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Gender Determination by Morphometric Analysis of Maxillary Sinus, Orbital Index and Foramen Magnum: A Retrospective CBCT Study

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Abstract

Background: Gender determination is a crucial aspect of forensic anthropology, playing a vital role in the identification process of unknown human remains. Recent advancements in imaging technologies, particularly Cone Beam Computed Tomography (CBCT), have the way for more accurate and non-invasive methods of gender estimation through morphometric analysis.[1]

The maxillary sinus, orbital index, and foramen magnum are anatomical structures that exhibit sexual dimorphism, meaning their dimensions differ between males and females.[1] The maxillary sinus, located within the maxillary bone, shows distinct variations in size and shape based on gender. Similarly, the orbital index, which is the ratio of the orbital height to its width, varies significantly between the gender.[2] The foramen magnum, a crucial structure at the base of the skull, also presents measurable differences in size and shape between males and females.[3]

This retrospective study aims to evaluate the efficacy of using CBCT to determine gender through the morphometric analysis of these anatomical structures.

Aim and Objectives: Aim of the study is to determine gender using morphometric analysis of maxillary sinus, orbital index &foramen magnum using CBCT.

Objectives of the study is to evaluate the morphometric analysis of maxillary sinus of height, width and depth, morphometric analysis of orbital index of height and width and to evaluate the morphometric analysis of foramen magnum of length width and shape.

Methodology: 90 CBCT images of patients were taken from the department database. The DICOM data will be imported to ROMEXIS 6.1.0 software. The age group selected between 13 and above.

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Maxillary Sinus: Axial view: a) The width was the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the lateral process of maxillary sinus in axial view. b) The depth was defined as the longest distance from the most anterior point to the most posterior point of the medial wall in the axial view. In coronal view a) The height was measured away from the inner surface of the anterior border of maxillary sinus and was defined as the longest distance from the lowest point of the sinus floor to the highest point of sinus roof in the coronal view.

Orbital Index: In coronal view a) Orbital height: Highest distance between the superior and inferior

orbital margin. b) Orbital width: Maximum lateral curved distance between the medial margin and lateral margin of the orbit.

Foramen Magnum: a) In axial view the anteroposterior dimension and transverse dimension are measured from the most prominent point. b) The shape of the foramen magnum determined based on the Richards and Jabbour classification. c) Shape of the magnum was found to be circle, semicircle, wide oval, heart, bipointed, birounded, venterally rounded and dorsally convergent.

Results: There were about 48.8% of males and 51.2% of females in the study. there is a significant difference in length, height and width of maxillary sinus between males and females and hence, maxillary sinus can be used as an effective parameter in gender determination. The length of orbital index was more in males than females and width of orbital index was less in males than females the mean differences between the gender was found to be statistically non-significant. The mean length and width of foramen magnum was more in males than females. This mean difference was found to be statistically significant (p-value=0.01), indicating foramen magnum's length, width and area can be used as an effective parameter in sex determination.

Conclusion: CBCT-based morphometric analysis of the maxillary sinus, orbital index, and foramen magnum is a reliable method for gender determination. This approach shows great potential for enhancing forensic anthropological practices and assisting in the identification of human remains. Future research should focus on validating these findings across larger and more diverse populations and exploring additional cranial landmarks to further improve the robustness of gender determination methods.

Keywords: Cone beam computer tomography (CBCT), Maxillary sinus, Orbital index, foramen magnum.

INTRODUCTION

Teeth are the most hardest and robust tissues of the human body. They are often resistant to decomposition even in major accidents, crime, burial, or other severe exposure to the elements. Forensic dental identification plays a primary role in the identification of remains when postmortem changes, traumatic tissue injury, or lack of fingerprint record invalidate the use of visual or fingerprint method.[1,2] Several craniofacial indices have been used to determine the identity. The OI is one of the craniofacial indices used to estimate the gender of unknown people. The human orbit is a complex anatomic region.[3] Each of its four bony walls has its own unique features and is perforated by a number of fissures and foramina that carry important nerves and blood vessels.[3] One well-utilized parameter of orbital morphology is the orbital index (OI) which is defined as a ratio between the orbital height to its width.[4] Foramen Magnum (FM) reaches its maximum size early in childhood and is not affected by secondary sexual changes. Considering the complex structure of maxillary sinuses, magnetic resonance imaging (MRI) and computed tomography (CT) are the gold standard methods to depict the true anatomy of the Highmore's antrum.[5] Nevertheless, their use is limited by high dose, cost, or restricted accessibility. These drawbacks were overcome with the introduction of cone-beam computed tomography (CBCT).[6]

MATERIALS AND METHOD

Inclusion Criteria:

- Full skull CBCT images covering the posterior maxillary region.
- CBCT images having good resolution and image clarity

Exclusion Criteria:

- CBCT images with maxillofacial trauma involving PH fracture.
- CBCT images with pathology in the posterior maxillary region and bone disorders such as osteoporosis or skeletal asymmetries were excluded.
- CBCT images with artifacts.

