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Original Article

Determining Sexual Dimorphism of Maxillary Sinus Using Cone Beam Computed Tomography: An Observational Study

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Abstract

Introduction: Radiography is used in forensics for the identification of humans. In the skull bones, the zygomatic bone and maxilla including the maxillary sinus (MS) tend to remain intact even if the other bones are badly disfigured. Sex determination is an essential element for human identification to which the maxillary sinuses may contribute.

Aims: The main aim of this study was to determine sexual dimorphism of MS using cone beam computed tomography (CBCT) 3D images.

Materials and Methods: 40 CBCT scans (20 males and 20 females) were selected from Oral Medicine and Radiology Department. Age range of the patients was between 20 and 70 years. Height, length, and width of MS were measured bilaterally and compared to evaluate the differences between sexes.

Results: Bilateral length, height, and width in males showed insignificant results. Length in females of the right and left sides was insignificant but height and width of bilateral MS showed significant results. Length of males and females of both sides when compared showed insignificant results. Bilateral height and width of both sexes showed extremely significant results. Area calculated was also statistically significant.

Conclusion: MS height and width can be helpful as an aid in forensic anthropology for sex determination.

Key words: Cone beam computed tomography, Maxillary sinus, Sex determination

INTRODUCTION

Human identification aims to establish a subject's personal identity and is important for social, religious, and economic reasons. Gender determination based on anthropometric characteristics is fundamental to human identification. It has been demonstrated that the maxillary sinuses remain intact in certain cases such as decomposed, burnt, and highly fragmented remains and they can be used as a gender estimation method when conventional gender indicators are absent. Although the dimensions of the maxillary sinus (MS) are population-specific, depending on several factors such as race, genetics, maternal health culture, and environmental quality conditions during prenatal development, their measurements after puberty have emerged as a reliable factor in gender determination when MS reaches its full size.[1]

In forensic science, sexual dimorphism remains a crucial initial step toward the establishment of positive identity of the deceased individual. 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

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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. Next to the pelvis, the skull is the most easily sexed portion of the skeleton. Although the determination of sex from the skull is not reliable until after puberty, the craniofacial structures have the advantage of being composed largely of hard tissue, which is relatively indestructible. It has been reported in previous studies that the maxillary sinuses are significantly larger in males than in females.[2]

Various techniques have been used to assess sexual dimorphism varying from dry skull or cadaveric studies to use of radiographic techniques or combinations. Imaging modalities involving panoramic radiography, computed tomography (CT) imaging, and cone beam CT (CBCT) have been used. CBCT is a preferred 3D imaging modality in the maxillofacial region since it is a volumetric imaging modality which is ideal for capturing anatomic structures with less radiation exposure, cost-effective, and shorter acquisition time than CT. Hence, the present study was an attempt to assess the sexual dimorphism using dimensions of MS in CBCT images.

MATERIALS AND METHODS

A total of 40 CBCT scans (20 males and 20 females) were selected from Oral Medicine and Radiology department without any sinus, periapical, and periodontal pathologies. Age range of the patients was between 20 and 70 years. Only high-quality reconstructed images of bilateral maxillary sinuses were selected and all low-quality images with blurring or artifacts caused by metallic objects were excluded.

Height, length, and width of MS were measured bilaterally and compared to evaluate the differences between sexes. The CBCT images were reconstructed with the help of CS 3D imaging software. The mean value of each measurement was then calculated. Width and length distances were measured in the axial section whereas the height distances were measured on coronal cross-section.

Descriptive analysis using mean and standard deviation was performed, followed by a comparison between sexes with *P*-value being <0.05 using unpaired Student's *t*-test. To perform the present study, institutional ethical clearance was obtained.

RESULTS

Right MS was longer in males and left MS was longer in females. Right MS had more dimensions than left in males and females when height was measured. Right MS was wider in both males and females.

Mean and standard deviation of length of right and left MS in males were 35.47 ± 2.400 and 34.61 ± 2.707 which were not statistically significant [Table 1 and Figure 1].

