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Original Research Paper

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GENDER DETERMINATION: THE GREAT HOLE AND THE PYRAMIDAL HOLLOW IN FORENSICS- A 3D CBCT STUDY

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ABSTRACT

INTRODUCTION: Identification of skeletal and decomposing human remains is one of the most difficult skills in forensics. Estimation of gender of skeletal remains is an essential element of any medicolegal investigation. Human skeleton shows sexually dimorphic traits, and estimation of gender of skeletal remains is thus, based on morphological and morphometric examination.

AIM: To determine the presence of sexual dimorphism in Foramen Magnum and Maxillary Sinus of live South Indian individuals using Cone beam Computed Tomography.

MATERIALS AND METHODS: This retrospective study consisted of CBCT images of 50 patients (25 males and 25 females). 3D images of the patients were assessed where, Foramen Magnum measurements (anteroposterior dimension and transverse dimension), circumference and area were obtained from reformatted axial sections and dimensions of right and left maxillary sinuses (craniocaudal dimension, mediolateral dimension, anteroposterior dimension) and volume were measured in coronal and sagittal sections using Romexis software.

RESULTS: The morphometric measurements of the foramen magnum and maxillary sinus facilitate determination of gender.

CONCLUSION:. As crimes have become increasingly sophisticated, new forensic investigation techniques need to be improved and developed following emergence of new advanced imaging and technological resources.

KEYWORDS : Gender, foramen magnum, maxillary sinus, CBCT, Romexis.

INTRODUCTION:

In a scenario with minimum forensic evidence, the identification of sex and ethnicity is a challenge and sex markers that are both accurate and reliable are an asset in investigation. Sex identification is a preliminary step in forensic analysis of skeletal remains and several researchers have attempted to analyse the sex predicting attributes of various parts of the crania[1]. Gender determination in unidentified skeletons is not always an easily and correctly performed procedure. In explosions, warfare and other mass disasters, identification may be extremely complicated because of skeletal fragmentation. The skull, pelvis and femora are the most useful for radiological determination of gender[2]. The length, height and circumference of the foramen magnum (FM) and maxillary sinus (MS) has been used to determine gender in unidentifiable human remains. The FM is an important landmark of the skull base and is of particular interest in anthropology, anatomy, forensic medicine and other medical fields. Maxillary sinuses of various species are known to exhibit sexual dimorphism. However the MS is larger in males than in females in contemporary human populations.

On the other hand, technological advances, such as digital imaging systems, have significantly increased the level of detailed information available to practitioners while mitigating the level of patient radiation exposure.

Based on this background, this study was done to estimate different dimensions of the maxillary sinuses and Foramen magnum to determine gender of an individual and sexual dimorphism.

The aim of the study was to access the measurements of foramen magnum and to assess the measurements of maxillary sinus and to set forth a database that is useful for sex identification.

MATERIALS AND METHODS:

The study was conducted in the Department of Oral Medicine and Radiology and the study group consisted of 50 (25 males and 25 females) South Indian individuals, ranging in age from 18 to 60 years. The 3D CBCT images were taken with PLANMECA PROMAX 3D CBCT unit (fig:1) and was assessed in Romexis software (fig:4).

Inclusion criteria: All CBCT scan images taken for dental purposes, with visible sinus walls and foramen magnum. Exclusion criteria: Maxillary sinuses with pathologies deforming the sinus walls, incompletely visualised images. This Retrospective analysis was carried out within the time period May 2015 to August 2015. No patients were voluntarily given a CBCT exposure for the study purpose.

Foramen magnum (FM) measurements were obtained from reformatted axial sections of CBCT images(fig:5 , fig:6).

- Foramen magnum sagittal diameter (FMAPD) → antero-posterior dimension.
- Foramen magnum transverse diameter (FMTD) → greatest width.

The CIRCUMFERENCE was calculated based on the standard formula $=2*3.14*[(FMSD)^2+(FMTD)^2/2]^{1/2}$

The shape of the Foramen Magnum was estimated based on Richards GD, Jabbour RS (2011)et al classification (fig: 8).

Maxillary sinus (MS) measurements were obtained from reformatted coronal, sagittal and axial sections of CBCT images (fig:7).

- Height of the maxillary sinus (coronal images) → craniocaudal diameter.
- Depth of the maxillary sinus(saggital imagess) → anterioposterior diameter.
- Width of the maxillary sinus(axial sections) .

