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Orbital Morphometry: A Computed Tomography Analysis

Jaswinder Singh, FRACDS, MOMFS,*
 Roselinda Ab Rahman, MClintDent,*
 Zainul Ahmad Rajion, BDS, GradDipClintDent, PhD,[†]
 Johari Abdullah, BS&IT(Hons), MSc(Dentistry),[‡]
 and Irfan Mohamad, MD, MMed(ORL)[‡]

Introduction: The human orbit is a complex anatomic region, which plays predominant role in the evaluation of craniofacial complex. A thorough understanding of the relationship of the distance from orbital rim to the important vital structures of the orbital apex is required for the surgeon to perform safe and effective surgery.

Objectives: To evaluate and compare the depth and distances from various points of the orbital rim to the fissures and foramina of the orbital apex between genders in the local population.

Methodology: Linear measurements were conducted on 60 orbits from 30 patients who had undergone head computed tomography scan. These measurements were done utilizing the multiplanar reconstruction modes on computed tomography images with minimum slice thickness of 1 mm.

Results: Males have statistically significant larger orbits than females with higher mean measurements in all parameters, except for the distance from posterior ethmoidal foramen to the optic canal which was the same. However, there were no significant differences in all parameters between the right and left orbits.

From the *Oral and Maxillofacial Surgery Unit; [†]Craniofacial Imaging Unit, School of Dental Sciences; and [‡]Department of Otorhinolaryngology—Head and Neck Surgery, School of Medical Sciences, Universiti Sains Malaysia Health Campus, Kota Bharu, Malaysia.

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Address correspondence and reprint requests to Dr Roselinda Ab Rahman, MClintDent, Oral and Maxillofacial Surgery Unit, School of Dental Sciences, Universiti Sains Malaysia Health Campus, 16150 Kota Bharu, Kelantan, Malaysia; E-mail: roselinda@usm.my

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Conclusion: This study provides the absolute limit of safe internal orbital dissection in respect to the local population. Despite males having larger orbits than females, it is clinically negligible.

Key Words: Computed tomography, morphology, orbit, surgery

The human orbit is part of a complex anatomic region in the head. Each of its 4 bony walls has its own unique feature and they are perforated by a number of fissures and foramina that carry vital neurovascular structures.¹

A thorough understanding of the internal orbital anatomy, in particular, the relationship of the orbital rim to the important soft tissues of the orbital apex, is required for the surgeon to perform safe internal orbital dissection and for the placement of grafts for reconstruction of orbital floor defects. Care must be given to prevent any damage caused by such maneuvers to the orbital neurovascular structures.²

There have not been any local records in Malaysia of such parameters that may be used as a reference to surgeons. Therefore, local orbital morphometry records are useful for preoperative planning and prediction of postoperative outcomes in midface surgeries.³ These figures may also assist orbital graft manufacturers to provide products with more accurate dimensions corresponding to the local orbital morphometry. References of orbital morphometry of the local population can play a crucial role in facilitating surgeons who are working on this area to be more precise with their surgical dissections to minimize complications specifically pertaining to the depth of the human orbit.

METHODOLOGY

A retrospective review on head computed tomography (CT) scan images was conducted to evaluate the orbital morphometry of adult patients in Hospital Universiti Sains Malaysia (Hospital USM). The distance measured includes from:

1. the supraorbital notch to the superior aspect of the orbital opening of the optic canal
2. the infraorbital rim point above the infraorbital foramen to the opening of the optic canal
3. the fronto-zygomatic suture to the optic canal
4. the fronto-zygomatic suture to the anterior extent of the superior orbital fissure
5. the inferior orbital margin to the anterior extent of the inferior orbital fissure
6. the midpoint of anterior lacrimal crest to the optic canal
7. the midpoint of anterior lacrimal crest to the anterior ethmoidal foramen
8. the anterior ethmoidal foramen to the posterior ethmoidal foramen
9. the posterior ethmoidal foramen to the optic canal

All adult patients were scanned using the Siemens Somatom Definition, AS+ 128-slice (Siemens, Erlangen, Germany) CT machine. These scans are done with contiguous image slice series thickness of 1 mm. Patients with abnormalities involving orbits such as traumatic injury, midface surgery, craniofacial syndromes, or orbital pathology such as Graves disease, infection, orbital lymphoma, optic nerve glioma will be excluded.

The CT scan images of the head were acquired at a slice thickness of 1 mm. The slice series had a matrix of 512 × 512 pixels each. These CT images were retrieved from the Picture Archiving and Communication System (PACS) server at the Radiology Department, Hospital USM to a Dell Precision T7500

TABLE 1. The Mean Difference of Distances Points From the Right Orbital Rim to the Optic Canal Between Gender (n = 30)