Mean and standard deviation of length of the right and left MS in females was 33.84 ± 2.008 and 34.25 ± 3.447 which were not statistically significant [Table 2 and Figure 2].

Mean and standard deviation of height of the right and left MS in males were 35.49 ± 1.807 and 34.83 ± 1.657 which were not statistically significant [Table 3 and Figure 3].

Mean and standard deviation of height of the right and left MS in females was 32.07 ± 0.896 and 30.80 ± 1.668 which were statistically significant [Table 4 and Figure 4].

Mean and standard deviation of width of the right and left MS in males were 31.46 ± 2.120 and 29.58 ± 3.584 which were not statistically significant [Table 5 and Figure 5].

Mean and standard deviation of width of the right and left MS in females were 26.58 ± 1.313 and 24.46 ± 1.802 which were highly statistically significant [Table 6 and Figure 6].

Table 1: Evaluation and comparison of the length of maxillary sinus in males

Males *n*=20	Mean±standard deviation	*P*-value	Significance
Right	35.47±2.400	0.46	Not significant
Left	34.61±2.707		

Table 2: Evaluation and comparison of the length of maxillary sinus in females

Females *n*=20	Mean±standard deviation	*P*-value	Significance
Right	33.84±2.008	0.22	Not significant
Left	34.25±3.447		

Table 3: Evaluation and comparison of the height of maxillary sinus in males

Males	Mean±standard deviation	*P*-value	Significance
Right	35.49±1.807	0.40	Not significant
Left	34.83±1.657		

Table 4: Evaluation and comparison of the height of maxillary sinus in females

Females	Mean±standard deviation	*P*-value	Significance
Right	32.07±0.896	0.04	Significant
Left	30.80±1.668		

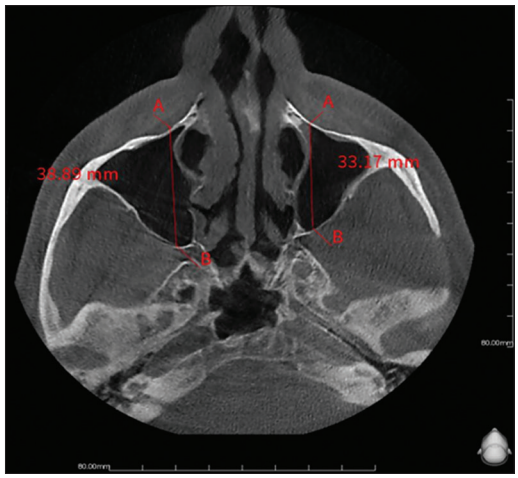

Figure 1: Measurement of the maxillary sinus (MS) length (Male). Point A is the most anterior point of anterior wall of MS. Point B is the most posterior point of posterior wall of MS

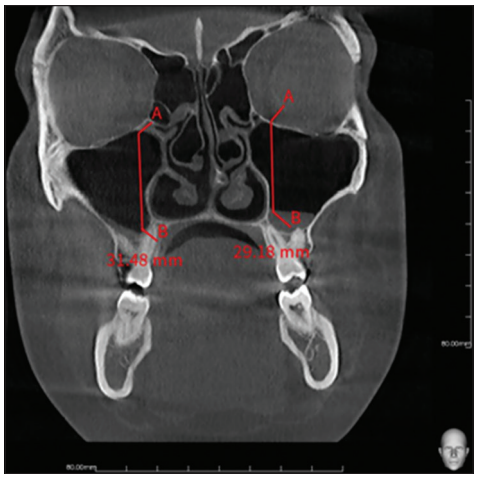

Figure 4: Measurement of height of maxillary sinus (Female). Point A is the highest point on sinus roof. Point B is the inferior point on the sinus floor

