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**Title:** Metoptic canal and Warwick's foramen: Incidence and morphometric analysis by several reference points in the human orbit

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#### **Abstract**

**Objective:** Several canals and foramens in the human orbit are well known in the literature. However, little is known about some minor canals or structures including metoptic canal and Warwick's foramen. The aim of the present study was to make morphometric measurements and to determine the incidence of the metoptic canal and Warwick's foramen in the Turkish population.

**Materials and methods:** Ninety-two dried human skulls were examined. All skulls were obtained from the Turkish population and collection of the Anatomy Department of the

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University of xxxxxx. The metoptic canal and Warwick's foramen were identified in the skulls. Incidence of these structures and diameters were determined. Morphometric measurements were made using various reference points in the orbit.

**Results:** Of the 92 dry human skulls, the metoptic canal was detected in 20 of them. This canal was detected unilaterally. The metoptic canal was observed in 11 (11.9%) dry skulls in the right side, whereas it was observed in 9 (9.7%) dry skulls in the left side. There were no statistically significant differences according to the side for any of the measurements recorded ( $p>0.05$ ). The Warwick's foramen was observed in 12 (13.0%) skulls of all dry skulls. This foramen was also present unilaterally and was right sided in 7 (7.6%) skulls and left sided in 5 (5.4%) skulls.

**Conclusions:** Determination of additional foramen in the orbit is contributed to the literature. The presence of the metoptic canal and Warwick's foramen and their relationship with other structures in the orbit may have clinical significance in surgical operations.

**Keywords:** Metoptic canal, Orbit, Optic canal, Warwick's foramen

## Introduction

The human orbit is related to the middle cranial fossa through various canals and openings, such as optic canal and superior orbital fissure. These structures are mostly available; however, the Warwick's foramen and metoptic canal are less frequent [1-3]. Various canals and openings connect the orbit with the cranial cavity. The infraorbital, ethmoidal, zygomatic, and optic canals, as well as the superior and inferior orbital fissures, are well known. However, some minor canals can be rarely present [4]. Optic canal variations are less frequent and relatively rare [1, 5, 6]. Generally, the shape of the optic canal is rounded and elliptical [6]. The optic nerve and the ophthalmic artery pass through the canal. The optic canal can acquire a shape similar to a keyhole, or it can be double [5, 7]. In the latter case, the smaller lower canal is referred to as the ophthalmic canal and transmits to the ophthalmic artery [2, 8]. Duplication of the optic canal has been reported several times in the literature [2, 5, 7]. Many authors

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believe that these variations result from the developmental anomalies of the optic strut [9]. In the ossification process of the optic strut, a smaller canal can be seen downwards of the optic canal and referred to as the metoptic canal [2, 6, 9]. This canal or foramen usually closes at 2 months of fetal life or within the first few years of birth [6, 9]. Some authors have found an aberrant ophthalmic vein [10], whereas others have not observed structures passing through it [6, 9]. The persistence in adult life of the metoptic canal has also been reported, but its incidence is not known [11, 12]. In the literature, the Warwick's foramen and its incidence are also less frequent. The Warwick's foramen, a crescentic or round foramen, is located between the inferior end of the superior orbital fissure and the foramen rotundum [7, 13]. This foramen connects the middle cranial fossa with the orbit [2]. It is hypothesized that the inferior ophthalmic vein enters through the presence of this foramen [7]. The aim of the present study was to determine morphometric measurements and incidence of the metoptic canal and Warwick's foramen in the Turkish population. In the literature, little is known about the incidence of the metoptic canal and Warwick's foramen and their morphology [1]. To the best of our knowledge, this is the first morphometric analysis of these structures using various reference points. Localization of the metoptic canal and Warwick's foramen and their distance from selected reference points are clinically important for ophthalmologists and neurosurgeons. Knowledge of the relationship of these structures with the other structures in the orbit can be significant during surgical operations.

### **Materials and methods**

In the present study, 92 dried human skulls were examined. All skulls were obtained from the Turkish population and collection of the Anatomy Department of the University of Xxxxxx. Ethical approval was not needed in our study. Informed consent was not obtained because only bone material was used. No information regarding the age and sex of the skulls was available. None of the orbits was abnormally disrupted by the orbital due to a previous orbital surgery or trauma.

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The metoptic canal and Warwick's foramen were identified. Incidence of these structures and diameters were determined. Measurements were made using the tpsDig2 program.

Measurements made between different points were as follows (Figs. 1–2):

For the metoptic canal (Fig. 1):

1. distance between the frontozygomatic suture and the base of the metoptic canal,
2. distance between the superior aspect of the superior orbital fissure (peak point of the superior orbital fissure) and the base of the metoptic canal,
3. distance between the Whitnall's tubercle and the base of the metoptic canal,
4. distance between the superior aspect of the optic canal and the base of the metoptic canal,
5. distance between the supraorbital notch and the base of the metoptic canal.

For the Warwick's foramen (Fig. 2):

1. distance between the base of the foramen rotundum and Warwick's foramen,
2. distance between the base of the superior orbital fissure and Warwick's foramen.

