ORIGINAL RESEARCH

A STUDY ON MORPHOMETRIC ANALYSIS OF ORBIT IN ADULT SKULLS AND CT IMAGES

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ABSTRACT:

Background:Orbits are four-sided pyramidal cavities, with its base opens into the face. It has four borders, frontal bone forms the superior margin, maxilla and zygomatic forms the inferior margin, inferior margin is formed by maxillary and zygoma and lateral border is formed by zygoma and frontal bone. Orbit apex is approximated by the medial end of superior orbital fissure.Orbits are four-sided pyramidal cavities, with its base opens into the face. It has four borders, frontal bone forms the superior margin, maxilla and zygomatic forms the inferior margin, inferior margin is formed by maxillary and zygoma and lateral border is formed by zygoma and frontal bone. Orbit apex is approximated by the medial end of superior orbital fissure.Objectives: Orbital morphometry is an important consideration during surgical procedures such as reconstructive surgeries, maxillofacial and ophthalmic surgeries.The objectives of this study are, to measure the following dimensions of orbit in skulls as well as in CT scan images:Shape of the orbital rim, Perimeter of the orbital rim (Pm), Height of the orbit (Ht), Breadth of the orbit (Br), Orbital index (Ht / Br x100), Length of lateral wall, medial wall, roof and floor, Intra-orbital distance, Extra-orbital distance

Keywords: ?.

INTRODUCTION:

The orbital cavity contains the visual apparatus including the eyeball, muscles, vessels, nerves, lacrimal apparatus, and fascial strata. It has been observed that various events such as neoplastic, congenital, vascular, endocrine disorders and traumatic etc. affect greatly the orbit.[1] Craniofacial asymmetry can be assessed by the measuring bony orbital volume (BOV) and orbital shape. It is evident that this morphometric study is valuable in assessing injury severity and complications in preoperative strategy and helps in fruitful planning.[2] Orbits are four-sided pyramidal cavities, with its base opens into the face. It has four borders, frontal bone forms the superior margin, maxilla and zygomatic forms the inferior margin, inferior margin is formed by maxillary and zygoma and lateral border is formed by zygoma and frontal bone.

Orbit apex is approximated by the medial end of superior orbital fissure. It in linked with middle cranial fossa through optic canal.[3] Bony orbits are made up of 7 bones i.e., frontal bone (pars orbitalis), lacrimal bone, ethmoid bone (lamina papyracea), zygomatic bone, orbital surface of the body of the maxilla), orbital process of palatine bone and greater and lesser wing of sphenoid bone.[4]

The orbital approaches in orbital surgeries may be extraorbital surgical approaches for orbital tumours or transorbital surgical approaches. It is evident that the cranio orbito zygomatic approach helps in accessing numerous pathologies involving the skull base and the unreached areas under the brain. Inferior orbital fissure is a vital and important anatomical area in such surgeries in which some of the skull base osteotomies expand. There is requirement of recognizing inferior orbital fissure. Various surgical interventions such as maxillectomy is complicated by injuries to the orbital contents, ethmoidal arteries, lacrimal apparatus as well as optic nerve. Hence it becomes necessary to have thorough andextensive knowledge of local anatomy. Transcranial approach can be used for removal of the cranioorbital tumours completely.[5] The trans-orbital surgical approach can reach the lateral compartment of the orbit through tinclude: the lateral approach; the superior approachmakes entry into the superior orbit and is the only route which can explore all parts of the optic nerve even the optic canal. The superolateral approach has advantages over the two preceding routes, as it gives access to the superior and lateral parts of the orbit. Huanmanop et al,[6] showed the length of the orbit on the right side in males was 4.52 mm and left side was 4.54 mm. In females on the right side was 4.38 mm and left side was 4.43. They found that the roof of the orbit is very thin, but reinforced laterally by greater wing of sphenoid and anteriorly by supra orbital margin. Shimizu et al,[7] found that in the lateral orbital wall, the lateral surgical approach involves several procedures, including exploration for fractures, decompression, excision of the lacrimal gland, and orbitozygomtic craniotomy. The mean measured distances from FZ to SOF, FZ to IOF, and FZ to OC were 39.94 mm, 29.08 mm,44.25 mm, respectively, in males, and 39.12 mm, 27.32 mm, 43.58 mm, respectively, infemales. The values of FZ OF distance are greater than those measured in Indian (35 mm), inU.S. (36.59 mm), Korean (34.3 mm), and Thai individuals (34.3 mm). Also, the distance from FZ-IOF is greater than that measured in Indian (25 mm), Korean (24.8 mm) and Thai individuals (24 mm) but less than that of U.S (40.92 mm). The present study aimed to measure the bony orbit in detail in adult dry adult skulls and also to study side and sex differences.

Objectives:

Orbital morphometry is an important consideration during surgical procedures such as reconstructive surgeries, maxillofacial and ophthalmic surgeries.

