Original Article

Mastoid and Magnum – Hidden Key in Forensics – A Retrospective Three-Dimensional Cone-Beam Computed Tomographic Study

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ABSTRACT

Introduction and Aim: The identification of skeletal remains and decomposing them is the most challenging skill in medicolegal investigations. Gender determination utilizing the skeletal remains has been of keen interest. This study aims to assess the role of the foramen magnum (FM) and mastoids in gender determination through osteometric analysis using cone-beam computed tomography (CBCT).

Materials and Methods: A retrospective analysis of the osteometric measurements in relation to FM (shape, length, width, and area) and mastoid process (length, width, height, angle, area, and intermastoid distance) was assessed in 60 CBCT images in Planmeca ProMax three-dimensional midface machine using Romexis software, taken for the purpose of various dental treatments in the Department of Oral Medicine and Radiology, Meenakshi Ammal Dental College, Chennai.

Results: $P < 0.005$ was obtained through IBM SPSS software version 19 using *t*-test analysis. On analysis of the foramen magnum and mastoid process parameters for gender determination males had higher values than the females. The outcome of this study shows that the mastoid parameters can be more effective in determining the gender when compared to FM.

Conclusion: Throughout history, dental forensics has played a major role in the identification of human remains. CBCT is gaining more popularity in the recent times over the other conventional radiographic techniques because of lesser radiation exposure, better accuracy thus it could widen the frontiers of forensics. With the emerging trends in forensics, this study will reveal the explicit aid of FM and the mastoid process using CBCT in forensic odontology.

Key Words: *Cone beam computed tomography, forensics, foramen magnum, mastoid, osteometric measurements*

Introduction

A man is born into this world with an identity and deserves to die with the same. However, this is impossible at a number of instances such as mass disasters, natural calamities, and inhuman activities which put forth a huge amount of unidentified human bodies with only their skeletal remains retrieved.[1] The identification of these skeletal remains is of paramount importance in medicolegal investigations and anthropological works. Personal identification of an individual in a catastrophic zone is the principal objective of forensics science. Thus, gender determination plays an important role in personal identification as it narrows the probability to 50% in forensics.[2]

Skeletal material is usually analyzed to construct the individuals' biological profile in the absence of soft tissues. Recognition of skeletal remains still remains a challenging task in many cases of massive disasters for forensic odontologists. The pelvis and skull were the most often investigated skeletal components for gender determination.

The craniofacial structures have the advantage of being composed largely of hard tissue, which is relatively indestructible such as the mastoid, foramen magnum (FM), and the occipital condyles.[3] The anatomical position, abundant tissue coverage, and the skull thickness of the FM in the basal region of the occipital bone are likely to survive the physical insults than the other parts of the skull, therefore, makes it relatively well protected, thus preserving it for forensic evaluation. It is a three-dimensional (3D) circular or oval aperture within the occipital bone centrally. FM transmits the medulla oblongata and its membranes. Other structures that pass through FM are the spinal accessory nerve and vertebral arteries.[4,5]

The mastoid process with its compact and protected nature in the skull also serves as an aid in gender determination in forensics.[6,7] It is conical in shape and its prominence projects from under the surface of the mastoid portion of the temporal

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bone, located just behind the external acoustic meatus, and is lateral to styloid process. Certain studies have reported that its morphological characters are valuable in gender determination.[8,9]

Cone-beam computed tomography (CBCT) with its 3D technology provides us with an accurate evaluation of the osseous structures in the maxillofacial region. CBCT with 3D technology and less radiation compared to CT has gained popularity in recent times. This plays a vital role in forensic anthropology. With this background, this study aims to determine the gender with various parameters of FM and mastoid process using archived CBCT images.

Materials and Methods

This study included a total of 60 retrospective analyses of full skull CBCT images from the Department of Oral Medicine and Radiology, Meenakshi Ammal Dental College and Hospital, Chennai, taken using Planmeca ProMax 3D mid proface unit using Romexis software which was taken for various dental procedures. The inclusion criteria included patients of above 20 years of age. Images with any pathology, fractures, and artifacts pertaining to the region of interest were excluded in this study. Images of 30 male and *30* female patients were retrieved to assess various magnum and mastoid parameters of the skull base. The parameters such as the length, width, circumference, and shape are determined in FM. Pertaining to the mastoid process, the parameters such as length, width, height, area, intermastoid distance, and intermastoid angle are determined in the mastoid process.

