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The Role of Cone Beam Computed Tomography in Sex Identification of a Sample of Egyptian Population Using Maxillary Sinus Predictors

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Abstract **Purpose:** to investigate the possibility of sex identification from radiographic maxillary sinus measurements among a sample of Egyptian population. **Materials and methods:** The present study comprised of 100 living non-pathological Egyptians of 200 maxillary sinuses bilaterally 50 males and 50 females aged 20-70 years. All the participants were scanned with cone beam computed tomography (CBCT) for various purposes. Maxillary sinus width, depth, bizygomatic distance and intermaxillary distance were measured from axial images and height was measured from coronal images. All measures were obtained between the widest points of all the sinuses, and volumes of maxillary sinuses on both sides were calculated using the following equation: (Width × Depth × Height × 0.5). **Results:** Non-statistically significant difference was revealed between the right and left maxillary sinuses. All measurement of males showed statistically significantly higher mean values than females. The significant predictors for gender were: sinus volume and inter-maxillary distance. The discriminate functions at group centroids (Group means) were 0.620 for males and -0.620 for females. **Conclusion:** The dimensions and volume of the maxillary sinus of male were found to be larger than those of female. Discriminant function analysis declared that maxillary sinus volume and intermaxillary distance were the best discriminant parameters for sexual dimorphism.

Keywords: *CBCT, maxillary sinus, sex identification, forensic*

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1. Introduction

Post-mortem identification, a forensic procedure, is troublesome to perform. Forensic odontology helps individual identification through those forms from claiming similar dental identification, post mortem profiling from dental records and examination assumes a paramount part in the identification about corpses. Next to the pelvis, the skull is the most reliable sex indicator, yet the determination of sex from the skull is not dependable until following puberty. Skull obliges the most frequent sexing in medico legal situations. It seems to be the principle dependable bone exhibiting sexually dimorphic traits, because skull has a high resistance to adverse environmental conditions over time, resulting in the greater stability of dimorphic features as compared to other skeletal bony pieces [1-7].

The maxillary sinuses appear at the end of the second embryonic month, and they scope their mature sizes and tend to settle at the age of about 20 years when the permanent teeth fully develop. The radiographic pictures may give adequate measurements of maxillary sinuses for use in morphometric forensic analysis that cannot be approached by other means [2,6,7,8,9].

Sexual dimorphism refers to the systemic distinction in the structure (either in shape or size) between individuals of different sexes in the same species. Maxillary Sexual dimorphism is one of its integral aspects as it has been reported that maxillary sinuses remain sound despite the skull and other bones may be badly deformed in victims who are incinerated thus narrowing down the diagnosis toward a correct possibility [6,7,8,9].

Forensic anthropology have used different radiographic techniques to assess paranasal dimensions for sex identification of an individual including measurements on dry skulls, conventional radiography, computed tomography (CT), and cone-beam computed tomography (CBCT). The evolution of Cone-Beam Computed (CBCT) technology in the clinical management of patients is gaining importance in some forensic contexts due to its fast scan time, relatively low cost, beam limitation and improved metric accuracy with isotropic voxel resolutions and simplicity, thus, allowing age estimation and person identification. It gives three dimensional data of an entity within an object that can be studied in an integrated interactive manner. The multiplanar sectioning of the reconstructed data set allows unlimited virtual dissections of the specimen without further physical harm [7,9-13].

2. Materials and Methods

The present study comprised archived data of 100 living non-pathological Egyptians of 200 maxillary sinuses bilaterally 50 males and 50 females aged 20-70 years. Wide age range was included in the study to provide applicable data of sinus identification in different ages in forensic science. All the participants were scanned with CBCT for various purposes using a Promax® 3DMid CBCT device (PlanmecaOy, Helsinki, Finland), at Oral& Maxillofacial Radiology department, Faculty of Dentistry, Cairo University.

The CBCT measurements were gained using "***PlanmecaRomexis viewer 3.5.1.R***" software with the distance measurement tool. The measurements were done on multiplanar coronal and axial images. All the CBCT measurements were done twice at two different sessions and the average of the two measurements was considered the final one.

Coronal and axial images were used for the radiographic evaluation of the inferior and superior walls of maxillary sinus and to observe the anterior and posterior limit of the sinus. Width, depth, bizygomatic distance and intermaxillary distance were measured from axial images; height was measured from coronal images. All measures were taken between the widest points of all the sinuses, and volumes of maxillary sinuses on both sides were calculated using the following equation: (Width × Depth × Height × 0.5).