Parameter	Gender		Mean Difference (95% CI)	t-Statistic (df)	P Value
	Male	Female			
	Mean (SD)	Mean (SD)			
SON-OC	45.26 (0.67)	43.53 (1.12)	1.73 (1.04, 2.41)	5.143 (28)	<0.001
IOF-OC	45.71 (0.46)	44.05 (1.27)	1.66 (0.93, 2.39)	4.755 (17.54)*	<0.001
IOF-IFS	24.60 (0.82)	23.27 (1.21)	1.33 (0.54, 2.11)	3.529 (28)	0.001
FZ-OC	47.32 (0.70)	45.66 (1.06)	1.66 (0.99, 2.33)	5.062 (28)	<0.001
FZ-SOZ	38.21 (0.31)	36.88 (1.17)	1.51 (0.78, 2.13)	4.514 (28)	0.002
ALC-OC	42.14 (0.78)	40.83 (1.11)	1.29 (0.68, 2.38)	4.229 (28)	<0.001
ALC-AEF	20.75 (0.44)	19.51 (1.62)	1.63 (0.99, 2.12)	4.523 (28)	0.002
AEF-PEF	11.40 (0.92)	10.23 (1.18)	1.20 (0.67, 1.11)	4.581 (28)	0.005
PEF-OC	9.31 (1.16)	9.24 (1.27)	0.12 (0.92, 1.15)	4.252 (28)	0.487

AEF, anterior ethmoidal foramen; ALC, midpoint of anterior lacrimal crest; FZ, fronto-zygomatic suture; IFS, anterior extent of the inferior orbital fissure; IOF, infra-orbital rim point above the infraorbital foramen; OC, optic canal; PEF, posterior ethmoidal foramen; SON, supra-orbital notch.

* Equal variance not assumed.

workstation in Digital Imaging and Communications in Medicine, or DICOM, format. The linear measurements will be done using multi-planar reconstruction mode within the Centricity PACS-IntegradWeb software.

In this study, 10 subjects were randomly used to assess the reproducibility of the measurements. For intraexaminer variability, the researcher calculated all of the measurements of these 10 orbits twice on different days. For interexaminer variability, another observer, a craniofacial imaging expert, performed the same measurements independently on the same 10 subjects. Both the intraexaminer variability and interexaminer variability were analyzed by calculating the intraclass correlation coefficient from SPSS version 21 software.

RESULTS

Demography

A total of 30 subjects who attended Radiology Department Hospital USM for CT scan of the head were included. They comprised 15 males and 15 females were selected (Table 1).

The age ranged from 18 to 80 years old. The mean age was 46.2 (standard deviation 19.59) years old.

Comparison of Mean Distances Between Orbital Sides

The mean distances were measured for each orbital side, that is, right orbit (Table 1) and the left orbit (Table 2). An independent *t* test was carried out to identify if there is any statistical significance in differences between the right and left orbital depth values irrespective of gender. Interestingly, the distance from the posterior ethmoidal foramen to the optic canal was the only parameter displaying no statistical significance (right, with $P = 0.487$; left, with $P = 0.517$) between genders irrespective of the side of orbit. We found that there are no significant differences between the right and left orbits (Table 3). All *P* values of all parameters are more than 0.05.

Comparisons of Mean Distances Between Gender

While comparing the measurements between gender, we had observed that the supra orbital depth (SOC-OC) of males to be

TABLE 2. The Mean Difference of Distances Points From the Left Orbital Rim to the Optic Canal Between Gender (n = 30)

Parameter	Gender		Mean Difference (95% CI)	t-Statistic (df)	P Value
	Male	Female			
	Mean (SD)	Mean (SD)			
SON-OC	45.23 (0.61)	43.59 (1.12)	1.64 (0.96, 2.32)	4.986 (21.75)*	<0.001
IOF-OC	45.62 (0.47)	44.09 (1.24)	1.53 (0.81, 2.24)	4.467 (18.03)*	<0.001
IOF-IFS	24.59 (0.84)	23.30 (1.29)	1.29 (0.48, 2.11)	3.255 (28)	0.003
FZ-OC	47.10 (0.74)	45.85 (1.02)	1.25 (0.59, 1.92)	3.855 (28)	0.001
FZ-SOZ	38.20 (0.27)	36.83 (1.15)	1.69 (0.73, 2.08)	4.493 (28)	0.002
ALC-OC	42.07 (0.76)	40.17 (1.11)	1.24 (0.65, 2.31)	4.102 (28)	0.001
ALC-AEF	20.56 (0.41)	19.55 (1.58)	1.61 (0.87, 2.12)	4.219 (28)	0.004
AEF-PEF	11.38 (0.89)	10.26 (1.24)	1.17 (0.66, 1.09)	4.590 (28)	0.003
PEF-OC	9.35 (1.13)	9.37 (1.26)	0.11 (0.92, 1.14)	4.251 (28)	0.517

AEF, anterior ethmoidal foramen; ALC, midpoint of anterior lacrimal crest; FZ, fronto-zygomatic suture; IFS, anterior extent of the inferior orbital fissure; IOF, infra-orbital rim point above the infraorbital foramen; OC, optic canal; PEF, posterior ethmoidal foramen; SON, supra-orbital notch.

* Equal variance not assumed.

