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Original Research

Morphometric Analysis and Clinical Importance of Foramen Ovale

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ABSTRACT
Objective: This study aimed to reveal the length, width, area, and perimeter measurements of foramen ovale (FO) with excessive bone count and correlation status.
Methods: On basis cranii externa of crania, a metric scale was put in a place near to FO. Each FO was photographed with a metric scale, and length, width, area, and perimeter of FO were calculated by using the Image J software program.
Results: The average values of the length, width, area, and perimeter of the FO are 7.05±1.43 mm, 3.30±1.24 mm, 15.68±9.51 mm^2, and 20.89±6.16 mm on the right side, and 6.83±1.53 mm, 3.30±1.34 mm, 15.61±8.73 mm2, and 21.00±6.41 mm on the left side, respectively.
Conclusion: The fact that the number of measured bones in this study is quite high and the perimeter and area measurement parameters in the study can make this study unique compared with other studies. Thus, this study can shed light on clinical studies.
Keywords: Basis cranii, foramen ovale, morphometry, percutaneous approach, photogrammetric measurement.

INTRODUCTION

Foramen ovale (FO) is a large opening that localizes posteromedially in the sphenoid bone (1) and it transmits the mandibular nerve, the accessory meningeal artery, a lesser petrosal nerve, and an emissary vein. It also connects the infratemporal fossa and the middle cranial fossa (2, 3).

Length of the FO was found to be about 3.85 mm in the new born and 7.2 mm in adults in the study of Yanagi (4). Morphometric analysis of the FO is mentioned in many studies worldwide for why anatomical variations in dimensions and shape of the FO are important for surgeons, radiologists, and anatomists (2, 5).

Abnormal position of the FO also has great importance. Skrzat et al. (6) mentioned that an atypical location of the FO and neighboring osseous structures may influence the anatomical organization of the nerves, which run through this hole. Especially, mandibular nerve and its divisions (lingual and inferior alveolar nerves) may have an abnormal course. That is why, it may be possible for the nerves to become entrapped or compressed between the osseous structures and muscles, causing neuralgia (6).

In this study, length, width, area, and perimeter of the FO were analyzed using the Image J software program. Besides this, an asymmetrical location between the right and left sides of the holes was found. Not many studies mention these parameters that are analyzed by the Image J software program. In addition, perimeter analysis of the FO is not usual data that are studied before. It is thought that the data obtained in this study will contribute more to the literature since it is made in a large bone population.

METHODS

This study was carried out in compliance with the Helsinki Declaration, and Ethics Committee approvals were obtained where appropriate. In this study, FO was examined in 100 cranium and 33 basis cranii of the Anatomy Department of Ege University Medicine Faculty. In norma basilaris regions of crania, a metric scale was put in a place near to FO. Then, each FO was photographed with a camera (Nikon coolpix P610; 60´ wide optical zoom ED VR, 4.3–258 mm, f: 3.3–8.2). The photographs have been uploaded to the software program Image J, and metric calibration of each photograph has been achieved. After calibration, the length (FOL), width (FOW), area (FOA), and perimeter (FOP) of each FO were measured. After the measurements, the correlation status of these parameters with each other and the comparison of the right and left sides with each other were calculated with the SPSS (version 20.0) statistical package program (IBM SPSS Corp.; Armonk, NY, USA). In addition, the symmetry and asymmetry of the hole on the right and left sides were analyzed.

RESULTS

The average values of the FOL of the FO are 7.05±1.43 mm (max/min: 11.29/3.34 mm) on the right side and 6.83±1.53 mm (max/

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Table 1. Mean, Standart deviations (SD), t and p values for foramen ovale parameters

parameters	Side	N	Mean	Std. Deviation (SD)	t	p
FOL	right	133	7.05	1.43	–0.06	0.94
	left	133	6.83	1.53		
FOW	right	133	3.30	1.24	–0.14	0.88
	left	133	3.30	1.34		
FOA	right	133	15.68	9.51	1.21	0.22
	left	133	15.61	8.73		
FOP	right	133	20.89	6.16	0.01	0.99
	left	133	21.00	6.41		

