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Original Research Article

Maxillary Sinus Morphometrics as a Predictor for Gender Determination- A CBCT Study

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Abstract

Introduction: Skull is most commonly found and recovered intact among all the bones of the body. Though, anthropometric measurements can determine the gender of the individual, the morphometric analysis of the skull can also aid in gender determination. Morphometric analysis of maxillary sinus can be accurately measured using new imaging modalities like CBCT. ***Aims and Objectives:*** To assess the accuracy of maxillary morphometric parameters in gender determination. ***Materials and Methods:*** 200 maxillary sinus CBCT images were acquired retrospectively from the database to measure various parameters of the maxillary sinus. All measurements were carried out using CS software-Ver.3.3.11. All the values were recorded on an excel sheet and were subjected to statistical analysis. ***Results:*** Comparison of the measurements of maxillary sinus between males and females showed that the overall parameters were significantly greater in males than in females. The final result of the discriminative analysis shows that the ability of maxillary sinus to identify gender was 69% in males, 68% in females with an overall accuracy of 68.5%. ***Conclusion:*** Maxillary sinus morphometrics can be helpful in predicting the gender of the individual. The role of the oral radiologist in gender determination is important as his expertise in the field of head and neck radiology along with CBCT interpretations of maxillary morphometrics can help the forensic team to predict the gender of an individual.

Keywords: Morphometrics, Gender Determination, CBCT.

INTRODUCTION

Forensic anthropology involves skeletal analysis, which is a primary component in the age and sex determination of an individual obtained from the skeletal remanants [1]. Often the skeletal remains recovered either in a fragmented, incomplete or commingled state especially in catastrophes like explosions and other mass disasters [2]. As most conventional bones like skull, pelvis and long bones, etc used for gender determination, but may not be recovered intact for skeletal analysis. Gender identification is a classical procedure in forensic medicine, as gender assessment constitutes an important step in constructing a postmortem profile of an individual [3, 4]. In the craniofacial region, denser bones like maxillary sinus protect its integrity and thus became an alternate area in forensic medicine for gender determination [5]. Maxillary sinuses are the largest and first paranasal sinus to develop air spaces in the maxillary bone and show morphological variations in size, shape, and volume. Maxillary sinuses appear at the end of the second embryonic month and stabilize when permanent teeth fully develop at the age of about 18- 20 years [6]. The procedures like measuring the maxillary sinuses anatomy or by conducting plain radiography will give the cognizance about the pneumatization of human paranasal sinus [7]. The morphometric forensic analysis of maxillary sinuses is adequate by using the radiographic images. However, the multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI) provides three-dimensional reconstructions images in the assessment of maxillary sinus morphology [8, 9]. Due to disadvantages like less accessibility, high cost, dose, and other drawbacks, the latest imaging modality like a cone beam computed tomography (CBCT) has its own applications in the field of forensic medicine for gender determination. The integrated interactive manner of an object can be obtained as a series of contiguous cross-sectional images by CBCT [10]. The use of CBCT in forensic anthropology provides several advantages for post-mortem forensic imaging like relatively low cost, low dose, simplicity, less time, portability and good resolution of skeletal components [11]. Hence CBCT

imaging gives the most promising results in certain studies like 3D reconstruction, age estimation, sexual dimorphism, and anthropological assessment. Sexual dimorphism of the maxillary sinus using CT scan images has been done in several studies, but till date, only a few Indian studies have reported the use of CBCT in the gender assessment [12]. Thus the present study is conducted to assess the accuracy of maxillary morphometric parameters in gender determination.

MATERIALS AND METHODS

Sample Collection

Five hundred CBCT sans of bilateral maxillary sinuses were retrospectively retrieved from the database of the oral radiology unit for a period of April 2015-May 2017. The scan CBCT images obtained were screened that is pliable to the inclusion and exclusion criteria were selected for the present study. Finally, 200 CBCT scans of bilateral maxillary sinuses (right and left) with 100males and 100females subjects with age ranging between 20 to 70 years were selected and evaluated for the following parameters: width, length, height, area, perimeter, and volume. Only high quality reconstructed images of bilateral maxillary sinuses were included. Blurred or artifacts caused by metallic objects with low-quality images scans with pathologically destructed maxillary sinus from trauma, tumors or other diseases and history of previous surgeries were excluded from the study. All the retrieved scans obtained by using a CBCT scanner(Kodak 9300 3D imaging system) with a variable field of view 11x13 cm, 90kvp, 6mA and exposure time of 10.8 seconds.