TABLE 3. The Overall Mean Difference of Distances Points From the Orbital Rim to the Optic Canal Between Sides (n = 30)

Parameter	Side		Mean Difference (95% CI)	t-Statistic (df)	P Value
	Right	Left			
SON-OC	44.40 (1.26)	44.41 (1.22)	-0.02 (-0.66, 0.62)	-0.52	0.959
IOF-OC	44.88 (1.26)	44.86 (1.20)	0.03 (-0.61, 0.66)	0.08	0.934
IOF-IFS	23.93 (1.22)	23.95 (1.26)	-0.01 (-0.65, 0.62)	-0.04	0.967
FZ-OC	46.49 (1.22)	46.47 (1.08)	0.02 (-0.58, 0.61)	0.06	0.956
FZ-SOZ	37.70 (1.20)	37.71 (1.22)	-0.08 (-0.61, 0.73)	-0.40	0.932
ALC-OC	41.56 (1.22)	41.55 (1.20)	0.06 (0.64, 0.74)	0.14	0.944
ALC-AEF	19.93 (1.26)	19.91 (1.23)	-0.02 (-0.51, 0.94)	-0.77	0.891
AEF-PEF	11.33 (1.20)	10.32 (1.14)	0.01 (-0.61, 0.98)	0.50	0.637
PEF-OC	9.31 (1.08)*	9.30 (1.02)*	0.06 (-0.91, 0.80)	-0.24	0.811

AEF, anterior ethmoidal foramen; ALC, midpoint of anterior lacrimal crest; FZ, fronto-zygomatic suture; IFS, anterior extent of the inferior orbital fissure; IOF, infra-orbital rim point above the infraorbital foramen; OC, optic canal; PEF, posterior ethmoidal foramen; SON, supra-orbital notch.

45.25 mm $\pm$ 0.64 mm. This appears larger than the overall superior orbital depth of females which recorded 43.56 mm $\pm$ 1.11 mm. The female patients display a wider range in supra orbital depth from 41.85 to 45.55 mm as compared with males who exhibit depths ranging from 44.15 to 46.55 mm.

Similarly, the inferior orbital depth values of male patients are higher than those of females. The mean orbital floor depth (IOF-OC) of males is seen at 45.67 mm $\pm$ 0.46 mm. This remains 1.6 mm more than the female subjects. Again, the females tend to show a wider range of 3.70 mm than males with 1.75 mm. The independent *t* test was repeated to identify any significant difference in orbital depths between genders irrespective of right or left orbits. Both of the above-measured parameters, that is, the supra and infra orbital depth differences between the 2 genders are statistically significant (*P* < 0.001).

Among the males, the distance from the rim point (IOF) to the anterior extent of the inferior orbital fissure (IFS) ranged from 23.10 to 25.95 mm with a mean distance of 24.50 mm $\pm$ 0.81 mm while in females, it ranges between 20.85 and 25.50 mm with a mean distance of 23.28 mm $\pm$ 1.24 mm. The difference between these distances of the 2 sexes gave a *P* = 0.002, which is statistically significant.

The differences in lateral orbital depth (FZ-OC) between genders are statistically significant with *P* < 0.001. Males tend to display a larger overall depth with a mean value of 47.21 mm $\pm$ 0.71 mm ranging from 45.80 to 48.40 mm. The female subjects on the other hand range from 43.40 to 47.60 mm with a mean depth of 45.75 mm $\pm$ 1.01 mm. These findings are similar to the mean distance of the fronto-zygomatic (FZ) suture to the superior orbital fissure (SOF) where the male subjects measured a higher value with 38.15 mm $\pm$ 0.30 mm compared with the females with 36.97 mm $\pm$ 1.15 mm.

The depth of this important fissure ranges from 35.10 to 39.00 mm in males to slightly shallower limits of females who range between 35.00 and 38.80 mm. Again, we see a statistical significance between genders corresponding to this measurement with a *P* = 0.02.

As for the medial orbital wall, we measured the overall depth from the anterior lacrimal crest (ALC) to the optic canal (OC) and the distance to anterior ethmoidal foramen (AEF). Overall means of the medial orbital depth in both genders are 42.04 mm $\pm$ 0.80 mm and 40.89 mm $\pm$ 1.03 mm for the males and females respectively. The *P* value for this parameter was recorded < 0.001 which dictates statistical significance between the 2 genders. We observed that the

anterior ethmoidal foramen is located deeper in males than in female subjects with mean measurements of 20.73 mm $\pm$ 0.41 mm and 19.46 mm $\pm$ 1.59 mm respectively (statistically significant with *P* = 0.003).

We observed a similar trend of the male patients displaying greater mean values when determining the distance from the anterior ethmoidal foramen to the posterior ethmoidal foramen. The males logged a mean of 11.42 mm $\pm$ 0.93 mm compared with the 10.23 mm $\pm$ 1.17 mm in females. Despite portraying a statistical significant gender difference *P* = 0.010, both sexes displayed a similar range of 4 mm in distance between measurements.

As mentioned in the earlier Results section, the only parameter that did not display any statistical difference between gender and sides of the orbit was the distance from the posterior ethmoidal foramen (PEF) to the OC. The *P* values for this measurement in all comparisons were above 0.05. The males recorded a mean of 9.32 mm $\pm$ 1.14 mm which was similar to that of female subjects with 9.21 mm $\pm$ 1.28 mm (Table 4).