The objectives of this study are, to measure the following dimensions of orbit in skulls as well as in CT scan images:

1. Shape of the orbital rim
2. Perimeter of the orbital rim (Pm)
3. Height of the orbit (Ht)
4. Breadth of the orbit (Br)
5. Orbital index (Ht / Br x100)
6. Length of lateral wall, medial wall, roof and floor

7. Intra-orbital distance
8. Extra-orbital distance

MATERIALS & METHODS:

All these parameters will be compared between the two genders and also between the two sides (right and left). This study may provide a database to determine normal orbit values in Indian population, which may be gainfully utilised by ophthalmologists, oral and maxillofacial surgeons and also forensic experts.

Inclusion criteria: Adult skulls and cranial CT scans with complete orbital margin.

Exclusion criteria: Skulls and CT scans with diseases of orbit like orbital fracture, other bony orbital pathology, orbito-facial cleft etc.

Methodology

Bone study was done on 200 (110 males and 90 females) adult skull bones of confirmed sex available in the Department of Anatomy, …… The individuals were accepted as "adult" at age of 18 years and older. Sex determination of the skulls was done using non-metric traits as mentioned in the table below.

Table 1: Non-metric cranial traits used for sex determination

SNo	Cranial	Male	Female
1	General size	Large	Small
2	Architecture	Rugged and rough	Smooth and gracile
3	Supra-orbitalridges	Medium to large in size	Small to medium in size
4	Mastoid processes	Medium to massive in size	Small to medium in size
5	Occipital area	Muscle lines andprotuberance well developed	Muscle lines andprotuberance less developed
6	Frontal eminences	Less developed	Prominent and projecting
7	Parietal eminences	Less developed	Prominent and projecting
8	Orbits	Squared, lower, relativelysmaller in size with rounded margins	Less squared(rounded),higher, relatively large in size with sharp margins
9	Forehead	Steeper, sloping and less rounded	More vertical and rounded
10	Cheek bones	Heavier, more laterally arched	Lighter and more compressed
11	Palate	Larger, broader, tends moretou-shape	Smaller, broader, tendsmoretoparabolicshape
12	Foramenmagnum	Largerandbroader insize	Smallinsize
13	OccipitalCondyles	Larger	Relativelysmaller

A retrospective radiological study was done on 200 adult (110 males and 190 females) cranial CT scans of adult of known gender available in the Department of Radiodiagnosis.

In case of skull bones, shapes of both side orbits were visually assessed to determine whether square or round. The perimeter (pm) of the orbit was measured by pressing a loop of thread along the outer margin of the orbit. The thread was then measured on sliding vernier caliper.The orbital height (Ht) was measured as the distance between the midpoint of the upper and lower margins of the orbital cavity and orbital - breadth (Br) was measured as the distance between the midpoint of the medial and lateral margin of the orbit by using manual vernier caliper.

Orbital index (OI) was measured by using the following formula, OI = orbital height / orbital breadth x 100

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

1. Megaseme (large): The orbital index is 89 or over.
2. Mesoseme (intermediate): Orbital index between 89 and 83.
3. Microseme (small): Orbital index 83 or less.

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 (optic foramen OF) using a thick strip of paper. The length of the paper was then measured with vernier caliper. In the same way the length of medial wall, roof and floor of the orbit was measured from the midpoint of medial margin, upper and lower margin to the apex of the orbit respectively.

In the same skull using vernier caliper, the Intra-orbital distance (IOD) was measured between the midpoints of medial margins of two orbits, whereas the Extra-orbital distance (EOD) was measured between the midpoints of the lateral margins of two orbits. All measurements were recorded to an accuracy of 0.1mm.In case of cranial CT scans, by visual examination of the images, shape of the orbits were noted to be either round or square.In cranial CT scans all the parameters were measured by using anatomical landmarks as mentioned below.

Table 2: Definition of anatomical landmarks of the orbit and relevant length parameters

Orbital landmarks/Orbital length	**Definition**
Maxillofrontal (Mf)	Junction between fronto-maxillary suture and medial orbital rim
Ectoconchion (Ec)	Junction between the lateral orbital rim and the horizontal line that divides the orbital foramen into two equal parts
Supraorbital point (Os)	Superior junction between the superior orbital rim and the perpendicular bisector line of line Mf-Ec
Infraorbital point (Oi)	Inferior junction between the inferior orbital rim and the perpendicular bisector line of line Mf-Ec
Point on the optic foramen (Of)	Optic foramen
Orbital height	Os-Oi
Orbital breadth	Mf-Ec
Orbital landmarks/Orbital lengthparameters	Definition
Lateral orbital wall length	Ec-Of

Medial orbital wall length	Mf-Of
Orbital roof length	Os-Of
Orbital floor length	Oi-Of
Intra-orbital distance (IOD)	Mf-Mf
Extra-orbital distance (EOD)	Ec-Ec

The data obtained were tabulated and analysed statistically by computing descriptive statistics like mean, standard deviation and range. Mann-Whitney test was done to find out the statistical significance of all parameters of orbits, with respect to gender and side (right and left side).

The statistical analysis for comparison of shape of the orbit between male and female skulls was done by Chi-square test. The results were considered significant when $p < 0.05$ and was considered highly significant when $p < 0.001$.