Method

90 CBCT images of patients were taken. These scans were performed by planmeca Promax 3D Mid Proface in a standing position. The age group selected between 13 and above. The DICOM data will be imported to ROMEXIS 6.1.0 software.

1) Orbital Index:

a) Orbital height: Highest distance between the superior and inferior orbital margin.

b) Orbital width: Maximum lateral curved distance between the medial margin and lateral margin of the orbit.

2) Foramen magnum:

In axial section the anteroposterior dimension and transverse dimension are measured from the most prominent point.

Maxillary Sinus

1) Axial view:

a) The width was the longest distance perpendicular from the medial wall of the sinus to the most lateral wall of the lateral process of maxillary sinus in axial view.[7]

B) The depth was defined as the longest distance from the most anterior point to the most posterior point of the medial wall in the axial view.[8]

c) The height was measured away from the inner surface of the anterior border of maxillary sinus and was defined as the longest distance from the lowest point of the sinus floor to the highest point of sinus roof in the coronal view.[9]

RESULTS

Table 1: Demographic details of study participants

Gender	n (%)	Mean Age (Mean ±S.D)
Males	44 (48.8)	34.40±12.27
Females	46 (51.2)	36.60±13.73
Total	90 (100)	35.50±13.1

Table 1 shows demographic details of study participants. There were about 48.8% of males and 51.2% of females in the study. The mean age of males was 34.40±12.27 and mean age of females was 36.60±13.73.

Table 2: Comparison of length of maxillary sinus (axial view) in right and left side between males and females

Side	Length of Maxillary sinus (axial view)			
	Male (Mean ±S.D)	Female (Mean ±S.D)	Mean difference	p-value
Right	36.09 ±4.25	34.13 ±4.77	1.96	0.04*
Left	35.13 ±5.52	33.16 ±4.09	1.97	0.04*

Independent sample t-test; *p-value<0.05-statistically significant

Table 2 shows comparison of length of maxillary sinus (axial view) in right and left side between males and females.

Interpretations

In right side, the mean length of maxillary sinus was more in males (36.09 ±4.25) than females (34.13 ±4.77). This mean difference of 1.96 was found to be statistically significant (p-value=0.04).

In left side, the mean length of maxillary sinus was more in males (35.13 ±5.52) than females (33.16±4.09). However, this mean difference of 1.97 was found to be statistically significant (p-value=0.04).

This indicates that there is a significant difference in length of maxillary sinus between males and females and hence, length of maxillary sinus can be used as an effective parameter in sex determination.

Table 3: Comparison of width of maxillary sinus (axial view) in right and left side between males and females

Side	Width of Maxillary sinus (axial view)			
	Male (Mean ±S.D)	Female (Mean ±S.D)	Mean difference	p-value
Right	25.71 ± 4.86	23.35 ± 4.64	2.36	0.02*
Left	24.60 ± 5.96	22.4 ± 3.76	2.2	0.03*

Independent sample t-test; *p-value<0.05-statistically significant

Table 3 shows comparison of width of maxillary sinus (axial view) in right and left side between males and females.

Interpretations

In right side, the mean width of maxillary sinus was more in males (25.71 ±4.86) than females (23.35 ±4.64). This mean difference of 2.36 was found to be statistically significant (p-value=0.02)

In left side, the mean length of maxillary sinus was more in males (24.60 ±5.96) than females (22.4 ±3.76). This mean difference of 2.2 was found to be statistically significant (p-value=0.03)

This indicates that there is a significant difference in width of maxillary sinus between males and females and hence, width of maxillary sinus can be used as an effective parameter in sex determination.

Table 4: Comparison of height of maxillary sinus (Coronal view) in right and left side between males and females.

Side	Height of Maxillary sinus (Coronal view)			
	Male (Mean ±S.D)	Female (Mean ±S.D)	Mean difference	p-value
Right	33.38 ±6.84	30.6 ±5.49	2.78	0.03*
Left	41.0 ±6.32	38.2 ±6.93	2.8	0.04*

Independent sample t-test; *p-value<0.05-statistically significant

Table 4 shows comparison of height of maxillary sinus (Coronal view) in right and left side between males and females.

Interpretations

In right side, the mean height of maxillary sinus was more in males (33.38 ±6.84) than females (30.60 ±5.49). This mean difference of 2.78 was found to be statistically significant (p-value=0.03).