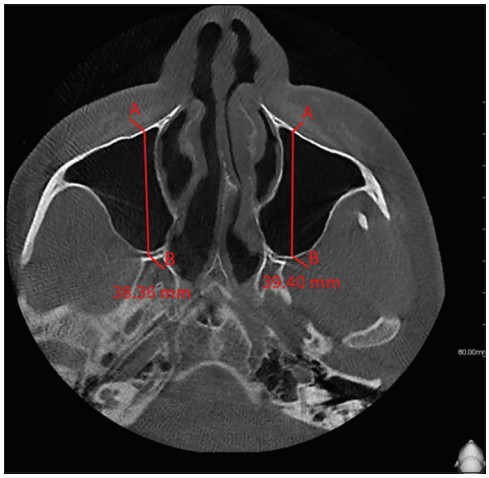

Figure 2: Measurement of the maxillary sinus (MS) length (Female). Point A is the most anterior point of anterior wall of MS. Point B is the most posterior point of posterior wall of MS

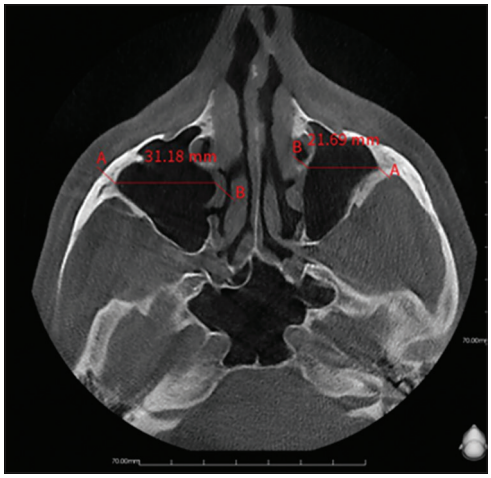

Figure 5: Measurement of width of maxillary sinus (MS) (Male). Point A is the most lateral point on the anterolateral aspect of MS. Point B is the most medial aspect on the posterolateral wall of MS

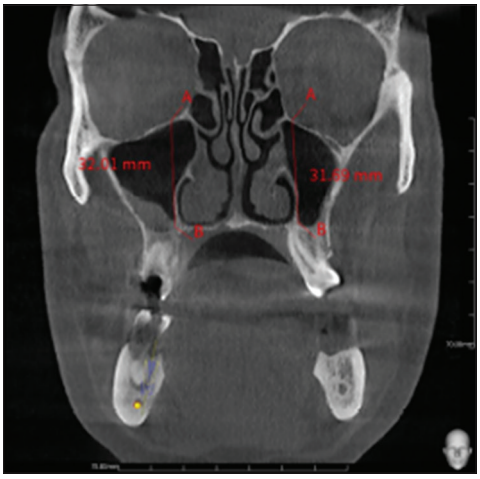

Figure 3: Measurement of the height of maxillary sinus (Male). Point A is the highest point on sinus roof. Point B is the inferior point on the sinus floor

Table 5: Evaluation and comparison of the width of maxillary sinus in males

Males	Mean±standard deviation	*P*-value	Significance
Right	31.46±2.120	0.17	Not significant
Left	29.58±3.584		

Table 6: Evaluation and comparison of the width of the maxillary sinus in females

Females	Mean±standard deviation	*P*-value	Significance
Right	26.58±1.313	0.007	Highly significant
Left	24.46±1.802		

Mean and standard deviation of length of the right side MS in males and females were 35.47 ± 2.400

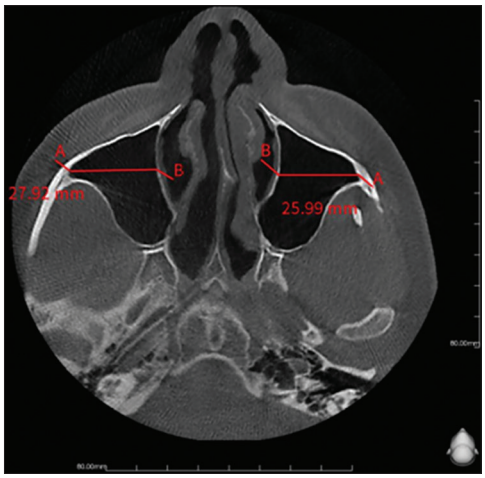

Figure 6: Measurement of width of maxillary sinus (MS) (Female). Point A is the most lateral point on the anterolateral aspect of MS. Point B is the most medial aspect on the posterolateral wall of MS

and 33.84 ± 2.008 which were not statistically significant [Table 7].