After reformatting the CBCT images of FM in the axial section, the anteroposterior dimensions (length) and the transverse dimension (width) are measured from the most prominent point with the help of the length measurement tool and noted [Figure 1]. The area is determined with the standard formula of Teixeria's $A = \pi \times ([L + W]/4)^2$ and the area is calculated. The shape of the FM is determined according to the Richards and Jabbour[10] classification; accordingly, the shape of the magnum was found to be circle, semicircle, wide oval, heart, bipointed, birounded, ventrally rounded, and dorsally convergent [Figure 2].

After reformatting the CBCT images of the mastoid process in three planes, the following parameters are measured. In the Axial section the mastoid width i.e., the mediolateral dimension is measured [Figure 3]. In the coronal section, the intermastoid distance is marked between two mastoids of either side and the angle formed between these mastoids gives the intermastoid angle. The sagittal section gives mastoid length which is measured from the portion to the posterior end mastoidale and the height is measured perpendicular from the mastoid length till the tip of the mastoid process. The area of the mastoid is determined with the standard formula $\pi\ (ML/2) \times M$.[11]

All the data collected were tabulated and subjected for statistical analysis using IBM SPSS (Statistical product and service solutions. version 22 2020, International business machine corporation,chicago, Armonk and New York) software version 19. A significant *P< 0.05* was obtained and paired *t*-test was done to see the difference between the gender and the dimensions.

Results

In the present study, a total of 30 males and 30 females were analyzed. The mean age of the study population is 48.2 ± 10 years with gender distributed equally between males and females. FM and mastoid process dimensions were measured to determine the gender. Description statistic was used to find the mean value and t-test was used to analyze the significant association between gender and dimension of FM and mastoid process and a value of $P < 0.05$ was considered statistically significant.

Table 1 shows the dimension of FM. The mean length of FM for males was 37.13 mm and for females was 34.09 mm. The mean width of FM for males was 30.06 mm and for females was 28.91mm. The mean circumference of FM for males and females were 890.10 and 781.35mm^2, respectively [Table 1 and Graph 1]. On comparison of the values between both the gender, males had higher values than females. A significant *P* value of 0.001 (length), 0.042 (width), and 0.035 circumference from t-test indicated a statistical significance between FM length, width, and circumference dimension among gender.

In relation to the shape of FM, the wide oval and ventrally rounded shape were more common among the male gender,

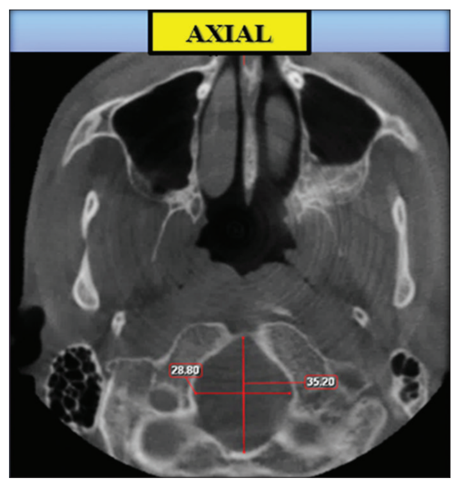


Figure 1: Axial section of foramen magnum with anteroposterior and transverse dimensions

Table 1: Foramen magnum

Parameters	Sex	Mean (mm)	SD	*P*
Length or maximum anteroposterior diameter	Male	37.13	2.88	0.001
	Female	34.09	1.98	
Width or maximum transverse diameter	Male	30.06	2.84	0.042
	Female	28.91	2.48	
Shape of foramen magnum	Male	4.37	2.09	0.265
	Female	3.83	2.43	
Circumference of foramen magnum	Male	890.10	121.6	0.035
	Female	781.35	84.46	

* *P* vale - < 0.05 significant, SD - standard deviation

whereas the circle and birounded shape were more common in the female population. *P >0.05* was obtained in relation to the shape of the FM [Table 1 and Graph 2].

In relation to the mastoid process, the mean length for males and females was 33.06 mm and 27.49 mm, respectively. The mean height of the mastoid process for males and females was 22.37 mm and 18.99 mm, respectively. The mean width for females and males was 16.34 mm and 15.23 mm, respectively. The mean intermastoid distance for males and females was 103.39 mm and 98.30 mm and mean intermastoid angle for males and females were 95.83° and 92.49°, respectively. In relation to the surface area of the mastoid process, the mean value for males and females was 1170.74 and 827.97mm^2, respectively [Table 2 and Graph 3]. On comparison of the values between both the gender, males had higher values when compared to the females. A statistical significant $P < 0.005$ between gender and mastoid process parameters was seen in relation to length (0.000), height (0.026), width (0.015), intermastoid distance (0.002), and surface area (0.000). $P > 0.005$ was obtained in relation to the intermastoid angle. This shows that the mastoid process is lengthier in males when compared with females. The mean value of the mastoid process in males is significantly larger than those in females.