2.1. Image Analysis

The width: Measuring the longest distance between lateral and medial walls of the sinus from axial cut. (Figure 1).

The depth: Measuring the longest distance from the most anterior point to the most posterior point of the medial wall from axial cut. (Figure 2)

The height: Measuring the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof from coronal cut. (Figure 3)

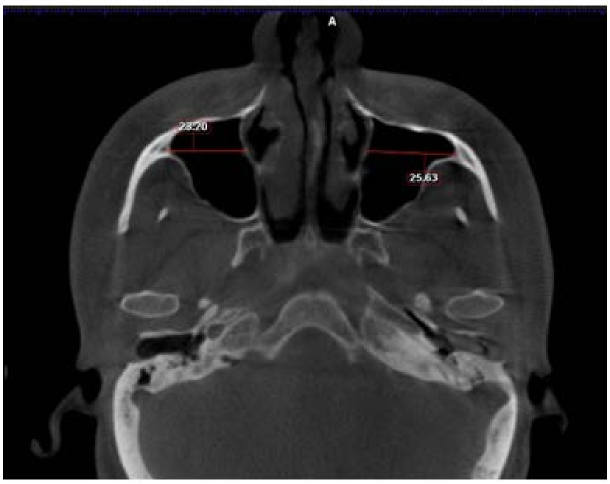

Figure 1. Showing the width distance in axial cut

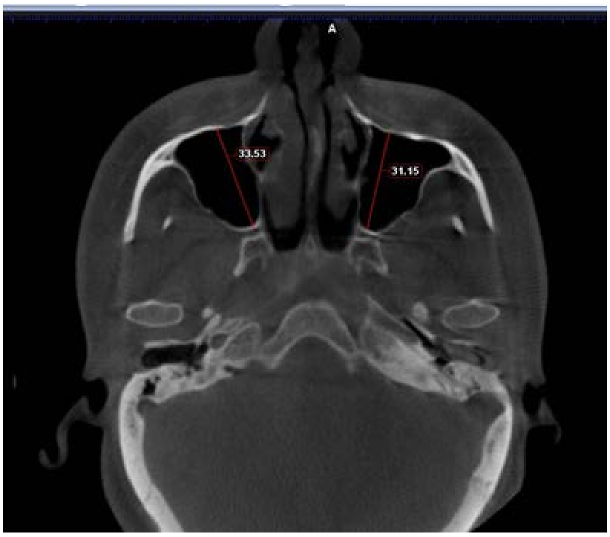

Figure 2. Showing the depth distance in axial cut

Figure 3. Showing height distance in coronal cut

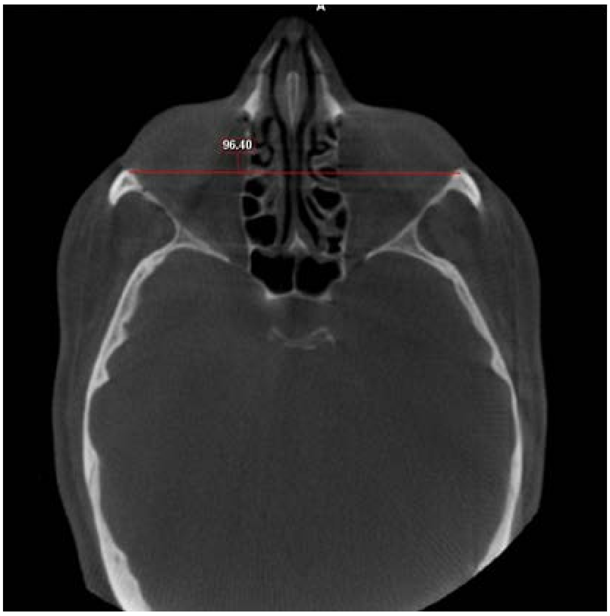

Figure 4. Showing the bizygomatic distance in axial cut

The Bizygomatic distance: Measuring the maximum distance between the most prominent points of the right & left zygomatic arches from axial cut. (Figure 4)

The Intermaxillary distance Measuring the maximum distance between medial walls of right & left maxillary air sinuses from axial cut. (Figure 5)

Two independent well trained radiologists with experience more than 10 years made all the CBCT measurements after appropriate training and working on the software used in this study ***(Planmeca Romexis viewer 3.5.1.R).***