The statistical analysis was done using statistical Package for Social Sciences (SPSS) software and Microsoft word excel were used to generate graphs and tables.

RESULTS:

The observations that were made as per the parameters are listed in the tables below and the measurements of the right and left orbits of the individual skull bones and CT scans are completely tabulated in the master chart.

Comparison of orbits in male and female skulls:

1. Shape of the orbit

Two different shapes of the orbit were noted in 200 skulls (110 Males and 90 females). The shapes were noted as either round or square.Higher number of male skulls were found to have square shape while higher number of female skulls were found to have round shape. Statistically significant association was observed between shape and gender (P<0.001).

Table 3: Comparison of the shape of the orbits in male and female skulls

Shape	**Male**		**Female**		**$\chi 2$**	**P-Value**
	N	**%**	**N**	**%**		
Round	20	18%	65	72%	52.115	<0.001*
Square	90	82%	25	28%		

*denotes significant association

2. Perimeter (Pm):

The Pm of the male orbits ranged between 11.3 – 13.2 m, whereas in case of female orbits it was 11 – 14cm. When the mean values were compared between the two genders, the z value was found to be -11.52, which was highly significant (P<0.001).

Table 4: Comparison of Pm of orbit in male and female skulls

Parameter	Gender	Mean	Std dev	SE ofMean	MeanDifference	Z	P-Value
Perimeter	Male	12.34	0.32	0.022	0.713	-11.52	<0.001*
	Female	12.12	0.44	0.034			

3. Height of the orbit (Ht):

The highest value of the Ht was observed in both male and female orbits as 4.0 cm and the lowest was observed in the female orbits as 3.0 cm. When the mean values were compared between the two genders, the z value was -7.108, which was highly significant (P<0.001).

4. Breadth of the orbit (Br):

In male orbits, the range of breadth was observed as 3.4 – 4.6 cm, whereas in case female orbits it was 3.4 – 5.2 cm. When the mean values were compared between the genders, the value was -8.337, which was highly significant (P<0.001).

Table 5: Comparison of Ht and Br between male and female orbits in skulls

Parameter	Gender	Mean	Std dev	SE ofMean	MeanDifference	Z	P-Value
Height	Male	3.10	0.11	0.02	0.115	-7.118	<0.001*
	Female	3.12	0.09	0.01			
Breadth	Male	4.12	0.22	0.02	0.213	-8.117	<0.001*
	Female	4.10	0.20	0.02			

5. Orbital index (OI):

In male skulls, the range of OI was 70.5 – 98.3, whereas in case of female skulls, it was 62.6 – 93.7. When the mean OI was compared between the two genders, the z value was -1.225, which was not significant (P=0.112).

Table 6: Comparison of OI in male and female skulls

Parameter	Gender	Mean	Std dev	SE of Mean	Mean Differenc	Z	P-Value
OI	Male	84.60	8.12	0.51	-0.821	-1.602	0.112
	Female	85.32	5.55	0.40			

6. Lateral wall length (LWL):

The highest value of the lateral wall length was same in both the genders (5.1cm), whereas thelowestvaluewasnotedinthefemaleskulls(3.8cm). When the mean values between the two genders were compared, the z-value was – 12.322, which was highly significant (P<0.001).

7. Medial wall length (MWL):

The highest value of the medial wall length was 5.10cm in both the genders, and the lowest value was noted in the female orbits as 3.40cm. When the mean values between the two genders were compared, the z-value was -7.711, which was highly significant (P<0.001).

8. Roof length (RL):

The highest value of the roof length was same in both the genders (6.0 cm), whereas the lowest value was noted in the female orbits as 4.18 c.m. When the mean values between the two genders were compared the z-value was -11.331, which was highly significant (P<0.001).

9. Floor length (FL):

The highest value of the floor length was same in both the genders (5.2 cm), and the lowest value of 3.6cm was noted in the female orbits. When the mean values between the two genders were compared the z value was -7.11, which was highly significant (P<0.001).

10. Intra-orbital distance (IOD):

The highest value of the IOD was observed in the male orbits as 3.3 cm and the lowest value was observed in the female orbits as 2.1cm. When the mean values between the two genders were compared the z-value was -7.321, which was highly significant (P<0.001).

11. Extra-orbital distance (EOD):

The highest value of the EOD was observed in the male orbits as 11.9 cm and the lowest value was observed in the female orbits as 9.8cm. When the mean valueswerecompared the z-value was -8.889, which was highly significant (P<0.001).

Comparison of right and left side orbits in overall skulls:

Table 7: Comparison of Pm, Ht, Br and OI between right and left side orbits in overall skulls

Parameter	Side	Mean	Stddev	SE ofMean	MeanDifference	Z	P-Value
Perimeter	Left	12.22	0.62	0.04	0.018	-0.312	0.780
	Right	12.19	0.61	0.04			
Height	Left	3.33	0.22	0.02	-0.015	-0.625	0.491
	Right	3.15	0.21	0.02			
Breadth	Left	4.28	0.25	0.02	0.003	-0.212	0.812
	Right	4.27	0.25	0.02			
OI	Left	84.72	7.44	0.51	-0.411	-0.344	0.700
	Right	85.33	7.41	0.51			

Comparison of orbits in male and female cranial CT scans:

1. Shape of the orbit:

Two different shapes of the orbit were noted in 200 adult cranial CT scans (110 Males and 90 females). The shapes were noted as either round or square.

