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Letter to the Editor

An anatomical study of the medial wall, lateral wall, roof, and floor of the Filipino orbit

Dear Editors,

The orbit is an important anatomic landmark as it connects the brain with the face, paranasal sinuses, and nose.[2] When operating around and within the orbit whether through superior, inferior, medial, or lateral approach, surgeons heavily rely on precise understanding of orbital osteology to avoid complications and achieve successful operative results which entail mastery of neurovascular structures and foramina in each orbital wall.[1,3,4]

In the medial orbital wall, the ALC, AEF, and the PEF are used as surgical landmarks to avoid injuring the anterior ethmoidal artery, vein, and nerve, and the posterior ethmoidal artery, vein, and nerve respectively.[1,5] In the lateral orbital wall, the FZS and the COF are used as surgical landmarks to avoid injuring the meningolacrimal artery.[6] In the inferior orbital wall, the inferior orbital rim and ION/F are used to guide surgeons to avoid the infraorbital nerve, artery, and vein.[10,11] In the superior orbital wall, the SON/F is used as surgical landmark to avoid injuring the supraorbital nerve and vessels.[12] Meticulous dissection should be done when working along the orbital walls since damaging these neurovascular structures will result in sensory nerve blockade, bleeding, and poor visualization during surgery.[1,3,7–9,13,14]

Based on available literature, there have been widely differing ranges in the measurements and location of these landmarks, and even presence of accessory foramina which make it more difficult to work around and within the orbit.[1,6–14] Studies on bony orbital distances in the Filipino population have been done utilizing radiographs and CT scan to measure landmarks in the medial wall and lateral wall.[15,16] However, to our knowledge, there have been no studies regarding direct measurement of the distances between the ethmoidal foramen, COF, ION/F, and SON/F with landmarks in the medial wall, lateral wall, floor, and roof of the Filipino orbit respectively. Hence, this study aimed to document and analyze the location and morphometric relations of these landmarks with reference points in each orbital wall of adult Filipino dry skulls in the collection of the University of Santo Tomas Faculty of Medicine and Surgery ossarium and to determine safe distances to which oculoplastic and maxillofacial surgeons may refer when doing surgeries around and within the Filipino orbit.

1. Materials and methods

A total of 100 orbits from 50 adult dry skulls were included in the study. The skulls were all from the collection of the University of Santo Tomas Faculty of Medicine and Surgery Anatomy Department ossarium. Permission for access of dry skulls was secured from the dean of the University of Santo Tomas Faculty of Medicine and Surgery and Chairman of the University of Santo Tomas Faculty of Medicine and Surgery Anatomy Department. The study was subjected to the University of Santo Tomas Hospital Research Ethics Committee for approval prior to its commencement. The study also adheres to national and international ethical guidelines such as the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use, National Ethical Guidelines for Research Involving Human Participants 2022, and the Data Privacy Act of 2012 and its Implementing Rules and Regulations of 2016. Only adult dry skulls with intact orbital walls and foramina were included in the study. Skulls with deformities or damage to the orbit and adjacent structures were excluded in the study.

Single determination direct measurements of surgical landmarks in the included skulls were done to corresponding reference points per orbital wall by the principal investigator using foldable wire and Castroviejo caliper (0.5 mm accuracy) calibrated against standard ruler and tape measure. The morphometric measurements to the different reference points were then estimated using mean and standard deviation and quartile scores alongside their respective 95% confidence intervals (CI) and ranges of values.

For the medial orbital wall (Supplementary A, B), the distance from the ALC to the AEF, PEF, and OC (Supplementary Fig. 1) and the distance from the AEF to PEF, and PEF to OC (Supplementary Fig. 2) were measured. For the lateral orbital wall, the distance from the FZS to the midpoint of the LGF, lateral aspect of OC, lateral aspect of SOF, midpoint of SOF, midpoint of IOF, and lateral aspect of IOF were measured (Supplementary Fig. 3). The distances from the COF to the midpoint of the SON/F, SOF, FZS, and OT were also taken (Supplementary Fig. 4). For the superior orbital wall, the distance from the SON/F to the LGF, lateral aspect of the SOF, midpoint of SOF, midpoint of OC were measured (Supplementary Fig. 5). For the inferior orbital wall, the distance from the ION/F to the inferior orbital rim, midpoint of OC, midpoint of IOF, midpoint of LGF, lateral aspect of IOF were taken (Supplementary Fig. 6).

