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Forensic Odontology: Original Research Article

Evaluation of Orbital Morphometry Using 3D Computed Tomographic Images in Biological Sex Determination: A Retrospective Study

Sudhaa Mani Mani, Yasmeen Ahamed S, Ambiga P, Valarmathi Ramalingam, Sivaraman G, Balan N

Department of Oral Medicine and Radiology, Vivekanandha Dental College for Women, Tiruchengode,Tamilnadu, India

Abstract

Background: Forensic science, also known as Criminalistics is a field of science that uses science for investigation and its application in civil and criminal proceedings. One of the main challenges is to identify the dead during criminal and mass disaster investigations. **Aim:** The study aims to evaluate the morphometry of the orbital aperture and to verify its relationship with biological sex discrimination using three-dimensional Computed Tomography (3D CT). **Study Design:** This retrospective study involves 100 3D CT images of 50 males and 50 females (age 18-60 years). **Materials and Methods:** The exclusion criteria were congenital anomalies affecting the head and neck region, orbital fracture, systemic diseases affecting bone and head and neck tumor. Eight orbital parameters such as Orbital width, orbital height, orbital roof length, orbital floor-length, lateral orbital wall length, medial orbital wall length, intraorbital distance, and extra orbital distance were measured for all the 3D CT images using RadiAnt DICOM Viewer (64 bit). **Statistical Analysis:** Descriptive statistics including mean, standard deviation, and percentage distribution were calculated. Mann Whitney U-test assessed the comparison between groups. The linear regression equation and Wilk's lambda were also calculated for every parameter. **Results:** All the orbital measurements except for intraorbital distance were statistically significant between male and female subjects. Totally, 92.0% of the individuals were correctly classified. **Conclusions:** Orbital measurements were significantly larger in males than in females. Orbits exhibit the least dimensional change throughout one's life. Hence, it could be used as an adjunct in biological sex determination.

Keywords: Biological sex determination, forensic science, orbital aperture, three-dimensional computed tomography

Introduction

Forensic science, also known as criminalistics is the field in which science is applied for the proceedings of civil and criminal lawsuits. The main problem faced by a forensic scientist is the establishment of the identity of an individual. Biological sex determination and age estimation are of paramount importance in the forensic field for the recognition of a person. Though the determination of biological sex can be done by DNA analyses, this procedure is costly and time-consuming in mass disasters like tsunamis, earthquakes, wars, or accidents. Hence the recovery and analysis of skeletal remains of the individual play main role in biological sex determination as the data from previous studies have shown that biological sex can be determined in 98% of cases using the entire skeleton and in 90% of cases using the skull alone.[1,2]

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In terms of biological sex determination, orbit, which is one of the craniofacial parameters, plays a crucial role. Sexual dimorphism in orbit has been proved by various studies.[3-7] Orbit is the pyramid-shaped bony cavity situated on either side of the root of the nose. Bones contributing to the framework of each orbit are the maxilla, zygomatic, frontal, ethmoid, lacrimal, sphenoid, and palatine bones. Each orbit contains eyeball and related muscles, vessels, nerves, and lacrimal apparatus.[8] Previous studies have proven that the

Address for correspondence: Dr. Sudhaa Mani Mani, MDS, Professor, Department of Oral Medicine and Radiology, Vivekanandha Dental College for Women, Tiruchengode - 637 205, Tamilnadu, India.
E-mail: drsudhaamanimds@gmail.com

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orbital dimensions differ based on biological sex, age, and ancestry.[9,10] The orbital size was significantly smaller in women than in men.[11] In a study done by Graillon *et al.*, the mean total orbital volume (the sum of right and left in an individual) was higher in males (52,039 ± 1617 mm^3) than females (47,244 ± 1366 mm^3). With an increase in age, the ptosis of the skin and soft tissues around the eye occurs,[12] that will ultimately result in increased width of the orbital floor.[13] In multiple studies, it has been shown that the bony midface undergoes a process of bony resorption and volume loss with increasing age.[12,14] There are differences in the projection of the globe within the orbit, interpupillary distance, and palpebral fissure width with a difference in the ancestry.[9,10] With this background, the present study aims to evaluate the morphometry of the orbital aperture and to verify its relationship with biological sex discrimination using three-dimensional Computed Tomography.

