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Morphometric Study of Orbit in Skull Bones: Direct Measurement Study

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Abstract

The essential segments of the skeleton are the human skull and cranium which have received significant attention in forensic research especially in the analysis of ethno-racial relationship. The features within it (example orbit) may give further insight into the understanding of the craniofacial anthropometry. Understanding the structural disposition of the human body is aided by the advances in medical imaging techniques such as radiography, MRI, CT scan etc. But direct measurement on dry skulls is a more natural perspective in assessing the orbital cavities.

Conclusion: Periorbital and facial injuries are mainly caused by assaults and falls and at times may involve the forehead. Such injuries necessitate cranial and orbital reconstructions to correct both esthetic and functional deficits. Care must be taken to prevent damage to the neurovascular structures contained in the orbit or within its walls. In order to achieve this, the surgeon needs to have a proper understanding of the human orbital structure, its relationship with both intra- and extracranial structures, and associated key surgical and anatomical landmarks.

Keywords: Orbit; Shapes; Length; Orbital index.

Introduction

The two orbital cavities are situated on either side of the saggital plane of skull between the cranium and the skeleton of the face. Thus situated, they encroach about equally on these two regions. Each orbital cavity is essentially intended as a socket for the eyeball and also contains associated muscles, nerves, vessels and in essence lodges the visual apparatus. This is an anatomical region which is of clinical and surgical interest to many disciplines like ophthalmology, oral and maxillofacial surgery and neurosurgery.

In the adult human, the orbits are four sided pyramidal cavities: Its base opens into the face and has four borders, superior margin: frontal bone, Inferior margin: maxilla and zygomatic, Medial margin: frontal, lacrimal and maxilla, and Lateral margin: zygomatic and frontal. Its apex is pointing back into the head and lies near the medial end of superior orbital fissure and contains the optic canal which communicates with middle cranial fossa. Seven bones make up the bony orbit: Frontal (Pars orbitalis), Lacrimal bone, Ethmoid bone (Lamina papyracea), Zygomatic bone (Orbital process of the zygomatic bone), Maxillary bone (Orbital surface of the body of the maxilla), Palatine bone (Orbital process of palatine bone), and Sphenoid bone (Greater and lesser wings). The orbit is a bony pyramid with four walls: a roof, lateral wall, floor, and medial wall. The base of the pyramid is the orbital entrance, which is roughly rectangular. It measures 4 cm wide by 3.5 cm high and is rotated laterally. Because of this lateral rotation, the lateral orbital rim is approximately at the equator of the globe, making the globe relatively exposed laterally. The apex of the orbital pyramid is situated 44–50 mm posterior. The medial orbital

walls are parallel, approximately 2.5 cm apart and separated by paired ethmoid sinuses. The orbital volume is roughly 30 ml, of which 7 ml is occupied by the globe (Standring S, 2005).[8] Also, since the orbit is developed around the eye, it has a tendency towards being spheroidal in form, and its widest part is not at the orbital margin but about 1.5 cm, behind this. Patniak et al. (2001)[3] stated that in each orbital cavity, the width is usually greater than the height, the relation between the two is given by the orbital index, which varies in different races (Orbital Index = Orbital Height/Orbital Breadth). Taking the orbital index as the standard, three classes of orbit have been described.

CT has revolutionized the diagnosis and management of ocular and orbital diseases. The use of thin sections with multiplanar scanning and the possibility of 3-D reconstruction permits thorough evaluation. Quantification of eye and orbit anthropometric variation within the normal population is important for prediction and prevention of eye injury. With CT images, accurate measurements can be collected for bony structures of the orbit that surround and protect the eye. Accurate measurements of eye and orbit anthropometry are valuable in the design of eye protective equipment and modeling of facial impacts for injury prediction purposes. (Ashley A et al., 2010).[7]

Not many studies have been done pertaining to morphometry of orbit in Indian population especially in south Indian skulls. Hence, this study of morphometry of orbit in skulls becomes essential to develop a database to determine normal orbit values in South Indian population.

Aims and Objectives

This study is aimed at evaluating the morphology and morphometry of orbit related to gender and side wise in South Indian population and to get normative/baseline data regarding orbit.