In left side, the mean height of maxillary sinus was more in males (41 ±6.32) than females (38.2 ±6.93). This mean difference of 2.8 was found to be statistically significant (p-value=0.04).

This indicates that there is a significant difference in height of maxillary sinus between males and females and hence, height of maxillary sinus can be used as an effective parameter in sex determination.

Table 5: Comparison of length of orbital index (coronal view) in right and left side between males and females

Side	Length of orbital index (coronal view)			
	Male (Mean±S.D)	Female (Mean±S.D)	Mean difference	p-value
Right	36.60±2.68	36.23±3.30	0.36	0.56
Left	36.38±3.19	35.32±3.43	1.05	0.13

Independent sample t-test; *p-value<0.05-statistically significant

Table 5 shows comparison of length of orbital index (coronal view) in right and left side between males and females.

Interpretations:

In right side, the mean length of orbital index was more in males (36.60 ±2.68) than females (36.23 ±3.30). This mean difference of 0.36 was found to be statistically non-significant.

In left side, the mean length of orbital index was more in males (36.38 ±3.19) than females (35.32 ±3.43). This mean difference of 1.05 was found to be statistically non-significant.

Table 6: Comparison of width of orbital index (coronal view) in right and left side between males and females

Side	Width of orbital index (coronal view)			
	Male (Mean ±S.D)	Female (Mean ±S.D)	Mean difference	p-value
Right	31.60 ±2.14	32.21 ±2.79	-0.6	0.25
Left	31.38 ±2.88	31.93 ±3.86	-0.54	0.37

Independent sample t-test; *p-value<0.05-statistically significant

Table 6 shows comparison of width of orbital index (coronal view) in right and left side between males and females.

Interpretations

In right side, the mean width of orbital index was less in males (31.60 ±2.14) than females (32.21 ±2.79). However, this mean difference of -0.6 was found to be statistically non-significant.

In left side, the mean width of orbital index was less in males (31.38 ±2.88) than females (31.93 ±3.86). However, this mean difference of -0.54 was found to be statistically non-significant.

Table 7: Comparison of length, width and area of foramen magnum (axial view) between males and females

Side	Foramen magnum (axial view)			
	Male (Mean ±S.D)	Female (Mean ±S.D)	Mean difference	p value
Length (mm)	37.53 ±1.88	33.91 ±1.91	3.62	0.01*
Width (mm)	30.12 ±1.76	27.92 ±2.62	2.2	0.01*
Area (mm2)	998.14±112.3	750.258±2.23	247.882	<0.001*

-Independent sample t-test; *p-value<0.05-statistically significant

Table 7 shows comparison of length and width of foramen magnum (axial view) between males and females.

Interpretations

The mean length of foramen magnum was more in males (37.53 ±1.88) than females (33.91 ±1.91). This mean difference of 3.62 was found to be statistically significant (p-value=0.01).

The mean width of foramen magnum was more in males (30.12 ±1.76) than females (27.92 ±2.62). This mean difference of 2.2 was found to be statistically significant (p-value=0.03).

The mean area of foramen magnum was more in males (998.14±112.3) than females (750.258±2.23). This mean difference of 247.88 was found to be statistically significant (p-value<0.001).

This indicates that there is a significant difference in length, width and area of foramen magnum between males and females and hence, foramen magnum's length, width and area can be used as an effective parameter in sex determination.[10]

DISCUSSION

This study compared the length and width of maxillary sinus, orbital index and foramen magnum

between males and females and also explored to identify if any gender differences are present in these parameters.[11]

Identification of human remains especially after crime scenes, sexual assaults and disasters is crucial and forensic sciences play a vital role in this identification process.[12] The forensic anthropologists consider that identification of age, gender, race and stature in body remains as very important.[13] Among these, gender identification is believed to be of utmost importance.[14] Lip prints, finger prints can help in the gender identification to an extent; however it should also be noted that the risk of contamination of body remains with external environment can hinder this identification process.[15] Many studies have proved that pelvic remains were useful in gender identification.[73] However, it is not always possible to obtain pelvic bones during mass disasters.[16] In such situations, skull bone can be used for gender identification as it is robust in nature and has fewer chances to get damaged grossly.[74]

Few studies have explored the gender differences in various parts of skull bone.[70,71] The present study is one of the very first studies to explore the gender differences in length and width of maxillary sinus, orbital index and foramen magnum using CBCT.[17] Foramen magnum being in a much protected area under the base of the skull can be a valuable tool for gender identification.[18] On the other hand, maxillary sinus is very intact and resists physical insults such as violence and explosions and can be used as a tool in forensic sciences.[19] Few gender identification studies have been conducted using orbital apertures because of the morphological variations present between the males and females. Hence, maxillary sinus, foramen magnum and orbital index were used in the present study to find out the gender differences.[20]