Measurements of the Sample Data

Digital image communication in medicine (DICOM) compatible CS 3D imaging software (version 3.2.9, copyright Carestream health Inc.) used to analyze the reconstructed image sections. At a 1,366x768 resolution and measurements were done in axial and coronal cross-sectional views. All the images were viewed using two-fold magnification and screen brightness has modified to a standardized slice thickness of 300 micrometers. Mean values of each linear measurement were calculated. Width and length distances were measured in the axial sections (Table-1; Fig 1 & 2), but the height is calculated in coronal sections (Table-1; Fig-3). Area, perimeter and volume were recorded manually for both the right and left maxillary sinuses (Table-1).

Table-1: Showing different maxillary sinus parameters

Parameters	Units	Measuring references
Width	mm	The longest perpendicular distance from the medial wall to the lateral wall of the lateral process of the maxillary sinus in the axial sections.
Length	mm	Longest measurement of the maxillary sinus in anterior to posterior directions.
Height	mm	Longest distance from the superior point of sinus wall(roof) to the inferior aspect of the maxillary sinus floor.
Area	cm^2	Area= length x width
Perimeter	cm	Perimeter = 2 x length + 2 x width
Volume	cm^2	Volume = length x width x height x1/2

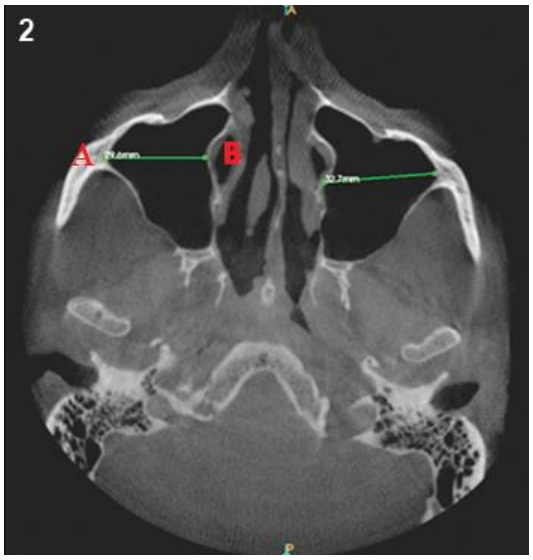


Fig-1: Axial section showing the width of the maxillary sinus, where A represents the lateral wall and B represents the medial wall of the maxillary sinuses

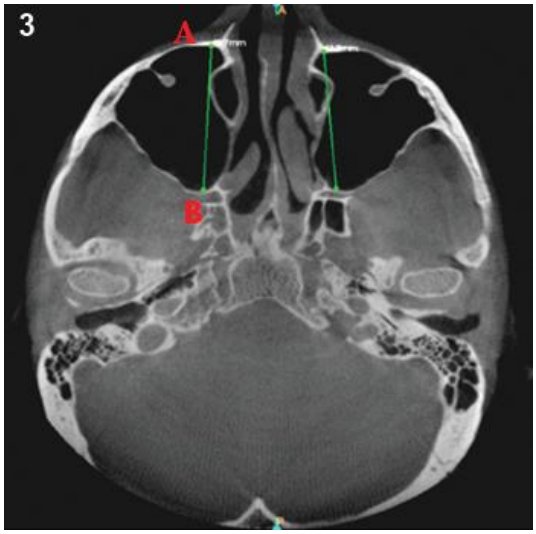


Fig-2: Axial section showing the length of the maxillary sinus, where A represents the most anterior aspect and B represents the most posterior aspect of the maxillary sinus

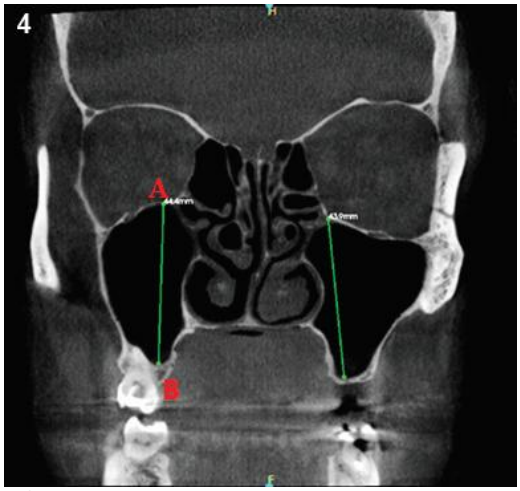


Fig-3: Coronal section showing the height of the maxillary sinus, where A represents the superior point (roof) and B represents the inferior point (floor) of the maxillary sinus