Materials and Methods

This retrospective study included 100 3D reconstructed Computed Tomographic images (50 males and 50 females of age 18-60 years) selected from the CT database of the department of Oral Medicine and Radiology, from January 2018 to January 2019. The study was done after approval from the Institutional Ethical Committee (Vivekanandha Dental College for Women) with Registration No. ECR/784/Inv/TN/2015. The ethical certificate number was VDCW/IEC/123/2018 dated 15.11.2018. The study was conducted by following all the protocols and principles under the purview of Helsinki declaration (1964 and later).

All the images were obtained from the CT scanning system (Toshiba Aquilion 16, 200 VAC, 60 kW generator, 7.5 MHU tube) with a slice thickness of 1.25 mm, the matrix of 512 × 512 pixels each. The inclusion criterion for this study were the availability of 3D Computed tomographic images of individuals aged 18–60 years. Previous studies[15,16] revealed that people from different ancestry/ethnicity have shown great variation in skeletal morphology. Hence all the images belonging to patients' from same ancestry (confirmed from patients' records) were included.

The exclusion criteria were any congenital anomalies affecting the head and neck region, orbital fracture, systemic diseases affecting bone and head and neck tumor. The sample size was calculated with the formula

$$n = \frac{z^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2}$$

p: prevalence = 60%

d: precision = 10%

$Z_{1-\alpha/2}$: Desired Confidence level = 95%

d: clinical allowable error

With the above-mentioned criteria for inclusion and exclusion, out of the 300 images that were analyzed, 100 CT images were included and the remaining 200 CT images were excluded. Eight linear orbital parameters were measured in the 3D CT images. The parameters were Orbital width, orbital height, orbital roof length, orbital floor-length, lateral orbital wall length, medial orbital wall length, intraorbital distance, and extra orbital distance.[3,10,17] The measurement method for each parameter is the linear distance between one anatomical reference point to the other. All the aforementioned parameters were already validated with previous studies that are done in the dry human skull.[5] Table 1 and Figure 1 defines each anatomical landmark and the definition of the aforementioned eight parameters. The measurements were done using Radiant Viewer DICOM software (64 bit Version 4.1.6).

The measurements were done three times repeatedly by the same radiologist. The second measurement was conducted after 2 weeks, for which the results were blinded to minimize the bias. This was done to minimize the intra-observer variability. The measurements were also done by another examiner for measuring the inter-observer reliability.

Table 1: Definition and description of Orbital Parameters

Orbital Parameter	Measurement and Definition
Maxillofrontal (Mf)	The junction between frontomaxillary suture and medial orbital rim
Ectoconchion (Ec)	The junction between the lateral orbital rim and the horizontal line that divides the orbital foramen into two equal parts
Supraorbital point (Os)	The superior junction between the superior orbital rim and the perpendicular bisector line of line Mf-Ec
Infraorbital point (Oi)	The inferior junction between the inferior orbital rim and the perpendicular bisector line of line Mf-Ec
Optic foramen (Of)	A point on the optic foramen
Orbital width	Mf-Ec
Orbital length	Os-Oi
Medial orbital wall length	Mf-Of
Lateral orbital wall length	Ec-Of
Orbital roof length	Os-Of
Orbital floor length	Oi-Of
Intraorbital distance (IOD)	Mf-Mf
Extra orbital distance (EOD)	Ec-Ec

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Statistical analysis

All the data were analyzed using SPSS software (Version 22.0). Descriptive statistics including mean, standard deviation, and percentage distribution were calculated. A comparison between groups was assessed using the Mann Whitney U-test. The linear regression equation and Wilk's lambda were also calculated for every parameter. The sensitivity and specificity of the results were also calculated.

