Original Article

The Localization and Incidence of Metoptic Canal and Warwick's Foramen in Adult Skulls from West Anatolia

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Abstract

Purpose: Metoptic canal (MC) is located between the superior orbital fissure and the optic canal. Warwick's foramen (WF) is viewed on the inner side of the orbit together with the foramen rotundum and superior orbital fissure. The aim of the present study was to determine the presence and incidence of MC and WF and to examine their morphometric characteristics in a sample of Turkish skulls from West Anatolia. **Materials and Methods:** A total of 153 dried human skulls and 11 dried skull bases from a West Anatolian Turkish population collected at the Anatomy Department of Dokuz Eylul University were examined. The presence and incidence of the MC and of WF were determined. The distance between reference points and the structures examined within the orbit was measured using a caliper. Student's *t*-test was used for comparisons between the right- and left-sided measurements. SPSS 22.0 software pack was used for statistical analysis. **Results:** MC was detected in 10 of the 153 dry human skulls: 4 (2.6%) on the right side, 5 (3.2%) on the left side, and 1 (0.06%) bilaterally. There were no statistically significant differences between right and left side measurements ($P > 0.05$). WF was observed in 2 (18.2%) of the 11 dry skulls, and both were on the left. **Conclusion:** The relationships between MC, WF, and other anatomical structures may be of clinical importance in surgical operations involving the orbit.

Keywords: *Foramen rotundum, metoptic canal, optic canal, orbit, superior orbital fissure, Warwick's foramen*

Introduction

The optic canal and superior orbital fissure represent the two main anatomical openings connecting the orbit to the cranial cavity. While anatomical variations of the optic canal are quite uncommon, those involving the superior orbital fissure are frequent and well-established. However, minor connections between these two main cavities are not present in all human orbits, and therefore, studies involving these are scarce as compared to major channels. An artery or vein can frequently pass through the small channels within the skull, posing the risk of serious bleeding during surgery.[9] A difference in the ossification patterns is thought to be responsible for the formation of MC, which has a keyhole-like appearance. MC is a channel ranging in length from 120 μm to 1.2 mm that passes through the optical strut[23] and it can be observed below the optic canal during the ossification process.[4,9,17,20] It usually closes within 2 months before birth or within the first few years of life.[17,20,26]

WF is an extremely rare anatomical structure with a reported incidence of < 1%, and not surprisingly, has been subject to very few publications. It is located between the superior orbital fissure and the foramen rotundum, connecting the orbit with the cranial cavity. Bertelli and Regoli described the Warwick foramen (WF) as a rare (0.74%) variation of the superior orbital fissure.[4]

WF has a crescentic or round shape, and the inferior ophthalmic vein (IOV) is thought to pass through it, although no clinical relevance has been reported so far.[4,5,15,17,28] Possibly, this vein connects the cavernous sinus and the pterygoid venous plexus.[15] Since the IOV may serve as a route for transmission of facial infections to the cavernous sinus, sound radiological and surgical knowledge on the location of WF may be useful for clinicians. De Lott *et al*. were the first investigators to report a patient with limited diffusion on magnetic resonance imaging (MRI) in both the superior orbital vein (SOV) and the IOV in a patient with cavernous sinus thrombosis (CST) due to masticator

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space abscess.[12] It was the first report of CST with MRI evidence of restricted diffusion, not only in a thrombosed SOV but also in a thrombosed IOV.[12] Lee *et al*., in their article on cavernous sinus syndrome, reminded the fact that both cavernous sinuses receive venous drainage from various structures in the face and eye and that the superior and IOVs flow anteriorly into the sinus.[22] CST is a life-threatening and rapidly progressing emergency that generally results from facial trauma and paranasal sinus infections attributed to *Staphylococcus aureus*.[7] Due to the involvement of critical anatomical structures, CST can be associated with significant mortality[13,25] or long-term complications such as hemiparesis and blindness.[7,25]

Despite the definitions of numerous well-established foramina and canals in the orbit, WF and metoptic canal (MC) are not commonly observed in anatomical samples and related studies are scarce.[4,6,9,10,14,17,19,25,27]

Detailed knowledge of the anatomy of WF and MC may be of clinical significance in certain neurosurgical procedures involving mass lesions, herniation due to increased intracranial pressure, orbital or skull base traumas, isolated fractures, or the fractures of the adjacent bone complex such as the superior orbital margin, zygoma, sphenoid, or temporal bones. In this regard, morphometric measurements of MC and WF and their distance to certain important anatomical reference points may provide valuable insights for neurosurgeons.