### **Statistical analysis**

Descriptive statistics were applied to all the parameters collected from the dry skull measurements using the SPSS version 22.0 program. Differences between the orbital measurements of the right and left sides were analyzed. From these measurements, means and standard deviations were calculated. For the determination of the differences between sides and differences in diameters, the Student's t-test was used. For all analyses, a p-value <0.05 was accepted as statistically significant.

### **Results**

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Of the 92 dry human skulls, the metoptic canal was detected in 20 of them (Fig. 1). This canal was detected unilaterally. The metoptic canal was observed in 11 (11.9%) dry skulls in the right side, whereas it was observed in 9 (9.7%) dry skulls in the left side.

The average distances from the frontozygomatic suture, superior aspect of the superior orbital fissure, Whitnall's tubercle, superior aspect of the optic canal, and superior aspect of the supraorbital notch to the metoptic canal were  $29.51 \pm 11.20$ ,  $15.80 \pm 4.26$ ,  $22.85 \pm 9.95$ ,  $8.90 \pm 2.74$ , and  $40.62 \pm 8.87$  mm in the right side, respectively. The average distances from the frontozygomatic suture, superior aspect of the superior orbital fissure, Whitnall's tubercle, superior aspect of the optic canal, and superior aspect of the supraorbital notch to the metoptic canal were  $27.98 \pm 5.67$ ,  $15.98 \pm 3.42$ ,  $21.66 \pm 4.77$ ,  $9.21 \pm 2.42$ , and  $42.24 \pm 12.77$  mm in the left side, respectively (Table 1).

There were no statistically significant differences according to the side for any of the measurements recorded ( $p > 0.05$ ). The diameters of the metoptic canal were determined. The mean standard deviation of the diameter of the metoptic canal was detected at  $1.08 \pm 0.56$  mm. The narrowest diameters at 0.4 mm and larger diameter at 1.9 mm were determined. No significant differences were observed in diameter in the right and left sides ( $p > 0.05$ ).

In our study, the Warwick's foramen was also determined (Fig. 2). This foramen is located between the inferior end of the superior orbital fissure and the foramen rotundum. The Warwick's foramen was observed in 12 (13.0%) skulls of all dry skulls. This foramen was determined unilaterally and was right sided in 7 (7.6%) skulls and left sided in 5 (5.4%) skulls. The shape of the foramen was variable. The foramen was determined to be generally rounded in shape. The diameter was somewhat variable, ranging from 0.5 mm to 2.1 mm. The mean caliber of this foramen was determined at  $1.23 \pm 0.59$  mm. The average distances from the base of the superior orbital fissure and the base of the foramen rotundum to the Warwick's foramen were measured at  $5.44 \pm 1.85$  and  $7.27 \pm 2.47$  mm in the right side, respectively. The average distances from the base of the superior orbital fissure and the base of the foramen rotundum to the Warwick's foramen were  $5.96 \pm 2.47$  and  $6.18 \pm 1.50$  mm in the left side, respectively (Table 2).

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## Discussion

The region of the orbital apex is narrow, and in this region, there are several canals and openings (superior orbital fissure and optic canal) through which the nerves and vessels enter and exit [1, 2]. In addition, in the literature, there are available data according to the morphometric analysis and incidence of these structures. However, some minor canals are rarely present, such as metoptic canal and Warwick's foramen whose incidence and general characteristic have never been studied sufficiently [1, 3].

Morphometric measurements of the metoptic canal and Warwick's foramen were made using various reference points in the orbit, and their incidence was also determined. The presence of these structures (all of them are unilateral) is considered to be unusual findings.

In the literature, duplication of the optic canal has been reported several times [5, 7, 11, 14, 15]. Several hypotheses have been made to explain the existence of such variation. Authors believe that this variation is the result of developmental anomalies of the optic strut [9]. According to Kier, the optic strut is the inferior root of the lesser wing and develops in two steps. The first step is anteroinferior, and the second step is posterosuperior. All two segments extend from the lesser wing to the sphenoid body. Ossification of the anteroinferior segment, the ophthalmic artery running inferior part and optic nerve coursing superiorly [2]. During 5 months of fetal life, the foramen turns into a canal as an additional segment of the optic strut. This segment is the posterosuperior and diverges from the anteroinferior. This minor canal is referred to as the metoptic canal and can be found in fetus, newborns, and infants [1, 6, 9, 10]. Some authors stated that the aberrant ophthalmic vein travels in this canal [10]. However, Kier [9] and Radoievitch [6] have not observed vascular structures running through it.