Results

The percentage of age distribution among male and female subjects is presented in Table 2. Table 3 reveals the mean age and biological sex of the individual. All the orbital measurements except for intraorbital distance were statistically significant between male and female subjects [Table 4 and Figure 2]. Cohen's kappa statistics for inter-observer variability revealed 0.80 with a substantial agreement between the observers. Sexing accuracies rate according to clinical variables of discriminant functions [Table 5] reveal that the accuracy rate of Intraorbital distance was high for males. The accuracy rate of orbital width was high for females. Table 6 depicts the Wilk's lambda test of equality of group means, in which it was revealed that the *P* value is significant for all the orbital parameters. Sensitivity is defined as the true positive and specificity is defined as the true negative and the sensitivity of the result was 96% and the specificity was 88% using the Chi-square test. Simple Linear Regression equations are mentioned separately for all eight parameters in Table 7a and Discriminant analysis [Table 7b] revealed that 92.0% of original groups were correctly classified.

Discussion

The human orbit is part of a complex anatomic region in the head. The orbital measurements are one of the craniofacial variables that have been successfully applied in anthropological studies for human identification. Several circumstances like the exploration of mass graves, war victims, and natural disasters may necessitate the use of anthropometry to identify the sex of a person from the available skeletal remains.

Deepali Jain *et al.*[5] analyzed the orbital measurements in the dry skull of 200 individuals. The extra orbital distance was found to be the best parameter with the highest accuracy of 76.0% whereas in our study, the intraorbital distance presented with the highest accuracy rate of about 63.0%. The possible deviation for the result might be because of the difference in the ancestry, method of measurement. Mekala *et al.*[11] studied 200 skulls. The results showed that height and breadth are significantly larger in males than in females. This is in accordance with our study where there was a statistically significant difference between male and female subjects in both orbital width and orbital height. Naren Sarkar *et al.*[16] conducted a study on 92 skulls and only 68.5% of the cases are

Table 2: The percentage of age distribution among male and female subjects

Age	Biological Sex				Total	(%)	Sig
	Male	(%)	Female	(%)			
<20	3	6%	6	12%	9	9%	0.481#
21-30	12	24%	9	18%	21	21%	
31-40	3	6%	5	10%	8	8%	
41-50	7	14%	12	24%	19	19%	
51-60	11	22%	7	14%	18	18%	
>60	14	28%	11	22%	25	25%	
Total	50	100%	50	100%	100	100%	

#*P*>0.05 - not significant

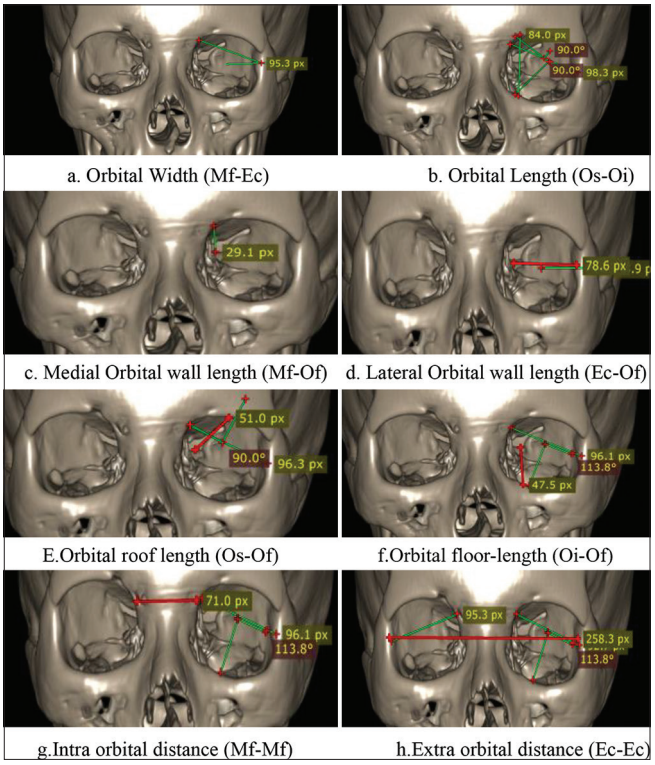


Figure 1: Depicts the measurement of anatomical landmark in 3D CT image

Table 3: Reveals the mean age with Biological sex of the individual

AGE	Mean	SD	Std. Error	95% CI for Mean		Minimum	Maximum	*p - value*
				Lower	Upper			
MALE	47.8	18.5	2.6	42.5	53.0	19	80	0.36#
FEMALE	44.4	18.0	2.5	39.3	49.5	18	77	
TOTAL	46.1	18.2	1.8	42.5	49.7	18	80	