The VOLUME of maxillary sinus was calculated based on the formula = (HEIGHT × DEPTH × WIDTH × 0.5) % of dimorphism = {(Xm/Xf) – 1} × 100

Fig 1: PLANMECA PROMAX 3D CBCT UNIT

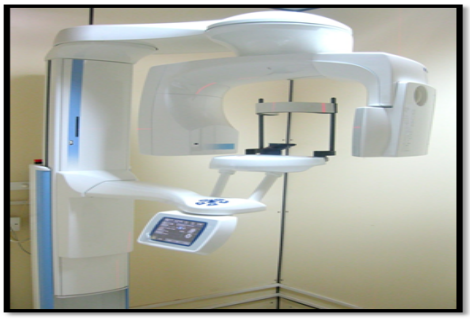


Fig 2: PATIENT POSITIONING WITH LASER MARKERS

Fig 3: PLANMECA PROMAX WORKING PANEL

Fig 4: REFORMATTED IMAGES IN ROMEXIS VIEWER

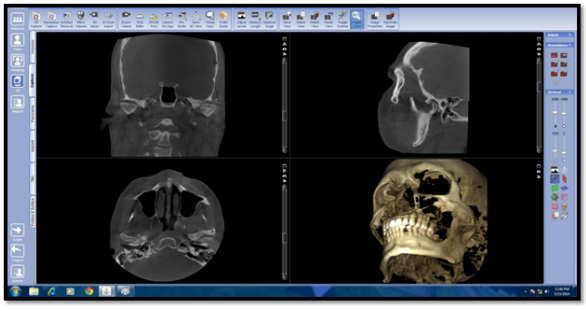


Fig 5: AXIAL SECTION OF FORAMEN MAGNUM

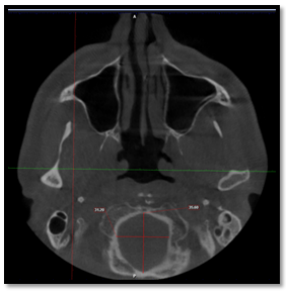


Fig 6: 3D REFORMATTED IMAGE OF FORAMEN MAGNUM

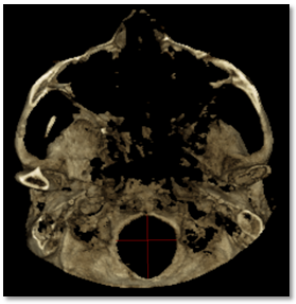
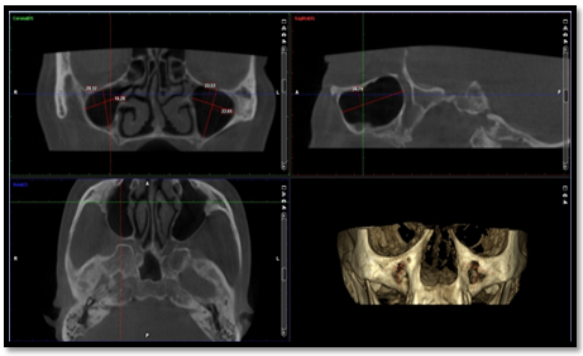


Fig 7: REFORMATTED IMAGE OF MAXILLARY SINUS IN CORONAL, AXIAL AND SAGGITAL SECTIONS ALONG WITH 3D IMAGE



RESULTS:

The results were tabulated and the values were made note of. A total of 25 female and 25 male skull CBCT images were analysed and the shape of FM, its dimensions and MS dimensions were made note of. The shape of FM was categorised based on *Richards GD et al* classification as circular, semicircle, heart like, wide oval, bi- rounded O, ventrally rounded O, bi pointed O, dorsally convergent O. Mean Values Of Foramen Magnum Measurements such as antero posterior dimension and transverse dimension (table:1) were made note of from which the area and circumference were calculated and correlated With Gender. The anatomical Variances of Shape Of FM In Gender Determination were tabulated (table:2). Following this the superoinferior, anteroposterior and mediolateral dimensions of maxillary sinus were measured for right and left sinus in males and females and the volume of MS was derived. The mean values of dimensions and volume of right and left sinus for both populations were calculated and tabulated (table:3) and percentage of sexual dimorphism of MS was calculated (table:4) .

The mean AP dimension of FM in males was 38.2804 and in females was 35.3148, the mean TD in males was 30.2288 and in females was 28.5168, the mean area of FM in males was 910.212 and in females was 792.275, the mean circumference of FM in males was 106.593 and in females was 100.813.

TABLE 1: MEAN VALUES OF FORAMEN MAGNUM MEASUREMENTS CORRELATED WITH GENDER

S. No	Anteroposterior Dimension	Transverse dimension	Area	Circumference	P - Value
Males	38.2804	30.2288	910.212	106.593	0.01
Females	35.3148	28.5168	792.275	100.813	0.01

TABLE 2: ANATOMICAL VARIANCES OF SHAPE OF F. MAGNUM IN GENDER DETERMINATION

S. No	Circular	2 Semi Circle	Heart Like	Wide Oval	Bi-Rounded Oval	Ventrally Wide Oval	Bi-Pointed Oval	Dorsally Convergent Oval
Males	2	1	2	4	1	1	1	3
Females	6	3	3	7	-	4	5	2

