Oncology
and Radiotherapy ©
Vol.15 Iss.3:001-9 • Research Article

An anatomical study of orbital dimensions and its utility in orbital reconstructive surgery

Zeba Khan[1], Gulrez Nadeem[2], Humera Khan[3], Al-Moutassem Billah Khair[2]

[1]Department of Anatomy, Grant Government Medical College and Sir JJ Group of Hospitals, Mumbai, India
[2]Basic and Medical Sciences Department, College of Dentistry, Ajman University, Ajman, U.A.E.
[3]Department of Clinical Sciences, College of Pharmacy and Health Sciences, Ajman University, Ajman, U.A.E.

SUMMARY

Objectives: The orbit is a craniofacial structure and the orbital cavity contains the visual apparatus, including the eye ball and associated muscles, vessels, nerves, lacrimal apparatus, and fascial strata. A large number of traumatic, congenital, vascular, neoplastic and endocrine disorders may adversely affect the orbit. In these cases, the measurements of orbital index, bony orbital volume, orbital perimeter and a description of the orbital shape may have crucial clinical applications for estimating craniofacial asymmetry, the severity of the injury, and probable complications in preoperative planning and in postoperative assessment. Importance of Craniofacial measurements and study of orbital morphology is important for ethno-racial and sex discrimination, craniofacial surgery and anthropological assessment. The relationship between the height and breadth of the orbit varies amongst various human populations.

Materials and Methods: This study compares orbital dimensions and orbital index in the Maharashtra population. 60 dried adult human skulls (120 orbits) irrespective of sex were randomly selected from the Anatomy Department in Grant Government Medical College, Mumbai, India. The orbital height and breadth were measured and orbital Index was calculated. The data were statistically analysed for means, Standard Deviation (SD) (significant at p≤ 0.05).The other parameters measured were orbital volume, orbital perimeter and orbital opening area.

Results: The mean orbital height for the left and right sides were 3.575 ± 0.329 cm and 3.580 ± 0.301 cm while, their orbital breadth were 4.008 ± 0.362 and 4.008 ± 0.326 mm respectively. The mean orbital index of 120 orbits was 89.342 ± 3.987. The bony orbital volume of 120 orbits was measured to be 25.595 ± 1.119 ml and Orbital opening area was found to be 11.339 ± 1.799 cm while the orbital rim perimeter is 13.15 ± 1.343 cm.

Conclusion: The Maharashtrian population belongs to the Megaseme category. The existing data is not enough on Maharashtrian population, so it is necessary to study the morphometry of the orbit in these populations. Positive correlation was observed between volume of orbits and the orbital opening area. These findings may play a key role in orbital reconstruction.

Key words: orbital dimensions, orbital morphology, orbital index, orbital volume, orbital tumours, megaseme, mesoseme, microseme

Address for correspondence:

Gulrez Nadeem, Basic and Medical Sciences Department, College of Dentistry, Ajman University, Ajman, U.A.E, email: g.nadeem@ajman.ac.ae, gulrez.nadeem@yahoo.comm

Word count: 6588 **Tables:** 06 **Figures:** 07 **References:** 65

Received: - 03 February 2021

Accepted: - 19 February, 2021

Published: - 29 March 2021

INTRODUCTION

The orbits are composed of 7 bones and are conical structures. They separate the upper facial skeleton from the middle face and enclose the organs of vision. Orbit is pyramidal in shape and its walls, apex, and base are perforated by various foramina and fissures having several irregularities where ligaments, muscles, and capsules attach [1]. Understanding of ocular anatomy is vital for clinical assessment and treatment of patients [2]. Orbital measurements are crucial to study of craniofacial parameters as human orbit is a complex clinico-anatomical region which plays an important role in evaluation of craniofacial complex in forensic anthropology, orbital reconstructive surgeries, maxilo-facial surgery, neuro-surgery and in sex determination. There is little difference between the orbits in the skulls of male and female up to puberty. After this the male skull takes on its secondary sexual characters while the female skull remains more infantile in form [3]. Orbital anatomy is vital in surgical corrections of the bony orbit and the efficient working of the visual apparatus [4]. Walls of the orbit are not flat instead they are curvilinear in shape, and serve the purpose of maintaining the projection of the ocular globe and to cushion it when subjected to blunt force [1].