1. To study the morphology and morphometry of orbit in the skulls that is segregated according to gender.
2. This study employs the use of direct measurement on dry skulls as it will present a different and a more natural perspective in assessing the orbital cavities.
3. The parameters taken for this study are shape of the orbit, perimeter, height, breadth, length of the lateral wall, medial wall, roof and floor. Intra orbital distance and extra orbital distance.
4. To compare this study with previous studies.

Materials and Methods

Osteometric study was done using 100 bones obtained from the Department of Anatomy, Narayana Medical College, Nellore and also Sri Padmavathi Medical College for Women (SVIMS) Tirupathi.

The materials required for the study were thread, metallic scale and vernier calipers. Two measurements were made for each parameter to get an average value The methods employed were according to (Mekhla D 2012):

1. In the case of shape both sides orbits were visualized assessed to determine whether square or round.
2. The Perimeter (Pm) of the orbit was measured by pressing a loop of thread along the outer margin of orbit. The thread was then measured on a metallic scale and the readings were noted.
3. The Height of the orbit (Ht) was measured as the distance between the midpoint of the upper and lower margins of orbital cavity.
4. Breadth (Br) of the orbit was measured as the distance between the midpoint of the medial and lateral margin of the orbit by using manual vernier calipers.
5. Orbital Index was measured by using the following formula:

Orbital Index = Orbital height/Orbital breadth × 100.

Taking the orbital index as standard, three classes of the orbit were recognized:

1. Megaseme (Large): The orbital index is 89 or over.
2. Messeme (Intermediate): Orbital index between 89.
3. Microseme (Small): Orbital index 83 or less.
4. Length of the lateral wall of the orbit was measured from the midpoint of the lateral margin of the orbit to the apex of the orbit using a thick strip of paper. The length of the paper was then measured using metallic scale and vernier calipers.
5. Length of the medial wall of the orbit was measured from the midpoint of medial wall of the orbit to the apex of the orbit.

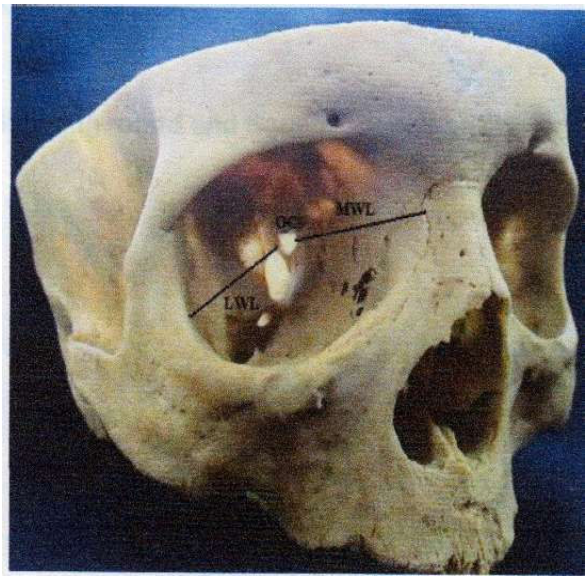
6. Roof length of the orbit was measured from the midpoint of the upper margin of the orbit to the apex of the orbit.[7] Floor Length of the orbit was measured from the midpoint of the lower margin of the orbit to the apex of the orbit.
7. Intra orbital distance was measured between the midpoints of medial margins of medial of two orbits.
8. Extra orbital distance was measured between the midpoints of lateral margins of two orbits.

Results and Discussion

The orbits are paired structures, located on the anterior part of the face and protected by the lids. Each orbit can be compared to a tiny jewel box that has very precious contents, all carefully wrapped in fatty tissue. Morphologically, each orbit is a four sided pyramid with a posterior apex and anterior base. Knowledge of the orbital osteology is paramount in adequately choosing and performing an orbital approach. Understanding the critical topographical elements in this area helps to classify an orbital lesion and provides a solid basis in choosing the most adequate intra orbital route for the treatment (Fig. 1).

Shape of the orbit

E Pretorious et al. (2006)[11] in their study found two shapes of the orbit namely square which was 73.33% in males and round which was 26.77%, in females the square shape was observed in 2% and the round shape was observed in 80%. A study done by Mekhala D (2014)[20] in her study also reported that the Orbit had two shapes round and square. In females the round percentage being 72% and square being 28%. In males square shape was seen in 80% and round shape was seen in 20% of the skulls. In the present study in males square shape was seen in 66.7% and round shape in 33.3%. In females square shape was seen in 30.2% and round shape in 69.8% respectively (Fig. 6, Table 1). There is a difference in the percentages in present and previous studies. These variations may be due to, interobserver variations or small sample size in the previous study or racial differences seen in South African population.