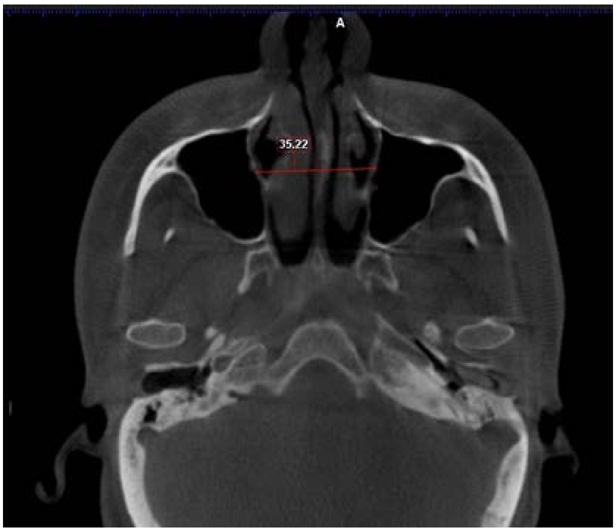

Figure 5. Showing the intermaxillary distance in axial cut

3. Statistical Analysis

Data were presented as mean, standard deviation (SD, minimum, maximum and 95% Confidence Interval (95% CI) values. Paired t-test was used to compare between right and left side measurements. Student's t-test was used to compare between males and females. Cronbach's alpha reliability coefficient and Intra-class Correlation Coefficient (ICC) were used to determine inter-observer agreement.

Stepwise discriminant analysis was conducted to predict gender (Male or Female) from the different maxillary measurements. Stepwise statistics reveals the significant predictors which are used to determine the discriminate function. Then group centroids (group means) are calculated, they represent the determinant points for discrimination between males and females. Finally, classification table represents the percentage of accurately classified cases according to the discriminate function.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM Corporation, NY, USA. SPSS Inc., and an IBM Company. Statistics Version 20 for Windows.

4. Results

4.1. Descriptive Statistics

The present study was conducted on 100 subjects; 50 males (50.0%) and 50 females (50.0%). Descriptive statistics of the present study are presented in Table (1). Comparisons between right and left sides revealed non-statistically significant difference between the two sides, so the mean of the two sides was used in further statistical analysis.

4.2. Inter-observer Agreement

There was a very good inter-observer agreement regarding all measures with Cronbach's alpha values ranging from 0.956 to 0.990.

4.3. Comparison between Males and Females

All measurement of males showed statistically significantly higher mean values than females Table 2.

4.3.1. Gender Estimation

A discriminant analysis was conducted to predict gender (Male or Female). The significant predictors for gender were: sinus volume and inter-maxillary distance.

The discriminate function is:

$$D = 0.093\ sinus\ volume + 0.218\ Inter$$
$$-\ maxillary\ distance - 9.848.$$

The discriminate functions at group centroids (Group means) were 0.620 for males and -0.620 for females.

Classification results revealed that 66.0% of the males were correctly classified while 74.0% of the females were correctly classified according to the prediction equation. Hence, the overall correct classification was 70.0%.

Table 1. Descriptive statistics of the different maxillary measurements

Gender	Measurement	Mean	SD	Minimum	Maximum
Male	width (mm)	24.6	3.8	14.8	33.4
	depth (mm)	33.7	3.4	26.2	41.5
	height (mm)	35.9	5.4	24.8	51.6
	volume (cc)	30.6	10.0	10.8	57.9
	Inter-maxillary distance(mm)	35.0	3.3	26.4	40.8
	Bi-zygomatic distance(mm)	93.5	7.2	80.1	110.7
Female	width (mm)	22.3	3.7	15.2	31.2
	depth (mm)	31.4	3.5	22.4	37.7
	height (mm)	31.4	4.2	22.4	45.1
	volume (cc)	22.7	7.4	9.3	35.8
	Inter-maxillary distance(mm)	32.7	3.2	24.4	39.6
	Bi-zygomatic distance(mm)	88.7	6.3	71.2	100.2

Table 2. Mean, standard deviation (SD) values and results of Student's t-test for comparison between males and females

Measurement	Males (n=50)		Females (n=50)		*P*-value
	Mean	SD	Mean	SD	
Sinus width	24.6	3.8	22.3	3.7	0.004*
Sinus depth	33.7	3.4	31.4	3.5	0.002*
Sinus height	35.9	5.4	31.4	4.2	<0.001*
Sinus volume	30.6	10.0	22.7	7.4	<0.001*
Inter-maxillary distance	35.0	3.3	32.7	3.2	<0.001*
Bi-zygomatic distance	93.5	7.2	88.7	6.3	0.001*

*: Significant at $P \leq 0.05$.