Tumors of the orbit

Tumors of the orbit comprise of around 4% of the ophthalmic pathologies [5]. The orbit is a complex structure and for the purpose of surgical procedures, can be anatomically divided into well-defined intraconal and extraconal compartments depending on the muscle cone formed by the extraocular rectus muscles and their intermuscular septae [6]. This division assists in simplifying the diagnostic approach. Various approaches to the orbit have been developed [7]. Studies regarding the orbital statistics of races in different regions and modern diagnostic methods help in development of the best possible surgical interventions. Data regarding orbital anatomy, bony involvement of tumors and their anatomical localization in relation to the bony orbit may prove beneficial for surgical planning. Management of orbital lesions can be challenging, especially due to its location and surgical intervention is often needed Direct approaches to various parts of the orbit are now possible with the help of these diagnostic advances and the development of surgical techniques. Aim of surgery should be radical organ-preserving thus minimizing patient disability and preservation of visual function. Orbital and periocular reconstructive surgery frequently need volume restoration and augmentation. Reconstruction of the Orbit and Anophthalmic Socket Using the Dermis Fat Graft has been described by Jovanovic, 2020 [8] in a review. Since, tumors of the orbit are a great diagnostic problem it is imperative to use all diagnostic methods possible. Some of the surgical techniques used in cases of some of the orbital tumors which are based on Orbital dimensional accuracy can be seen in Table 1.

Orbital index

Orbital Index is the best way to determine the shape and size of Orbits in different population groups and races. It can be measured manually in human skulls or radiologically. But manual measurements are always better and confirmatory. Hence, this morphometric study is done by Vernier

Calipers to determine the height, breadth and Orbital index in dry human skulls. The Orbital index varies with race, regions and even within the race and hence determines the shape of the face in different population groups and even is helpful in interpretation of fossil records and skull classification [12]. By using Orbital dimensions based on race, we can do makeover of human face, body and the whole skeleton. Taking Orbital index as standard, 3 classes of orbit have been classified Megaseme, Mesoseme and Microseme [13-15] where

Megaseme (Large): Orbital index is 89 or more. Seen in Yellow races.

Mesoseme (Intermediate): Orbital index is between 83-89. Seen in White races.

Microseme (Small): Orbital index is 83 or less. Seen in Black races.

Orbital volume

Quantification of orbital volume is valuable to the evaluation and subsequent management of many orbital pathologies. The structure of the orbit can be influenced by innumerable factors such as intraorbital tumors, inflammatory and congenital diseases as well as trauma [16]. Anatomical alterations in orbital structure have a significant impact on clinical decisions as well as surgical outcomes [17]. Soft tissue of the orbit is present within the bony orbital cavity. Along with bony orbital cavity another important parameter is effective orbital volume, which is the difference between the eyeball volume and the orbital cavity volume [18]. It determines an evaluation of the accessible space in the orbital cavity to accommodate the eyeball. Measurement of orbital volume is significant as it varies with age, race and sex [19-21]. Any alteration in the restricted volume of the orbit, its shape and size is related to exophthalmos and enophthalmos [22, 23]. In case of reconstructive plastic surgery, the primary reason of surgical intervention in trauma or congenital deformity is restoration of the bony anatomy of the orbital cavity resulting in rectification of globe position and subsequent visual correction [24]. Orbital volume replacement is required in case of reconstruction of a post-enucleation or post-evisceration socket, which is accomplished by a blend of an intraorbital graft/implant and an ocular prosthesis [8].

Several methods are used in measurement of orbital volume. Skeletons that were found in North America and are now present at the Peabody Museum of Archaeology and Ethnology, Harvard University were assessed for orbital volume using 1-mm glass beads and a graduated cylinder while Linear measurements were taken with calipers and paper rulers [20]. Advances in radiological techniques of Computed Tomography (CT) [25-27] and three-dimensional magnetic resonance tomography (3D-MRI) [16] have enabled detailed imaging of the orbit. Although direct measurement on dry skulls is more reliable in calculating the orbital cavities [2]. The normal orbital volume can play a key role as it can be used as controls in patients with unilateral orbital reconstruction. 3D-assisted quantitative determination of orbital volume is a feasible technique for orbital volume assessment in patients. The OsiriX software can be used as a comprehensive preoperative planning and imaging tool by the operating surgeons for orbital volume measurement and computed tomography reorientation [27]. Volumetric assessment following orbital trauma provides an insight into post-traumatic risk assessment [28].