Mean and standard deviation of length of the left side MS in males and females were 34.61 ± 2.707 and 34.25 ± 3.447 which were not statistically significant [Table 8].

Mean and standard deviation of height of right side MS in males and females were 35.49 ± 1.807 and 32.07 ± 0.896 which were extremely statistically significant [Table 9].

Mean and standard deviation of height of left side MS in males and females were 34.83 ± 1.657 and 30.80 ± 1.668 which were extremely statistically significant [Table 10].

Mean and standard deviation of width of right side MS in males and females were 31.46 ± 2.120 and 26.58 ± 1.313 which were extremely statistically significant [Table 11].

Mean and standard deviation of width of left side MS in males and females were 29.58 ± 3.584 and 24.46 ± 1.802 which were extremely statistically significant [Table 12].

Mean and standard deviation of area of MS in males were 34.14 ± 2.320 and 33.00 ± 0.269 which was statistically significant [Table 13].

Mean and standard deviation of area of MS in females were 30.83 ± 1.005 and 29.83 ± 1.065 which were statistically significant [Table 14].

Mean and standard deviation of area of MS in both males and females were 33.57 ± 2.463 and 30.33 ± 3.986 which were statistically significant [Table 15].

Table 7: Comparison of the length of maxillary sinus (right) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Right	35.47±2.400	0.11	Not significant
Female	Right	33.84±2.008		

Table 8: Comparison of the length of maxillary sinus (left) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Left	34.61±2.707	0.79	Not significant
Female	Left	34.25±3.447		

Table 9: Comparison of the height of maxillary sinus (right) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Right	35.49±1.807	0.0001	Extremely significant
Female	Right	32.07±0.896		

Table 10: Comparison of the height of maxillary sinus (left) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Left	34.83±1.657	0.0001	Extremely significant
Female	Left	30.80±1.668		

Table 11: Comparison of the width of maxillary sinus (right) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Right	31.46±2.120	0.0001	Extremely significant
Female	Right	26.58±1.313		

Table 12: Comparison of the width of maxillary sinus (left) in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Left	29.58±3.584	0.0008	Extremely significant
Female	Left	24.46±1.802		

It has been observed that the overall parameters of the MS in males were significantly higher. Comparison between male and female groups on both right and left sides showed statistically significant differences with respect to height and width, whereas insignificant results with respect to length. Area of both the sides when compared between males and females showed significant results. Thus, in the

Table 13: Evaluation of the area of maxillary sinus in males

Side	Mean±standard deviation	*P*-value	Significance
Right	34.14±2.320	0.04	Significant
Left	33.00±2.069		

Table 14: Evaluation of the area of maxillary sinus in females

Side	Mean±standard deviation	*P*-value	Significance
Right	30.83±1.005	0.04	Significant
Left	29.83±1.065		

Table 15: Comparison of the area of maxillary sinus in both genders

Gender	Side	Mean±standard deviation	*P*-value	Significance
Male	Right and Left	33.57±2.463	0.04	Significant
Female	Right and Left	30.33±3.986		

present study, height and width were the better predictors for sexual dimorphism. The discriminative analysis showed that the accuracy of MS measurements was 75% in females and 72% of males with overall accuracy of 73.8%.