5. Discussion

The skull is the most influencing sexed part of the skeleton. The craniofacial structures have the benefit of being composed largely of hard tissue, which is relatively indestructible [7].

Bones of preadolescent individuals are not effective for sex determination because the secondary sexual characteristics don't appear until the bones are remodeled under the influence of estrogen and androgen at puberty. The reliability of sex determination from maxillary sinus dimensions is not feasible until the maxillary sinus reaches its full size after puberty. To overcome this problem, in this study, samples below the age of 20 were excluded [9].

CBCT is a recently introduced an effective and noninvasive diagnostic imaging modality in clinical dentistry because of its limited radiation exposure and the ability of providing reliable accurate challenging images simulating reality especially in case of massive destruction of the skeleton. Image enhancing soft wares allow the 3-dimensional reconstruction of the CBCT images [7,13].

Due to the complex anatomic structure of maxillary sinuses, CBCT imaging has provided an essential adjunctive radiographic technique for maxillary sinus assessment. Therefore, in this study, we have chosen CBCT for evaluating maxillary sinus dimensions [9].

In this study, the measurements were done by two radiologists. There was very good inter-observer agreement regarding all measures with Cronbach's alpha values ranging from 0.956 to 0.990. One of the limitations of this study was that some selection bias might have occurred by the subjective selection of the slice by each reader.

In This investigation, Comparisons amongst right and left sides uncovered non-factually critical contrast between the two sides, so the mean of the two sides was utilized as a part of further measurable examination.

Against our outcomes, Amin and Hassan 2012 [2] revealed that the estimations of the correct maxillary sinus are bigger than those of the left sinus in females, and these outcomes were acknowledged in Turkey by Teke et al 2007 [14] and affirmed by Uthman et al 2011 [1] and Amusa et al 2011 [15].

Supporting our results, Ekizoglu et al 2014 [3] found that the comparison of values of right and left maxillary sinus estimations in the two guys and females did not demonstrate a huge distinction (for all variables $P > 0.05$).

It has been pronounced in past examinations that the maxillary sinuses are fundamentally bigger in men than in females in most maxillary sinus estimations. To begin with, men need correspondingly greater lungs to encourage their moderately more enormous muscles and body organs. Second, they require a bigger aviation route, which starts with the nose and nasopharynx. Along these lines, physiological changes in nasal hole size and shape happen as an immediate aftereffect of breath related requirements [5,7].

The traditional measurements that are used for morphometric analyses of maxillary sinus are anteroposterior (AP), transverse (T), and cephalocaudal (CC) diameters, and the volume of maxillary sinus which is obtained by means of these parameters [volume = (AP × T × CC) × 0.5)]. Because of complex anatomical characteristics, it must be suggested that the simple measurements, particularly the calculation of volume, are inaccurate and prone to error [3,16,17].

Following our results the mean sinus width for males was 24.6mm, 33.7mm for sinus depth, the mean sinus height for males was 35.9 and the mean volume was 30.6cc. While in females the mean sinus width was 22.3mm, sinus depth 31.4mm, the mean sinus height was 31.4mm and the mean volume was 22.7cc.

In consistence with our results, Gray's Anatomy described the overall measurements of the maxillary sinus to be as 32 mm in anterior-posterior diameter, 25 mm in mediolateral diameter (transverse), and 35 mm in superior-inferior diameter (cephalo-caudal) [2,18].

Sahlstrand-Johnson et al [11] in 2011 assessed the dimensions of 120 maxillary and frontal sinuses using head CT images. They reported that the mean value of the maxillary sinus volume was 15.7 ± 5.3 cm3 and significantly larger in males than in females with no statistically significant correlation between the volume of maxillary sinuses with age or side.

Approximating our results, Baweja et al 2013 [19] assessed the average sinus depth to be 34.1 ± 5.1 mm for male and 33 ± 5.6mm for female. The average sinus AP reported by Baweja et al 2013 [19] was 37.3 ±8.0 mm for male and 36.9 ±7.4 mm for female.

Gender determination is really important for identification. In this study all measurement of males showed statistically significantly higher mean values than females.

Amin and Hassan 2012 [2] estimated that the transverse, cephalo-caudal, and size of the maxillary sinuses of the female were smaller than those of men. cephalo-caudal and size of the left maxillary sinus showed significant differences between males and females.