Orbital perimeter and Orbital opening area

Shape of orbit in children is rounder, but with age the width increases and it becomes more rectangular. It is rotated laterally due to which the lateral orbital rim is approximately at the equator of the globe, thus exposing the globe relatively laterally [29]. Orbital rim perimeter is an important aspect of orbital opening area. It can be divided into medial, lateral, superior and inferior rim. The medial orbital rim is less defined in comparison

Tab. 1. Some of the surgical techniques used in cases of some of the orbital tumours can be seen in the following table

SN	Author	Tumour	Surgical Approach
1	Park et al. 008 [7]	Cavernous Hemangioma Fibroangioma Neuroendocrine carcinoma Lymphoma Schwannoma	Fronto orbital approach
2	Park et al. 2008 [7]	Glioma Squamous cell Carcinoma Teratoma fibroangioma	Lateral orbital approach
3	Cherekaev et al. 2015 [9]	Skull Base Tumors Spreading Into The Orbit And Paranasal Sinuses	Orbitozygomatic Approaches
4	Lystratenko et al. 2019 [5]	Plasmacytoma	Lateral Orbitotomy
5	Lystratenko et al. 2019 [5]	Rhabdomyosarcoma	Fronto-Orbito-Zygomatic Approach
6	Pribila et al. 2010 [10]	Glomus Cell Tumor	Orbitocranial Approach
7	Yan and Wu, 2004 [11]	Orbital Cavernomas	Anterior Orbitotomy

to other rims. The lateral orbital rim is the least projected thus facilitating lateral vision [1]. The widest circumference of the orbit is around 1 cm behind the rim [29].

Prior data of the orbital morphometry will lead to better surgical outcomes. Since, there are few studies pertaining to morphometry of orbit in Maharashtrian population, present study of morphometry of orbit in skulls will help in developing a database to determine normal range of orbital values and orbital indices in this region. It will aim at documenting standard values of Orbital index, Orbital Volume, Orbital perimeter and Orbital opening area in dry human skulls present in the Anatomy Department of "The Grant Government Medical College", Mumbai, India and comparing them with available data from other population groups. These would be very beneficial in anthropological studies, exploring trends in evolutionary and ethnic differences, craniofacial surgeries and diagnosis and treatment of craniofacial anomalies.

MATERIALS AND METHODS

Adult skulls of unknown sex were collected from Grant Government Medical College and Sir JJ Group of Hospitals, Mumbai India. 60 normal adult skulls (120 orbits) were selected for the study. Skulls with craniofacial malformations and fractures were excluded from the study. The morphometric analysis of the orbit was designed for 3 categories [30, 31].

Parameters regarding the general morphology and the shape of the orbit. Four fixed points on the orbital opening were used:

- Maxillofrontale Point (MF): The junction between the frontomaxillary suture and the medial orbital rim.
- Ectoconchion Point (EC): The junction between the lateral orbital rim and the horizontal line that divides the orbital opening into two equal parts.
- Supraorbital Point (SO): The superior junction between the superior orbital rim and the perpendicular bisector line of line MF- EC.
- Infraorbital Point (IO): The inferior junction between the inferior orbital rim and the perpendicular bisector line of line MF- EC.

The following dimensions were measured using Vernier Caliper with 0.01 mm accuracy calibrated in millimeters [30, 32].

The parameters studied were:

- Orbital height: between SO-IO (Figure 1)
- Orbital breadth: between MF- EC (Figure 2)
- Orbital Index (OI)=height of orbit / orbital breadth × 100.
- Orbital rim perimeter (Figure 3)
- Orbital opening area = 22/7 × A× B where A and B are the halves of orbital height and breadth respectively
- Bony Orbital Volume (BOV): Balloon was placed in the socket of orbit and water was filled in the opening of balloon from the optic canal side (Figure 4). This amount was measured by pouring it in measuring cylinder. Pilot studies were done to compare this method with that of the water-filling method in which three-dimensional models were made for the bony orbits. Each model was immersed in graduated cylinder filled with distilled water. The displaced water was measured and represented the volume in ml [33]. The results were the same hence balloon method was used for the volume measurement of all skulls.

Measurements were recorded and expressed Means ± Standard Deviation and range (Min. value-Max. value of each measurement). The data obtained was tabulated and analysed statistically using SPSS software version 20, and Microsoft word excel were used to generate graphs and tables. The results were considered significant when p value <0.05 and was considered highly significant when p value <0.001.