In this study, we aimed to determine the incidence of MC and WF in a sample of West Anatolian skulls along with morphometric measurements.

Materials and Methods

In this study, 153 human-dried skulls and 11 dried skull bases from West Anatolia stored at the Anatomy Department of Dokuz Eylul University were evaluated. Ethical approval was not obtained for this study as it did not require the participation of any live subjects instead only bony material was used. The age and sex of the skulls were unknown, and none of the bones had deformity from previous orbital surgery or trauma. After the identification of MC and WF, the incidence of these structures was determined [Figures 1 and 2]. Figures 3 and 4 show the measured distances from WF and MC, and the predefined anatomical landmarks, respectively. Measurements within the orbit were performed using a caliper (Mitutoyo, Japan). SPSS 22.0 (SPSS Inc., Chicago, IL, USA) software pack was used for statistical analysis. Student's *t*-test was used to determine the differences between measurements within the same side and between the right and left sides. $P < 0.05$ was considered statistically significant.

Metoptic canal and Warwick's foramen measurements

Following measurements related to MC were made: (i) the distance between frontozygomatic suture and metoptic

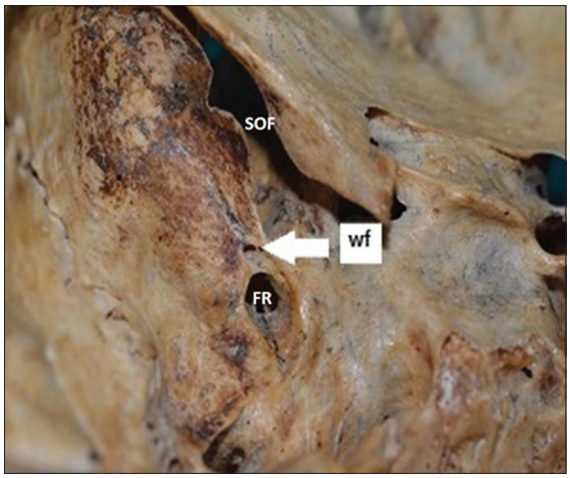


Figure 1: View from the inside of the skull base. WF: Warwick's Foramen, FR: Foramen rotundum, SOF: Superior orbital fissure

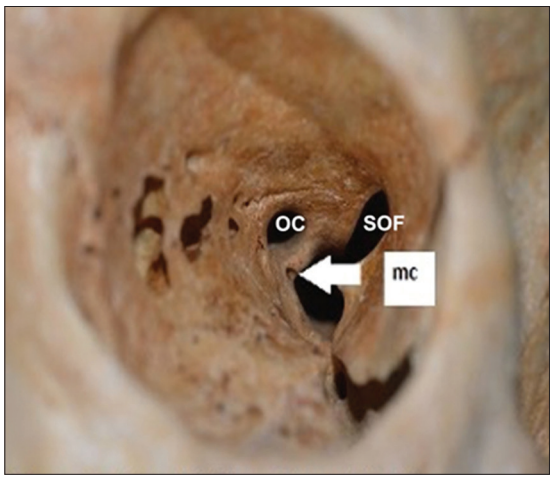


Figure 2: Front view of orbit. MC: Metoptic canal, OC: Optic canal, SOF: Superior orbital fissure

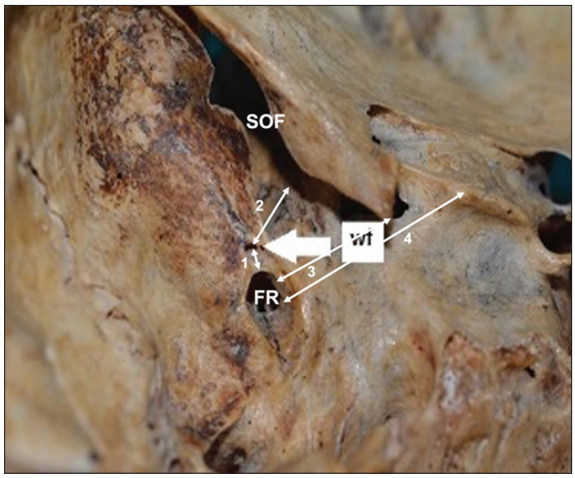


Figure 3: The measurements between the Warwick's foramen and defined anatomical points (1) Distance between Warwick's foramen and foramen rotundum (WFFR); (2) Distance between Warwick's foramen and supraorbital fissure (WFSO); (3) Distance between Warwick's foramen and processus clinoideus anterior; (4) Distance between Warwick's foramen and processus clinoideus medius. WF: Warwick's Foramen, FR: Foramen rotundum, SOF: Superior orbital fissure

canal (FZMC) and (ii) the distance between supraorbital notch or foramen and metoptic canal (SNMC). In addition, the distances between WF and the following structures were measured: foramen rotundum (WFFR), superior orbital fissure (WFSO), anterior clinoid process (WFACP), and medial clinoid process (WFMCP).