Fernandes 2004 [20] also confirmed that the maxillary sinuses are larger in males than in females in Europe and these results resembling ours. But in Zululand, the maxillary sinuses are narrower in males than in females. This might a chance to be demonstrated as the maxillary sinus has a racial role or due to the higher ages of the specimens. The study accounted for no significant difference between males and females for the maxillary sinus width. On the other hand, maxillary sinus depth, height and volume indicated significant differences between the sexes. Slight discrepancy between our results and those of Fernandes may be attributed to many factors like different Ethnic and racial groups with difference in body stature, skeletal size, height of an individual; sample size, genetic, environmental factors and pneumatization process of sinus in different age and sex groups with a maximum growth period of the sinus at the third decade in males and at the second decade in females [5,9,17].

Ekizoglu et al 2014 [3] study of the morphometric characteristics of maxillary sinus in Turkish population described that all maxillary sinus measurements of males were significantly higher than those of females ($P < 0.001$). Uthman et al 2011 [1] and Teke et al 2007 [14] also reported greater values for maxillary sinus width, length, and height in males.

In consensus with our results, Masri et al 2013 [8] revealed that the males tended to have larger sizes of all variables of the maxillary sinus (width, depth, height and volume) than those of females, though only height and width showed significant differences.

Emirzeoglu et al 2007 [21] examination of coronal CT filter pictures taken from 77 Turkish patients (38 female and 39 male subjects) matured in the vicinity of 18 and 72 years exhibited critical contrast of maxillary sinus volume amongst guys and females (Males: 19.8±6.3 cm3; Females: 16±5 cm^3) [8].

Jasim and AlTaei 2013 [22] and Jehan et al 2014 [4] confirmed our results that the measurements of the volume and dimensions of maxillary sinuses in both dentate and edentulous groups were larger in males compared with females and they tend to decrease with the older age. These results were also supported by Kanthem et al 2015 [6].

Paknahad et al 2017 [9] reported that while a significant sex difference was found in the length and height of maxillary sinus, there was no significant difference between sexes in maxillary sinus width which is not exactly the same of our findings.

A discriminant analysis was conducted to predict gender (Male or Female). The significant predictors for gender were: sinus volume and inter-maxillary distance. The discriminate functions at group centroids (Group means) were 0.620 for males and -0.620 for females.

Classification results revealed that 66.0% of the males were correctly classified while 74.0% of the females were correctly classified according to the prediction equation. Hence, the overall correct classification was 70.0%.

Amin and Hassan 2012 [2] showed that multidetector computed tomography (MDCT) estimations of cephalo-caudal and size of the left maxillary sinuses are useful component in sex assurance in Egyptians. The investigation detailed that the right prescient exactness was 70.8% in guys and 62.5% in females.

Ekizoglu et al 2014 [3] found that the accuracy rate according to gender was 80% for female gender and 74.3% for male gender (mean accuracy of whole study population was 77.15%). Teke et al 2007 [14] reported rates for the measurements, which was 69.3% for male gender and 69.4% for female gender with overall accuracy rate of 69.3%.

According to the results of Paknahad et al 2017 [9], the classification accuracy was 78% for females and 74% for males with an overall accuracy of 76%. On the other hand, Fernandes et al 2004 [23] reported higher accuracy rate of 79.2%, using different parameters of the skull including maxillary sinus measurements.

Attia et al 2012 [24] study reported that maxillary sinus dimension measurements, especially the right height, are valuable in studying the sexual dimorphism with overall accuracy 69.9%.However, Tambawala et al 2016 [7] and Uthman et al 2011 [1] studies about sex determination from maxillary sinus dimensions using CT scan showed that the maxillary sinus height was the best discriminant parameter that could be used to study sexual dimorphism with an overall accuracy of 71.6%.

Supporting our results, Jehan et al 2014 [4] concluded that the strongest correlated variable with bizygomatic distance was the intermaxillary distance ($r = 0.3037$) in male & AP diameter of sinus ($r = 0.5980$) in female.

Sharma et al 2014 [5] found that 65.16% of guys and 68.9% of females were sexed accurately and the general rate for sexing maxillary sinuses effectively was 67.03% and sinus AP was the best discriminant parameter with a general precision of 69.81%.

The differences in the reported accuracy rates of the previous studies was probably due to diverse ethnic and racial groups, variation in the methodological and statistical analysis applied, different radiographic techniques, and different sample size. Paknahad et al 2017 [9].

6. Conclusion

The dimensions and volume of the maxillary sinus of male were found to be larger than those of female. Discriminant function analysis declared that maxillary sinus volume and intermaxillary distance were the best discriminant parameters for sexual dimorphism.

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