OC - Optic canal, LWL - Lateral wall length, MWL - Medial wall length

Table 1: Comparison of the shape of orbit in male and female skulls

Shape	Male		Female		Chi-square	*p*-value
	N	%	N	%		
Round	19	33.3%	30	69.8%	13.019	< 0.0001 (Sig.)
Square	38	66.7%	13	30.2%		
Total	57	100%	43	100%		

Table 2: Comparison of Gender between PMR and PML

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean Difference	Z	*p*-value
PMR	Males	12.87	0.50	0.07	0.56	4.87	< 0.0001 (Sig.)
	Females	12.30	0.62	0.09			
PML	Males	12.88	0.48	0.06	0.57	5.08	< 0.0001 (Sig.)
	Females	12.32	0.60	0.09			

Fig. 1: Skulls

Fig. 2: Measurements of Pm, Ht and Br

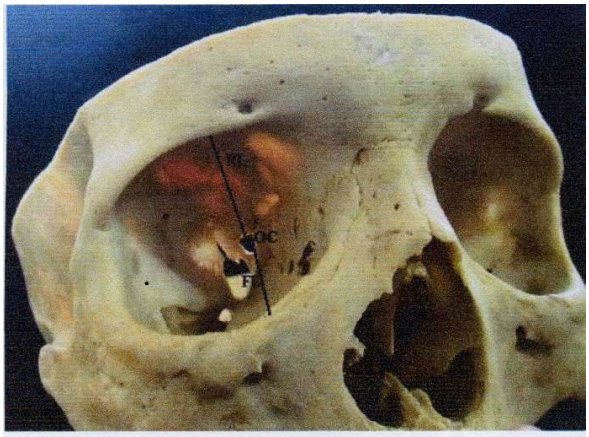


Fig. 3: Measurements of Roof Length (RL) and Floor Length (FL) OC - Optic Canal

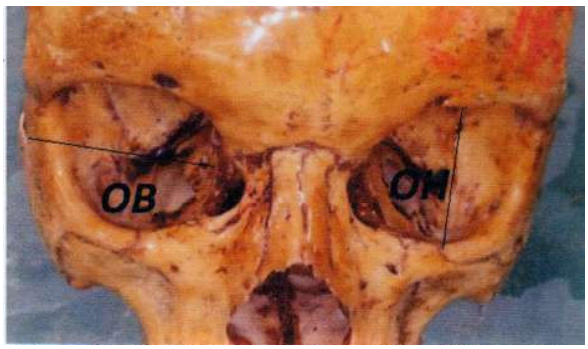


Fig. 4: Measurements of Orbital Breath and Height

Orbital Dimensions

Perimeter of the Orbit

In the study done by Mekhala D (2014)[20] the mean value was 12.93 on right side and 12.91 on the left side the *p* - value was 0.543. In the present study, the mean value of perimeter in males on the right side is 12.87 and left side is 12.88 the *p* - value is < 0.0001. In females the mean value of the perimeter on right side is 12.30 and left side is 12.32 and the *p* - value is < 0.0001. When compared with previous authors the results of present study are more or less equal (Table 2 and Fig 2). Accurate measurement of perimeter of orbit is very important to design the eye protective equipment's.

Height of the orbit

In the work done by Sayee Rajangam et al., (2010)[13] the mean value of the height in males on the right side is 3.5 and left side is 3.37. In females the mean value of height was 3.2 on right side and 3.08 on the left side the *p* - value on right side was 0.397 and left side was 0.174. In a study done by Sanjai S et al., (2007)[14] the mean height value was 3.314 in males and 3.289 in females and the *p* - value being 0.255. In the work of Jaswinder Kaur et al., (2012)[12] 12 the mean value of height on right side is 3.19 and left side is 3.22. In the work of Mekhala D et al., (2014)[20] the mean value of height in males on the right side is 3.55 and left side is 3.53 and the *p* - value is 0.487. The same work totally in males is 3.62 and