#*P*>0.05 - not significant

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Table 4: Depicts the pattern of variation in orbital measurement between sexes

The pattern of variation in orbital measurements between the sexes (mm)									
Orbital Parameter	Sex	Mean	SD	SE	95% CI for Mean		Minimum	Maximum	Sig
					Lower	Upper			
Orbital width	MALE	29.80	1.55	0.21	29.363	30.245	24.6	33.9	
	FEMALE	26.47	2.03	0.28	25.893	27.047	19.6	32	<0.001
Orbital length	MALE	23.38	2.46	0.34	22.682	24.082	18	29.9	
	FEMALE	21.32	2.15	0.30	20.711	21.937	18.1	30	<0.001
Floor length	MALE	13.58	1.60	0.22	13.127	14.041	10.1	16.7	
	FEMALE	11.88	1.8	0.25	11.372	12.396	9.2	19	<0.001
Roof length	MALE	15.26	1.86	0.26	14.734	15.794	11	18.2	
	FEMALE	12.24	2.39	0.33	11.562	12.922	5.4	18.4	<0.001
Lateral wall length	MALE	27.41	1.63	0.23	26.953	27.883	21.7	31.5	
	FEMALE	23.35	2.31	0.32	22.695	24.013	18.2	29.3	<0.001
Medial wall length	MALE	5.31	3.18	0.45	4.412	6.224	3	25.4	
	FEMALE	3.50	0.87	0.12	3.259	3.757	2.4	5.8	<0.001
Intra orbital distance	MALE	22.48	9.74	1.37	19.712	25.252	14.1	88	
	FEMALE	19.82	2.59	0.36	19.088	20.564	14.3	26.8	0.066[#]
Extra orbital distance	MALE	78.23	4.09	0.57	77.072	79.4	61.6	89	
	FEMALE	74.22	3.17	0.44	73.321	75.127	67.3	84.4	<0.001

[#]*P*>0.05 - not significant

Table 5: Depicts the sexing accuracies rate according to clinic variables of discriminant functions

Variables	Biological sex			
	Male	(%)	Female	(%)
Orbital width	27	54%	33	66%
Orbital length	27	54%	24	48%
Floor length	19	38%	27	54%
Roof length	22	44%	28	56%
Lateral wall length	26	52%	23	46%
Medial wall length	28	56%	20	40%
Intra orbital distance	37	74%	26	52%
Extra orbital distance	28	56%	22	44%

Table 6: Reveals the tests of equality of group means

Tests of Equality of Group Means					
	Wilks' Lambda	*F*	df1	df2	Sig.
Orbital width	0.535	85.012	1	98	0.000
Orbital length	0.832	19.742	1	98	0.000
Floor length	0.798	24.785	1	98	0.000
Roof length	0.664	49.592	1	98	0.000
Lateral wall length	0.489	102.453	1	98	0.000
Medial wall length	0.867	14.997	1	98	0.000
Intra orbital distance	0.966	3.466	1	98	0.066
Extra orbital distance	0.766	29.974	1	98	0.000

correctly classified; whereas in our study 92% of the subjects are correctly classified.

Laboni Ghorai *et al.*[17] evaluated the orbital aperture dimensions in Indian individuals using digital posteroanterior view radiographs. This study demonstrated that the orbital aperture width and the inter-orbital distance are larger in males than in females in Indian individuals. In the present study orbital width, orbital height and inter orbital distance were greater in males than females.