Higher number of male orbits was found to have square shape, while higher number of female skulls was found to have round shape. Statistically significant association was observed between the shape and the gender (P<0.001).

2. Perimeter (Pm):

In the male orbits, the Pm ranged between 11.1– 14.1cm, whereas in case of female orbits it was11.2 – 13.2cm. When the mean values of Pm were compared between the genders, the z value was found to be -11.522, which was highly significant (P<0.001).

3. Height of the orbit (Ht):

In case of male orbits, the Ht of the orbits ranged between 3.4– 4.8cm, whereas in case of females it was 3.5 – 4cm. When the mean values were compared between the two genders, the z value was observed to be -9.222, which was highly significant (P<0.001).

4. Breadth of the orbit (Br):

In both the male and female orbits, the breadth of the orbit ranged between 3.4 – 5.6cm. But when the mean values were compared between the two genders the z value was - 8.263, which was highly significant (P<0.001).

5. Orbital index (OI):

In case of male orbits the range of the OI was found to be 66.5 – 94.7, whereas in case of female orbits it was 67.3 – 94.7. When the mean values of the OI were compared there was no significant differences between the genders (P=0.754).

6. Lateral wall length:

The highest value of the lateral wall length (5.8cm) was noted in the male orbits, whereas the lowest value (4.cm) was noted in the female orbits. When the mean values were compared between the genders, the z value was found to be -11.913, which was highly significant (P<0.001).

7. Medial wall length:

The highest value of the medial wall length (5.8cm) was found in the male orbits, whereas the lowest value (3.2cm) was noted in the female orbits. When the mean values were compared there was a significant difference between the genders (P<0.001).

8. Roof length:

The highest value of the roof length was observed in the male orbits as 5.8cm, but the lowest value (4.4cm) was found to be same in both the genders. When the mean values were compared, there was a significant difference between the genders (P<0.001).

9. Floor length:

Similar the roof length, the highest value of the floor length was also observed in the male orbits, and lowest value was same in both the genders. When the mean values of the two genders were compared, there was a significant difference (P<0.001).

10. Intra-orbital distance (IOD):

The highest value of the IOD was observed in the male orbit as 3.2cm and the lowest value was observed in the female orbits as 2.1cm. When the mean values were compared between the two genders, the z value was -7.114, which was highly significant (P<0.001).

11. Extra-orbital distance (EOD):

The highest value of the EOD was observed in the male orbit as 11.3cm and the lowest value was observed in the female orbit as 9.4cm. When the mean values were compared between the two genders, the z-value was -9.124, which was highly significant (P<0.001).

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Comparison of right and left side orbits in female cranial CT scans:

Table 8: Comparison of length of lateral wall, medial wall, roof and floor n right and left side orbits in overall CT scans

Parameter	Side	Mean	Std dev	SE ofMean	MeanDifference	Z	P-Value
Lateral Wall	Left	4.20	0.31	0.02	0.008	-0.301	0.861
	Right	4.29	0.31	0.02			
Medial Wall	Left	4.39	0.38	0.03	0.000	-0.047	0.948
	Right	4.39	0.38	0.03			
Roof	Left	5.13	0.33	0.02	-0.009	-0.316	0.737
	Right	5.14	0.33	0.02			
Floor	Left	4.72	0.30	0.02	0.005	-0.224	0.739
	Right	4.71	0.30	0.02			

Figure 1: Anatomical landmarks of the Orbit and relevant length parameters.

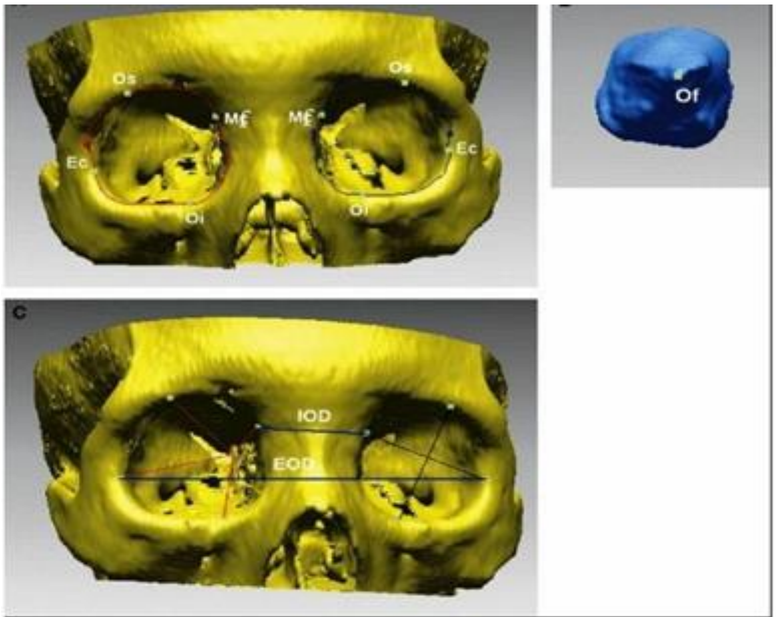

Figure 2: Figure shows round and square shaped Orbits.

