

Morphometric Analysis of the Orbit in Dry Skulls of North Indian Population: A Direct Measurement Study

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Abstract

Introduction: Human orbit is a complex anatomical region, comprising visual apparatus along with its neurovascular structures. Morphometric analysis of orbit is of significant value for anthropologists, anatomists, forensic experts and surgeons. The objective of this study was to provide gender-related data on various orbital parameters in the North Indian population, and to compare the results with previous authors. **Materials and Methods:** The orbital dimensions of 86 dry adult skulls (45 males and 41 females) were used for direct measurement with vernier caliper. The calculation was carried out on both the right and the left sides. All the data obtained were tabulated and statistically analyzed. **Results:** The mean orbital height for males and females was 32.53 ± 2.00 mm and 32.43 ± 1.57 mm while the mean orbital width was 39.98 ± 1.81 mm and 39.37 ± 1.65 mm, respectively. The mean volume of the bony orbit was 26.09 ± 2.15 ml in males, and 24.04 ± 2.30 ml in females. Orbital index was calculated by using the formula $Ht/Br \times 100$. The mean orbital index was 81.51 ± 6.11 mm and 82.54 ± 5.38 mm in males and females respectively, which classified both genders in the microseme category of orbit. There was no statistically significant difference observed between the right and left side of the orbital parameters. **Conclusion:** Comparison of findings with earlier research reveals that the anatomical character of the orbital cavity differs greatly, not only because of the diversity of the parameters used, but also because of ethnic variations, different methods of measurement and sample size. Data collected in the present investigation could serve as a baseline orbital morphometric data for the North Indian population, which is very useful during plastic surgery, maxillofacial and neurosurgery, as well as in forensic science.

Keywords: Orbit, North Indian skulls, morphometry, Orbital index.

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INTRODUCTION

The orbits are craniofacial bony sockets positioned on either side of the sagittal plane of skull, comprising the visual apparatus including the eye ball, related muscles, nerves, vessels, lacrimal apparatus, fascial strata and fat. They enable the visual axis to be oriented correctly, and establish the spatial relation between the eyes which is important for both binocular vision and eye motion in conjugation [1, 2].

Morphometric parameters of orbit are of significant value in many specialties, including ophthalmology, optometry, oculoplastic surgery, traumatology and oral maxillofacial surgery. Orbital indices are also an important predictor for the assessment and treatment of craniofacial syndromes and post-traumatic deformities. This is also relevant in various other fields such as analysis of fossil records,

classification of skulls in forensic medicine, explanation of trends in evolutionary and ethnic differences. Therefore, detailed knowledge of the orbital anatomy is essential [3-6]. Since the morphology of the orbit seems to be dependent on the population as indicated by the previous authors [3, 7-10], the present study was undertaken to provide morphometric orbital data in the dry skulls of the North Indian population.

MATERIALS AND METHODS

The present study sample consists of 86 dry adult human skulls of unknown sex. None of the skulls had any injury, congenital deformity or artifacts. On the basis of morphology, 45 male and 41 female skulls were differentiated [11-13].

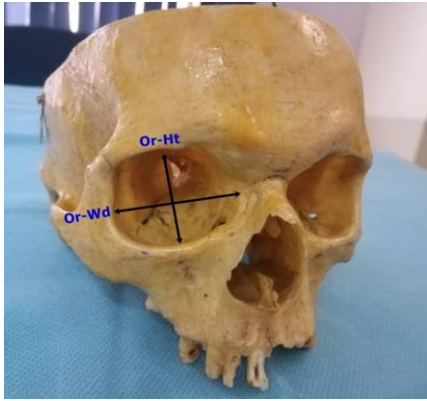


Fig-1: Photograph showing the measurements of orbital width (Or-Wd) and orbital height (Or-Ht)



Fig-2: Measurement of bony orbital volume using the water filling method.

Measurements were calculated for the dimensions of the orbits (Figure-1) placing the skull in

Frankfurt’s horizontal plane [11, 14, 15]. The analyzed parameters were:

- a. Orbital height (Or-Ht) → The distance between upper and lower margins of the orbital cavity perpendicular to the horizontal axis of the orbit was calculated.
- b. Orbital width (Or-Wd) → Measured from the point on the medial margin of the orbit where the frontal, lacrimal and maxillary bones intersect (Dacryon point) to the junction between the lateral orbital margin and the horizontal line which divides the orbital opening into two equal parts (Ectoconchion point).
- c. Orbital index (Or-I) → Orbital height / orbital width x 100.
- d. Orbital volume (Or-Vol) → The water displacement method was used to determine the volume of the bony orbit. Briefly, for the bony orbits three-dimensional models of plasticine were made. Each model was immersed in a graduated cylinder filled with distilled water. The displaced water was measured, representing the orbital volume (Figure-2).