Results

Among 153 human skulls, MC was present on the right side in 4, on the left side in 5, and bilaterally in one [Table 1]. The mean FZMC length was 49.62 ± 4.30 mm on the right and 52.47 ± 3.05 mm on the left. The mean SNMC length on the right was 50.83 ± 4.38 mm and 54.02 ± 1.84 mm on the left [Table 2].

In 11 orbits, WF was never observed on the right and was present only on the left in two (18.2%) [Table 3]. The mean WFFR length on the right was 1.86 ± 0.25 mm, the mean WFSO length was 2.37 ± 0.42 mm, the mean WFACP was 14.78 ± 1.07 mm, and the mean WFMCP was 20.66 ± 1.29 mm [Table 4].

Discussion

The orbit harbors narrow channels through which arteries, veins, and nerves pass. These structures and channels are important for both clinical and anatomical studies. Among these, MC and WF have been relatively less studied and characterized. The aim of the current study was to provide data regarding the distances between these rare structures and other anatomical landmarks as well as the incidences of these structures, which could be especially useful for surgeons working in the field of orbital surgery. The majority of these channels are thought to close during the development of the orbit, but there is little information regarding their clinical significance in adult skulls. Furthermore, further studies may be warranted to determine whether age and gender affect the development of these channels. In addition,

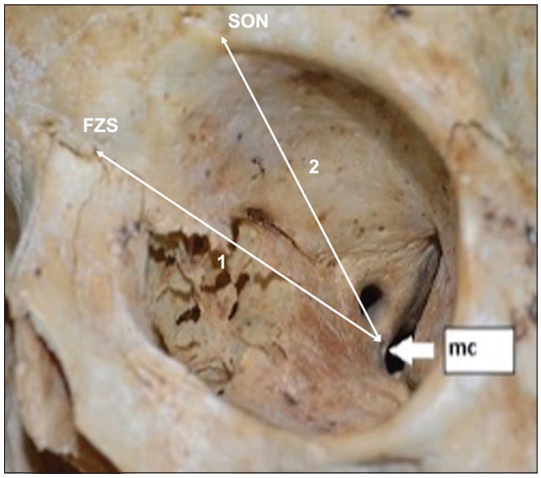


Figure 4: The measurements made between the metoptic canal and defined anatomical points (1) The distance between the frontozygomatic suture and the metoptic canal (FZMC); (2) The distance between the supraorbital notch or foramen and the metoptic canal (SNMC). SON: Supraorbital notch or foramen, FZS: Frontozygomatic suture, MC: Metoptic canal

Table 1: Number and percentage of metoptic canal's found on the right and left sides

	n (%)
MC right	
Presence	4 (2.6)
Absence	149 (97.4)
Total	153 (100.0)
MC left	
Presence	5 (3.2)
Absence	148 (96.8)
Total	153 (100.0)
MC bilaterally	
Presence	1 (0.06)

MC: Metoptic canal

Table 2: Mean distances between the metoptic canal and the reference points (mm)

MC	*n*	Minimum	Maximum	Median	Mean	SD	*P*
FZMC							
Right	5	44.98	53.96	50.98	49.62	4.30	0.414
Left	6	47.35	55.85	52.89	52.47	3.05	
SNMC							
Right	5	44.29	54.65	52.43	50.83	4.38	0.233
Left	6	50.83	55.90	54.56	54.02	1.84	

MC: Metoptic canal, FZMC: Frontozygomatic suture and metoptic canal, SNMC: Supraorbital notch or foramen and metoptic canal, SD: Standard deviation

Table 3: Number and percentage of Warwick's foramen's found on the right and left sides of the skull base

	n (%)
WF right	
Presence	0
Absence	11 (100.0)
Total	11 (100.0)
WF left	
Presence	2 (18.2)
Absence	9 (81.8)
Total	11 (100.0)

WF: Warwick's foramen

Table 4: Mean distances between the Warwick's foramen and the reference points (mm)

Left	*n*	Minimum	Maximum	Median	Mean	SD
WFFR	2	1.68	2.04	1.86	1.86	0.25
WFSO	2	2.07	2.66	2.37	2.37	0.42
WFACP	2	14.02	15.54	14.78	14.78	1.07
WFMCP	2	19.75	21.57	20.66	20.66	1.29

SD: Standard deviation, WFFR: Warwick's foramen and foramen rotundum, WFSO: Warwick's foramen superior orbital fissure, WFACP: WF and anterior clinoid process, WFMCP: WF and medial clinoid process

there is no information on possible pathologies of the nerve or vascular structures that pass through these channels between the anterior and posterior parts of the orbit, which may emerge in the presence or absence of these channels.