Statistical Analysis

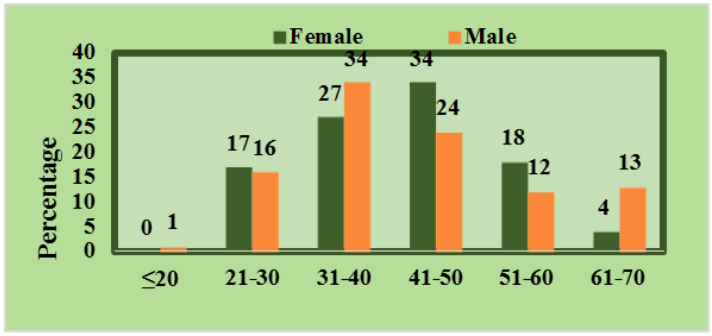
The mean and standard deviation of both right and left maxillary sinuses measurements were calculated and compared by using unpaired t-test with a p-value less than 0.05 taken as a significant level.

RESULTS

The present study with a sample size of 100 males and 100 females with their age ranging from 20 to 70 years were considered (Table-2 and Bar chart 1) and the percent frequency of the sample group individuals were between the age of 30-50 years.

Table-2 and Bar chart-1: Represents the sample distribution according to the age and gender group

Age	Female		Male	
	Frequency	Percent	Frequency	Percent
≤20	0	0	1	1
21-30	17	17.0	16	16.0
31-40	27	27.0	34	34.0
41-50	34	34.0	24	24.0
51-60	18	18.0	12	12.0
61-70	4	4.0	13	13.0
Total	100	100.0	100	100.0



The right maxillary sinus parameters were measured and compared between males and females by using the independent t-test. The mean values differences of maxillary sinus parameters like length (mm), height (mm), area (cm^2) and perimeter (cm) were found to be statistically significant ($p<0.05$) between males and females (Table-3).

Table-3: Showing the comparative parameters of right maxillary sinus between the genders

Parameter	Sex	Mean	SD	SE of Mean	Mean Difference	P-Value
Right Maxillary Sinus Length (cm)	Female	35.89	3.04	0.30	-2.62	<0.01
	Male	38.51	3.88	0.39		
Right Maxillary Sinus Width (cm)	Female	23.78	3.48	0.35	-0.40	0.42
	Male	24.18	3.57	0.36		
Right Maxillary Sinus Height (cm)	Female	33.41	3.83	0.38	-1.56	<0.001
	Male	34.97	4.19	0.42		
Right Maxillary Sinus Area	Female	856.32	162.83	16.28	-85.91	<0.001
	Male	942.23	197.82	19.78		
Right Maxillary Sinus Perimeter	Female	119.13	10.59	1.06	-6.34	<0.001
	Male	125.48	12.92	1.29		
Right Maxillary Sinus Volume	Female	16273.54	20902.59	2090.26	-282.51	0.90
	Male	16556.06	4652.08	465.21		

The left maxillary sinus parameters were measured and compared between males and females by using the independent t-test. The mean values differences of maxillary sinus parameters like length (mm), height (mm), area (cm^2), perimeter (cm) and volume (cm^2) were found to be statistically significant ($p<0.05$) between males and females (Table-4).

Table-4: Showing the comparative parameters of left maxillary sinus between the genders

Parameter	Sex	Mean	SD	SE of Mean	Mean Difference	P-Value
Left Maxillary Sinus Length (cm)	Female	36.21	3.16	0.32	-1.83	<0.001
	Male	38.04	3.72	0.37		
Left Maxillary Sinus Width (cm)	Female	23.64	3.35	0.33	-0.47	0.31
	Male	24.12	3.25	0.32		
Left Maxillary Sinus Height (cm)	Female	33.52	3.76	0.38	-2.09	<0.001
	Male	35.61	4.49	0.45		
Left Maxillary Sinus Area	Female	858.69	159.99	16.00	-63.49	<0.001
	Male	922.18	178.10	17.81		
Left Maxillary Sinus Perimeter	Female	119.70	10.37	1.04	-4.58	<0.001
	Male	124.28	11.83	1.18		
Left Maxillary Sinus Volume	Female	14584.19	3680.04	368.00	-1999.71	<0.001
	Male	16583.90	4447.17	444.72		

Discriminant analysis was done to evaluate the maxillary sinus parameters for gender determination. All the right and left maxillary sinus parameters was found to be a significant factor ($p<0.05$), except right maxillary sinus width and volume ($p>0.05$) and left maxillary sinus width ($p>0.05$) for gender assessment (Table 3 & 4).