Table 3: Comparison of Gender between HTR and HTL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
HTR	Males	3.77	0.28	0.04	0.20	3.81	< 0.001 (Sig.)
	Females	3.56	0.24	0.04			
HTL	Males	3.75	0.28	0.04	0.19	3.54	< 0.001 (Sig.)
	Females	3.56	0.24	0.04			

Fig. 5: Measurements of IOD and EOD

Fig. 6: Showing round and Square shaped orbits

in females 3.45 and the *p* - value is < 0.001. In the present study, the mean value of height in males on the right side is 3.77 and females is 3.56. To the left side in males the mean value is 3.75 and females is 3.56. The *p* - value is < 0.001 significant. The values are high compared to the other authors (Figs. 4,5 and Table 3). These differences may be due to racial differences as seen from the population studied or due to variations in sample size.

Breadth of the orbit

In the study of Sayee Rajangam et al., (2012)[13] in males towards the right side the mean value of the breadth of the orbit is 4.17 and left side is 4.08. In females to the right side it is 3.72 and to the left it is 3.69. The *p* - value is 0.07 for males and 0.145 in females. In the study of sanjai Sangvisichien et al., (2007)[14] in male the mean value of the orbital breadth is 4.01 and in females it is 4.05 the *p* - value is < 0.001. In a study done by Mekhala D (2014)[20] in males the values were 4.29 and 4.05 in females and the *p* - value is < 0.001. In the present study the mean value of orbital breadth the value in males on the right side is 4.48 and left is 4.47 the *p* – value is < 0.001 which is significant. In females on the right it is 4.19 and left is 4.18. The *p* - value < 0.001 and is significant (Fig. 4 and Table 4). In the study of Ukoha U et al., (2011)[6] the mean orbit value is towards the right 3.603 and left 3.498 and the *p* - value is > 0.05. The study of Jaswinder Kaur et al., (2012)[12] in the right side it is 3.97 and left side it is 3.88 and the *p* - value is 0.823.

Orbital Index

In the present study, there is no significant difference observed in the orbital index, between the genders and also sides. According, to the standard classification, the mean orbital index of both genders in the present study belongs to Megaseme category. In the present study, the OI mean value in males is on the right 90.2 and left is 88.13 and the *p* - value is 0.02 which is significant. In females on the right it is 87.34 and left is 87.03

Table 4: Comparison of Gender between BR and BL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
BR	Males	4.48	0.35	0.04	0.29	4.43	< 0.001 (Sig.)
	Females	4.19	0.31	0.05			
BL	Males	4.47	0.35	0.05	0.29	4.43	< 0.001 (Sig.)
	Females	4.18	0.29	0.04			

Table 5: Comparison of Gender between OIR & OIL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
OIR	Males	90.2	6.22	0.83	2.86	2.29	0.02 (Sig.)
	Females	87.34	6.10	0.93			
OIL	Males	88.13	12.64	1.67	1.10	0.53	0.60 (Not Sig.)
	Females	87.03	6.15	0.94			

and the *p* - value is 0.60 which is not significant. In the present study, the values are more in males compared to females. The authors conclude that, the OI can be used as simplest and most efficient method to indicate racial differences and sexual differences. (Table 4).

In the study of Sayee Rajangam et al., (2007)[13] in Indian population the OI on the right side in males is 73.55 and left is 75.27. In females on right side is 66.79 and left side is 65.03 and the *p* - value is 0.003 in male. In females IOI is 66.79 on right side and 65.03 on left side and *p* - value is 0.028 and belongs to Microseme category. In the study of Sanjai Sangavicichien et al., (2012)[14] in Thais the OI mean value in males is 83.50 and females is 86.61. The *p* - value is 0.027 and belongs to Mesoseme category. The category is Microseme in males and Mesoseme in Females. In the study of Mekhala D (2012)[20] in Indians in males the OI was 84.62 and 85.46 in females and the *p* - value is 0.104 and the category is Mesoseme.