DISCUSSION

The most dreadful consequence of internal orbital surgery is the postoperative complications that may lead to loss of vision. This concern is based on the perception that too vigorous or a careless orbital dissection may cause direct injury to the optic nerve.⁴ This postoperative sequela can be related to retrobulbar hemorrhage and retinal artery spasm, with an incidence of 3:1000.⁵ Holt and Kline have identified traumatic optic neuropathy as a noniatrogenic problem with an incidence of between 2% and 3%.^{6,7} while other authors believe excessive intraorbital edema or hematoma as a cause of compression of the vascular system, with resultant ischemic injury.^{4,8}

Although Stankiewicz mentions that direct intraoperative iatrogenic optic nerve damage is possible, it seems unlikely with current standard of internal orbital surgical techniques. The reason is that to traumatize the optic nerve during dissection, the surgeon must first encounter the contents of the inferior or superior orbital fissures, the origin of the ocular muscles, and the tendinous annulus of Zinn.⁹

Numerous studies have attempted to identify safe distances from anatomic landmarks to serve as clinical guidelines.^{2,10,11} They attempted to answer the same questions as our study objectives, however by using dry skulls and numerous extraorbital and intraorbital landmarks for reference points, and they incorporated instrumentation that, although precise, may not be practical in the clinical setting.

TABLE 4. The Overall Mean Difference of Distances Points From the Orbital Rim to the Optic Canal Between Gender (n = 30)

Parameter	Gender		Mean Difference (95% CI)	t-Statistic (df)	P Value
	Male	Female			
	Mean (SD)	Mean (SD)			
SON-OC	45.25 (0.64)	43.56 (1.11)	1.68 (1.00, 2.36)	5.007 (28)	<0.001
IOF-OC	45.67 (0.46)	44.07 (1.25)	1.59 (0.87, 2.32)	4.628 (17.72)*	<0.001
IOF-IFS	24.60 (0.81)	23.28 (1.24)	1.31 (0.53, 2.10)	3.425 (28)	0.002
FZ-OC	47.21 (0.71)	45.75 (1.01)	1.46 (0.81, 2.11)	4.579 (28)	<0.001
FZ-SOZ	38.15 (0.30)	36.97 (1.15)	1.48 (0.74, 2.11)	4.426 (28)	0.002
ALC-OC	42.04 (0.80)	40.89 (1.03)	1.28 (0.64, 2.33)	4.139 (28)	<0.001
ALC-AEF	20.73 (0.41)	19.46 (1.59)	1.64 (0.98, 2.09)	4.477 (28)	0.003
AEF-PEF	11.42 (0.93)	10.23 (1.17)	1.19 (0.60, 0.98)	4.502 (28)	0.010
PEF-OC	9.32 (1.14)*	9.21 (1.28)*	0.11 (0.80, 1.01)	0.241 (28)	0.478

AEF, anterior ethmoidal foramen; ALC, midpoint of anterior lacrimal crest; FZ, fronto-zygomatic suture; IFS, anterior extent of the inferior orbital fissure; IOF, infra-orbital rim point above the infraorbital foramen; OC, optic canal; PEF, posterior ethmoidal foramen; SON, supra-orbital notch.

*Equal variance not assumed.

The use of dried skulls also eliminated the ability to identify and differentiate the soft tissues of the orbital apex. Moreover, using numerous extraorbital and intraorbital landmarks on skulls significantly increases the possibility for anatomic variability by incorrect or inaccurate landmark localization among specimens. This amplifies the probability for variation among landmarks as well as the possibility of compounding the error with multiple measurements. Although useful from an anthropologic perspective, their investigation is of limited value in the clinical setting.²

McQueen et al¹⁰ in 1994 performed a similar study using sophisticated instrumentation on 54 cadaver orbits by exenterating the eyes and then taking direct measurements from the orbital rims to the optic canal with an electronic digital caliper. Although the reference points chosen (anterior lacrimal crest, infraorbital foramen, supraorbital notch or foramen, and fronto-zygomatic suture) are identifiable during surgical intervention, there is considerable variation in their location in the human population. Moreover, when an intact globe is present, direct measurements into the internal orbit are impossible with the instrumentation used.

Our study methodology was designed to be a simple, surgically oriented investigation to assist the surgeon in clinical practice in establishing ranges for orbital dissection to minimize the chance of iatrogenic optic nerve damage. This has led us to the use of CT in evaluating and producing our measurements. Our method is precise as it uses measurements taken at the mid-axial orbital rim for standardization based on axial CT scan rather than three-dimensional reformatted images.

Our reference points are from the outmost boundaries of the orbit (orbital rim) which were readily reproducible with minimal variability from high-resolution digital CT images. These CT images were based on intact orbits of living patients which will be useful in providing precise data for the surgical setting as opposed to dry skulls that display anatomical landmark discrepancies due to tissue changes which is usually caused by the skull preservation process itself. These discrepancies are obvious in skulls that were prepared with the hot maceration technique. This technique can cause the skulls to undergo shrinkage thus making it inappropriate for scientific measurements.¹²

Since the anatomy of orbital fissures and foramina seems to be dependent on the population selected as suggested by the previous reports,^{10,11,13–15} the present study was conducted to provide the morphometric data in the orbits of adults in our local population. Furthermore, the reported significant differences in the measurement

parameters between sides and genders in Thai, Korean, and Egyptian adults have brought us to conduct similar comparisons to clarify whether the variations were dependent on these 2 factors in our study.