The gender assessment was done by the classification of functional coefficients and accuracy levels for each parameter (Table-5). By using Discriminative statistical analysis, all the right and left maxillary sinus parameters (length, height, area, perimeter and left maxillary sinus volume) was found to be the accurate discriminant parameters for gender assessment. However, the right maxillary sinus volume shows an overall accuracy of 64.5% (Table-5).

Table-5: Showing Discriminative statistical analysis includes classification function coefficients and accuracy levels in gender assessment

Parameter	Female		Male		% Correctly Classified as Constant
	Constant	Coefficient	Constant	Coefficient	
Right Maxillary Sinus Length (cm)	-53.63	2.95	-61.64	3.17	64.00
Right Maxillary Sinus Width (cm)	-23.48	1.92	-24.25	1.95	57.50
Right Maxillary Sinus Height (cm)	-35.32	2.07	-38.64	2.17	57.50
Right Maxillary Sinus Area	-11.86	0.03	-14.22	0.03	61.50
Right Maxillary Sinus Perimeter	-51.54	0.85	-57.10	0.90	63.50
Right Maxillary Sinus Volume	-1.27	0.00	-1.29	0.00	64.50
Left Maxillary Sinus Length (cm)	-55.73	3.04	-61.41	3.19	62.50
Left Maxillary Sinus Width (cm)	-26.41	2.18	-27.45	2.22	55.50
Left Maxillary Sinus Height (cm)	-33.45	1.95	-37.66	2.08	61.00
Left Maxillary Sinus Area	-13.56	0.03	-15.53	0.03	60.50
Left Maxillary Sinus Perimeter	-58.59	0.97	-63.11	1.00	61.50
Left Maxillary Sinus Volume	-7.08	0.00	-8.95	0.00	59.00

In the present study, the final result accuracy in gender assessment analysis shows that 69% of males and 68% of females (Table-6).

So the overall accuracy of the significant parameters in the present study is 68.5% in gender assessment of the given sample (Table-6).

Table-6: Shows the accuracy in the gender assessment

Actual gender	Predicted gender		% Correctly Classified as Constant
	Female	Male	
Female(100)	68	32	68.5
Male(100)	31	69	
Total(200)	99	101	

DISCUSSION

Skull is most commonly found and recovered intact among all the bones of the body, so the morphometric analysis of the skull also aid in gender determination. Variations factors like different ethnic and racial difference, skeletal size, height, genetic & environmental factors, anatomical variations of sinus, pneumatization process of sinus, etc, can also influence the sinus morphometrics [13, 14]. The availability of the entire skeleton gives 100% accurate results in gender assessment of an individual, whereas 98% from both the pelvis and the skull. However, the gender assessment of the skull is not reliable until puberty [15]. In the craniofacial region, the denser bones like maxilla and zygoma are not easily devastated. So many studies had reported the significance of maxillary sinus in gender assessment and reported that the morphometric measurements of the maxillary sinus in males are higher compared to females [13]. In maxillary bone, the maxillary sinuses are the largest airspaces and stabilize after the second decade of life which are properly visualized and measurements adequately with the CBCT scanned images. In the present study was conducted by using the maxillary sinus morphometrics are used as a predictor for gender determination using CBCT scan images of 200 subjects (100 males and 100 females) were taken.

In the present study, significant differences were found in the morphometric measurements of maxillary sinus parameters like length, height, area, perimeter and volume on both right and left sides between the males and females (Tables 3 & 4), this is in accordance to the Enlow explanations that males have bigger lungs to support their massive muscular and body organs. Secondly, the nasal cavity size and shape is wider and larger in males and it depends on the physiological changes [16]. A study by Tambawala SS *et al.*, [2] for comparison between males and females groups, demonstrated that females show statistically significant lower values for both the right and left maxillary sinus parameters like length, height, and width. In accordance to this study, the present study also shows statistically significant differences between genders in relation to the right and left maxillary sinus length, height, area, and perimeter measurements, except the right maxillary sinus width and volume and the left maxillary sinus width, which were not statistically insignificant.