Metoptic canal incidence

Earlier, Macchi *et al*. reported that the MC is a somewhat overlooked anatomical entity found in 8.74% of orbits.[23] Chockalingam and Babu found MC only in 4 (7.8%) of the 32 dry human skulls; 3 were found on the right orbit and 1 was found on the left.[9] Hizay and Sindel found MC in 20 of the 92 dry human skulls, unilaterally. The authors observed MC in 11 (11.9%) skulls on the right and in 9 (9.7%) skulls on the left.[17] Regoli and Bertelli identified MC in 8% of the orbits they examined.[27] We identified the presence of MC in 10 of 153 (6.5%) dry human skulls: 4 (2.6%) of these were on the right, 5 (3.2%) were on the left, and 1 (0.06%) was bilateral. In some previous studies, bilateral canals were not found at all, or the majority of unilateral canals were localized on the right side. On the other hand, there was a more balanced distribution of MC in terms of the side in the present study. It remains to be seen whether these differences between published reports are related with ethnic origin or developmental factors. We also measured the distance between MC and frontozygomatic suture and the supraorbital notch to provide some information for surgical procedures involving this area.

Warwick's foramen incidence

The size and morphological characteristics of WF and adjacent structures play an important role in determining the most appropriate operative techniques to approach the skull base or for gender determination in forensic medicine. Preoperative assessment of the WF for determining the operative safe zone needs to include correlations between surgical and morphometric parameters. Furthermore, a detailed knowledge of the bony anatomy of this anatomical area may improve the general safety of the surgery.

Until now, WF has been studied only scarcely, research on its incidence has never been done, and little is known regarding the structures transmitted through it.[5,28] Furthermore, the morphology and size of this foramen appear to be highly variable. Based on a groove running backward into the cavernous sinus, Warwick hypothesized that it could convey an IOV.[28]

Chockalingam and Babu failed to observe any WF in 32 dry skulls studied.[9] Bertelli, in his study of 943 skulls, reported a WF incidence of 0.74%. In that study, WF was never bilateral, with 8 and 6 on the left and right orbits, respectively.[3] Furthermore, in another study, 0.6%–0.7% of the skulls examined by Regoli and Bertelli were found to have WF.[27]

WF incidence was higher (2.17%) than previous reports in the study by Araya *et al*., who examined dry skull specimens of Chilean origin. In that study, there was one case with right-sided WF, one with left-sided WF, and one with bilateral WF.[2] Hizay and Sindel, in their study of 92 skulls, found the frequency of WF to be 13.0%. All WFs were unilateral, with 7 (7.6%) on the right, and 5 (5.4%) on the left.[17] Similarly, in another previous study, WF was bilateral only in one case.[5] In our study, 11 human dry skull bases were examined for the presence of WF. Although the number of bone samples was small, we observed a unilateral left canal in 2 (18.2%). This may have been due to ethnic differences, developmental factors, or just coincidental.

Morphometric measurements

We also performed morphometric measurements in our study to provide data that can aid in surgical procedures. For this purpose, several anatomical reference points were used, including the frontozygomatic suture, supraorbital notch, foramen rotundum, superior orbital fissure, and anterior and medial clinoid processes. Groups were compared in terms of these measurements and no statistically significant difference was found ($P > 0.05$).

Metoptic canal measurements

The distances between MC and frontozygomatic suture reported in the study by Hizay and Sindel were 29.51 ± 11.20 mm and 27.98 ± 5.67 mm on the right and left sides, respectively.[17] The corresponding figures reported by Chockalingam and Babu were 5.1 and 6.5 cm.[9] In the present study, the measured distance was 49.62 ± 4.30 mm on the right and 52.47 ± 3.05 mm on the left side, similar to the results of Chockalingam and Babu, although they were slightly lower. These differences may reflect ethnic variations.

The distance between MC and supraorbital notch reported by Hizay and Sindel was 40.62 ± 8.87 mm on the right and 42.24 ± 12.77 mm on the left vs. 5.3 cm and 6 cm in another study by Chockalingam and Babu.[9,17] In the present study, this distance was 50.83 ± 4.38 and 54.02 ± 1.84 mm on the right and left sides, respectively, in general agreement with those of Chockalingam and Babu.