Normal values of orbital indices are vital measurements in the evaluation, and diagnosis of craniofacial syndromes and posttraumatic deformities, and knowledge of the normal values for a particular region or population can be used to treat abnormalities to produce the best esthetic and functional results Ebeye O et al., (2013).[15]

Length of lateral wall of orbit

Thanasil Huanmanop et al., (2007)[4] reported that there was no significant gender difference in the length of the lateral wall. And the length of the lateral wall was significantly larger on the left side compared to right side. He reported in males on the right side 4.68 and left side 4.78. In females the mean value in females to the right side is 4.64 and left side is 4.66 and the *p* - value is > 0.05 in males and > 0.05 in females. In the study of Mekhala D (2012)[20] in males the value is 4.70 and females 4.31 the *p* - value is < 0.001. The same study of Thanasil Huanmanop et al., (2007)[4] the right side mean value is 4.66 and the left side value is 4.72 and the *p* - value < 0.001. In the study of Mekhala D (2012)[20] the right side mean value 4.52 and left side is 4.51 and the *p* - value is 0.695. The lateral wall of the orbit continues to grow throughout the childhood, producing a wider adult orbit Song XING et al., (2012)[10].

In the present study, (Fig. 4 and Table 6) the mean value of the length of the lateral wall of the orbit in males on the right side is 4.86 and 4.87 on the left side, the *p* - value being < 0.001 which is significant. In female the values are 4.49 on right side and 4.50 on the left side the *p* - value being < 0.001 which is significant. The slight variations between the values may be due to racial variations.

Table 6: Comparison of Gender between LWLR and LWLL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
LWLR	Males	4.86	0.34	0.04	0.37	5.57	< 0.0001 (Sig.)
	Females	4.49	0.32	0.05			
LWLL	Males	4.87	0.32	0.04	0.37	5.91	< 0.0001 (Sig.)
	Females	4.50	0.29	0.04			

Table 7: Comparison of Gender between MWLR and MWLL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
MWLR	Males	4.83	0.39	0.05	0.44	5.44	< 0.0001 (Sig.)
	Females	4.39	0.43	0.06			
MWLL	Males	4.85	0.38	0.05	0.44	5.54	< 0.0001 (Sig.)
	Females	4.41	0.42	0.06			

Table 8: Comparison of Gender between RLR and RLL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
RLR	Males	5.30	0.37	0.05	0.50	6.36	< 0.001 (Sig.)
	Females	4.80	0.41	0.06			
RLL	Males	5.28	0.34	0.05	0.46	6.27	< 0.001 (Sig.)
	Females	4.82	0.38	0.06			

Table 9. Comparison of Gender between FLR and FLL

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
FLR	Males	5.07	0.38	0.05	0.19	2.87	0.01 (Sig.)
	Females	4.88	0.29	0.04			
FLL	Males	5.07	0.37	0.05	0.18	2.73	0.01 (Sig.)
	Females	4.89	0.28	0.04			

Table 10: Comparison of Gender between IOD and EOD

	Gender	Mean	Std. Dev.	S.E. of Mean	Mean difference	z	*p*-value
IOD	Males	3.26	3.35	0.44	0.52	1.09	0.32 (Not Sig.)
	Females	2.74	0.22	0.03			
EOD	Males	11.21	0.66	0.09	0.20	1.52	0.13 (Not Sig.)
	Females	11.00	0.63	0.10			

The junction of this wall with the roof and floor of the orbit are smooth and rounded anteriorly but weakened for about half the distance by superior orbital fissure and for some two-thirds of the distance by the inferior orbital fissure Patnaik VVG et al., (2001)[3]

Length of Medial wall of orbit

In the study of Thanasil Huanmanop (2010)[4] the mean value of the medial wall of the orbit to the right side is 4.23 and to the left side is 4.18. In females it is 4.22 and 4.24 the *p* - value for males is > 0.05 and females is > 0.05. The same study to the right side showed 4.21 and left showed 4.23 the *p* - value is > 0.05. In the study of Mekala D (2012)[20] in males towards the right is 4.52 and left is 4.51 and in males is 4.53 and 4.22 in females. *p* - Value in male and female is < 0.001 and to the right and left is 0.695. Thanasil Huanmanop (2007)[4] have reported that there were no significant differences in the length of the medial wall of orbit betwen the genders and sides. In the present study, the length is significantly larger in males than females (Fig. 4 and Table 7).

In the present study, the mean value of medial wall of the orbit in males on right side is 4.83 and left side is 4.085 and the *p* - value is < 0.0001 which is significant. In females on the right it is 4.39 and left 4.41 and the *p* - value is < 0.0001 which is significant.