Yongrong Ji *et al.*[18] calculated the orbital parameters using the 3D-reconstruction method and the average measured values of orbital width and extra orbital distance were significantly higher in males than in females. Orbital height was not a statistically significant difference which is in contrast with our study. Kang *et al.*[13] analyzed the morphometric characteristics of the orbital cavity using three-dimensional computed tomography in Asians. The orbital length was statistically significant between males and females, which is in accordance with our study. The study done by Ahsen kaya *et al.*[19] determined that both left and right orbital width and orbital height of males were significantly larger than females. This is similar to our study where orbital width and orbital height were statistically significant.

Limitations and Future Prospects

This study included the images of patients from same ethnicity. Hence, patients of different ethnicity could be included in the study. Increase in the sample size of the study might have yielded better results. In the near future, the study can be done with CBCT for better accurate values and its increased availability in the dental institutes itself when compared with CT units.

Conclusion

Orbital measurements were significantly larger in males than females. Hence this could be used as an adjunct in the biological sex determination of Forensic sciences. Orbit exhibits the least dimensional change throughout one's life.

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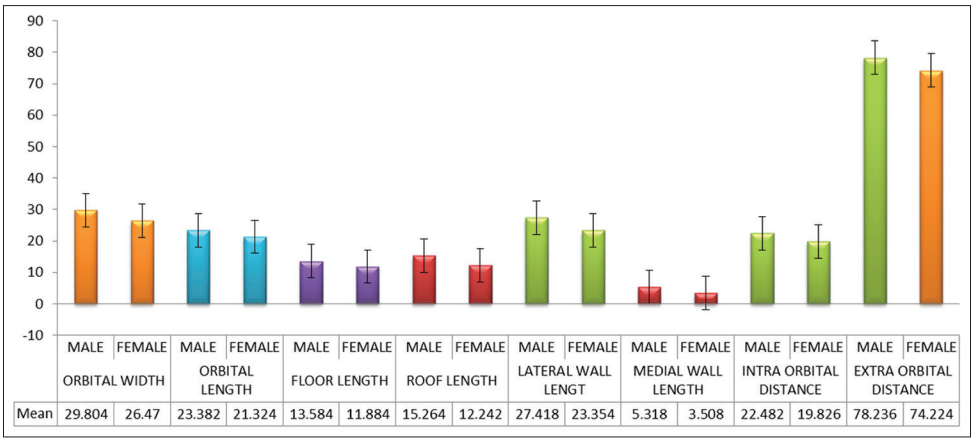


Figure 2: Represents the mean of orbital measurements of eight linear parameters between sexes (mm)

Table 7: (a) linear regression equation for the linear parameters (b) classification result

(a): Linear Regression Equation

Variables	*R*	R^2	Linear Equation	Sig
ORBITAL WIDTH	0.682	0.465	33.138-3.334×	<0.001
ORBITAL LENGTH	0.409	0.168	25.440-2.058×	<0.001
FLOOR LENGTH	0.449	0.202	15.284-1.700×	<0.001
ROOF LENGTH	0.580	0.336	18.286-3.022×	<0.001
LATERAL WALL LENGTH	0.715	0.511	31.482-4.064×	<0.001
MEDIAL WALL LENGTH	0.364	0.133	7.128-1.810×	<0.001
INTRA ORBITAL DISTANCE	0.185	0.034	25.138-2.656×	>0.05
EXTRA ORBITAL DISTANCE	0.484	0.234	82.248-4.012×	<0.001

(b): Classification Results

Classification Results[a]

	Biological sex	Predicted Group Membership		Total
		1	2	
Original				
Count	1	48	2	50
	2	6	44	50
%	1	96	4	100
	2	12	88	100

[a]92.0% of original grouped cases correctly classified.

Hence, it can be used as an adjunct for the identification of the individual in a mass disaster. Lateral wall length and extra orbital distance are the most statistically significant parameters. Assessment of 3D-CT images of people from different ancestry could have further improvised the results.

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Conflicts of interest

There are no conflicts of interest.

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