Overall, we observed a similar range of measurements from our subjects to those of our Asian counterparts, that is, the Thais and Koreans in terms of orbital wall depth. Comparatively, the Thais,¹⁶ the Koreans,¹³ and the Chinese¹ have smaller orbital dimensions compared with the Indians,¹¹ Turkish,¹⁴ Egyptians,¹⁷ Kenyans,¹⁵ and mixed Americans.¹⁰

In view of the superior orbital wall, the supra-orbital notch is easily identifiable close to the superior orbital rim and therefore was used as the reference point for the measurement in this quadrant. The mean measured distance of the supraorbital depth (SON-OC) in our study was 44.05 mm $\pm$ 1.24 mm. This was similar to the measurements of the Thais (44.7 mm), Koreans, and Chinese (44.9 mm) but smaller than the 48.65 mm from the United States by McQueen et al 1995, Indians (45 mm), Turkish (45.3 mm), Egyptians (49.64 mm in males and 48.16 mm in females), and Kenyans (53.25 mm in males and 51.93 mm in females). Hence, procedures involving the orbital roof such as orbital decompression, exploration for fracture, and excision of cranio-orbital tumors should be approached with more caution for our subjects with the least depth.

The lateral wall of orbit is of significant importance in procedures such as exploration of lateral wall fractures, decompression, excision, and orbito-zygomatic craniotomy.⁹ We measured the depth from the FZ suture corresponding to 2 vital structures, that is, the optic canal and SOF. The FZ-OC value of Indians is the lowest (43 mm) followed by the Egyptians (44.24 mm in males and 43.58 mm in females) and the Chinese with 45.3 mm. Our study interestingly reported a larger mean of 46.48 mm $\pm$ 1.13 mm. The Thais recorded a mean of 46.9 mm, the Koreans were 47.4 mm, and McQueen study was 47.1 mm.

Despite showing the second lowest FZ-OC distance, the Egyptians recorded the highest FZ-SOF mean of 39.94 mm for males and 39.12 for the females. Our study displayed the second highest mean distance of 37.18 mm $\pm$ 1.14 mm followed by McQueen subjects with 36.59 mm, and both Chinese and Indians with 35 mm. The superior orbital fissure of both Thais and Koreans lays the closest to the FZ suture with a distance of 34.3 mm.

As for infraorbital depth (IOF-OC), we recorded the second lowest mean measurement (44.87 mm $\pm$ 1.23 mm) after the Chinese population with 44.38 mm followed by all the above-mentioned studies (Thais; 46.2 mm, Koreans; 45.5 mm, Indians; 48 mm,

McQueen study; 49.7 mm, Egyptians; 51.7 mm for males and 50.53 mm for females, and finally the Kenyans; 55.1 mm for males and 53.6 mm for females). The Kenyan population is shown to have much deeper orbits compared with our study by up to 11 mm. This could be attributed to the lower cranial index recorded among Africans due to their longer glabella maximal lengths relative to the cranial vault height.¹⁸ Relatively, the use of shorter orbital probes or retractors may be considered for the Asian patient compared with those required for the Egyptians and Kenyans.

However, our subjects displayed the highest distance ($23.94 \text{ mm} \pm 1.23 \text{ mm}$) from the infraorbital rim to the most anterior point of the inferior orbital fissure (IOF–IFS) among Asians (Thais; 21.7 mm, Koreans; 21.6 mm, and Chinese 22.8 mm) and remarkably similar to the other populations (Indians; 24 mm, Egyptians; 24.62 mm in males and 23.60 mm in females, Kenyan; 23.65 mm in males and 22.28 mm in females). This variation found in our study will allow a larger marginal area of safe infraorbital dissection when dealing with the neurovascular bundle passing through the infraorbital fissure. A safety measure taken to avoid injury to this vasculature is to locate the anterior extent of the inferior orbital fissure. This is made easier by utilizing the measurements obtained above.

This difference may, however, not be clinically significant when compared with the Caucasian and Kenyan population as shorter fissural depth of Asians could be a reflection of their shorter infraorbital depth relative to that of the former.¹

On the other hand, McQueen et al¹⁰ in 1995 from the United States observed much higher value of 37.43 mm. This discordance may be due to the inclusion of both Caucasian and Negroid skulls in the study and the data of Negroid skulls were not shown separately.¹⁰ Another possible reason is that these differences are probably contributed by errors in measurement on the different reference points on the skulls themselves.