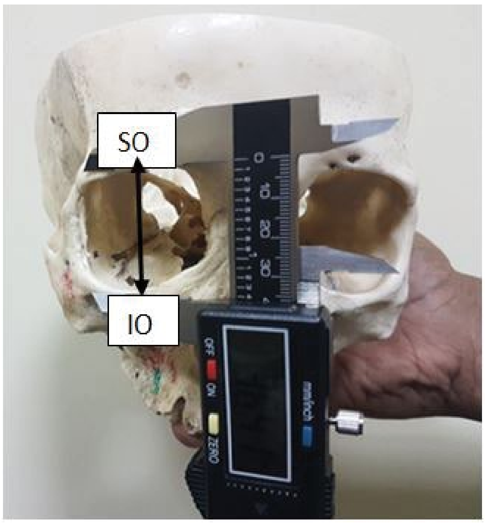

Fig. 1. Measurement of Orbital Height

Tab. 2. Comparison of orbital height, orbital breadth, orbital index, orbital rim perimeter orbital opening area and bony orbital volume between left and right side orbits

Parameter	Left Orbit (60)		Right Orbit (60)		Total Orbits (120)		p	SEM
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range		
Orbital Height (cm)	3.575 ± 0.329	2.8 -4.1	3.580 ±0.301	2.9-4	3.577 ± 0.314	2.8 -4.1	0.9309	L=0.042 R=0.039
Orbital Breadth (cm)	4.008 ± 0.362	3 -4.4	4.008 ±0.326	3.1-4.3	4.008 ± 0.343	3.0 -4.4	1	L=0.047 R=0.042
Orbital Opening Area (cm²)	11.337 ± 1.875	6.6- 13.852	11.342 ±1.735	7.063- 13.514	11.339 ± 1.799	6.6- 13.852	0.987	L=0.308 R=0.285
Orbital Rim Perimeter (cm)	13.262 ± 0.448	12.2- 14.2	13.248 ± 0.439	12.4-14.1	13.15 ± 1.343	12.2 -14.2	0.869	L=0.058 R=0.057
Orbital Index (%)	89.312 ± 4.506	78.571- 97.619	89.373 ± 3.427	80.487- 95.238	89.342 ± 3.987	78.571- 97.619	0.934	L=0.581 R=0.442
Bony Orbital Volume (ml)	25.590 ± 1.104	23.9- 28.3	25.602 ± 1.143	24-28.4	25.595 ± 1.119	23.9- 28.4	0.954	L=0.143 R=0.148

SEM: Standard Error Mean; P: significance; L: Left Orbit; R= Right Orbit; SD: Standard Deviation