The results showed that all the dimension values of FM and mastoid process are more for males when compared to females; this shows that mastoid and FM show anatomic variability between genders which can be used for gender determination.

Table 2: Mastoid process

Parameters	Sex	Mean	SD	*P*
Length	Male	33.06	3.22	0.000
	Female	27.49	3.53	
Height	Male	22.37	3.55	0.026
	Female	18.99	3.01	
Width	Female	16.34	2.43	0.015
	Male	15.23	2.53	
Intermastoid distance	Male	103.39	5.04	0.002
	Female	98.30	4.71	
Intermastoid angle	Male	95.83	7.93	0.83
	Female	92.49	7.07	
Surface area	Male	1170.74	265.81	0.000
	Female	827.97	225.72	

* *P* value < 0.05 significant, SD - standard deviation

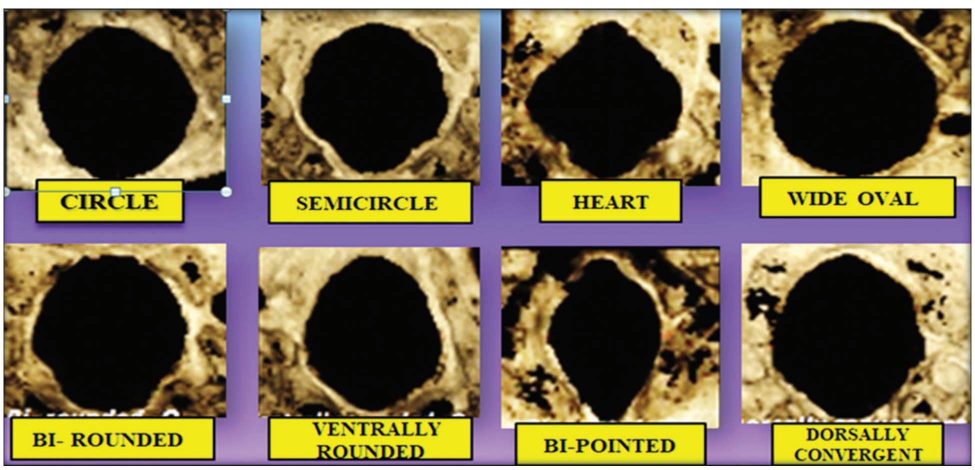


Figure 2: Shapes of foramen magnum- Jabbour *et al*. classification

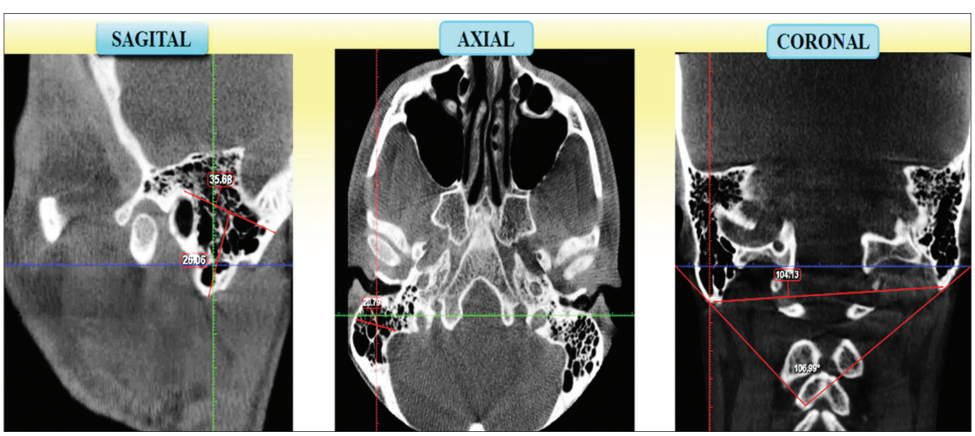
