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MORPHOMETRIC EVALUATION OF FRONTAL AND MAXILLARY SINUSES FOR GENDER DETERMINATION USING CBCT-A RETROSPECTIVE STUDY

Dental Science

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ABSTRACT

The present study was aimed to assess the utility of the dimensions of the frontal and maxillary sinuses in gender determination using CBCT images. This retrospective study included 150 CBCT full skull images which were morphometrically analyzed by two observers. The height, transverse and anteroposterior dimensions of the sinuses were recorded after going through different slices in the various sections of the scans. Volume of the maxillary sinus was also calculated . The results showed a statistically significant difference between males and females with regards to the anteroposterior and transverse dimensions of right and left frontal sinuses and also in the mean height and left anteroposterior dimensions of maxillary sinuses. A higher mean volume of maxillary sinus was noted in males as compared to females. Moreover, discriminant function analysis was performed using both the sinus measurements.

KEYWORDS

Frontal Sinus, Maxillary Sinus, Gender Determination, Transverse Dimension.

INTRODUCTION

Determination of the gender of an unknown person is very crucial in the forensic identification process. The dimorphic characteristics of various human bones like pelvis, skull bones, mandible, clavicle and femur aid in gender estimation (Afrianty et al;2013).The skull is the second most common osseous structure used for forensic investigation after pelvis as it is the most preserved part after death (kiran et al.;2014). The trabecular pattern of the bone, teeth, alveolar bone, contours of cavities and sinuses can be analyzed from the skull bones using different radiographic examinations (Marques et al.; 2014).

Among the skull bones, the frontal bone may be recovered intact in the fragmented remains in most of the cases. Frontal sinuses are paired, irregular shaped paranasal sinuses that are located between the inner and the outer chambers of the frontal bone (Lee et al.;2010). The normal development of frontal sinuses is considered to end by the age of 20 years and it gets stabilized after this age (Shah et al.;2003). Likewise the maxillary sinus dimensions also tend to stabilize after the age of puberty and also remains intact even when the skull bones are badly disfigured (Sharma SK et al.2014).The dimensions of these sinuses were found to be different among males and females and also in both sides (Lee et al.;2010, Sharma et al.2014).

Eventhough various radiographic techniques are available for visualizing these paranasal sinuses (Fatterpekar et al.2008), cone beam computed tomography provides an imaging which is more accessible for the population and also it uses a low dose of exposure to the patient as compared to CT imaging. Frontal and maxillary sinuses can be visualized in the coronal and axial slices of CBCT images and its dimensions can be compared in different sections. Hence CBCT images can be used as a reliable additional method in the forensic investigation purposes (Marques et al.;2014).

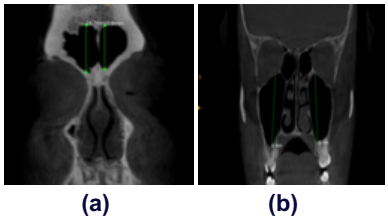
Various studies reported in the literature used either maxillary sinus (Sharma et al.; 2014, Teke et al.; 2007, vidya et al.; 2013) or frontal sinus (Kiran et al.;2014,Lee et al.;2010,Uthman et al.;2010) for gender determination, but very few studies have used them together and were conducted using CT imaging. Most of the studies have not been performed in Indian population. With the above background the present study was designed to assess the utility of the dimensions of the frontal and maxillary sinuses in CBCT images in gender determination in a subset of Indian population.

MATERIALS AND METHODS

The present study included 150 CBCT full skull images (79 males and 71 females) of the subjects with the age range from 20 to 83years, who had given an informed consent for using their CBCT records for research purposes. The images with congenital aplasia of sinuses, evidence of fracture lines or cysts and tumors in the maxillofacial region, the images showing errors and artifacts obscuring visibility of the frontal and maxillary sinuses were excluded from the study.

All the images were assessed using CS 3D (Carestream three dimensional) imaging software. The frontal and maxillary sinus (Height, transverse and antero posterior) dimensions were measured separately on the right and left side in the axial and coronal sections and the greatest measurements were recorded after going through different slices. The axial slices were parallel to orbitomeatal line and coronal slices were perpendicular to this line.