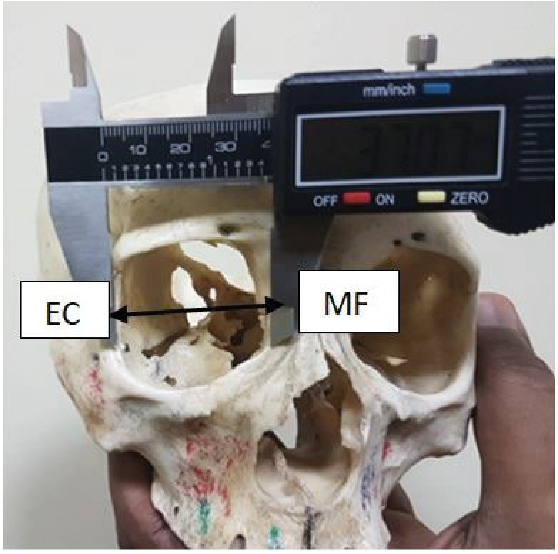

Fig. 2. Measurement of Orbital Breadth

Fig. 3. Measurement of Orbital Perimeter

Fig. 4. Measurement of Orbital Volume

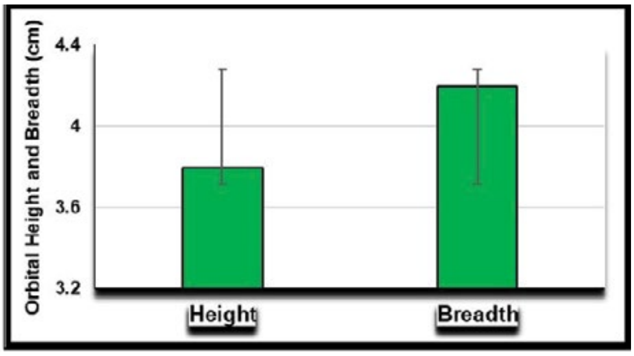

Fig.5. Bar Diagram showing mean of height and breadth of 120 orbits

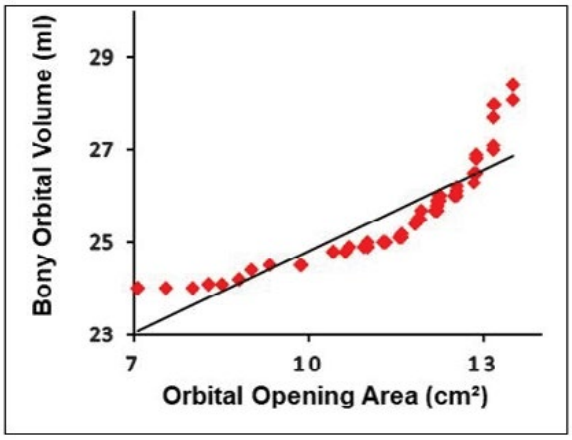

Fig.6. Positive Correlation graph (Left Orbit)

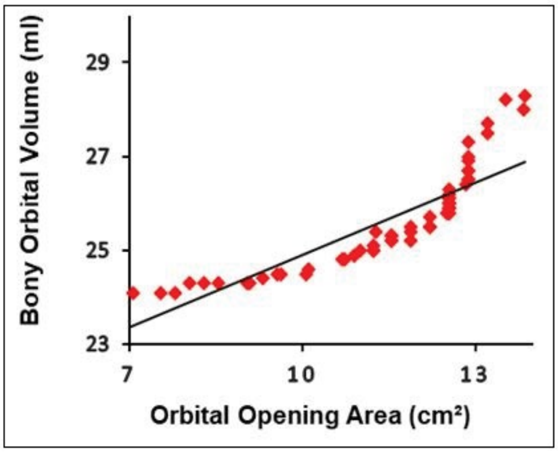

Fig.7. Positive Correlation graph (Right Orbit)

RESULTS

The data measured regarding general parameters for the right and left orbits in the skulls are shown in Table 2. Bilateral

Tab. 3 Classification of Orbital Cavity according to Orbital Index (OI) in adult dry skulls

Category	Total Orbits (n=120)			Left Side Orbit (n=60)		Right Side Orbit (n=60)	
	n	%	OI (%) ± SD	n	OI (%) ± SD	n	OI (%) ± SD
Microseme OI ≤ 83	8	6.66	80.749±3.079	5	79.761±1.683	3	81.707±1.724
Mesoseme OI 83 to 89	44	36.66	85.952±3.703	19	86.111±3.928	25	85.952±3.703
Megaseme OI ≥ 89	68	56.67	92.490±3.885	36	93.681±5.568	32	92.619±3.703

Tab. 4 Orbital index of various population groups measured by different authors

SN	Author	Population Group	Orbital Index	Category
1	Joshi et al. [35]	North Indian	Left-80.67 Right-80.75	Microseme
2	Divya et al. [36]	South Indian	Left-85.48 Right-84.49	Mesoseme
3	Nagaraj et al. [37]	South Indian	Left-88.26 Right-86.52	Mesoseme
4	Narsinga et al. [38]	South Indian	Male-86.13	Narsinga Rao (2015) [38]
5	Mekala et al. [39]	South Indian	Left-84.82 Right-85.22	Mesoseme
6	Gosavi et al. [40]	South Indian (Maharashtra)	81.88	Microseme
7	Munguti et al. [41]	Kenya	Male-82.57 Female-83.48	Microseme Mesoseme
8	Ebeye et al. [42]	Nigerian	78.36	Microseme
9	Kaur et al. [32]	North Indian	81.65	Microseme
10	Rajangam et al. [4]	Indian	Left-75.3 Right-73.6	Microseme Microseme
11	Ukoha. U et al. (2011) [2]	Nigerian	89.21	Megaseme
12	Sanjay et al. [43]	Thailand	Male-83.5 Female-86.61	Mesoseme Mesoseme
13	Lal et al. [44]	Sri Lankan	Male left 80.74 ± 5.85 Male right 77.83 ± 5.11 Female: left 85.47 ± 5.7 Female right: 83.31 ± 5.39	Microseme Mesoseme (Female)
14	Igbigbi et al. [45]	Malawians	Males-94.35 Females-96.03	Megaseme
15	Present Study (2021)	Maharashtrian	Left-89.312 Right-89.373	Megaseme Megaseme