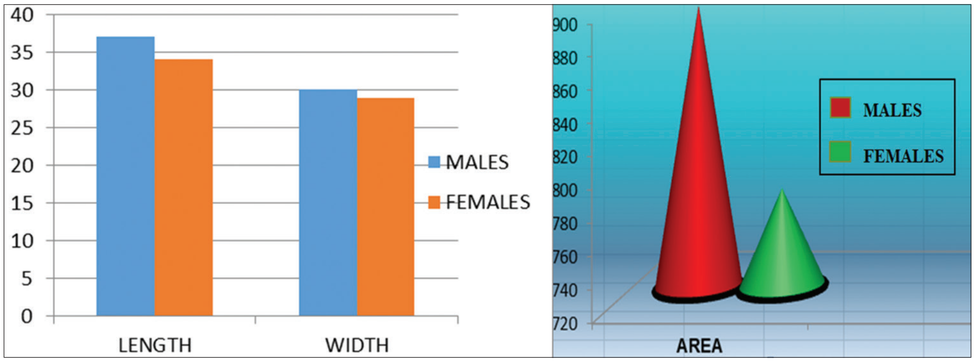
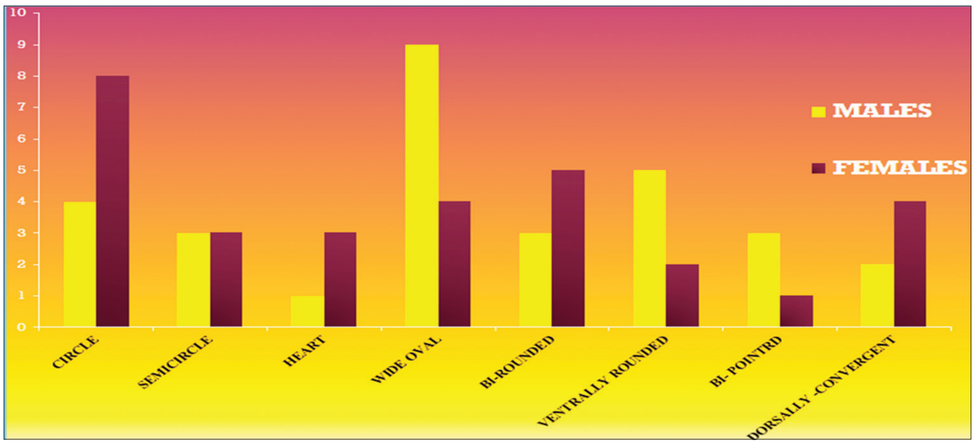


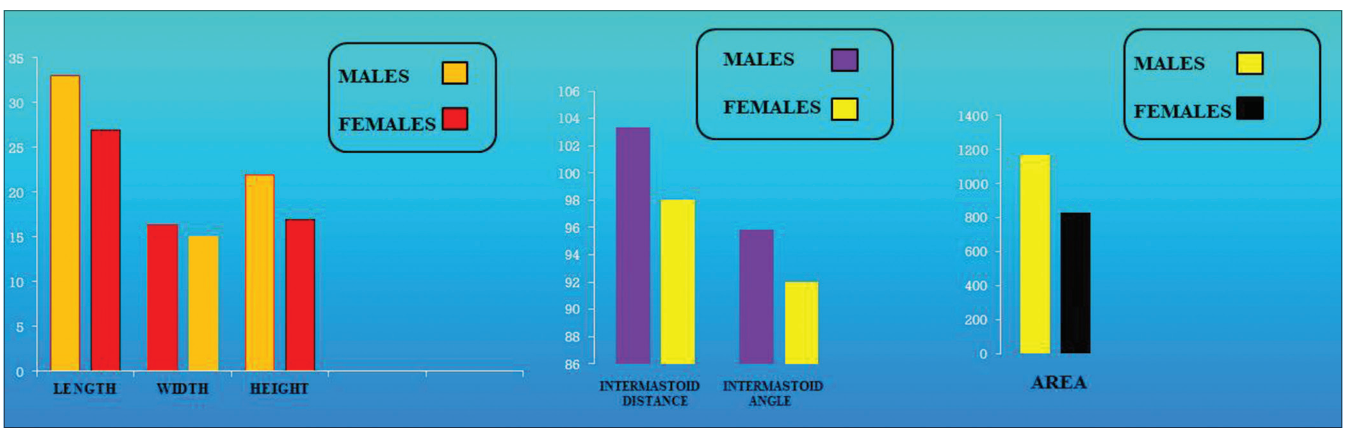
Figure 3: Sagittal, axial, and coronal sections of the mastoid process with measurements



Graph 1: Foramen magnum - mean length, width, and area in males and females



Graph 2: Foramen magnum - predominance of shapes in males and females



Graph 3: Mastoid process - mean length, width, height, intermastoid distance, and angle area in males and females

Discussion

The statistical results of the present study in relation to the mastoid process and FM reveal a significant $P < 0.05$. Therefore, this craniometric assessment can definitely serve as an effective tool in gender determination. On comparison between the mastoid and FM parameters, the mastoid parameters serve more effective than the later.