FIG 8: 3D REFORMATTED IMAGE OF FORAMEN MAGNUM SHOWING VARIOUS SHAPES

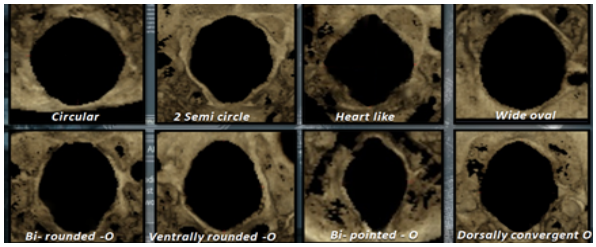


Fig 9: AXIAL SECTIONS OF FORAMEN MAGNUM IN FEMALE POPULATION

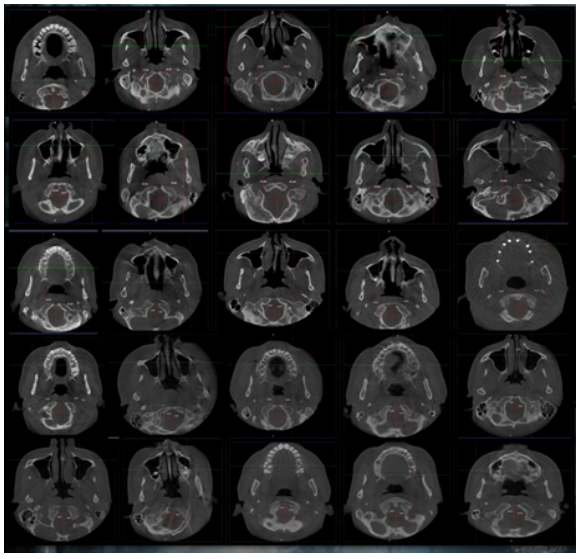
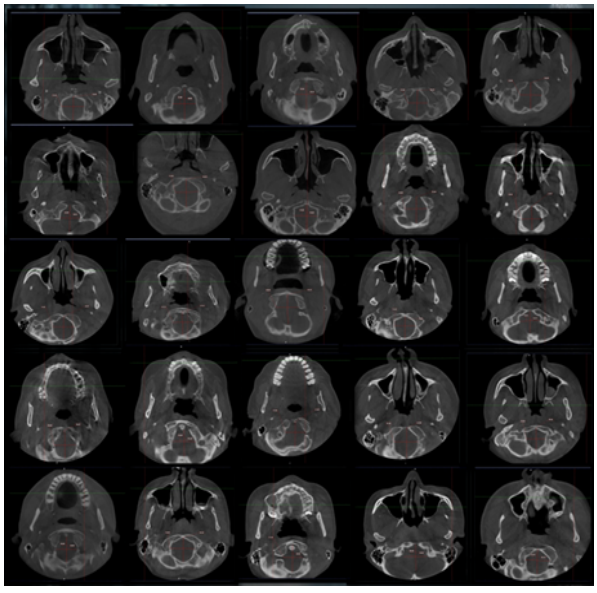


Fig 10: AXIAL SECTIONS OF FORAMEN MAGNUM IN MALE POPULATION



The mean SI dimension of right MS in males was 31.069 and females was 24.5558, left MS in males was 30.31867, in females was 25.151; mean AP dimension of right MS in males was 29.36767 and in females was 23.585, left MS in males was 28.2666 and in females was 23.2176; mean ML dimension of right MS in males was 33.44 and in females was 30.0198, left MS in males was 33.3463 and in females was 305846; mean volume of right MS in males was 26.1919 and in females was 20.2537, volume of left MS in males was 24.5831 and in females was 10.1268. The values were tabulated and the p value was calculated using SPSS software which revealed significant results.

TABLE 3: MEAN VALUES OF THE DIMENSIONS AND VOLUME OF RIGHT AND LEFT SINUS

N-FEMALES= 25 MALES= 25	SUPERO INFERIOR DIMENSION	ANTERO POSTERIOR DIMENSION	MEDIO LATERAL DIMENSION	VOLUME (ml)
MALES (RIGHT)	31.069	29.36767	33.44	26.1919903
MALES (LEFT)	30.31867	28.26667	33.34633	24.5831703
FEMALES (RIGHT)	24.5558	23.585	30.0198	20.2537750
FEMALES (LEFT)	25.151	23.2176	30.5846	10.1268875

TABLE 4: % OF SEXUAL DIMORPHISM OF MAXILLARY SINUS

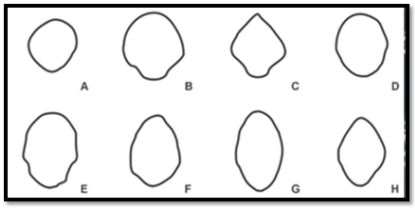
	SUPERO INFERIOR DIMENSION (%)	ANTERO POSTERIOR DIMENSION (%)	MEDIO LATERAL DIMENSION (%)	VOLUME (%)	P- VALUE
RIGHT	26.52408	24.51842	11.39315	81.495	0.05
LEFT	20.54658	21.74674	9.029806	75.281	0.05