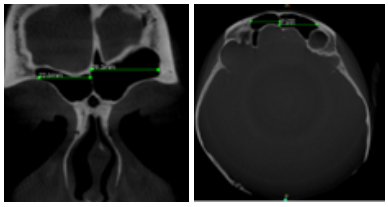
Height was measured in the coronal section as the measurement from the upper most point in the superior wall of the sinus to the corresponding point in the inferior wall of the sinus (Figure a,b).



(a) (b)

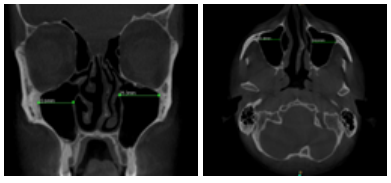
Figure (a) and (b):CBCT images showing measurement of the height of frontal (a) and maxillary sinus (b) from coronal section.

The frontal and maxillary sinus transverse dimensions (width) were measured from coronal and axial sections as the distance between the outermost point in the lateral wall to the medial wall.(Figure c,d,e,f).



(c) (d)

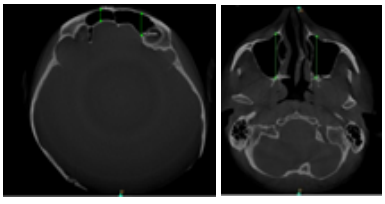
Figure (c) and (d): CBCT images showing measurement of transverse dimensions of frontal sinus from coronal (c) and axial



(e) (f)

Figure (e) and (f): CBCT images showing measurement of transverse dimensions of maxillary sinus from coronal (e) and axial

The antero posterior dimensions were recorded using the axial sections as the longest length anteroposteriorly (Figure g,h).



(g) (h)

Figure (g) and (f): CBCT images showing measurement of anteroposterior dimensions of frontal ((g) and maxillary (h) sinus from axial section.

20 percent of the measurements were made by two observers. The first observer made the measurements twice with an interval of one week between the observations.

Maxillary sinus volume of each side was calculated and recorded using the formula:-
Volume of the maxillary sinus= anteroposterior (axial) X craniocaudal (coronal) X
1/3mediolateral (axial). (Hamdy et al.; 2014)

The inter and intra observer variability was assessed using intraclass coefficient test program and the variability in the frontal and maxillary sinus measurements were analyzed using unpaired student t- test. A p-value of less than 0.05 was considered to be statistically significant.
In order to discriminate between males and females, discriminant analysis was carried out and separate formulas were derived for calculating the discriminant value (D). For frontal sinus, a positive discriminant value denoted female gender and a negative value denoted male gender. For maxillary sinus, a positive value indicated male gender and a negative value indicated female gender. The gender derived from the mathematical equation is compared with that of the actual gender and the results were tabulated.

RESULTS

In the present study, the intraclass coefficient test showed a near perfect to strong agreement for intraobserver and interobserver calibrations respectively.All the evaluated parameters such as height, anteroposterior dimension and transverse dimension (both in the axial and coronal sections) were higher in males as compared to females on both right and left sides. Also a significantly higher mean values were observed in males for transverse dimension in the coronal section and anteroposterior dimension in the axial section on both right and left sides.

Table-1 Frontal sinus measurements for the whole sample (* - statistically significant)

parameters	Males (right)	Females(right)	P value	Males (left)	Females (left)	P value
Height (coronal)	22.5mm ±9.22	20.5mm± 8.09	0.079044	22.8mm ±8.9	21.7mm ±8.6	0.226162
Transverse (coronal)	23.42m m±6.2	21.21mm ±7.1	0.022294 *	24.18m m±7.9	21.82m m±6.7	0.026906*
Transverse (axial)	24.55m m±7.4	23.06mm ±8.05	0.119529	24.82m m±8.84	23.34m m±8.14	0.144017
Anteroposterior (axial)	12.87m m±4.6	10.91mm ±3.6	0.002648 *	13.88m m±4.6	11.71±3.6	0.000874*

The dimensions of the maxillary sinus (height, width /transverse and anteroposterior) were more in males on both the sides as compared to females. A significant difference was noted between the mean height in males and females on both sides .Also a statistically significant difference was observed between the mean anteroposterior dimensions in males and females on left side. The mean volume of the maxillary sinus calculated was significantly higher in males on both right and left sides.