We noted that the supraorbital depths are shorter than the infraorbital depth for all the above studies. Therefore, it is expected that the floor of the orbit will be longer anteroposteriorly than the roof. This difference is caused by defect on the orbital roof as the superior orbital fissure and the anterior opening of the optic canal extend more anteriorly in the orbital roof than defect on the orbital floor created by the much laterally extended inferior orbital fissure.¹⁵

The medial wall of the orbit contains anterior ethmoidal foramen and posterior ethmoidal foramen which anterior and posterior ethmoidal vessels passed through. The anatomy of these foramina is important when performing procedures such as ethmoidal vessel ligation for epistaxis, exploration of the medial orbital wall fractures, and orbital decompression surgery.¹

As mentioned earlier, these foramina are considered to be the key landmarks for procedures involving the medial wall. These foramina mark the estimated level of the roof of the ethmoidal labyrinth, the floor of the anterior cranial fossa, and transmit branches of the ophthalmic arteries and nasociliary nerves from the orbit to the anterior cranial fossa.¹⁹ Thorough knowledge of their location and variations is important during medial orbital wall surgeries.

Therefore, the midpoint of the anterior lacrimal crest was identified as a point of reference at the outer rim. This location is easily identifiable by CT images as well as by manual palpation. From our CT images, we measured the distance between the ALC to AEF, AEF to PEF, PEF to OC, and the overall mean length of the medial wall (ALC–OC).

Our study produced the lowest mean figure of $19.67 \text{ mm} \pm 1.37 \text{ mm}$ for the distance of ALC–AEF as opposed to the Egyptians with the highest mean value of 26.76 mm for males and 26.17 mm for females. The AEF in Thais are located considerably deeper (23.5 mm) followed by Indians (24 mm) and the Chinese (24.9 mm). The Koreans have shown a similar depth

(21 mm) of the AEF to McQueen study (22 mm). Therefore, we recommend cautious dissection of the medial wall in our local population as the location of this foramen is slightly shallower.

After establishing the location of the anterior ethmoidal foramen, we observed that the posterior ethmoidal foramen lays $11.16 \text{ mm} \pm 0.93 \text{ mm}$ further posteriorly along this same dissection plane. This value was smaller than those of the Thai study (13.20 mm) but was similar to the Chinese study (11.45 mm). The Turkish study displayed the shortest gap between the AEF and PEF with a mean of 9.8 mm, whereas the McQueens study quoted the highest gap with 12.35 mm.

The PEF are noted to have variability in numbers and our study found 19 orbits (31.67%) to have multiple posterior ethmoidal foramina. This was half of what was reported by Huamanop study of Thai orbits (62%) and considerably less of the Chinese subjects (59%). However, the Turkish and Indians have even lower incidence of multiple PEF with 28% and 25% respectively. Knowledge of these ethnic variations is essential in surgical procedures for control of epistaxis that requires ligation of all the ethmoidal arteries²⁰ and hemostasis during medial orbital wall surgeries.¹⁹

The distance between the posterior ethmoidal foramen to the optic canal is also variable. This measurement was $9.19 \text{ mm} \pm 1.16 \text{ mm}$ in our study and it was the only parameter that did not display any statistical difference between sides and gender. Our figure was similar to McQueen study of 9.15 mm. This is also much larger than our Asian counterparts', that is, the Chinese (5.71 mm), the Thais (6.3 mm), and the Indians (7 mm). The Turkish study revealed this distance to be around 6.8 mm, which is about the same size as the Asians. Despite having a generous amount of distance from the posterior ethmoidal foramen to the optic canal in our study, we urge that further posterior dissection from the PEF is done carefully as the optic canal may lay closer than expected as the lowest distance recorded by the Chinese study was 1.3 mm.

As for the average depth of the medial orbital wall (ALC–OC), the Asians generally observe a smaller distance when compared with other population. The lowest mean distance was seen in Koreans (40.5 mm). The Chinese orbits were similar with an average medial wall depth of 40.6 mm. Our local population displayed a mean depth $41.21 \text{ mm} \pm 0.86 \text{ mm}$ followed by the Turks (41.5 mm), Indians (42 mm), McQueen study (43.3 mm), Egyptians (47.5 mm), and Kenyans (47.25 mm for males and 46.21 mm for females). We can conclude that the Egyptian and Kenyan orbits permit a deeper medial wall dissection range when compared with the shallower depths of the Asian orbits (Table 5).

When addressing the issue of statistical significance between genders with regard to orbital depth, not all of the above-mentioned studies can precisely quantify this information. This is due to inconsistent and gender-biased subject accusation for scientific measurements. For instance, Rontal et al¹¹ in 1978 used the occipital protuberance to distinguish the sex of Indian skulls, but failed to detect any difference in the measurements that he made between the presumptively "male" and "female" skulls. This similar method of gender identification was also used by Fetouh and Mandour¹⁷ in 2014 when working with Egyptian adult dry skulls.

The Korean study in 1999 by Hwang and Baik did not differentiate the sex of the Korean skulls while Karakas et al only measured male white skulls.^{13,14} Therefore, it is difficult to conclude any accurate gender differences in orbital morphometry from their studies.