Tab. 5 Orbital Volume of various population groups measured by different authors

SN	Author	Population Group	Orbital Volume
1	Shyu et al. [27]	Taiwanese	Male: left orbit-24.3 ± 1.51 Right orbit- 24.7 ± 1.17 Female: Left orbit- 21.0 ± 1.21 Right orbit- 21.1 ± 1.30
2	Pan TH [47]	Chinese	29.3 ± 2.5 ml
4	Furuta M [48]	Japanese	Male: 23.6 ± 2 cm^3 Female: 20.9 ± 1.3 cm^3
5	Osaki et al. [20]	American	26.2 ml
6	Oono R, [49]	Japanese	Male: Left orbit-25.9 cm^3 Right orbit-26.0 cm^3 Female: Left orbit-23.2 cm^3 Right orbit- 23.1 cm^3
7	Forbes et al. [26]	American	Male: 23.63 cm^3 Female: 23.92 cm^3
8	Fetouh et al. [30]	Egyptian	Male: 28.75 ± 1.57 Female: 25.68 ± 1.21
9	Ji et al. [31]	Chinese	Male: 26.02 Female: 23.32
10	Erkoç et al. [46]	Turkish	Male: 32.21 ± 1.55 cm3 Female: 31.11 ± 1.87
11	Reznick et al. [50]		30 ml
12	Chau et al. [51]	Hongkong Chinese	Male: 22.2 ml Female: 19.81 ml
13	Ye et al.[52]	Korean	23.94 ml ± 3.47 cm3
14	Acer et al. [33]	Turkish	17.8 ml
15	Deveci et al [53]	Caucasian	28.41 ml
16	Present study, 2021	Indian	Left orbit: 25.590 ± 1.104 Right orbit: 25.602 ± 1.143

Tab. 6 Orbital Perimeter of various population groups measured by different authors

SN	Author	Population Group	Orbital Rim Perimeter
1	Weaver et al. [64]	American	Male: 114.74 ± 5.49 mm Female: 112.15 ± 5.44 mm
2	Ji et al. [31]	Chinese	Male: 12.65 ± 0.45 cm Female: 12.20 ± 0.43 cm
3	Anguraj S. [65]	Indian	Male: 11.70 cm Female: 11.16 cm
4	Fetouh et al. [30]	Egyptian	Male: 12.60 ± 0.202 cm Female: 12.28 ± 0.35 cm
5	Present study	Indian	13.15 ± 1.343 cm

measurements from all 60 skulls were analysed. Overall mean ± standard deviation of Orbital Index for this sample size (120) orbits was 89.342 ± 3.987. There was no asymmetry observed in right and left orbits as significant differences were not seen between the right and left orbits as $p>0.05$. Table 3 classifies Orbital Cavity according to Orbital Index (OI) in adult dry skulls. While overall mean of OI indicates that orbits belonged to megaseme category. Further analysis of these orbits was done to ensure the exact number of orbits of each category. 68% of the orbits in study sample belonging to megaseme category while lesser number of orbits i.e. 44% and 8% belonged to mesoseme and microseme categories.

While significant differences were not observed between the left and right orbits of the particular skull regarding the different parameters such as orbital height, breadth, orbital opening area, orbital rim parameter, bony orbital volume with $p>0.05$ (Table 2) the differences are highly significant ($p<0.0001$) with regards to comparison of orbital height and breath 3.577±0.314 and 4.008±0.343 respectively and SEM values as 0.029 and 0.031 (Figure 5). Positive Correlation (r) was observed between bony orbital volume and orbital opening areas in both left ($r=0.8738$) and right ($r=0.8844$) orbits (Figures 6 and 7) and was highly significant with $p<0.0001$.

DISCUSSION

Standards based on ethnic or racial data are important to understand the different patterns of craniofacial growth resulting from racial, ethnic, and sexual differences [34]. Due to the complex shape of orbit thorough knowledge of anatomy of the orbit and meticulous surgical skills are needed to minimize the downsides of intraorbital surgery.

The Orbital dimensions are significantly important in ophthalmology, oral maxillofacial surgery and neurosurgery. In each orbital cavity, the breadth is usually greater than the height, and the relation between both of them is evident by orbital index. The orbital index is high in the child, the vertical diameter of the orbital opening being practically the same as the horizontal, but later the transverse increases more than the vertical [3]. Orbit may be exposed to many surgeries, such as orbital decompression, enucleation, exenteration, optic nerve decompression and vascular ligation. To avoid injuries to the important structures in the orbit, mainly neurovascular bundles passing through various foramina and fissures, precise knowledge of the anatomy plays significant role.