1.1. Sample size computation

Sample size (priori) computation for one-sample *t*-test was conducted using GPower version 3.1.9.4. From the study of Yoon et al.,[1] the mean AEF-EF value for a Korean sample was 14.04, and this was used as the hypothesized mean $(\overline{X}_0)$ cognizant of the similarity in being of Asian descent. In contrast, the study of Mehta & Perry (2015) estimated a mean AEF-EF of 13.42 (SD = 2.02) which was used as the hypothesized mean $(\overline{X}_1)$ and standard deviation (SD1).[4] These values can be used to estimate an effect size d of 0.307. With these parameters and with a minimum

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power of 80%, an effect size d of 0.307, and a significance level of 5.00% (two-tailed), a minimum sample size of 67 participants is necessary. The unit will be in terms of orbits. Hence, the study should include 67 orbits or 34 individual skulls.

1.2. Statistical analysis

Statistical analyses were conducted using STATA MP-Parallel Version Statistical Software, Version 18, College Station, TX: StataCorp LP. Descriptive statistics involved mean and standard deviation for normally-distributed, continuous data; median and interquartile range for ordinal and non-normally-distributed data; and, frequency and percentage for categorical variables. The morphometric measurements of the different reference points were estimated using mean and standard deviation and quartile scores alongside their respective 95% confidence intervals (CI) and the ranges of values[17]

2. Results

A total of 100 orbits from 50 skulls were included in the study. Supplementary Table 1 presents the descriptive statistics of the morphometric measurements of the medial wall of the included dry skulls. It can be noted that the mean measurements of ALC to AEF, ALC to PEF, and ALC to OC were 25.50 mm, 38.53 mm, and 46.23 mm, respectively. Results also showed that the median measurements of these parameters were 26.00 mm, 39.00 mm, and 47.00 mm, respectively. It can also be seen in the table that the measurements of AEF to PEF had a mean value of 13.03 mm and a median of 14.00 mm, while the PEF to OC had a mean value of 7.7 mm and a median of 8.00 mm.

The descriptive statistics of the morphometric measurements of the lateral wall of the included dry skulls are depicted in.

Supplementary Table 2 results showed that the mean morphometric measurements of FZS to LGF, FZS to OC, FZS to lateral SOF, FZS to midpoint SOF, FZS to midpoint IOF, and FZS to lateral IOF were 13.61 mm, 46.96 mm, 34.38 mm, 41.71 mm, 34.75 mm, and 25.22 mm, respectively. The median values of these reference points were 14.00 mm, 46.00 mm, 35.00 mm, 42.00 mm, 34.00 mm, and 26.00 mm, respectively. It can also be noted that the reference point of COF to SON/F had a mean value of 35.90 mm and a median of 36.00 mm, and the parameter from COF to SOF had a mean of 8.87 mm and a median of 8.00 mm. The mean value of the reference COF to FZS was 26.60 mm, and it had a median of 26.00 mm. In addition, the parameter of COF to OT had a mean of 29.00 mm and a median of 29.00 mm.

Supplementary Table 3 illustrates the descriptive statistics of the morphometric measurements of the orbital roof of the included dry skulls. Analyses indicated that the mean morphometric measurements of the reference points SON/F to LGF, SON/F to lateral SOF, SON/F to midpoint SOF, SON/F to OC were 23.84 mm, 41.70 mm, 46.68 mm, and 44.94 mm, respectively. The median values of these reference points were 23.00 mm, 42.00 mm, 47.00 mm, and 45.00 mm, respectively.