Table 2-Maxillary sinus measurements for the whole sample (* - statistically significant)

PARAMETERS	Males (right)	Females (right)	P value	Males (left)	Females (left)	P value
Height (coronal)	35.54m m±6.2	32.24m m±4.1	0.000127*	35.47m m±6.5	32.07m m±4.7	0.000207*
Transverse (coronal)	25.45m m±4.3	24.77m m±4	0.162587	25.77m m±4.7	25.23m m±4.2	0.229482
Transverse(axial)	26.2mm ±4.5	25.59m m±4.2	0.202686	25.85m m±4.8	25.63m m±3.8	0.383949
Anteroposterior (axial)	38.23m m±3.5	37.39m m±2.9	0.058773	38.26m m±3.8	36.96m m±3.4	0.016015*
VOLUME	12243.16 mm^3 ±4071.3	10545.37mm^3±3547	0.005*	12132.38mm^3±4508.9	10359.82mm^3±1165.2	0.007*

Table 3- Discriminant analysis using frontal and maxillary sinus measurements.

Frontal sinus	D(right) = 2.846 + 0.009 (Height) + (-0.200) (Axial) + (-0.143) (Transverse Coronal) + 0.107 (Transverse Axial)		
	D(left)= 2.598 + 0.038 (Height) + (-0.228) (Axial) + (-0.125) (Transverse Coronal) + 0.099 (Transverse Axial)		
sides	**Accurately predicted males(%)**	**Accurately predicted females(%)**	**Wilk's lambda**
right	**51.89**	**67.6**	**0.9376**
left	58.2	61.9	0.9041
Maxillary sinus	D(right)= -4.235 + 0.229 (Height) + 0.098 (Axial) + (-0.181) (Transverse Coronal) + (-0.035) (Transverse Axial).		
	D(left) = -5.860 + 0.177 (Height) + 0.132 (Axial) + (-0.286) (Transverse Coronal) + 0.103 (Transverse Axial)		
Sides	**Accurately predicted males(%)**	**Accurately predicted females(%)**	**Wilk's lambda**
right	**96.2**	**5.6**	**0.901**
left	**75.9**	**46.47**	**0.884**

DISCUSSION

Frontal sinus

The present study examined the utility of morphometric analysis of frontal and maxillary sinuses in gender identification for forensic purposes on CBCT images.The inter and intraexaminer calibrations which were carried out to determine the reliability of the readings showed a strong agreement between the two readers. These results suggests the good reliability of the height, transverse and anteroposterior dimensions of frontal sinus. This high percentage of agreement allows using frontal sinus measurements for establishing the identification of unknown persons for whom frontal sinus radiographs are available (Uthman et al.;2010).

The results of the present study revealed that either right or left sinus can be used in gender determination as there is no significant

difference between right and left side measurements.The height of the frontal sinus had an insignificantly higher value in males both on the right and left side as compared to females. This variation in the dimensions in males and females could be due to difference in the cranial morphology and hyperpneumatization of sinuses because of high ventilation rate in males (Marques et al.;2014).These findings are similar to the findings reported in literature where the frontal sinus measurements are more in males (Lee et al.;2010,Tatlisumak et al.;2008,Ponde' et al.;2003). Moreover, males showed a significantly higher mean anteroposterior dimension (depth) in both right and left sides as compared to females. These findings are similar to other studies in which they found a statistically significant lower anteroposterior dimensions in females as compared to males (Tatlisumak et al.;2008,Ponde' et al.;2003,Hamed et al.;2014, Lee et al.;2010).

The males showed a higher transverse (coronal section) dimension in the right and left side as compared to females and this difference was significant which is in accordance with another studies reported in literature in which they found a statistically significant lower mean transverse values for females (Tatlisumak et al.;2008, Hamed et al.;2014,Belaldavar et al.;2014). This difference in the measurements with regard to the gender is due to the morphological differences in the cranium which could be due to genetic, nutritional, hormonal or muscular factors (Belaldavar et al.;2014).

Maxillary sinus

In the present study, the height of the maxillary sinus was found to be significantly more in males in both right and left sides as compared to females. Also the left anteroposterior dimension showed a significant difference between males and females. The relatively more massive muscles and body organs in males increases the respiration related needs which requires correspondingly bigger lungs and larger airway. This leads to physiological changes in the nasomaxillary complex which inturn leads to an increase in the size of maxillary sinuses in males (Enlow DH 1990).