DISCUSSION

Individual identification is often one of the most important priorities in mass disasters, road accidents, air crashes, fires, and even in the investigation of criminal cases. Matching specific features of an individual is an important aspect in forensics and can be performed by fingerprint analysis, DNA matching, anthropological methods, radiological methods, and other techniques which can facilitate age and sex identification. Sinus radiography is one such method that has been used for the determination of the sex of an individual.[3]

The maxillary sinuses are a pair of large air-filled cavities located superior to the posterior part of the dentoalveolar region of the maxilla. The MS has the shape of a pyramid and is the largest among the four paranasal sinuses. Dental CBCT machines were developed and commercialized near the end of the 1990s and since then they have been heavily used in dental research to assess the condition of the MS. CBCT scan produces a 3D image volume, and hence, its radiation dose is usually higher than a plain radiograph such as a panoramic or a periapical radiograph.[4]

In the present study, overall dimensions in males were higher as compared to females. This is because males have correspondingly bigger lungs to support relatively massive body muscles and organs and males need larger nasal cavity complex as a direct result of respiration-related needs such as warming and humidifying air.[5]

Our study was consistent with studies carried out by Elbaz *et al.* and Soman in 2019 where they assessed MS dimensions in a sample population of Egypt and Saudi by CBCT. They found that all MS parameters showed higher mean value in males when compared to females.[6,7]

Non-significant results were seen between right and left MS in males with respect to length, height, and width. However, in females, significant results were seen between right and left MS with respect to height and width but not length. Study conducted by Saccucci *et al.* in 2015 on gender determination using MS dimensions by CBCT resulted in no statistical difference in patient's MS volumes between genders. They concluded that it is not possible to use the MS to discern sexual differences in corpse identification.[8] Chaurasia and Katheriya in 2017 carried out a study in Lucknow that resulted in no significant difference in the study parameters among the age groups.[9]

When height, length, and width were compared between males and females of both sides of MS, extremely significant results were seen with respect to height and width. This shows that height and width were better predictors of gender identification. This was in consistent with study done by Prabhat *et al.* They evaluated sexual dimorphism through the dimensions of the MS: Length, height, and width on CBCT and showed that the overall values of the metrics of the MS were significantly higher in men compared to women. They also concluded that height is an important predictor of sexual dimorphism.[10] The results obtained in our study were in agreement with Azhar *et al.*, study as MS width was the discriminative parameter with an overall accuracy of 60%.[11]

In the present study, right side parameters were relatively greater than the left side which was in accordance with Bangi *et al.*[12]

The discriminative analysis showed that the accuracy of MS measurements was 75% in females and 72% of males with overall accuracy of 73% in the present study which was in contrast with the Bangi *et al.* where the accuracy rate was found to be 84% in males and 92% in females with the mean accuracy of 88%.[12]

According to study done by Farias *et al.*, gender assessment was established with an accuracy of 75% for females and 64% for males with an overall accuracy of 69.5%.[13] The discriminative analysis of a study carried out by Teke *et al.*

showed that the ability of the MS size to identify gender was 69.4% in females and 69.2% in males which was a low accuracy rate.[14]

Thus, the variations in some of the results of maxillary air sinus dimensions and volume in these studies are probably due to combination of many factors such as different ethnic and racial groups with differences in body stature, skeletal size, height and physique; genetic and environmental factors; anatomical variations of sinus; differences in osteoclastic and osteoblastic activity; and pneumatization process of sinus. Finally, it is recommended that the results should be taken into account, so that it can be used as a method of prediction of sex being helpful in cases of identification of bone remains, as it would achieve a greater contribution to the methods already known.

CONCLUSION

This study shows that the MS height and width can be reliable discriminant parameter that could be used for sex discrimination as results were quiet significant. With the advent of CBCT, studies can be planned on larger samples with low radiation exposure and relatively low cost. By conducting such studies, a baseline value can be generated for use in forensic applications. The limitations of this study included the small sample size, and no statistical formula was used to determine the sample size. Further studies are needed to conduct these analyses on a larger population and statistically determine the sample size. Furthermore, other paranasal sinuses can be included to determine sexual dimorphism and to further strengthen the overall accuracy.

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