The descriptive statistics of the morphometric measurements of the orbital floor of the included dry skulls are presented in Supplementary Table 4 it can be noted that the morphometric measurements of ION/F to inferior orbital rim was a mean of 6.90 mm and a median of 7.00 mm, while the parameter of ION/F to OC had a mean and a median of 49.33 mm and 50.00 mm, respectively. Analyses also showed that the mean measurements of the reference points of ION/F to midpoint IOF, ION/F to LGF, and ION/F to lateral IOF were 39.10 mm, 44.94 mm, and 29.03 mm, respectively, while their corresponding median values were 38.00 mm, 45.00 mm, and 28.00 mm.

3. Discussion

Surgical procedures around and within the orbit require careful dissection of the orbital walls taking into account surgical landmarks which may be used to guide the surgeon avoid important structures such as blood vessels and nerves that may cause profuse bleeding and palsy when damaged. In McQueen's study on orbital osteology surgical landmarks, they defined safe distance for dissection as 5 mm subtracted from the shortest measured distance from the optic nerve.[18] In medial orbital wall dissection in medial orbitotomy, medial wall reconstruction, surgical repair of medial wall fractures after periorbital trauma, and orbital decompression, after vertical incision is made in the conjunctiva between the caruncle and plica semilunaris, blunt dissection along the medial orbital wall can be done towards the posterior lacrimal crest until the periosteum overlying the anterior ethmoidal sinus is reached. Once the incision is taken down to the bone, the periosteum is elevated first to the ALC and then back to the AEF providing excellent exposure for the surgeon.[19]

Our results show that the mean measurements of ALC to AEF was 25.50 mm. Upon further dissection, the PEF would be about 13 mm posterior to the AEF, and the OC would be about 7.7 mm posterior to the PEF. This anatomical relationship that describes the distance between the ALC to the AEF, AEF to the PEF, and PEF to the OC is known as the ’24-12-6′ surgical guideline or “the rule of halves”. Based on available literature, there is variability in medial orbital wall measurements between populations so the ’24-12-6′ guideline is not constantly applicable for all ethnicities.[1,2,4,5] In our study measuring adult Filipino dry skulls, orbital wall measurements followed a ‘25.50-13-7.7' mm ratio. In the study by Hester et al.,[5] they found that the European population follow a ’24.72-13.78-7.53′ mm ratio and the Hispanic population follow a ’25.07-14.8-8.30′ mm ratio. In Mehta and Perry's study,[4] the African American population follow a ’25.15-13.56-5.47′ mm ratio and the Caucasian population follow a ’24.59-13.84-5.62′ mm ratio. In Abed's study,[20] the British Caucasian population follow a ’25.61-16.60-7.25′ mm ratio. In Piagkou's study,[21] the Greek population follow a ’23.21-9.78-4.30′ mm ratio. In Cheng's study,[22] the Chinese population follow a ’24.87-11.45-5.71′ mm ratio. In Hwang's study,[23] the Korean population follow a ’21-11.7-7.8′ mm ratio. In Yoon's study,[1] the Australian population follow a ’23.38-14.04-7.54′ mm ratio for straight line measurement and real line measurement (follows bony contour) of ’25-14-8′ mm ratio showing that real line distance on average is greater than relative straight line distance measurement (Supplementary Table 5).