A study by Azhar A *et al.*, [6] and Ayeesha U *et al.*, [17] stated that the left maxillary sinus width was the best discriminative parameter in gender determination with an accuracy of 61.3 % and 60%, in contrast to these studies our results showed that no statistically significant difference between genders in relation to the right and left maxillary sinus width dimensions and remaining other morphometric parameters like length, height, area, perimeter and left maxillary sinus volume shows significant differences between males and females with an overall accuracy of 68.5%.

A study conducted by Teke H *et al*., [13], showed the accuracy to identify gender by using CT is 69.3%, the results obtained in this study were almost similar to our study's prediction accuracy of 68.5%.

Amin MF and Hassan EI [1] concluded that cephalo-caudal (height) measurement of the maxillary sinus as the most reliable predictor for gender determination with an overall accuracy of 70.8% in males and 62.5% in females, which is similar to the present study that the height of the maxillary sinus measurement is statistically significant with an accuracy of 69% in males and 68% in females.

A study by Sharma SK *et al*., [3] for the measurements of maxillary sinus volume was done by CT showed the statistically significant for sinus length and volume and considered that the maxillary sinus length was the best parameter for gender determination with an overall accuracy of 69.8%, which is in accordance with the present study with an overall accuracy of 68.5%.

Other studies for gender determination by Prabhat M *et al*., [18] and Vidya CS *et al*., [19] done on similar populations by using different parameters of maxillary sinus (height, length, volume and width) and showed significant difference found in the right maxillary sinus volume between males and females, whereas in the present study the significant difference found in the left maxillary volume between genders.

A study by Prabath M *et al*., [18], Ayeesh U *et al*., [17] and Ekizoglu O *et al.*, [8] reported that the overall accuracy of the maxillary sinus in gender determination of 77.15%, 71%, and 83.3% respectively, which was higher compared with the present study predilection accuracy of 68.5%.

A study by Sharma SK *et al*., [3] showed that 68.9% of females and 65.16% of males were correctly predicted with overall percentage of 67.3%, while in the present study the predilection accuracy in gender determination is comparatively greater, which showed 68% of females and 69% of males with an overall accuracy of 68.5%.

A CBCT study conducted by Saccucci M *et al*., [10] for gender determination by using maxillary sinus showed that there was no statistically significant difference between gender in relation to the maxillary sinus volume, however, in the present study, the left maxillary sinus showed a statistically significant difference between the males and females.

The study by Fernandes CL [7] stated that the maxillary sinus differs in different ethnic population and found that the European crania having higher antral volume than the Zulu crania and according to the gender, males exhibiting larger volumes than females. In the Zulu racial population, males exhibiting narrow sinuses compared to females, hence the maxillary sinuses being wider in the European population.

In the European population the maxillary sinus parameters like length, height showed a significant difference between males and females, which is in accordance with the present study which also shows statistically significant between the genders.

Thus, the variations in the morphometric analysis of maxillary sinus parameters in various studies may due to the many factors like using different imaging techniques like CT, CBCT or may be done in various racial and ethnic groups with different genetic and environmental factors, which influences the anatomical and physiological alterations of the maxillary sinus morphology, sinus exhibiting differences in bone metabolism and in pneumatization process. This also highlights the further need to conduct the study on maxillary sinus morphometrics as a predictor tool in gender determination on a larger sample and in different racial and ethnic populations.

As most of the earlier studies on sexual dimorphism of maxillary sinus were performed by using computed tomography (CT), but only fewer CBCT imaging studies were performed till date. CBCT as advanced imaging technology has its own potential role in the dental and medical field. Its role in forensic medicine is expanding due to its advantages like a good resolution, low cost and no magnification and less affected by the metallic artifacts than the conventional computed tomography. So, CBCT is thus proven to be advantageous and serves as an alternative predictor tool in gender determination.

Limitations

The limitation includes the small sample size due to the brassbound inclusive and exclusive criteria of the study. There is no accurate statistical formula in determining the sample size and this emphasizes that further studies are needed on a larger and different population to statistically determine the sample size. The other limitation of the present study was that the samples retrived retrospectively and samples were randomly selected.

CONCLUSION

In conclusion, this study shows that the right maxillary sinus parameters in relation to height, length, area, perimeter and left maxillary sinus parameters in relation to height, length, area, perimeter, and volume are considered as the most reliable discriminant significant parameters in gender assessment. This study also proposes that CBCT imaging for assessment of maxillary sinus morphometrics in the forensic field are reliable, reproducible and accurate in gender determination.

We also suggest that the measurement of the maxillary sinus with other skeletal bones can also give an accurate result in the field of forensic anthropology.

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