FOL: Length of foramen ovale, FOW: Width of foramen ovale, FOA: Area of foremen ovale, FOP: Perimeter of foramen ovale.

min: 10.78/2.91 mm) on the left side. The average values of the FOW of the FO are 3.30±1.24 mm (max/min: 9.96–0.67mm) on the right side and 3.30±1.34 mm (max/min: 6.82/0.66 mm) on the left side. The average values of the FOA of the FO are 15.68±9.51 mm^2 (max/min: 48.12/0.91 mm^2) on the right side and 15.61±8.73 mm^2 (max/min: 47.25/0.8 mm^2) on the left side. The average values of the FOP of the FO are 20.89±6.16 mm (max/min: 48.07/5.24 mm) on the right side and 21.00±6.41 mm (max/min: 47.82/6.34 mm) on the left side. The test used for normality analysis is "Kolmogrov Smirnov". According to this test, only the mean length of the right side and the mean width of the right side (FOWR) fit the normal distribution. The mean area of the right sides (FOAR) and the mean perimeter of the right sides (FOPR), whose Skewness and Kurtosis are between –2 and +2, are considered to be in accordance with the normal distribution, and an independent sample t-test, which is a parametric test, was used. According to the t-test of the FO on the right and left sides, the "p" values of FOL, FOW, FOA, and FOP measurements are given in Table 1. According to the resulting "p" values, there is no significance between the right and left sides' values ($p > 0.05$). In both right and left sides, correlation status of the parameters (FOA, FOP, FOL, and FOW) with each other was also examined. According to Table 2, the weakest correlation is between the average values of the FOWR and the average values of the length of the left side. Although there is a weak correlation between FOWR and FOPL (mean perimeter of the left side), as shown in Table 2, it may not be considered because the "p" value is not significant. There is a strong correlation between the average values of the FOAR and the average values of the FOPR. In the comparison of right and left sides of the skull base regions, "73" FOs were found to be asymmetrical.

Main Points:

- In this study, the morphometry of the oval foramen was investigated using the Image J software program.
- The high number of bones used in the study may present meaningful data to the literature in terms of the results.
- In contrast with other studies in the literature, the circumference measurement (20.89±6.16 mm on the right sides and 21.00±6.41 mm on the left sides) of the oval foramen was examined, and the correlation of this measurement with the area measurement (15.68±9.51 mm^2 on right sides and 15.61±8.73 mm^2 on left sides) was observed.
- These parameters can be useful for percutaneous interventions planned to the foramen ovale.

DISCUSSION

Anatomical features of FO have great importance for surgeons who are interested in FO and related structures. Size and shape of FO are variable in each individual (7). In some cases, pterygospinous and ptergoalar ligaments may localize around the FO. In such conditions, mandibular nerve and its branches can be compressed by these bars and lead to trigeminal neuralgia (TN). The presence of these bars around the FO complicates trigeminal ganglion block by the transovale approach (8, 9).

TN is the painful condition of the face and is the most common occurrence of craniofacial neuralgias (10). Many anatomical and radiological studies have been performed to research relationship between the skull foramens and the incidence of the TN (11, 12). Liu et al. investigated narrow FO and its role in etiology of the TN. They studied the size of FO in patients with pain and patients with nonpain. The results were statistically significant. They suggested that narrow FO may be etiologically important in a small percentage of TN patients (13).

In this study, we studied short and long diameters, area, and perimeter of the FO.

It was observed that FO localized asymmetrically in 73 skull base. The study closest to this study in terms of length and width measurements was performed by Osunwoke et al. (11) (Table 3). There are a number of studies on FO in the literature, but there are almost none, including both area and perimeter measurements of FO with their correlation status. This study is similar in terms of area measurement and correlation values by Somesh et al. In the study by Somesh et al., area measurements are more than those in this study. When the study is examined, FOs are considered as ellipse and short and long diameters of the hole

Table 2. The pearson correlation coefficient 'r' and 'p' value of the continuous variables