Various anthropometric gender determination studies (Bhavya *et al*. 2019) with the help of dried skulls were done earlier. Although gender determination is more precise with the pelvis remains, at times during mass disasters is not available. Perhaps, the skull is the next chosen bone for gender determination. Skull being very robust in nature with the mastoid process and the foramen magnum being located in the protected position of the skull base can be readily used as a valuable tool in forensics to detect gender. Hence, this study utilizes the recent imaging modality, the three-dimensional CBCT images for analyzing the osteometric measurements of magnum and mastoid in both the genders. The outcome of this study would be an important frontier in forensics.

The mastoid process parameters such as the length, width, height, intermastoid distance, and area serve in effective gender determination with a confidence interval of 95%. In all these parameters, the males had a higher values when compared with the females. These results from our study were correlating with the following studies.

Manivanan *et al*, 2019, from their study on the osteometric assessment of mastoid process using CBCT, stated that the mastoid process could be used as a reliable indicator in gender determination with a significant *P* value.[8]

Amin, 2015, did an osteometric assessment using mastoid process in the Jordan population. The results of this study proved that mastoid parameters height, length, width, intermastoid distance, angle, and area were reliable in gender determination. Intermastoid angle was not correlating in our study as it was both equal in males and females in our study. This might be due to this alteration in the ethnic races of the population.[12] A study was also done in computed tomography by Deepa Gayathri *et al*., 2017, which also proved the mastoid process to be an effective gender determinator in forensics.[11] Shah *et al* in 2013[13] carried out a study in Gujarat population and determined the accuracy of mastoid process in gender determination. The results showed that there was significant craniometric difference of mastoid triangles among gender. This was also corelating the study done by Kemkes *et al.* in 2006[14] and Patnaik *et al*.[15]

The results of our study in relation to the foramen magnum showed a significant *P* value of < 0.05 on assessing the parameters like foramen magnum length, width and circumference than on comparison with the shape of the foramen magnum. The male population had higher values than females on comparison. The wide oval and ventrally rounded shape were more common in males, whereas in females, the circle and birounded shape were more common. The results of our study were correlating with the following studies. According to a CBCT study done by Saraswathi Gopal *et al*., 2018, among FM and maxillary sinus proved that FM exhibits variability in gender. The wide oval shape in males and circle shape in females were common; this was also correlating with our study. The results of their study also showed that FM width can also be used as a valuable parameter, but this was in contrast with our study.[9] In another CBCT study done by Jaitley *et al*. in 2016, circumference of FM can be taken as the best gender discriminator in forensics, which was correlating with our study.[16]

A study done by Akay *et al*., 2017, among the Turkish population also showed that the magnum parameters such as the length, width, and circumference are effective in gender determination. However, this study was in contrast with our studies in relation to shapes among gender. This may due to the difference in races among population.[17]

Ginay *et al* in 2000, analysed the areas of the foramen magnum which revealed that females had a lower values than males. The authors concluded that area of the foramen magnum could only be used as a supporting indicator for gender identification.[18] Study was the first of its kind to combine the osteometric assessment of both FM and mastoid process for gender determination using CBCT. From our results, we could conclude that both are effective in gender determination, but the mastoid process is more reliable and significant parameters than the FM. Thus, when both the bones are available for gender determination, the highest preference is given to the mastoid process.

Conclusion

Throughout history, dental forensics has played a major role in the identification of human remains. CBCT is gaining more popularity in the recent times over the other conventional radiographic techniques because of lesser radiation exposure, better accuracy thus it could widen the frontiers of forensics. So as dental professionals, we can continue to play a key role by maintaining quality CBCT records of each patient. Thus analyzing these parameters of the foramen magnum and mastoid process for gender determination in the pre and post mortem records would be one important frontier in forensics. Thus, the outcome of the present study proves that mastoid parameters can be more effective in determining the gender when compared to the FM.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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