Results of the present study show that mean Orbital height of the left side is 35.75 mm as compared to values of 30.96 mm by Rolly et al. [35], 31.8 mm by Divya et al. [36], 32.8 mm by Nagaraj et al. [37], 32.90 mm by Narsinga et al. [38], 32.20 mm by Ukoha et al. [2], 35.30 mm by Mekala et al. [39] and 33.7 mm by Rajangam et al. [4]. Thus, the value of our study is higher than any other group showing the difference in the region and population group. The mean Orbital height of the right side in the present study is 35.80 mm. In comparison the values for Rolly et al. is 32.37 [35], Divya et al. is 31.6 mm [36], Nagaraj et al. is 32 mm [37], Narsinga et al. is 36.2 mm [38], Ukoha et al. is 31.90 mm [2], Mekola et al. is 35.50 mm [39] and Rajangam et al. is 35 mm [4]. This value again is higher in our study depicting the change in the population group and region.

Results of the present study show that mean Orbital breadth of the left side is 40.08 mm as compared to 40.42 mm by Rolly et al. [35], 37.2 mm by Divya et al. [36], 35 mm by Nagarajet al. [37], 36.40 mm by Narsinga et al. [38], 35 mm by Ukoha et al. [2], 41.8 mm by Mekala et al. [39] and 40.80 mm by Sayee Rajangam (2012) [4]. This value is more from some studies but less than Rolly et al. [35], Mekala et al. [39] and Rajangam et al. [4] only. The mean Orbital breadth of the right side in the present study is 40.08 mm. In comparison the values for Rolly et al. is 40.31mm [35], Divya et al. [36] is 37.4 mm, Nagaraj et al. is 37 mm [37], Narsinga et al. is 36.5mm [38], Ukoha et al. is 36.3 mm [2], Mekala et al. is 41.7mm [39] and Rajangam et al. is 41.7 mm [4]. This value is also found to be less than Rolly et al. [35], Mekala et al. [39]and Rajangam et al. [4] only.

Orbital Index

The values for Mean Orbital index in the present study for left side is 89.31 and for right side is 89.37 respectively. Thus, the population group in the present study fall in the Megaseme (Large) group. This study adds to the data regarding Orbital Index of other studies. Table 4 shows the Orbital Index of various population groups done by many authors.

Orbital volume

Orbital volume is a significant determinant of the facial appearance and its understanding is likely to be of guidance in the determination of complicated clinical cases such as orbital decompression and deciding the size of orbital implants following enucleation. Furthermore, knowledge of the normal size and magnitudes of orbital contents may benefit in diagnosing unilateral ophthalmopathy [46] (Table 5).

Orbital volumetric changes with respect to gender are debatable. Some studies found larger orbital volumes in men than women while others did not report any significant difference as can be seen in the table-4 which has a comparative data of several studies compiled together. The Bony Orbital Volume (BOV) is a common parameter used to estimate the orbital changes or abnormalities [31]. In the present study, the total mean of BOV is 25.59 ml on the left side and 25.60 ml on the right side. This parameter of Orbital volume in the present study was more than Taiwanese, Hongkong, Chinese, Korean, Japanese and Turkish population groups whereas it was less than Egyptian and Caucasian populations (Table 5). All these variations in the Bony Orbital Volume reflect ethnic factors and different measurement methods. Orbital volume measurement may help the surgeon to predict the volume to be restored and to avoid probable complications [53]. A very interesting relationship between Orbital volume and Orbital opening area was observed in the present study which has not been documented by any other study. It showed that as the Orbital opening area increased the Orbital volume also increased emphasizing the fact that the orbital opening area is directly proportional to other dimensions of the Orbit (Figures 6 and 7).

It is very well known that the orbital volume varies with race and sex [54]. But there was no significant difference between the right and left orbital volumes in our study. Some other researchers have also reported insignificant differences between right and left orbital volumes [26, 46, 49]. Seiji et al. [55] observed skull asymmetry in most dry skulls in the height, breadth, perimeter and orbital opening area except in very few, that too only in vertical diameter and perimeter, and presumed that this asymmetry is a normal anatomical pattern. Genetic factors, environmental factors, or a combination of the two factors may play a role in craniofacial asymmetry between the right and left sides [56]. The difference between the right and left may be attributed to the differential growth of the two sides of the brain with dominance of the right side [57, 58]. Lanzieri et al. [59] observed domination of the left side is more common in face asymmetry. But Jain and Jain [60] proved that both halves of the skull are symmetrical. Intrauterine position of a foetus may also be a contributing factor in facial asymmetry [57]. A strong correlation was observed between age and orbital volume and it was reported that more than 95% of the growth of the adult orbit has already been completed by the first half of the teens [48]. Our study shows a strong correlation between orbital opening area and orbital volume in both left and right orbit (Figures 6 and 7). Strong correlation of orbital volume was observed with height of orbit by Furuta M [48].