In our study, the ALC to AEF measured 25.50 mm. In comparison with other population, the distances measured in our study from ALC to AEF are longer when compared to the distances measured by Karakas,[2] Rontal,[3] Hwang,[23] Yoon,[1] Huamanop,[24] and Cheng,[22] in Caucasian (23.9 mm), Indian (24 mm), Korean (21 mm), Australian (23.38 mm), Thai (23.1 mm), and Chinese (24.87 mm) populations, respectively. However, in comparison with the distances measured in Fetouh's study in Egyptian population[25] which measured 26.76mm and Abed's study in British Caucasian population[20] measuring 25.61 mm, our measurement is shorter. In our study, the ALC to PEF measured 38.53 mm. In comparison with other populations, the ALC to PEF measurements are also greater when compared by studies of the same authors, in Caucasian (35.6 mm),[2] Indian (36 mm),[3] Australian (36.53 mm),[1] and Thai (36 mm)[24] populations. In our study, the ALC to OC measured 46.23 mm. The measurement obtained is also greater when compared to Caucasian (41.7 mm),[2] Indian (42 mm),[3] Thai (42.2 mm)[24] populations and shorter than the Egyptian population (47.25 mm).[25] (Supplementary Table 5). Following McQueen's description of safe distance,[18] taking into account the shortest distance measured in our study from the ALC to OC of 37 mm for the Filipino population, we propose that when doing dissection in the medial orbital wall whether for medial orbitotomy, medial wall reconstruction, surgical repair of medial wall fractures after periorbital trauma, or orbital decompression, that the surgeon dissect only up to 32 mm otherwise, the optic nerve might get compromised. Furthermore, taking into account the shortest distance measured in our study from the ALC to AEF of 20 mm, in order to avoid nicking the anterior ethmoidal artery, vein, and nerve we propose careful dissection starting 15 mm from the ALC (Supplementary Table 6).

In the lateral orbital wall, the COF, which is a small opening usually on the roof or on the lateral wall of the orbit, and lateral to the lateral end of the SOF is used as a surgical landmark to avoid injuring the meningolacrimal artery: an anastomosis between the lacrimal branch of the ophthalmic artery and orbital branch of the middle meningeal artery.[6] Failure to locate this foramen and establish a safe operating field in lateral orbital approach orbital decompression, lateral wall exploration, lacrimal gland excision, or lateral orbitotomy can lead to hemorrhaging in the anterior cranial fossa.[1,6] During lateral orbital wall dissection whether through an upper eyelid crease incision extended laterally or lateral brow incision extended posterolaterally, the FZS is easily identifiable once the periosteum is elevated and subperiosteal dissection can be done to expose the lateral wall.[19] The distance measured in our study from the FZS to SOF in the lateral wall measure 34.38 mm. This is shorter when compared to Rontal's study on the Indian population (35 mm),[3] Huamanop's study on Thai population (34.5 mm),[24] McQueen's study on Caucasians (36.59 mm),[18] and Fetouh's study on Egyptians (39.94 mm)[25] and longer than Hwang's study on Koreans (34.30 mm).[23] The distance measured in our study from FZS to IOF measure 25.22 mm. This is longer when compared to studies by the same authors in the Indian (25 mm),[3] Korean (24.8 mm)[23] and Thai population (24 mm)[24] but shorter when compared to Caucasians (40.92 mm)[18] and Egyptians (29.08 mm).[25] The distance measured in our study from FZS to OC measure 46.96 mm. This is longer when compared to studies by the same authors in Indian (43 mm),[3] Egyptian (44.25 mm),[25] and Thai population (46.9 mm)[24] and shorter than Caucasians (47.10 mm)[18] and Koreans (47.4 mm).[23] In our study, the distance from the FZS to the COF is 26.60 mm. This is similar to Yoon's study in the Australian population which measures 26.59 mm.[1] (Supplementary Table 5). Taking into account the shortest distance measured in our study from the FZS to OC measuring 41 mm for the Filipino population, we propose that when doing dissection in the lateral orbital wall whether for orbital decompression, lateral wall exploration, lateral orbitotomy, or lacrimal gland excision, that the surgeon dissect only up to 36 mm to avoid damaging the optic nerve. In addition, taking into account the shortest distance measured in our study from the FZS to COF measuring 19 mm, in order to avoid nicking the meningolacrimal artery, we propose careful dissection starting 14 mm from the FZS. Taking into account the shortest distances measured in our study from the FZS to SOF and FZS to IOF measuring 28 mm and 20 mm respectively, we propose careful dissection starting 23 mm from the FZS to avoid the supraorbital vessels and nerve and 15 mm from the FZS to avoid the infraorbital vessels and nerve (Supplementary Table 6).

