminant functional analysis [Table 2], the sex predictability was the highest for height, followed by length, and the lowest for width. The sex assessment was established correctly with a mean accuracy of 71.3%. A receiver operating characteristic curve (ROC) was created which showed RSH, LSH, RSL, LSL under the curve, and hence, could be used as a good predictor for sex [Figure 4].

Discussion

The determination of sex from the remains of the human skeleton is an important forensic procedure. It has been reported that the accuracy rate of sex determination is 100% from a skeleton, 98% from both the pelvis and the skull, 95% from the pelvis only or the pelvis and the long bones, 90–95% from both the skull and the long bones, and 80–90% from the long bones only. Many previous studies clearly showed that the maxillary sinus exhibited anatomic variability between sexes. However, only limited studies have specified the population source—whether they were urban or rural. The present study was designed to determine the reliability and accuracy of maxillary sinus dimensions as a method for sex identification using CBCT in the rural population.

After birth, the maxillary sinus 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, and it continues again after the exfoliation of the teeth. Hence, we included patients of age 20–60 years, and edentulous scans of any age were excluded from the study. It was also noted that a few genetic diseases, post-infections, and environmental factors can affect the sizes of maxillary sinuses. Considering these, the scans of the subjects with such disease conditions were excluded from the study.

In Gray’s Anatomy, the overall measurements of the maxillary sinus are described as 32 mm in anterior-posterior diameter, 25 mm in mediolateral diameter (transverse), and 35 mm in superior-inferior diameter (cephalo-caudal). In the present study, the mean length (anteroposterior) measurement for the maxillary sinus was

| Table 1: Sex-wise comparison of measurements (height, length, and width) of maxillary sinus of right and left side |
| --- |
| Study Variable | Sex | n | Mean (mm) | Std. Deviation (mm) | t-test |
| RSH | Male | 30 | 40.5680 | 5.95081 | $t=4.784$, df=58, $P=0.00001$ |
| | Female | 30 | 34.2667 | 4.07818 | |
| LSH | Male | 30 | 40.3830 | 9.02682 | $t=3.281$, df=58, $P=0.002$ |
| | Female | 30 | 34.5257 | 3.76042 | |
| RSL | Male | 30 | 38.8147 | 3.21031 | $t=1.909$, df=58, $P=0.061$ |
| | Female | 30 | 37.1137 | 3.67641 | |
| LSL | Male | 30 | 38.5960 | 3.28446 | $t=2.298$, df=58, $P=0.025$ |
| | Female | 30 | 36.6617 | 3.23648 | |
| RSW | Male | 30 | 26.1163 | 4.55808 | $t=0.079$, df=58, $P=0.937$ |
| | Female | 30 | 26.0327 | 3.56374 | |
| LSW | Male | 30 | 26.1983 | 4.76999 | $t=0.995$, df=58, $P=0.324$ |
| | Female | 30 | 25.0603 | 4.06164 | |

*P<0.05, Significant

| Table 2: Discriminant Function Analysis for height and length of maxillary sinus |
| --- |
| Test Result Variable (s) | Area Under Curve | Sig | Optimum Cut-off Value (mm) | Sensitivity | Specificity |
| RSH | 0.080 | 0.00001 | 39.8650 | 63.3% | 100% |
| LSH | 0.836 | 0.00001 | 39.9550 | 73.3% | 100% |
| RSL | 0.653 | 0.041 | 38.8200 | 60.0% | 70% |
| LSL | 0.682 | 0.015 | 38.1550 | 63.3% | 70% |

Figure 4: ROC curves to find the optimum cut-off points, sensitivity, and specificity of measures in the identification of sex
38.8 mm ± 3.2 mm (males) and 37.1 mm ± 3.6 mm (females) on the right side and 38.5 mm ± 3.2 mm (males) and 36.6 mm ± 3.6 mm (females) on the left side. The mean width (mediolateral) measurement for maxillary sinus was 26.11 mm ± 4.5 mm (males) and 26.03 mm ± 3.5 mm (females) on the right side and 26.19 mm ± 4.7 mm (males) and 25.06 mm ± 4.1 mm (females) on the left side. The mean height (superoinferior) measurement for maxillary sinus was 40.5 mm ± 5.9 mm (males) and 34.2 mm ± 4.1 mm (females) on the right side and 40.3 mm ± 9.02 mm (males) and 34.5 mm ± 3.7 mm (females) on the left side.

The result of the present study showed higher values for height, length, and width of the maxillary sinus for males. These findings were consistent with the findings in the previous studies by Kanthem et al.,[1] Sathawane et al.,[3] Sherif et al.,[4] Prabhat M, et al.,[8] Tambawala SS et al.,[9] Teke HY et al.,[10] Paknahad et al.,[9] Ekizoglu O et al.,[11] Soman C,[12] and Fajarwati et al.[13] who found all the three dimensions (height, width, and length) having higher values in the males. In the present study, a statistically significant difference was found in the height (right and left) and length (left side) of the maxillary sinuses among the males and females. There was no significant difference between the sexes in the maxillary sinus width (right and left) and RSL. It was found that the most pronounced variable in the differentiation of the sex group was the maxillary sinus height on both the right and left sides, however, highly significant with the right side. The sex predictability was the highest for height, followed by length, and the lowest for width. Sex identification was established correctly with an accuracy of 71.3% in males and females. The discriminant equations were derived for both the right and left maxillary sinuses which can be used for the determination of sex. Amin MF and Hassan EI in their study also found that only the height of MS was significant in gender determination.[15] The findings from the present study where the width of the maxillary sinus was found not significant for gender determination was inconsistent with the studies by Urooge et al.,[10] Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, and Sheikh NN et al.[17] who observed a similar observation.

The accuracy rate of the present study on the discriminant analysis was 71.3% which was similar to the studies done by Sathawane et al.[18] (71%) and Urooge et al.[14] (71%). Prabhat M et al.,[8] Paknahad et al.,[9] and Ekizoglu O et al.[10] reported the overall accuracy rates of 77.15, 83.3, and 76%, respectively which were higher than the accuracy rate of the present study. The accuracy rates of the studies conducted by Amin MF and Hassan EI.[18] (70.8%), Sharma SK et al.[14] (69.81%), Azhar A et al.[18] (61.3%), and Sheikh NN et al.[17] (59%) were less than the accuracy rates of the present study. In the present study, an optimum cut-off value of 39.8 and 39.9 mm was found with a specificity of 100% for the right and LSH, respectively.

The present study also had a few limitations. First, the sample size of the present study was small, and thus, we plan to conduct further studies on a large sample size in the future. Being a retrospective study, other factors such as environmental factors, ethnic and racial groups, the history of maxillary sinus infections, etc., which could have caused variation in the maxillary sinus could not be known.

Conclusion

The results from the present study showed that the maxillary sinus exhibits anatomic variability among different sexes with the height of the maxillary sinus being a more accurate predictor. The present finding can be a valuable addition to the currently available data regarding metric variations in maxillary sinus for sex identification. These data can be utilized by forensic specialists, dentists as well as primary care physicians as they too sometimes need to function as forensic pathologists in the absence of a specialist especially in rural areas. We hope to further strengthen the forensic findings among the rural population with the findings from the present study.

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Conflicts of interest

There are no conflicts of interest.

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