In the current study, we used living patients with gender identification obtained from their medical records. We reported differences in the male and female orbital depths where the male subjects have shown to have deeper orbits than females in general. This would be probably due to the longer length of the male cranium relative to that of females as demonstrated by the lower

TABLE 5. Comparison of Overall Mean Distances Between the Current and Previous Studies

		Rontal (48 Orbits) Indians, 1978	McQueen (54 Orbits) USA, 1995	Karakas (62 Orbits) Turkish Males, 2002	Fetouh (104 Orbits) Egyptian, 2014	Cheng (194 Orbits) Chinese, 2008	Hwang (82 Orbits) Koreans, 1999	Huanmanopl (100 Orbits) Thais, 2007	This Study (60 Orbits)*
		Mean (mm)	Mean $\pm$ SD (mm)	Mean $\pm$ SD (mm)	Mean (mm)	Mean $\pm$ SD (mm)	Mean $\pm$ SD (mm)	Mean $\pm$ SD (mm)	Mean $\pm$ SD (mm)
From	To			Males	Females				
SON	OC	45	48.65 $\pm$ 3.31	45.3 $\pm$ 3.2	49.64	42.90 $\pm$ 2.27	44.9 $\pm$ 2.0	44.7 $\pm$ 2.3	44.05 $\pm$ 1.24
FZ	OC	43	47.10 $\pm$ 2.88	44.9 $\pm$ 2.5	44.25	45.31 $\pm$ 2.61	47.4 $\pm$ 3.0	46.9 $\pm$ 2.4	46.48 $\pm$ 1.13
IOF	OC	48	49.73 $\pm$ 2.71		51.76	43.01 $\pm$ 2.89	45.5 $\pm$ 2.5	46.2 $\pm$ 2.8	44.87 $\pm$ 1.23
IOF	IFS	24	37.43 $\pm$ 4.13		24.62	20.04 $\pm$ 2.29	21.6 $\pm$ 1.8	21.7 $\pm$ 2.0	23.94 $\pm$ 1.23
FZ	SOF	35	36.59 $\pm$ 4.30	37.7 $\pm$ 3.6	39.94	35.02 $\pm$ 2.84	34.3 $\pm$ 2.7	34.3 $\pm$ 2.5	37.18 $\pm$ 1.14
ALC	OC	42	43.29 $\pm$ 4.19		47.25	40.64 $\pm$ 2.32	40.5 $\pm$ 3.0	42.1 $\pm$ 2.1	41.21 $\pm$ 0.86
ALC	AEF	24	29.16 $\pm$ 3.13	23.9 $\pm$ 3.3	26.76	24.87 $\pm$ 1.91	21.0 $\pm$ 3.3	23.1 $\pm$ 2.6	19.67 $\pm$ 1.37
AEF	PEF		12.35 $\pm$ 3.19	9.8 $\pm$ 2.9		11.45 $\pm$ 2.41		13.2 $\pm$ 2.0	11.16 $\pm$ 0.93
PEF	OC	7	9.15 $\pm$ 2.24	6.8 $\pm$ 2.2		5.71 $\pm$ 2.04		6.3 $\pm$ 1.7	9.19 $\pm$ 1.16

cranial index values of males when compared with those of females.¹⁵

Although the differences in the orbital depths between sexes in our study gave a statistically significant *P* value, it may not be clinically significant since the actual overall difference is quite small (less than 2 mm). As a result, the orbital retractors or probes used in male patients may safely be used for the female patients over the same depths.

The results of our study support previous findings by other researchers who found the anatomy of the orbit to vary not only with race but also with sex. However, we found no statistical correlation in variation of orbital dimensions between sides. In our opinion, these differences probably represent the true anatomical variances between genetically different populations.

It is our opinion that the reported figures from these investigations must be thoroughly considered and fully evaluated before embarking on any orbital exploration. In the clinical setting, if the dissection is kept subperosteal and the orbital neurovascular structures remain attached to the periosteum, their detachment from the osseous internal orbit should be of minimal consequence.

To minimize the postoperative morbidity associated with internal orbital surgery, a thorough dissection must be performed to appropriately assess any fracture or pathology to provide adequate access for any indicated reconstruction. This thorough dissection must be synonymous with the knowledge of acceptable limits of various anatomic locations. Since there has not been any record of such data for our local population, our study has attempted to provide these limits for the surgeons (Table 5).

Undoubtedly, a safe dissection would not interrupt the origins of the extraocular musculature; jeopardize the sensory and motor functions of the trochlear, lacrimal, or frontal nerves; nor compromise the vascular supply by damaging the superior and inferior ophthalmic veins. With these structures as protective landmarks, there is no reason that optic nerve injury should occur iatrogenically.

Therefore, each case should be individualized with the risk–benefit ratio of the dissection kept in mind. In line with the suggestion of an arbitrary safe distance by subtracting 5 mm from the shortest measured distance from the rim point on each orbital wall,¹⁰ we have demarcated “safe distances” in orbital wall dissections for our local population.

We suggest that the safe distance for the superior wall exploration is about 37 mm. This distance would relatively protect the optic nerve in orbital roof dissections. As for the lateral wall, the recommended safe distance would be 30 mm. This is to avoid

any possible contact or damage to the neurovascular content of the superior orbital fissure before approaching the optic nerve.

The inferior wall or floor of the orbit can be safely dissected up to 37 mm in respect to the optic nerve. However, if the surgeon finds that the infraorbital nerve is exposed through the infraorbital groove, care should be taken not to damage this structure. The anterior extent of the inferior orbital fissure that houses the infraorbital nerve may be exposed at minimal depths of 20 mm from the infraorbital rim.