In the superior orbital wall or roof, the SON/F is usually present in the frontal bone at the junction of the medial one third and lateral two-thirds of the supraorbital margin wherein it transmits the supraorbital neurovascular complex, containing the supraorbital nerve and vessels which supply the skin of the forehead, scalp, upper eyelid, and nose.[12] This supraorbital neurovascular bundle is frequently encountered in surgical procedures such as brow lift, biopsy of superior orbital masses, excision of cranio-orbital tumors, orbital decompression, superior orbital wall fracture repair and exploration, and supraorbital nerve block. During superior orbital wall dissection, after an incision is made over the upper eyelid crease through the skin and orbicularis along the superior orbital wall towards the superior orbital rim, wherein the SON/F is easily exposed, dissection is done with great care to avoid inadvertent damage to the supraorbital neurovascular bundle.[19] In our study, results show that for the superior orbital walls of adult Filipino dry skulls, the mean distances of the SON/F to LGF, SON/F to lateral SOF, SON/F to midpoint SOF were 23.84 mm, 41.70 mm, and 46.68 mm respectively. In comparison with our measurement of SON/F to SOF in Filipino population (41.70 mm), the measurements of McQueen in the Caucasian (44.34 mm)[18] and Fetouh in the Egyptian population (46.23 mm)[25] is longer however, in comparison with Rontal's study on Indians (40 mm),[3] Hwang's study on Korean (40 mm),[23] and Huamanop's study in Thai population (40 mm),[24] our measurement is longer. In our study, the SON/F to OC measure 44.94 mm. The SON/F to OC measurements obtained in our study is shorter when compared to McQueen's study on Caucasians (48.65 mm)[18] and Fetouh's study on Egyptians (49.64 mm),[25] and similar to the studies of the same authors in Indian (45 mm),[3] Korean (44.9 mm)[23] and Thai (44.7 mm) population.[24] (Supplementary Table 5). Taking into account the shortest distance measured in our study from the SON/F to the OC of 38 mm, we propose dissecting the superior orbital wall posteriorly whether for excision of cranio-orbital tumors, orbital decompression, superior orbital wall fracture repair and exploration only up to 33 mm to avoid compromising the optic nerve. Taking into account the shortest distance measured from the SON/F to the SOF of 35 mm, in order to avoid nicking the supraorbital vessels and nerve, we suggest careful dissection starting 30 mm from the SON/F (Supplementary Table 6).

In the orbital floor, the infraorbital foramen is located on the maxillary bone about 1 cm inferior to the infraorbital rim/margin and transmits the infraorbital nerve and vessels.[10,11] The infraorbital nerve traverses the inferior orbital fissure into the inferior orbital canal and emerges onto the face at the inferior orbital foramen. It divides into several branches that innervate the skin and the mucous membrane of the midface, such as the lower eyelid, cheek, lateral aspect of the nose, upper lip, and the labial gum.[10,11] This makes the inferior orbital rim and foramen as important surgical landmarks in orbital floor exploration in orbital floor fractures, orbital decompression, maxillectomy, and anesthetics. When dissecting the orbital floor, whether done through transconjunctival, subciliary, or transantral approach, once reaching the infraorbital rim just above the infraorbital foramen, the periosteum is elevated without transgressing the orbital septum, otherwise, orbital fat herniation may occur and if dissection is done further, injury to the inferior oblique and inferior rectus muscle may occur. If orbital septum is not transgressed, dissection can then proceed posteriorly along the orbital floor.[19] Our results show that the morphometric measurements of the inferior orbital wall of Filipino dry skulls' ION/F to inferior orbital rim has a mean of 6.90 mm and the ION/F to OC had a mean of 49.33 mm. Our ION/F to OC measurements are longer than the measurements obtained by Rontal's study on Indian population (48 mm),[3] Hwang's study on Korean population (45.5 mm),[23] and Huamanop's study on Thai population (46.2 mm)[24] but shorter than measurements obtained by McQueen's study on Caucasians (49.73 mm)[18] and Fetouh's study on Egyptians (51.76 mm).[25] In our study, the ION/F to midpoint IOF, ION/F to LGF, and ION/F to lateral IOF were 39.10 mm, 44.94 mm, and 29.03 mm, respectively. The ION/F to lateral IOF measurements (ION/F to closest margin of IOF) in our study (29.03 mm) are longer when compared to measurements by the same authors in Indian (24 mm),[3] Korean (21.6 mm),[23] Thai (21.7 mm)[24] and Egyptian (24.62 mm)[25] individuals but shorter when compared to Caucasians (37.43 mm).[18] (Supplementary Table 5). Taking into account the shortest distance measured in our study from the ION/F to OC of 42 mm, we suggest that when dissecting posteriorly in the inferior orbital wall/orbital floor using the ION/F as landmark, whether for orbital floor exploration in orbital floor fractures, orbital decompression, or maxillectomy, that surgeons dissect only up to 38 mm to avoid nicking the optic nerve. Furthermore, using the inferior orbital rim as surgical landmark and considering the shortest distance measured from the ION/F to the inferior orbital rim of 5 mm, that surgeons only dissect up to 33 mm from the inferior orbital rim. Taking into account the shortest distance in our study measured from the ION/F to the lateral IOF of 22 mm, we suggest careful dissection starting 17 mm from the ION/F or 12 mm from the inferior orbital rim to avoid nicking the inferior orbital vessels and nerve (Supplementary Table 6).