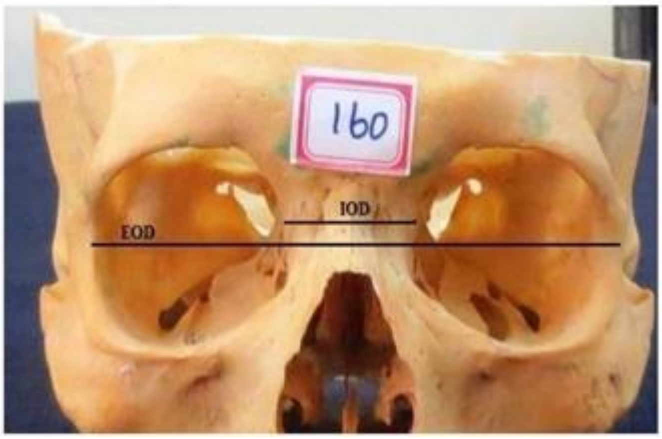

Figure 3: Measurement of IOD and EOD

DISCUSSION:

The orbits are located on front part of skeletal. It contains eyes and can be comparable to both having expensive matter. As described in literature, it is a sided pyramid with base located anteriorly and apex pointed posteriorly.[4] Surgeons should be thorough with the anatomical landmarks, marking, attachment and contents of orbits in ensuring successful surgical interventions.

This in turn decides selection of correct approach for surgery. Orbital pathologies can only be evaluated and subsequently classified if there is better access as well as the knowledge of area concerned. Anthropometry is the recording of variation in measurements of the human individual. Selection of specific approach helps in treatment planning. Orbits are exposed in numerous surgical processes such as in case of enucleation of orbits, orbital and optic nerve decompression, exenteration and vascular ligation.

Iatrogenic trauma and injury may only be inhibited if the surgeon is well versed with the anatomy of orbit especially neurovascular bundles passing through various foramina and fissures. The locations of various foramina in the orbit vary in different ancestral populations.On the basis of accurate anthropological measurements, the congenital or posttraumatic facial disfigurements can be treated. The recent research by various authors shows there is significant variation in morphometry of ocular and orbit among different races. Hence in this study we evaluated morphometric study of orbit in skull bones.

Orbital fractures are observed in more than 40% of maxillofacial injuries and thus represent the most common fractures of the midface.

Understanding its structure proportion and mechanical function is vital in ophthalmology, oral maxillofacial surgery and neurosurgery. Study of the Anatomy of the orbit allows the anaesthetist to understand how to insert needles within the orbit. Human face carries information that allows the identification of a single person. Additionally, reference anthropometric data of the orbital region are necessary for multiple diagnostic and forensic procedures (evaluations of traumas, chromosomal and single gene alterations, teratogenic - induced conditions such as fetal alcohol syndrome, facial reconstruction, etc). In the forensic context, the approach to race must be a pragmatic one. The skull is the best part of the skeleton to use for determination of racial affinity, both morphologically andosteometrically.

In skulls:

1. Shape of the orbit

In the present study, two different types of shapes were noted, either round or square. In the following section, gender distribution of orbital shapes in the present study will be compared with that of previous study. E.Pretorius et al conducted a study in which the female orbits were considered as round shaped and male orbits as square.

Similar to previous study, in the present study higher percentage of male skulls (80%) were found to have square shaped orbits, and higher percentage of female orbits (72%) were found to have round shaped orbits. But there is a slight difference in the percentages between the two studies. These variations may be due to racial differences as the previous authors have studied South African population.

It also could be due to interobserver variation or due to a smaller sample size (n=30) in the previous study.

In CT scans:

In CT scans also, higher percentage of male orbits (73%) were found to be square shaped, whereas higher percentage of female orbits (58%) were found to be round shaped. Not much literature is available regarding the gender differences in shape of the orbit in CT scans.

The differences in percentage observed between skull and CT images may be due to the plane or the level of section and angulation in case of CT. In the following section, the results of various dimensions of orbit (measurable parameters) in the present study will be compared with the results of various other studies. This is more important because the metric approach is more objective and less dependent on observer experience. So, inter-observer variations will be less. Its reliability is high and is also more amenable to statistical analysis. This facilitates comparison between samples and also between studies.

Orbital dimensions

In the present study, in both skulls and CT images, all orbital parameters (Pm, Ht, Br, lengths of lateral wall, medial wall, roof and floor) except OI were significantly larger in males compared to females.

There were no significant differences in the orbital parameters including OI between the two sides.