All the measurements were taken bilaterally and the data obtained were tabulated and statistically analyzed. Paired t-test was done to assess the statistical significance of all orbit parameters for sides and gender. Differences were considered statistically significant at $p < 0.05$.

RESULTS

The present study was conducted in 86 adult skulls, of which 45 were males and 41 were females. Table 1 displays the measured data for the right and left orbits in the male skulls. The mean orbital height was 32.90 ± 1.95 mm on the right and 32.16 ± 1.99 mm on the left side and the mean orbital width was 40.16 ± 1.80 mm on the right and 39.80 ± 1.80 mm on the left side. The mean volume of the bony orbit was 26.21 ± 2.13 ml on the right side and 25.96 ± 2.16 ml on the left side.

Table-1: Descriptive data and statistical significance of orbital dimensions in right and left male orbits

Parameter	Right	Left	p-value
	Mean±SD	Mean±SD	
Orbital height (mm)	32.90±1.95	32.16±1.99	0.17, ns*
Orbital width (mm)	40.16±1.80	39.80±1.80	0.47,ns
Orbital volume (ml)	26.21±2.13	25.96±2.16	0.67,ns
Orbital index	82.09±6.19	80.94±5.98	0.49,ns

$P < 0.05$ was considered statistically significant. ns*: not statistically significant.

Table-2 displays the measured data for the right and left orbits in the female skulls. The mean height on the right side was 32.05 ± 1.55 mm and on the left was 32.82 ± 1.50 mm and the mean width on the right side was 39.06 ± 1.46 mm and on the left was 39.68 ± 1.76 mm. The mean volume of bony orbit

measured was 24.07 ± 2.20 ml and 24 ± 2.39 ml, respectively, on the right and left sides. All of the measured parameters were higher on the right side than on the left side in males and females with no statistically significant differences ($p < 0.05$).

Table-2: Descriptive data and statistical significance of orbital dimensions in right and left female orbits

Parameter (mm)	Right	Left	p-value
	Mean±SD	Mean±SD	
Orbital height (mm)	32.05±1.55	32.82±1.50	0.07,ns*
Orbital width (mm)	39.06±1.46	39.68±1.76	0.16,ns
Orbital volume (ml)	24.07±2.20	24±2.39	0.91,ns
Orbital index	82.18±5.00	82.89±5.71	0.63,ns

P<0.05 was considered statistically significant. ns*: not statistically significant.

The orbital index was calculated using orbital height and width. The mean orbital index in males was 82.09±6.19 mm on the right and 80.94±5.98 mm on the left side, in females it was 82.18±5 mm on the right and 82.89±5.71 mm on the left side.

Table-3 compares the sum mean of parameters between males and females (right and left side). There was no statistically significant differences observed in measured parameters between males and females, except for the orbital volume where the difference was statistically significant (p<0.05).

Table-3: Descriptive data and statistical significance for orbital dimensions in total male and female orbits

Parameter (mm)	Male	Female	p-value
	Mean±SD	Mean±SD	
Orbital height (mm)	32.53±2.00	32.43±1.57	0.79,ns
Orbital width (mm)	39.98±1.81	39.37±1.65	0.07,ns
Orbital volume (ml)	26.09±2.15	24.04±2.30	0.00,s**
Orbital index	81.51±6.11	82.54±5.38	0.35,ns

P<0.05 was considered statistically significant. ns*: not statistically significant, s**: statistically significant.

The mean orbital index was 81.51±6.11 mm and 82.54±5.38 mm for males and females, respectively, indicating that the North Indian orbital group is microseme type.

DISCUSSION

Each orbit is shaped like a pyramid, with its apex directed posteriorly at optical canal and its base anterolaterally is formed by the orbital margin [1, 2]. Martins *et al.*, described the anatomical characteristics of the orbit and revealed that the structures in the orbit consist of seven bones, seven muscles and seven nerves [16]. Orbital morphometric analysis will also play an essential role in particular surgeries in the orbit, for instance, orbital decompression, enucleation, exenteration, optic nerve decompression and vascular ligation [3-6].