Finally, the medial wall of orbit can safely be dissected within 34 mm from the anterior lacrimal crest along the fronto-zygomatic suture line. This depth is adequate for the surgeon to encounter the ethmoidal foramina and vessels. Ligation of these vessels is possible at this depth but caution is advised to go any deeper as the optic nerve is closely approximated to the posterior ethmoidal foramen.

For these measurements to be of value in the surgical setting, any fractures involving the orbital rims must be anatomically reduced first before proceeding with further internal orbital dissection. The depths described above can be considered “safe” after the clinician understands the crucial anatomy of the orbital apex to avoid iatrogenic damage.

CONCLUSION

Although there is variation in orbital depths between sexes, the same surgical instruments and prosthesis can be applied for both groups during orbital surgery and reconstruction. In addition to this, we found no significant differences in all parameters between the right and left orbits which establishes symmetry of the both orbits in the same individual.

The figures that our study has produced are considered vital in preoperative treatment planning for those clinicians who operate in facilities that are not equipped with modern three-dimensional CT scan machines or software.

For these measurements to be of value in the surgical setting, any fractures involving the orbital rims must be anatomically reduced first before proceeding with further internal orbital dissection. The depths described above can be considered “safe” after the clinician understands the crucial anatomy of the orbital apex to avoid iatrogenic injury. Any procedure done beyond these distances, caution is advised. The nonsignificant difference between sides (right and left) indicates symmetry of the orbit which is useful in orbital reconstruction where the normal orbit can be used as a benchmark guide.

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Morphometric Analysis of Sella Turcica Using Cone Beam Computed Tomography

Yasin Yasa, DDS, PhD,* Ali Ocak, DDS, PhD,[†]
Ibrahim Sevki Bayraktar, DDS, PhD,[‡]
Suayip Burak Duman, DDS, PhD,[§]
and Ismail Gumussoy, DDS, PhD^{||}

Objective: The purpose of this study was to assess morphological shape and morphometric analysis of the sella turcica using cone

beam computed tomography (CBCT) in different planes of section (coronal and sagittal).

Materials and Methods: CBCT images of 177 subjects of which 51 males and 126 females in the age group of 11 to 73 years were included in the study population. Linear dimensions which include the length, depth, diameter, and interclinoid distance were measured and the shape of sella turcica was analyzed.

Results: Sella turcica had circular morphology in 69.5% of the subjects while flattened shape of sella turcica was observed in 16.4%, oval shape of sella turcica in 14%. There was no significant difference in the all measurements of sella turcica between males and females ($P > 0.05$). Diameter ($P < 0.01$), depth ($P < 0.001$), length ($P < 0.05$), and interclinoid distance ($P < 0.05$) of the sella turcica differed significantly with age.

Conclusions: The anatomical structure of sella turcica can be studied effectively in CBCT images. Linear dimensions and shape of sella turcica in the current study can be used as reference standards for further investigations.

Key Words: Anterior clinoid process, cone beam computed tomography, cone beam CT, morphology, pituitary, sella turcica

The pituitary gland can be defined as the primary gland of the body since it controls the majority of endocrine functions. It is housed in the sella turcica and is located in close proximity to numerous vital structures such as the sphenoid sinus, optic chiasm, cavernous sinus, and hypothalamus. The development of the sella turcica is closely related to that of the pituitary gland.¹ The functional matrix theory states that “the origin, development, and maintenance of all skeletal units are secondary, compensatory, and mechanically obligatory responses to temporally and operationally prior demands of related functional matrices.”² Based on this theory, it can be hypothesized that the pituitary gland serves as the functional matrix of the sella turcica. Literature reports have revealed that whenever the size of the pituitary gland changes, there is a corresponding change in the size of the sella turcica.^{3–7} Radiological assessment of enlarged or abnormally small sella turcica is associated with pathological conditions or hypofunction of the pituitary gland.^{8–13} Deviations in the pituitary gland and in the sella turcica are presumed to be interrelated, and understanding the anatomy and dimensions of the sella turcica is essential to understanding its normal appearance. Moreover, evaluation of the sella turcica is an imperative part of the assessment and diagnosis of the broad spectrum of pathology involved with the pituitary gland. Although there are morphological differences in every individual,

From the *Department of Maxillofacial Radiology, Faculty of Dentistry, Ordu University, Ordu; [†]Department of Maxillofacial Radiology, Faculty of Dentistry, Ataturk University, Erzurum; [‡]Department of Maxillofacial Radiology, Faculty of Dentistry, Eskişehir Osmangazi University, Eskişehir; [§]Department of Maxillofacial Radiology, Faculty of Dentistry, İnönü University, Malatya; and ^{||}Department of Maxillofacial Radiology, Faculty of Dentistry, Recep Tayyip Erdoğan University, Rize, Turkey.

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Address correspondence and reprint requests to Dr Yasin Yasa, DDS, PhD, Department of Maxillofacial Radiology, Faculty of Dentistry, Ordu University, Ordu, Turkey; E-mail: yasyasin@yahoo.com

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