Parameters	'r' and 'p' values	FOAR	FOAL	FOPR	FOPL	FOLR	FOLL	FOWR	FOWL
FOAR	r	–	.702	.739	.517	.565	.462	.530	.424
	p	–	.000	.000	.000	.000	.000	.000	.000
FOAL	r	.702	–	.563	.656	.412	.603	.252	.543
	p	.000	–	.000	.000	.000	.000	.003	.000
FOPR	r	.739	.563	–	.591	.511	.367	.408	.314
	p	.000	.000	–	.000	.000	.000	.000	.000
FOPL	r	.517	.656	.591	–	.244	.379	.123	.295
	p	.000	.000	.000	–	.004	.000	.152	.000
FOLR	r	.565	.412	.511	.244	–	.528	.505	.347
	p	.000	.000	.000	.004	–	.000	.000	.000
FOLL	r	.462	.603	.367	.379	.528	–	.190	.544
	p	.000	.000	.000	.000	.000	–	.025	.000
FOWR	r	.530	.252	.408	.123	.505	.190	–	.450
	p	.000	.003	.000	.152	.000	.025	–	.000
FOWL	r	.424	.543	.314	.295	.347	.544	.450	–
	p	.000	.000	.000	.000	.000	.000	.000	–

FOAR: area of right side, FOAL: area of left side, FOPR: perimeter of right side, FOPL: perimeter of left side, FOLR: length of right side, FOLL: length of left side, FOWR: width of right side, FOWL: width of left side.

Table 3. The table shows the morphometric findings of the length and width of the foramen ovale of each author

	Mean length (mm)		Mean width (mm)	
Study/Populationn (skull)	right	left	right	left
Osunwoke et al[25] (2009), n=87	7.01	6.89	3.64	3.60
Somesh et al[3] (2011), n=82	7.56	7.64	5.24	5.12
Khan et al[26] (2012), n=25	7.46	7.01	3.21	3.29
Wadhwa et al[27] (2012), n=30	6.50	6.80	3.70	4.00
Desai et al[20] (2012), n=125	8.14	7.98	5.26	5.88
Gupta et al[28] (2013), n=35	7.22	6.48	3.57	3.50
Patil et al[29] (2013), n=52	7.00	6.80	5.00	4.70
Patel et al[30] (2014), n=100	6.60	6.50	3.60	3.50
Ahmed et al[31] (2015), n=100	5.25	4.84	4.87	5.18
Rao et al[21] (2017), n=50	7.24	7.11	3.75	3.75
Bokhari et al[2] (2017), n=55	7.04	7.18	4.15	3.99
Current study (2020), n=133	7.05	6.83	3.30	3.30

are taken into account instead of radius (3). In this study, area and perimeter were calculated with the Image J software program photogrammetrically with the help of metric scale.

This study is ahead in terms of the number of measurements. In addition, the perimeter measurement of FO in this study may bring innovation according to other studies in the literature.

Considering that the area measurement takes place in an almost nonexistent literature, this study is quite up to date and different, including both area and perimeter measurements of the FO and comparing them with the correlation graph.

In recent years, studies on the controlled percutaneous approach to the oval FO have started to increase (14, 15). The major risk associated with the percutaneous approach is the serious complexity that can occur in neighboring structures (16, 17). In this regard, it may be beneficial for morphometric anatomical studies to support percutaneous approaches. Therefore, it is predicted that this study carries data that can be taken into account in the percutaneous approaches planned in the FO.

Information about morphology and morphometry of FO is essential for various invasive surgical and diagnostic procedures such as electroencephalographic analysis of the seizure for patients undergoing selective amygdalohippocampectomy, microvascular decompression by percutaneous trigeminal rhizotomy for TN, and percutaneous biopsy of cavernous sinus tumors (3, 18-21). Not only the morphological structure of the FO but also the t region of the hole with its adjacent anatomical structures is important (22-24). The distance of FO with its neighboring structures can also be considered in other studies and may carry information guiding percutaneous interventions.

CONCLUSION

According to other studies in the literature, the number of bones in this study is quite high, and at the same time, perimeter measurement is included in this study, unlike other publications. The high number of bones in this study and the use of photogrammetric measurement as a method can make the study take an important place in the literature.

Limitations

Difficulties in knowing the characteristics of dry bones such as age, gender, or race have been reported in the literature (32). The limitation of this study is that information about the age, sex, and race the examined bones is not known.

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