Gosavi *et al.*, evaluated 64 skulls from Maharashtra region and reported that the mean orbital height was 31.97±2.39 mm and 32.66±2.71 mm on the right and the left sides respectively, and the orbital width was 39.71±2.65 mm on the right side and 39.22±2.5 mm on the left side [17]. According to the study of Kaur in Punjab, India, the mean orbital height was 31.9 mm ± 2.2 mm and 32.2 mm ± 1.8 mm respectively for right and left sided orbital cavity. And the mean orbital width was 39.7 mm ± 2.2 mm and 38.8 mm ± 3.1 mm respectively for the right and the left orbital cavity [18]. The study of Lal *et al.* in Sri Lankan skulls showed that the mean orbital height in males on the right and left sides was 32.24±2.19 mm and 32.74±1.96 mm, with a width of 41.47±1.94 and 40.63±1.9 mm respectively. In females on the right and

the left side, the mean orbital height was 32.35 ± 1.93 and 32.65 ± 1.94 mm while the width was 38.91 ± 2.39 and 38.27 ± 2.1 mm respectively [19]. In a study on the South Indian population recorded that, the orbital height was 36.2 ± 2.3 mm in males and 34.5 ± 2 mm in females while the orbital width in males was 42.9 ± 2.7 mm and in females was 40.5 ± 2.4 mm [20]. In the province of West Bengal, a populated region in eastern India, Sarkar *et al.* has examined 92 skulls and has observed that the orbital height was 34.97±3.86 mm on the right and 35.22±3.84 mm on the left side, while the orbital width was 39.87±4.06 mm on the right and 39.93±3.97 mm on the left side in males. In females, orbital height was 35.63±5.17 mm on the right and 35.86±5.33 mm on the left side, while orbital width was 39.01±4.92 mm on the right and 39.17±4.92 mm on the left side [21]. According to Fetouh *et al.* who examined 52 adult Egypt skulls, orbital height in males on the right side was 35.83±1.23 mm while on the left side it was 35.27±1.35 mm and mean orbital width on the right side was 43.62±1.13 mm and on the left side was 42.6±0.94 mm. The mean orbital height for the female skulls was 35.53±0.95 mm on the right side and 34.71±1.12 mm on the left side and the orbiting width on the right side 42.75±1.35 mm and 42.0±1.37 mm on the left side [4]. In 2017, Yonguc *et al.*, measured 74 adult West Anatolian dry skulls and recorded an orbital height of 34.4 ± 2.3 mm and 34.1 ± 2.2 mm on the right and left sides respectively, with an orbital width of 37.1 ± 3.5 mm on the right and 37 ± 3.4 mm on the left side [22]. In the present study, the orbital height observed in males was 32.90±1.95 mm on the right and 32.16±1.99 mm on the left side and in females it was 32.05±1.55 mm and 32.82±1.50 mm on the right and left side respectively. The orbital width for males was

40.16±1.80 mm on the right and 39.80±1.80 mm on the left side and for females it was 39.06±1.46 mm and 39.68±1.76 mm on the right and left sides respectively. The overall mean orbital height was 32.53±2.00 mm in males and 32.43±1.57 mm in females while the mean orbital width was 39.98±1.81 mm for males and 39.37±1.65 mm for females. The right and left orbital heights and widths were not statistically significantly different, indicating left and right symmetry. These values are in congruence with Gosavi, Kaur and Lal, but, Fetouh and Mekala observed higher values in their study. The differences observed could be due to variation in sample size, method of study and geographical, environmental and genetic diversity.

Quantitative determination of orbital volume is valuable for the assessment and management of a number of conditions affecting the orbit [14, 23-25]. Fetouh et al. in Egyptian skulls recorded the mean right and left bony orbital volumes as 29.07±1.64 ml and 28.15±1.32 ml in males and 26.16±1.23 ml and 25.21±1.03 ml in females, respectively [4]. In a study in Turkey reported that the mean orbital volume in males

was 32.21±1.55 cm³ and in females was 31.11±1.87 cm³ [26]. Shyu *et al.*, studied the orbital volume of the Taiwan population and reported a mean of 24.7±1.17 ml and 24.3±1.51 ml respectively for the right and left orbits in males. The mean female orbital volume in the right and left orbit was 21.1±1.30 ml and 21.0±1.21 ml respectively [23]. Chau et al. in Hong Kong Chinese observed that bony orbital volume was 22.2 ml in males and 19.81 ml in females [27], whereas in a study of Japanese subjects, it was found to be 23.6±2.0 cm³ in males and 20.9±1.3 cm³ in females [28]. In a study conducted by Acer et al., documented that the mean bony orbital volume of the right orbital cavity was 22.35 ± 3.05 cm³ and 18.47 ± 2.52 cm³ respectively for males and females. Similarly the mean orbital volume of the left orbital cavity for males and females was 22.71 ± 2.80 cm³ and 18.16 ± 2.52 cm³ respectively [29]. In the present study, the mean bony orbital volume on the right and left sides in males was 26.21±2.13ml and 25.96±2.16ml, whereas in females was 24.07±2.20ml and 24±2.39ml respectively.