Table 9: Comparison of various dimensions with respect to various studies

Dimensions of the orbit	Authors	Male	Female	P
Perimeter	Yongrong ji et al,[8]	12.65	12.20	<0.001
	Ashley A. Weaver et al,[10]	11.47	11.21	0.20
	Present study	12.34	12.12	<0.001
Height of the orbit	Sayee Rajangam et al,[9]	Right – 3.5 Left – 3.37	Right – 3.2 Left – 3.08	0.397 0.174
	Sanjai Sangvicichien et al,[11]	3.314	3.289	0.255

	Present study	4.0	3.40	<0.001
Height of the orbit in	Yongrong ji et al,[8]	3.335	3.322	0.742
CT Scan	Ashley A. Weaver et al,[10]	3.244	3.175	0.41
	Present study	3.93	3.73	<0.001
Breadth of the orbit	Sayee Rajangam et al	Right – 4.17 Left – 4.08	Right –3.72 Left – 3.69	0.07 0.145
	Sanjai Sangvicichien et al	4.01	3.809	<0.001
	Present study	4.29	4.05	<0.001
Breadth of the orbit in	Yongrong ji et al,[8]	4.002	3.80	<0.001
CT Scan	Ashley A. Weaver et al,[10]	3.742	3.66	0.22
	Present study	4.59	4.36	<0.001
Orbital index	Sayee Rajangam et al,[9] Indians	Right – 73.55 Left – 75.27	66.79 65.03	0.003 0.028
	Sanjai Sangvicichien et al,[11]Thais	83.50	86.61	0.027
	MungutiJeremiah,[12]KENYANS	82.57	83.48	-
	Present study (Skull)Indians	84.60	85.20	0.104
	Present study (CT scan) Indians	85.80	85.80	0.754
Length of lateral wall of the orbit	Thanasil Huanmanop et al,[6]	Right – 4.68 Left – 4.78	4.64 4.66	>0.05 >0.05
	Present study	4.70	4.31	<0.001
Length of lateral wall of the orbit in CT Scan	Yongrong ji et al[8]	4.838	4.691	0.016
	Present study	5.1	3.8	<0.001
Length of medial wall of the orbit	Thanasil Huanmanop et al[6]	Right – 4.23 Left – 4.18	4.22 4.24	>0.05 >0.05
	Present study	5.1	3.4	<0.001
Length of roof of the orbit	Thanasil Huanmanop et al	Right – 4.52 Left – 4.54	4.38 4.43	<0.05 >0.05

	Present study	6.0	4.18	<0.001
Length of floor of the orbit	Thanasil Huanmanop et al[6]	Right – 4.69 Left – 4.65	4.61 4.53	>0.05 >0.05
	Present study	4.85	4.59	<0.001
Intra-orbital distance	Jeremiah Munguti et al[12]	1.891	1.826	0.331
	Present study	2.66	2.44	<0.001
Extra-orbital distance	Jeremiah Munguti et al[12]	9.94	9.64	<0.001
	Present study	11.3	9.4	<0.001

2. Perimeter of the orbit:

Not much literature is available to compare the gender differences of Pm in skulls. In CT scans:

It can be seen from the above table that the values of previous studies are lower when compared to present study.

But similar to present study, in Yongrong ji et alstudy,[8] a significant difference is observed in Pm of orbits between the two genders.The differences in the Pm values between the present study and the Yongrong ji et alstudy may be because of the racial differences as the study population is different andalso may be due to smaller sample size in their study (n=64).[8]Though the Ashley A. Weaver et al,[10] study was on Caucasian population, there are nosignificant differences in Pm of orbit between the two genders. The differences in Pm values observed between the present study and their study could be due to environmental and epigenetic influences such as climate, activity patterns and differences in the methodology of recording as explained earlier and also due to a smaller sample size in their study (n=39). The comparison shows that the results of the present study are similar to Yongrong ji et al,[8] study which shows no laterality between the two sides. The slightvariations between the values may be due to racial differences.

Accurate measurement of Pm of orbit is very important to design the eye protective equipments.

3. Height of the orbit

Sayee Rajangam et al,[9] in their study found that there was no significant difference in the Ht of the orbit between the two genders. The values are slightly lower than our findings, even though their sample consisted of Indian population. This may be due to their sample size being smaller (n = 72) and also they have not compared the Ht of the orbit between the genders irrespective of side.

Sanjai Sangvicichien et al,[11] have also reported that there was no significant difference in the Ht of the orbit between the two genders. And the values are also lower than our values. These differences may be due to racial differences as seen from the population studied or due to variations in the sample size.

The differences between the present study and the Ukoha U et al,[13]study may be because of the racial differences as they studied male skulls of Nigerian population and also due to variations in the sample size (n=70).

Though Jaswinder Kaur et al,[14] study was on Indian population, the minimal difference noticed could be due to environmental and genetic factors or due to a smaller sample size in their study (n=30). From the above table it can be seen that, in contrast to the present study, in both the previous studies there are no significant gender differences observed in the Ht of the orbit. And also the values are lower compared to the present study.

These differences could be due to racial and environmental factors and also due to variations in the sample size.

4. Breadth of the orbit

From the above table it is observed that in Sayee Rajangam et al,[9] study there are no significant differences present in the Br of the orbit between the two genders. Though the study was on Indian population, the values are lower than the present study. These differences could be due to smaller sample size in their study and also they have not compared the Br of the orbit between the genders irrespective of side.