Warwick's foramen measurements

In Hizay and Sindel's study, the measured distance between WF and foramen rotundum was 7.27 ± 2.47 mm on the right and 6.18 ± 1.50 mm on the left side.[17] This distance was only measured on the left side in our study (1.86 ± 0.25 mm). In the abovementioned study, the distance between WF and the superior orbital fissure was 5.44 ± 1.85 mm on the right side and 5.96 ± 2.47 mm on the left side.[17] In our study, only a left-sided measurement was possible (2.37 ± 0.42 mm).

Surgical importance of the foramens

Serious ocular injury has been shown to occur, but there is conflict about the rate of occurrence and localization.[11] The middle fossa injuries can lead to serious cranial nerve injuries when they involve the foramina through which cranial nerves are transmitted.[16,21] Attention has already been drawn to the structural variations and differences and relative strength of the walls of the orbit and their relationship with the intracranial structures such as WF. Fractures of the posterior 1/3 of the orbit are uncommon. The posterior orbit contains a number of significant and sensitive structures, including the optic nerve, ophthalmic vessels, and ocular muscles as well as their motor nerves, which may pose significant challenges for the surgeon.[18] The most common surgical procedures used to treat orbital lesions involve the lateral wall approach, transethmoidal approach, transmaxillary approach from the orbital floor, and transcranial approach, in which the orbital roof is removed.[24] It has been previously reported that injury to arteries passing through the small foramen during orbital surgery prolongs the duration of surgical operations and puts structures passing through the superior orbital fissure at risk. During surgery, deep dissection of the lateral wall of the orbit can often lead to bleeding, which can be severe.[1,8] Postoperative complications in orbital surgery include visual disturbances, enophthalmos, facial asymmetry, and orbital dystopia. Some of these complications may result from severe ischemia.[23] It may also be important to assess the WF before surgical interventions for cranial tumors, herniation due to increased intracranial pressure, and trauma in the orbit or skull base. Furthermore, fractures of the region may occur in isolation or can be independently associated with fractures of the adjacent bone complex such as the superior orbital margin, the zygoma, the sphenoid, or temporal bones. Orbital fractures can be generally divided into four types: zygomatic complex fractures, isolated fractures of the orbital rim, isolated fractures of the orbital walls, and complex comminuted fractures. Fractures of the orbit should be approached with caution and proper management is essential to prevent esthetic and functional complications. The purpose of surgery is to identify and characterize blunt ocular and periocular injuries and to identify orbital cranial nerve lesions and lesions of neighborhood structures such as WF as well as other associated complications. A consensus-based classification of injuries involving this region may assist in developing surgical reconstruction strategies and may allow meaningful comparisons between surgical outcomes. Consultation with ophthalmic, neurosurgical, plastic, and maxillofacial surgeons can be of crucial importance for demonstrating anatomical location and accompanying lesions as well as for proper treatment and follow-up. Good knowledge of the size and morphological characteristics of WF and the adjacent structures is crucial for establishing the safest and most appropriate operative techniques in neurosurgery or for gender determinations in forensic medicine. During the preoperative evaluation of WF for the operative safe zone, the correlation between both surgical and morphometric parameters of WF needs to be taken into consideration. Detailed knowledge of the bony anatomy of this region is of great importance in terms of the safety of the surgical procedure.

In this study, the distances between some rarely observed anatomical structures and reference points within the orbit were analyzed. Despite limitations in the sample size and measurement techniques, we believe that the data generated may be of use for future studies. Awareness of the presence of orbital structures such as small channels will have clinical implications and shed light to further studies with more detailed hypotheses and robust contributions to science. Confirmation of the existence of these channels in other regions and ethnical groups requires the examination and analysis of skulls from other geographical regions. Morphological and morphometric characteristics of the MC and WF may be useful for orbital surgeons who are dealing with a variety of procedures such as tumor resection, decompression, or posttraumatic orbital or anterior skull base reconstruction. We believe that the data generated in this study may be valuable for researchers in the fields of anatomy, orbital surgery, and neurosurgery.

Author contribution

F Aksu: Project development, Data collection and management, Manuscript writing and editing. S Karabekir: Data analysis, Manuscript writing. N Karabekir: Manuscript writing and editing.

Ethical approval

This is a study conducted with the approval of our university's anatomy department. It was made on bones belonging to the university in the anatomy laboratory. Ethical Approval obtained from the Anatomy Department of Dokuz Eylul University Medical School is submitted as a file.

Availability of data and materials

Data and materials are available to the authors and can be used.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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