There was no significant difference in height between the right and left sides both in males and females which demonstrates a nearly equal size of right and left maxillary sinus in an individual. This is in contrast with other studies which demonstrated an increased height of left maxillary sinuses in both males and females (Sharma et al.;2014,Ahmed et al.;2015). A study conducted by Uthman et al using helical CT images revealed a mean height of 43.3± 4.8mm in right side and 45.1±4.1mm in the left side in males and 39.9 ± 5.2mm for right side and 40 ± 4.8 mm for left side in females (Uthman et al.;2011). The mean height of the maxillary sinus in the present study was found to be a little lesser then that reported in literature which could be due to the racial difference in the subset of population studied and also could be due to the difference in the imaging modality used.

The mean anteroposterior dimension was a little higher in males in both right and left sides as compared to females. This difference with regard to the gender was statistically significant in the left side. This was in accordance with a study conducted in Turkey which reported a significantly higher dimension in males both in the right and left side (Teke et al.;2007). Another study conducted in India using CBCT scans also reported a lesser anteroposterior length in females as compared to males (Tambawala et al.;2016).

The mean anteroposterior values in the right and left maxillary sinuses were almost similar in males but in females the right anteroposterior dimension was greater as compared to left side. The results of the present study were similar to another study conducted in Turkey (Teke at al.;2007). The results were contradicted by studies reported in literature which stated a higher AP dimension in the left maxillary sinus in both males and females (Sharma et al.;2014,Ahmed et al.;2015).Another study conducted in Indian population reported almost similar anteroposterior dimensions in right and left side in both males and females (Tambawala et al.;2016).These differences in various studies could be attributed to multiple factors such as racial variations, special body stature, skeletal size, height and physique of the individual, environmental conditions and pneumatization process of the sinus (Ahmed et al.;2015).

Males showed a little larger transverse dimension in both the right and left side and this difference with regard to the gender was not significant.The findings were supported by other studies which also reported similar measurements in different genders (Sharma et al.;2014,Teke et al.;2007). Also, the measurements obtained in the present study does not show any statistically significant difference between the right and left sides. This indicates that both the sinuses in right and left sides may be considered as identical in size.

Males showed a significantly higher volume in right and left sides as compared to females. This finding is supported by various studies reported in literature (Sharma et al.;2014,Vidya et al.;2013,Karkas S, Kavakli A;2005). The increased volume of the maxillary air cells in the males could be attributed to the increased respiratory need, body stature and physique, genetics and environmental factors, anatomical variations or due to the difference in pneumatization process. The difference in maxillary sinus volume may account for the difference in the shape and morphology of male and female face in the midfacial region (Sharma et al.;2014).

Discriminant analysis using frontal and maxillary sinus measurements for determination of gender.

The discriminant function analysis is used to classify individuals in to two or more groups based on a set of measurements (Kiran et al.;2014). In the present study, the analysis showed a mid point or cut off score of zero. The present study showed that both the right and left frontal sinus measurements provide almost equal accuracy in the prediction of gender. A study conducted in Iraqi population using CT images of frontal sinus in gender determination, revealed an overall accuracy of 76.9% using discriminant function analysis (Uthman et al.;2010). Another Indian study reported an accuracy rate of 67.59% in differentiating males and females using discriminant function analysis (Kiran et al.;2014).The false prediction of gender in the present study could be attributed to the asymmetry and higher inter-individual variability in the morphology of frontal sinuses (Kiran et al.;2014).

In the discriminant function analysis carried out using maxillary sinus dimensions, the mid- point or cut off value was zero. The sub optimal gender prediction observed in the present study could be attributed to the individual variation of the sinuses due to genetic and environmental factors which may lead to variable results (Belaldavar et al 2014).

CONCLUSION

The prominent morphologic and anthropometic characteristics of the frontal and maxillary sinuses are of critical importance and these structures can be used as personal identification tools and most of their measurements show sexual dimorphism. A metric approach of gender determination is more accurate than the morphological method as these structures are more prone to structural and developmental changes. Further studies with larger sample sizes are recommended to establish the role of these cavities in the accurate prediction of gender.

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