Similar to present study, Sanjai Sangvicichien et al,[11] found a significant difference in the Br between the two genders. The reason for the lower values of the Br may be due to racial differences as seen from the population studied or variations in the sample size.

From the above comparison it can be seen that, similar to present study, there is a significant difference in the Br of the orbit between the genders in Yongrong ji et al study.[8] The reason for the lower values of the Br may be due to racial differences as seen from the population studied or variations in the sample size.

There were no significant differences in Br of orbit between the two genders in Ashley A. Weaver et al study involving Caucasian population. The differences in values could be due to environmental factors and differences in the methodology of recording as explained earlier and also due to a smaller sample size in their study.

5. Orbital index

OI has been studied by several authors. It has been reported that the racial and ethnic differences occur in OI amongst different population.

The present study aimed to compare the OI of the Indian population with available datafrom other populations of the world. According to standard classification, the mean OI of both the genders in the present study belongs to Mesoseme category. In the following section, the OI in the present study is compared with that of other studies.

It can be seen from the above table that the values reported by Sayee Rajangam et al,[9] are lower compared to our values. According to their study OI in males is significantly larger when compared to females. Though the study was done on Indian population, this group of population belongs to Microseme category, which is contrary to our results. This variation could be due to a smaller sample size.

Sanjai Sangvicichien et al,[11] and Munguti Jeremiah et al,[12] have reported that male OI was lower compared to females.

Table 10: Comparison of OI in the present study with that of previous studies (irrespective of sides and genders)

Authors	Population	OI	Category
Ukoha U et al,[13]	Nigerians	89.21	Megaseme
Jaswinder Kaur et al,[14]	Indians	81.65	Microseme
Present study (Skull)	Indians	85.80	Microseme
Present study (CT scan)	Indians	85.02	Microseme

Though Jaswinder Kaur et al,[14] study was also on Indian population, the OI values are lower compared to our results. Deepak S Howale et al,[15] have also studied Indian population and have reported a slightly higher mean OI (86.4) compared to our results.

They followed different classification to categorize the skulls according to OI. According to the classification which was followed in the present study, this group of Indian population can be placed under Mesoseme category which is similar to our results.

The importance of orbital index lies in its use for the interpretation of fossil records, skull classification in forensic medicine and the explanation of trends in evolutionary and ethnic differences. Normal values of orbital indices are vital measurements in the evaluation, and diagnosis of craniofacial syndromes and post traumatic deformities, and knowledge of the normal values for a particular region or population can be used to treat abnormalities to produce the best aesthetics and functional result. Variation of OI between and within the population could be due to genetic and environmental factors and also different patterns of craniofacial growth mainly resulting from racial and ethnic differences.The authors conclude that, the OI can be used as simplest and mostefficient method to indicate racial differences than sexual differences.

6. Length of lateral wall of the orbit

Thanasil Huanmanop et al,[6] have reported that there was no significant gender difference in the length of lateral wall. And the length of lateral wall was significantly larger on the left side when compared to right side.From the above table it can be seen that there is a slight variation in the values between the two studies. These differences could be because Thanasil Huanmanop et al,[6] have studied Thai population and also there is a difference in the methodology as explained earlier. Also their sample size was small when compared with the present study. From the above table it can be seen that the results of the present study are similar to that of the previous study which shows that the length of lateral wall is larger in males when compared to females. The minor differences between the values may be because of racial differences as they studied Chinese population and also due to variations in the sample size. The comparison showed that the results of the present study are similar to Yongrong ji et al,[8] study which shows no laterality in the length of lateral wall between the two sides. The slight variations between the values may be due to racial differences. The lateral wall of the orbit continues to grow throughout childhood, producing a wider adult orbit.

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 the superior orbital fissure and for some two-thirds of the distance by the inferior orbital fissure.[4]

7. Length of medial wall of the orbit

Thanasil Huanmanop et al,[6] have reported that there were no significant differences in the length of medial wall of orbit between the genders and also between the two sides.

But in the present study length of medial wall is significantly larger in males compared tofemales.From the above table it can be seen that there is a minor difference between the values of present study and the previous study. These differences could be attributed to the racial differences in the population studied, variations in the methodology or a smaller sample size.It can be seen from the above table that the results of the Yongrong ji et al,[8] study is similar to the results of our study except the slight variation between the values of male orbits. Other than racial differences, this could also be due to relatively smaller sample size in their study.

The comparison shows that the result of the present study is similar to Yongrong ji et al,[8] study which shows no significant differences in the length of medial wall of orbit between the two sides.Blow-out fractures of the orbit occur frequently in the medial and inferiorwalls, 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. Medial orbital wall trauma is strongly related with diplopia due to mechanical entrapment of the medial rectus muscle.

Hence, knowledge of dimensions of these walls of orbit becomes very important during reconstruction surgeries.