From the study results, it has been proved that there was a significant difference in length and height of maxillary sinus between males and females and hence, height and length of maxillary sinus can be used as an effective parameter in sex determination.[21] Also, length, width and area of foramen magnum were found to be statistically significant between males and females.[22]

From the study results, it is evident that the parameters related to foramen magnum can be used as an effective tool in sex identification.[23] This difference is possibly due to wide oval and rounded shape of foramen magnum in males and birounded shape of magnum in females.[24] The present study results were found to be in line with a CBCT study (Saraswati Gopal et al., 2018)[46] where shape of foramen magnum parameters showed variability based on gender.[25] In a CBCT study conducted by Jaitley et al., in 2016,[75] circumference of foramen magnum was found to have statistical significant difference between males and females. However, the present study results contrasted with few other studies. Akay et al., (2017) conducted a study among Turkish population and it was found to be less effective.[76] This might be due to difference in race between Indians and Turkish.[27]

Rossi et al. in 2012 conducted a study on 97 human skulls to evaluate the role of the orbital aperture dimensions in gender identification through PA Caldwell radiographic view.[77] The authors concluded that the orbital measurements such as width, area, and interorbital difference in both the genders were statistically significant. Sangvichien et al. evaluated 101 Thai human craniums and concluded the existence of significant difference between the males and females for orbital parameters.[78] One more study conducted by Ghorai et al. stated that orbital width and interorbital distance were significantly differed between males and females.[79] However, all the above studies showed contrasting results to the present study where no statistically significant difference is proved in orbital parameters between males and females.[28] This could be attributed to the racial difference present between Brazilians, Thai and Indians. However, one Indian study was done on 72 human skulls and affirmed that there is no statistically significant difference present in orbital height, breadth between males and females.[29] These results substantiated the present study findings.[80] However, it should also be noted that all other studies were conducted on skulls, whereas this is one of the very few studies to evaluate the orbital indices in CT scan, thus increasing the validity of the study.[30]

The study results with respect to maxillary sinus were found to be in line with many other studies.[31] In a study conducted by Kanthem et al[81], it was concluded that the dimensions of right and left maxillary sinuses were larger in males than females. Kawarai et al.(1999)[82] quantified the volume of healthy paranasal cavities through three dimensional CT imaging and concluded that paranasal sinuses were larger in males than females.34 Fernandes and Sahlstrand-Johnson et al. conducted a study in European crania and concluded that the maxillary sinus volume was significantly larger in males than in females.[83] Teke et al. in 2007 studied width, length and the height of the maxillary sinus in 127 adult patients by CT and

concluded that the measurements of the maxillary sinuses of males were larger than those of females.[84] In a study conducted by Uthman et al., maxillary sinus height was found to be the best discriminate parameter for gender identification.[85] In a study conducted by Attia et al., it was concluded that maxillary sinus dimension measurements, especially the right height, are valuable in studying the sexual dimorphism with overall accuracy 69.9%.[86] Vidya et al.,[87] in 2013 studied 30 dry skulls of south Indian origin. The results showed the measurements and volume of maxillary sinus of males were slightly more compared with females. The left width and right sided volume showed statistically significant values.[33]

CT scans are found to be an excellent diagnostic tool as it has good image modality and is used when detailed information is not available from standard radiographs.[34,35] CT scans usually provide accurate images of paranasal sinuses, orbital index and hence measurements can be made more precisely.[86] Previous studies have proved that CT is useful in identifying maxillary sinus measurements and also shown significant differences between males and females.[82,83] For these reasons, CT scan imaging was used in the present study to determine maxillary sinus, orbital index and foramen magnum dimensions.[37]

Sex determination is considered to be crucial especially during mass disasters. Usually DNA tracing and finger prints might be unavailable in such cases and hence, skull bones can be used as an effective tool in sex determination.[38] According to this study results, parameters such as maxillary sinus and foramen magnum of skull can be used as effective parameters in sex determination.[39]

This study also has few limitations. First, orbital index was not found to be statistically significant and this might be due to the smaller sample size of the present study.[40] A larger sample size in future studies can evaluate this parameter for sex determination more accurately. Second, the retrospective nature of the study which is less reliable can be a limitation. Third, not carrying out Reciever operative characteristics analysis and not assessing sensitivity and specificity of the parameters can be considered as one of the limitations.[41] Hence, future studies with larger sample size with prospective nature is recommended. Also, assessment of sensitivity and specificity of these parameters should be assessed in future for obtaining more reliable results.[42]

However, within the limitations, it was proved that maxillary sinus and foramen magnum parameters showed significant difference between males and females and hence can be considered in sex determination in forensics.[43]

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