Orbital volume evaluation is an important part of pre-operative assessments in Orbital tumors, orbital trauma and congenital deformity patients [27]. The pyramidal shape of orbit with numerous foramina and openings lead to difficulty in orbital volume evaluation. Variation exist in the evaluation of orbital volume in patients, as the anterior opening of the orbit does not lie within a single plane [25, 31]. Koppel et al. [61] studied orbital volume by using CT images and volume of the intraorbital prosthesis as determined by a volume displacement gravimetric method while water filling method was used by Acer et al. [33]. The water-filling method is considered to be the gold standard criterion for volume measurement, but its use is restricted to cadaver skulls [26, 33]. Although CT scans find wider use due to the ability to define bony structures in a better way [62, 63], MRI is favored in case of children due to lack of radiation exposure [51]. Although several methodologies have been proposed to assess the orbital volume (OV), however, they did not see a criterion standard study evaluating the results of the methodologies for the assessment of OV. The first report related to measurement of orbital volume by sand filling method dates back to 1933 in Northern Chinese male subjects in which orbital volume was found to be 29.3±2.5 ml [47]. The volume of the orbital cavity was taken by sealing all the orbital openings with plasticine and filling the cavity with sand upto the level of orbital margins. This volume of sand was measured by graduated glass cylinder. Orbital volume can be measured one-dimensionally [48].

Orbital perimeter

The orbital rim which is the margin of the orbital opening is a superficial structure that determines the orbito-facial appearance [31]. In the present study, the orbital rim perimeter was 13.26 cm on the left and 13.24 cm on the right and these values are more to that measured by Ji et al. [31] in Chinese (12.08 cm in males and 12.20 cm in females) and in a study done by Fetouh et al. [30] on Egyptian population which showed values of 12.6 cm in males and 12.28 cm in females (Table 6). It is also more than the Values of Weaver et al. [64] in American population and Anguraj S [65] in Indian radiological study. This shows the racial difference between Indian, Chinese and Egyptian and American populations. Researches indicate that the widest circumference of the orbit is inside the orbital rim at the lacrimal recess [1].

Orbital opening area

The total mean of the orbital opening area in the present study is 11.33 cm^2 on the left side and 11.34 cm^2 on right side where as the value in study by Fetouh et al. [30] was 11.08 cm^2 in males and 11.71 cm^2 in females. These values are approximate to that found in Chinese (11.8 cm^2 in males and 11.10 cm^2 in females) [31]. This value was found to be almost similar in all the three studies.

Thus, normal values of orbital indices are vital parameters in the evaluation and diagnosis of craniofacial deformities and post traumatic injuries. Hence, knowledge of the normal values for a particular region can be utilized to treat and produce best aesthetical and clinical results. As craniofacial deformities are very common, standards based on local data are desirable which reflect the different patterns of craniofacial growth based on racial, ethnic, social and dietary factors.

CONCLUSION

In depth study of orbit is significant for anatomists, ophthalmologists, oral and maxillo facial surgeons, neurosurgeons and forensic experts. The Orbital index from the present study is 89.312 on the left side and 89.373 on the right side. This, according to the classification show that the Skulls are Megaseme. Thus, the people are of Yellow races which correlates correctly with the region. Importance of orbital index lies in understanding of fossil records, skull classification in forensic medicine and the clarification of trends in evolutionary and ethnic disparities. Other morphometric parameters measured in the orbit of the Maharashtrian skulls examined showed values which differed when compared with other population groups. Also, side differences have been confirmed. The positive correlation between Orbital opening area and Orbital volume has been seen in this study, which will further help the reconstructing surgeon to come up with better post-operative results and also be used in forensic studies. Different patterns of craniofacial growth can be seen in different races. Accurate determination of orbital volume can be valuable in various clinical situations in which quantification of orbital volume is needed, including orbital decompression in Graves' orbitopathy, volume restoration in orbital fractures or other orbital reconstructive surgery in orbital tumors. However, more studies are needed to be done on normal population with a bigger sample size and the information gained and analyzed should be used before executing volumetric assessments and treatments in diseased, injured orbits and ophthalmic tumours, thus guiding in proper management.

FUNDING

None.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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