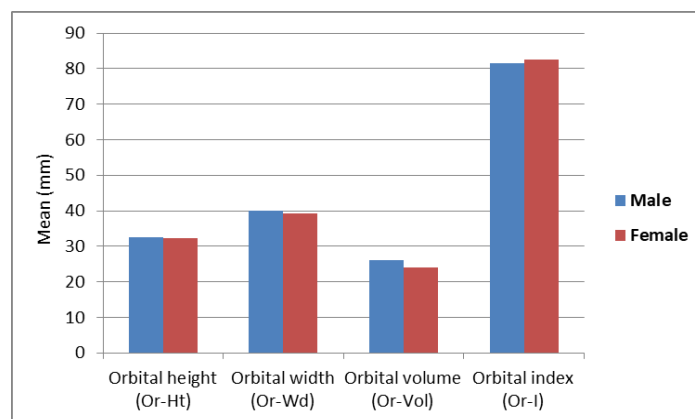


Fig-3: Bar diagram showing the Comparison of mean orbital morphometry values between male and female skulls

The present study result was found to be lesser than Fetouh and Erkoc, but greater than Shyu, Chau, Furuta and Acer. The variability in the results was due to the disparity in the methodology and the geographical position of the studies. The values of the measured parameters in the present study were greater in males than in females, which were statistically insignificant in height and width while being significant in volume (Figure-3). The discrepancy observed between the values on the right and left side of the calculated parameters could be due to the differential growth on both sides of the brain [30].

The relationship between the orbital height and the orbital width is determined by the orbital index (OI), which is defined as the ratio of the orbital height to the width multiplied by 100. Using the orbital index as a reference, three orbit groups have been identified, megaseme describes an OI of 89 or over and microseme describes an OI of 83 or less, while mesoseme describes an OI between 83 to 89 [20, 31]. The orbital index that

determines facial shape varies among different population groups. It means that orbits with greater width than height will have smaller orbital indices, while those with larger orbital indices will have wider faces [18, 31].

The present study observed that the mean orbital index in males was 82.09±6.19 mm for the right side and 80.94±5.98 mm for the left side, while in females it was 82.18±5.00 mm for the right side and 82.89±5.71 mm for the left side. The gross orbital index was 81.51±6.11 and 82.54±5.38 respectively for males and females. This classified the orbital cavity of the North Indian population under microseme category.

Mekala *et al.*, categorized the male and female orbital cavity under mesoseme with an average orbital index of 84.62 and 85.46 respectively in the South Indian population [20]. According to Narasinga et al. analysis in North Coastal Andhra Pradesh, the average orbital index for right and left orbits was 86.13 and 90.69 respectively, which listed right orbits as

mesoseme and left orbits as megaseme [32]. For the Central Indian population, the orbital index was 84.39 mm on the right side and 84.57 mm on the left side, according to Aggarwal et al [33]. In a study by Gosavi *et al.*, in the Maharashtra region classified the orbital cavity under the microseme with a mean orbital index of 81.88, while it was 81.65 according to Kaur in the Punjab region [17, 18]. Alam *et al.*, measured the orbital index in 50 skulls and observed that it was 82.60 ± 4.43 mm on the right and 82.76 ± 6.96 mm on the left [34]. In their analysis on the Egyptian skulls, Fetouh et al. recorded the orbital index as 82.20 ± 2.97 mm on the right side and 82.81 ± 3.02 mm on the left side in males and 84.13 ± 3.76 mm on the right side and 82.88 ± 3.31 mm on the left side in females [4]. An analysis carried out on the South Indian population recorded an orbital index of 84.62 ± 8.21 mm in males and 85.46 ± 5.93 mm in females [20]. Gopalakrishna *et al.*, analysis in Indian population identified 79.69% of right orbit and 75% of left orbit under microseme, while 20.31% of right orbit and 25% of left orbit under mesoseme category [35].

There are variations in studies regarding the orbital index. The transformation of the facial skeleton into adult form involved several factors. While in utero the basic structure is determined in accordance with genetically programmed blueprint, it is modified pre- and postnatally via functional matrices that react to environmental and epigenetic influences such as ethnicity, racial and dietary history [36-39]. In addition, the practice of using a pillow or some other object to support the head while sleeping is also important [30, 40].

Knowledge of a specific region's orbital indices may be used as guidance for further research and care of patients with craniofacial deformities.

CONCLUSION

This study provides valuable baseline orbital morphometric data in the dry skull of North Indian adults for clinical and surgical care in ophthalmology, oral and maxillofacial surgery, neurosurgery, plastic surgery and designing eye protective equipment. These morphometric parameters are mandatory for the assessment of orbital cavity in several orbital diseases such as congenital orbital dysplasia, orbital fractures and intraorbital tumours. These metrics, in particular orbital index, can also be used in interpretation of fossil records, skull classification in forensic medicine and in exploring the trends in evolutionary and ethnic differences.

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