The variability of measurements in the anatomy of the skulls in the different population groups may be attributed to ancestry following clinal distribution and admixture.[26] Asian crania in general have been found to be smaller than Caucasian crania, consistent with Bergmann's rule that states that body mass increases with colder environment to protect against heat loss.[27] The Filipino Negrito ethnic group show a high level of Denisovan admixture similar to Papuans and Indigenous

Australians. Austronesian migration to the Philippine islands who admixed with these earlier settlers resulted in modern Filipinos which have predominant Austronesian genetics with varying Negrito genetic admixture.[28]

There were several limitations in the study. We were unable to identify the age and gender of the skulls in the collection. In addition, we didn't account for the laterality of the orbits and presence of accessory foramina. This is an interesting focus for future studies as it would affect surgeries in the orbit if accessory foramina exists and if there are significant difference in measurements between the right and left orbit.

4. Conclusions

In our study, we were able to describe the morphometric measurements of adult Filipino bony orbits. We were able to document and analyze the location and morphometric relations of surgical landmarks in the medial orbital wall, lateral orbital wall, superior orbital wall, and inferior orbital wall and propose arbitrary safe distances for surgeons (Supplementary Table 6) based on McQueen's study which were elicited by taking into account the shortest distance measured from surgical landmarks to reference points per orbital wall then subtracting 5 mm from the distance.[18]

Knowledge of the distances obtained from dry skulls in the adult Filipino orbit with regards to the ALC, FZS and COF, ION/F, and SON/F with surgical landmarks in the medial wall, lateral wall, inferior wall, and superior wall, respectively along with direct visualization during dissection should aid surgeons avoid intra-operative and post-operative complications when doing surgery around and within the orbit.

Study approval

The authors confirm that any aspect of the work covered in this manuscript was conducted with the ethical approval of all relevant bodies and the study was performed in accordance with the Declaration of Helsinki,and the protocol was approved by the University of Santo Tomas Hospital Research Ethics Committee (approval number: REC-2023-07-057-TR-AP).

Author contributions

The authors confirm contribution to the paper as follows: Conception and design of study: LS, RJ; Data collection: LS; Analysis and interpretation of results: LS, RJ; Drafting the manuscript: LS, RJ; All authors reviewed the results and approved the final version of the manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

ALC	Anterior lacrimal crest
AEF	Anterior ethmoidal foramen
PEF	Posterior ethmoidal foramen
OC	Optic canal
OT	Orbital tubercle
FZS	Frontozygomatic suture
LGF	Lacrimal gland fossa
COF	Cranio-orbital foramen
SOF	Superior orbital fissure
SON/F	Superior orbital notch or foramen
IOF	Inferior orbital fissure
ION/F	Inferior orbital notch or foramen

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aopr.2024.10.002.

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