8. 8. Length of roof of the orbit

In contrast to our results, Thanasil Huanmanop et al,[6] have reported that the roof length of right side orbits in females was in significantly shorter than that of males. And there was no significant difference in the roof length between the left side orbits of males and females. These differences could be due to variations in the methodology as explained earlier. The reasons of lower values of the roof length compared to the results of the present study could be because of racial differences as their study population is different and also relatively smaller sample size (n= 50) in their study. Previous studies have reported that there were no significant differences in roof length of the orbit between the two sides, which correlates with the results of the present study. From the above table it can be seen that the results of present study is similar to that of the previous studies which shows that the roof length is larger in males when compared to females.

Minor variations in the values of roof length may be because of variation in the studied population and also smaller sample size in their study. Similar to the present study, Yongrong ji et al,[8] have reported that there was no significant difference in the roof length between the two sides. The reason for the minor variations in the values of roof length may be because they studied Chinese population and also smaller sample size in their study.

The roof of the orbit is very thin, but reinforced laterally by the greater wing of sphenoid & anteriorly by superior orbital margin. So the fractures which involve frontal bone tend to pass towards the medial side.[2]

9. Length of floor of the orbit

In skulls:

In Thanasil Huanmanop et al,[6] study there is no significant difference in floor length between the genders, which is similar to present study.

From the above table it can be seen that there is a minimal difference in the values of previous study and the present study. This could be due to racial differences and also they have not compared the floor length between the genders irrespective of side.

The comparison showed that the result of the present study is similar to previous studies. Both the previous studies have reported that there was no significant difference in thefloor length between the two sides.

In Jeremiah Munguti et al,[12] study the values are higher than the present study. These differences may be due to variation in the population studied and also due to difference in the methodology of recording.

It can be seen from the above table that, in the previous studies also floor length of orbits in males is significantly larger than in females, which correlates with the present study.

Thevariations in the values of floor length may be because of variation in the studied population and also smaller sample size in their study compared to the present study.

Yongrong ji et al,[8] have reported that there was no significant difference in the floor length between the two sides, which is similar to the results of the present study.

The reason for the minor variations in the values of floor length may be because they studied Chinese population and also smaller sample size in their study.

The floor of the orbit is frequently involved either in isolation as a so called 'pure' type of blow out fracture or more commonly as an impure fracture in association with other fractures in zygomatic area. This is because, the infra orbital groove & canal weaken the already thin (0.5mm thickness) floor further.[4]

Results of the present study demonstrated bilateral symmetry of the orbits. And also according to results of the present study, orbits are significantly larger in males than in females. The differences in the skulls between the two sexes are seen only after puberty. Adult males tend to be larger than females in a number of features due to combination of faster rates of growth during puberty and longer period of growth. A possible explanation for this finding could probably be the endocrine influence on postnatal growth of bones. At preadolescent age, bone growth in both sexes is almost at the same rate and they are of equal dimensions. But with onset of puberty in the female, the inhibitory effect of oestrogen on the osteoblast activities in the growing bone appears to retard the bone growth, hence, the lower dimensions recorded in this sex.

10. Intra-orbital distance

In skulls:

Jeremiah Munguti et al,[6] have reported that there was no significant difference in the IODbetween the genders, which is different from our results. This could be because, they studied disproportionately higher number of male skulls (n=80) compared to female skulls (n=33).The reason of lower value of IOD compared to our results could be due to racial differences as they studied Kenyan population or due to variations in the methodology.

In CT scans:
Yongrong ji et al,[8] have reported that IOD was significantly larger in males compared to females, which is similar to the present study.

11. Extra-orbital distance

In skulls:
In Jeremiah Munguti et alstudy,[12] the EOD is significantly larger in males than in females which correlates with the present study.
But the values of EOD are lower in the previous study than the present study. These differences could be due to racial differences as they studied Kenyan population or it Similar to the present study, in Yongrong ji et al,[8] study also, EOD is significantly larger in males when compared to females. But the lower values of EOD observed in their study could be due to racial differences or due to genetic and environmental factors.[17]
The interorbital distance was first defined by Cameron, a physical anthropologist, in studies of a small number of dried skulls.[16]
The IOD and EOD are significant factors that need to be considered during nasal bridge reconstruction, facial cosmetic surgeries and in the design of spectacle bridges. These measures have been known to vary with sex and race.[6]
The reason for the larger IOD and EOD in males could be due to large, broad facial skeleton of males and also due to a wider nasal ridge compared to that of female subjects.

CONCLUSION:

The present study was undertaken to determine the morphology and morphometry and sexual dimorphism of orbit both in human skulls and cranial CT scans. All the intended objectives were accomplished at the end of the study. From the above results, the authors conclude that significant sex differences ($P<0.001$)observed for all the parameters both in case of skull bones and CT scans except OI indicate that orbit is larger in males when compared to females. And also there were no significant differences in all parameters between the right and left side orbits, which demonstrated the symmetry of the two orbits in the same individual. According to the OI, the studied group of Indian population comes under Mesoseme category.
From the results of the study discussed, it can be concluded that the several anatomic parameters such as shape and dimensions of orbit should be taken into consideration during plastic surgery, maxillofacial and neurosurgeries. And also accurate measurements.of orbital dimensions are very important 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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