The differences could be due to racial or variations in the methodology or small sample size. Blow out fractures of the orbit occur frequently in the medial and inferior walls, the two thinnest area of the bony orbit. The medial wall is extremely fragile because of the presence of the adjacent ethmoid air cells and more anteriorly, the nasal cavity Patnaik VVG (20010)[3]. Medial wall trauma is strongly related with diplopia due to mechanical entrapment of medial rectus muscle B Dobrovat et al. (2011)[18]. The knowledge of the walls is most important during reconstruction surgeries.

Length of roof of orbit

In as side wise study of authors Jeremiah Munguti (2012)[5] the right side men value of the length of roof of orbit is 5.29 to the right and 5.31 on left side and the *p* - value is 0.927. Thanasil Huanmanop et al., (2007)[4] to the right side his vales were 4.45 and left side is 4.48 and the *p* - value is > 0.05. Thanasil Huanmanop et al., (2007)[4] in the gender wise study showed on the right side in males 4.52 and left side is 4.54. In females on the right side is 4.38 and left side is 4.43 and the *p* - value in males is < 0.05 and females > 0.05. In the study of Mekhala D (2012)[20] in males it is 5.15 and females it is 4.75 and the *p* - value is < 0.001. In the same study of Mekhala D (2012)[20] in the side wise towards the right side it is 5.24 and left side it is 4.23 and the *p* - value is 0.695.

In the present study, the mean value of the roof length of orbit in males on right side is 5.30 and left side is 5.28 and the *p* - value is < 0.001 which is significant. The roof length mean values in females to the right side it is 4.80 and left side is 4.82 and the *p* - value is < 0.001 which is significant (Fig. 3 and Table 8).

The roof of the orbit is very thin, but reinforced laterally by greater wing of Sphenoid and anteriorly by supra orbital margin. So, the fractures which involve frontal bone tend to pass towards the medial side. Chiarella S et al., (2009).[2]

Length of floor of orbit

In a gender wise study of the orbit Thanasil Huanmanop et al., (2007) 4 in males on the right

side the value was 4.69 on the right side and 4.65 on the left side and the *p* - value for the males is > 0.05 and in females to the right side it is 4.61 and left side is 4.53 and the *p* - value is > 0.05. In the study of Mekhala D (2012)[20] the values in males were 4.85 and in females 4.59 and the *p* - value is < 0.001. In the side wise study, Jeremiah Munguti (2012)[5] on the right it is 5.47 and left it is 5.48 and the *p* - value is 0.927. In the study of Thanasil Huanmanop et al., (2007)[4] on the right side it is 4.59 and 4.65 on the left side and the *p* - value is > 0.05. In the study of Mekhala D (2012)[20], in the right side it is 4.73 and left side is 4.72 and the *p* - value is 0.984.

In the present study, the floor length mean value in males on right is 5.07 and left side is 5.07 and the *p* - value is 0.01 which is significant. In females the right side is 4.88 and left side is 4.89 and the *p* - value is 0.001 which is significant (Fig. 3 and Table 9) Intra-orbital distance.

In the study of Jeremiah Munguti et al., (2012) the mean value of IOD in males is 1.891 and females is 1.826 and *p* - value is 0.331. In the study of Mekhala D (2012)[20] in males it is 2.66 and in females it is 2.44 and the *p* - value is > 0.001. In the present study, the IOD in females is 2.74 and males is 3.26 and *p* - *va*lue in both male and female is 0.32 which is not significant so, could not prepare statistic table (Fig. 5).

Extra-orbital distance

The present study showed the mean value of EOD as 11.21 in males and *p* - value being 0.13 which is not significant. In females it is 11.0 and the *p* – value is 0.13 which is also not significant. In the study of Jeremiah Munguti et al., (2012) in males EOD is 9.94 and females it is 9.64 and the *p* - value is < 0.001. In the study of Mekhala D (2012) the values in male was 10.97 and female was 10.33 and the *p* - value is < 0.001 (Fig. 5).

Conclusion

Normal values of orbital indices are vital measurements in the evaluation, and diagnosis of craniofacial syndromes and posttraumatic deformities, and knowledge of the normal values for a particular region or population can be used to treat abnormalities to produce the best esthetics and functional result. Accurate measurements of orbital dimensions are very important during plastic surgery, maxillofacial and neurosurgeries and also in the design of eye protective equipment. Also, these can be used during forensic and anthropological investigation of unknown individuals for determining gender, ethnicity, etc.

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