The presence of the metoptic canal has been reported although its incidence is insufficient [1, 11, 12]. Bertelli [1] examined dry adult and fetal human skulls in a total of 1303 skulls. They observed the metoptic canal and also classified them into four different types. They found type I as a duplication of the optic canal (diameter >2 mm), and types II, III, and IV differ from type I and from each other because of caliber (diameter <1 mm) and according to the traversing of

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the optic strut. Authors determined the incidence of these four types of metoptic canal at 0.64% (12 orbits), 1.96% (37 orbits), 3.66% (69 orbits), and 2.49% (47 orbits), respectively. In our present study, we observed 92 dry human skulls, and the metoptic canal was detected in 20 orbits. The metoptic canal was observed in 11 (11.9%) dry skulls in the right side, whereas it was observed in 9 (9.7%) dry skulls in the left side. In our study, the diameter of the metoptic canal was also detected. Generally, the diameter was <1 mm, and majority of the detected canals were similar type IV of the metoptic canal according to Bertelli. Type IV canal closes the superior orbital fissure and is located at the base of the optic strut (Fig. 1). We did not determine other types of the metoptic canals in the present study according to Bertelli's classification [1]. In contrast to other studies, in our study, we also made morphometric measurements. For this analysis, we used various reference points; frontozygomatic suture, superior aspect of the superior orbital fissure, Whitnall's tubercle, superior aspect of the optic canal, and superior aspect of the supraorbital notch to the metoptic canal were measured at  $29.51\pm 11.20$ ,  $15.80\pm 4.26$ ,  $22.85\pm 9.95$ ,  $8.90\pm 2.74$ , and  $40.62\pm 8.87$  mm in the right side, respectively, and  $27.98\pm 5.67$ ,  $15.98\pm 3.42$ ,  $21.66\pm 4.77$ ,  $9.21\pm 2.42$ , and  $42.24\pm 12.77$  mm in the left side, respectively. We statistically analyzed these measurements according to the sides. According to the results of these measurements, there were no statistically significant differences according to the side ( $p>0.05$ ).

In addition to the metoptic canal, we observed Warwick's foramen. This foramen is located between the inferior end of the superior orbital fissure and the foramen rotundum [7, 13]. This foramen has been reported in a few studies [1,7,13]. Little was known about the incidence of the Warwick's foramen and also the structure passing through it [1]. Bertelli observed the Warwick's foramen unilaterally in 14 (0.74%) cases [1]. The author found that the incidence of this foramen is very low. In our present study, the Warwick's foramen was determined unilaterally in 12 (13.0%) skulls of all dry skulls examined. The foramen was detected in the right side in 7 (7.6%) skulls and in the left side in 5 (5.4%) skulls. The shape of the Warwick's foramen was variable, rounded, or crescentic [1, 7]. In our study, we mostly determined a rounded shape. Bertelli found that the mean caliber of the rounded foramina is  $0.98\pm 0.60$  mm, and crescentic foramina is  $2.88\pm 0.95$  mm [1]. In the present study, we determined that the

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rounded foramina had a mean caliber at  $1.41\pm 0.58$  mm, whereas the mean caliber of the crescentic foramina was detected at  $0.88\pm 0.45$  mm. We also examined the morphometric analysis of this foramen. For these measurements, we used reference points, such as the base of the superior orbital fissure and the base of the foramen rotundum to the Warwick's foramen. Results of these measurements were  $5.44\pm 1.85$  and  $7.27\pm 2.47$  in the right side and  $5.96\pm 2.47$  and  $6.18\pm 1.50$  mm in the left side, respectively. To our knowledge, there was no study according to the analysis of this foramen.

In conclusion, there are some limitations in our study. A few number of bone materials could be considered as a limitation. In the literature search, there was no available study comparable with this study. We believe that the determination of additional foramen in the human orbit is contributed to the literature. Knowledge about this structure, especially localization and association with the other structures in the orbit, can have importance for surgeons who make operations in the region.

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### Figure legend

**Fig. 1.** Orbital view of the metoptic canal (arrow) and measurement points.

SON, supraorbital notch; MC, metoptic canal; OC, optic canal; SOF, superior orbital fissure; WT, Whitnall's tubercle; FZS, frontozygomatic suture.

**Fig. 2.** Intracranial view of the Warwick's foramen (arrow) and measurement points.

SOF, superior orbital fissure; WF, Warwick's foramen; FR, foramen rotundum.

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**Table 1.** Mean distance between the metoptic canal and the reference points (mm).

Reference points	Sides	n	Mean value	Standard deviation	p-Value
Frontozygomatic suture	Right	11	29.51	11.20	0.71
	Left	9	27.98	5.67	
Superior aspect of the superior orbital fissure	Right	11	15.80	4.26	0.92
	Left	9	15.98	3.42	
Whitnall's tubercle	Right	11	22.85	9.95	0.74
	Left	9	21.66	4.77	
Superior aspect of the optic canal	Right	11	8.90	2.74	0.79
	Left	9	9.21	2.42	
Superior aspect of the supraorbital notch	Right	11	40.62	8.87	0.74
	Left	9	42.24	12.77	

**Table 2.** Mean distance between the Warwick's foramen and the reference points (mm).

Reference points	Sides	n	Mean value	Standard deviation	p-Value
Base of the superior orbital fissure	Right	7	5.44	1.85	0.255
	Left	5	7.27	2.47	
Base of the foramen rotundum	Right	7	5.96	2.47	0.879
	Left	5	6.18	1.50	

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