DISCUSSION:

Identification of skeletal and decomposing human remains is one of the most difficult skills in forensic medicine. Sex determination is also an important problem in the identification. If almost all the bones composing the skeleton are present, sex estimation is not difficult. When the skeleton exists completely, sex can be determined with 100% accuracy. This estimation rate is 98% in the existence of the pelvis and cranium, 95% with only the pelvis or the pelvis and long bones and 80–90% with only the long bones. However, in explosions, warfare and other mass disasters like aircraft crashes, identification and sex determination are not very easy [2,15]. Next to the pelvis, the skull is the most easily sexed portion of the skeleton, but the determination of the sex from the skull is not reliable until well after puberty. The craniofacial structures have the advantage of being composed largely of hard tissue, which is relatively indestructible [2,16].

The morphometric variability observed in various studies is due to the diverse ethnic groups involved. Studies by Kanodia et al. in 2012 [3,4], Shepur et al. in 2014 [3,5], and Patel and Mehta in 2014 [3,6] are a few recent studies on morphometric variations of the foramen magnum. The study by Kanodia et al. involved 100 normal computerized tomography scans of posterior cranial fossa and 100 dry adult skulls without any bony abnormality; that by Shepur et al. involved 150 dry skulls and 30 CT scan images and Patel and Mehta studied 100 dry adult skulls. In all the studies, the sagittal diameter was significantly larger than the transverse diameter and this is consistent with the shape of the foramen. In almost all the studies, the mean dimensions of the foramen were more in males than in females [3]. This was observed by several authors such as Olivier [3,7], Routal et al. [3,8], Sayee et al. [3,9], Gruber et al. [3,10], and Raghavendra Babu et al. [3,11]. A study similar to the present one in Indian population by Raghavendra Babu et al. using Binary Logistic Regression and Receiver Operating Characteristic revealed a higher predictability of dimensions [3]. Studies by Catalina-Herrera [3,12], Holland [3,13], Uysal et al. [3, 14], and Uthman et al. [2, 3] also conclude that the foramen exhibits sexual dimorphism. The study by Uysal et al. uses Fisher's linear discriminant function test on three-dimensional computed tomography measurements and concludes that 81% accuracy in sexing is possible with foramen width. The circumference and area were the best discriminant parameters for sex determination with an overall accuracy of 67% and 69.3%, respectively [2,3].

FIG 11: FORAMEN MAGNUM SHOWING VARIOUS SHAPES ACCORDING TO RICHARDS, G. D. AND JABBOUR, R. S17



Considering the maxillary sinus, in the present study, the dimensions and volume of maxillary sinuses of right and left side were notably larger in males compared with females. They showed statistically significant values with a higher percentage of sexual dimorphism in the case of volume [18]. Kawarai *et al*. in 1999 did a study on volume quantification of healthy paranasal cavities by three dimensional CT imaging in 20 Japanese subjects and confirmed that paranasal sinuses were individually and on the whole, apparently larger in case of males than females [18, 19]. Fernandes and Sahlstrand-Johnson *et al*. stated that the mean value of the maxillary sinus volume was significantly larger in males than in females. In addition to this, Fernandes, found that the European crania had significantly larger maxillary sinus volume than Zulu crania [18, 19, 20]. In case of Egyptians cephalocaudal and size of the left maxillary sinuses are a useful feature in gender determination [18, 21]. Teke *et al*. in 2007 studied width, length and the height of the maxillary sinus in 127 adult patients by CT and observed that the measurements of the maxillary sinuses of males are larger than those of females. The mean estimated rate of gender was detected at 69.3% [18, 22]. Accordingly Uthman *et al*., maxillary sinus height was the best discriminate parameter that could be used to study sexual dimorphism with overall accuracy of 71.6% [18, 23]. Attia *et al*. study concluded that maxillary sinus dimension measurements, especially the right height, are valuable in studying the sexual dimorphism with overall accuracy 69.9% [18,24].

The present study reveals statistically significant increase in APD, TD and area of FM were noticed in males compared to females. However shape was almost similar in both sexes (most common-oval) and the height, length, width and volume of maxillary sinuses on each side of males were slightly more compared with females giving us statistically significant results thus coinciding with previous authors.

CONCLUSION:

Gender determination is an important step in forensic science. The result of the present study has demonstrated that the Foramen Magnum and the Maxillary sinus exhibits an anatomic variability between the genders. This can thus be used in correlation with other available skeletal parameters for gender determination when complete skeleton is not available.

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