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ORIGINAL PAPER

An Anatomical Evaluation of Normal and Aberrant Foramen Ovale in Skull Base with Its Clinical Significance

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ABSTRACT

Introduction: *Foramen ovale is one of the most significant foramina of skull base and transmits mandibular nerve. Its detailed knowledge is crucial in treatment of trigeminal neuralgia and various diagnostic practices.*

Aim: *Aim of the study was to provide anatomical data of foramen ovale regarding number, shape, diameters and its relation to nearby bony landmarks.*

Material and method: *The present study was ethically approved and 100 dry adult human skulls were included in the study to evaluate 200 foramina ovale. Non-metric parameters were observed and metric parameters were measured with Vernier calliper and goniometer.*

Results: *Different kinds of shapes were found in foramen ovale. Variant features in the form of bony spine, ridge, foramen or bar were identified. The means of anteroposterior and transverse diameter of foramen ovale were found to be 8.16 and 4.97 mm on the right side, and 7.68 and 4.74 mm on the left side. The mean distance of its anterior and posterior ends from the midsagittal plane were 22.69 and 28.92 mm on the right side, and 22.18 and 22.66 mm on the left side. Distance from the lateral border of foramen ovale to the posterior end of zygoma and midpoint of infratemporal crest was found to be 30.65 and 21.05 mm on the right, and 30.30 and 20.87 mm on the left side. The mean of angle of foramen ovale with midsagittal was 45.44º on the right side and 45.78º on the left side.*

Conclusion: *Variations found in foramen ovale are key points to keep in mind while operating in this region. Measured metric parameters were found to a higher extent on the right side than the left one. The present study will be helpful for both further research and neurosurgeons operating in this region.*

Keywords: foramen ovale, mandibular nerve, trigeminal neuralgia, development.

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INTRODUCTION

Foramen ovale (FO) is located in the infratemporal surface of the sphenoidal greater wing that develops from alisphenoids. Mandibular nerve, accessory meningeal artery, lesser petrosal nerve and emissary veins pass through it. During intrauterine life, the mandibular nerve comes to lie at its position through FO and membranous bone surrounds the nerve trunk. In the eighth week of intrauterine life, the first centre of ossification appears in this region. In the seventh month of foetal life, the earliest formation of perfect ring-shaped FO is observed. Later on, during the development process, any of the bones can overgrow, thus resulting in morphological irregularities such as spine, tubercle, bar, or foramen. These irregularities may compress the mandibular nerve, causing trigeminal neuralgia.

Given the above-mentioned conditions, the trigeminal nerve needs to be approached through the FO (1). Therefore, FO morphological and morphometric details are extremely important.

Because of its location in the junction of intracranial and extracranial zone, FO is useful in various diagnostic practices, most importantly in order to analyse seizures via EEG during selective amygdalahippocampectomy (2) and CT guided FNAC techniques for diagnosing deep pathologies. Thus, craniotomy or other open surgical procedures in the skull can be avoided (3).

Therefore, knowledge of FO position is clinically important when giving anaesthesia in the mandibular nerve and enables access to the trigeminal nerve (4). Thus, detailed anatomy of these foramina and their relation to each other as well as nearby landmarks is of utmost importance for the concerned neurosurgeons (5). ❑

MATERIAL AND METHOD

Study design

The present research was a descriptive cross-sectional study conducted on 100 dry human skulls in the Department of Anatomy, Government Medical College Amritsar, India.

Ethical clearance

Synopsis was approved by the institutional ethical committee of the Government Medical College Amritsar via letter no. 1446 dated 23.06.2017.

Inclusion and exclusion criteria

Human skulls, dentulous or partially dentulous, without any damage or pathological deformity were included in our research. Skulls of children, damaged or malformed skulls were excluded from the study.

Methodology

Number and shape of foramen ovale was observed. Distances were measured with the digital Vernier caliper to the nearest count of 0.01 mm. Angle was measured with a goniometer.

The following metric parameters of FO were measured: 1) anteroposterior diameter as L in Figure 1; 2) transverse diameter as M in Figure 1; 3) distance between the anterior end and the midsagittal plane (MSP) as N in Figure 1; 4) distance between the posterior end and MSP as O in Figure 1; 5) distance between the lateral border and zygoma as P in Figure 1; 6) distance between lateral border and infratemporal crest as

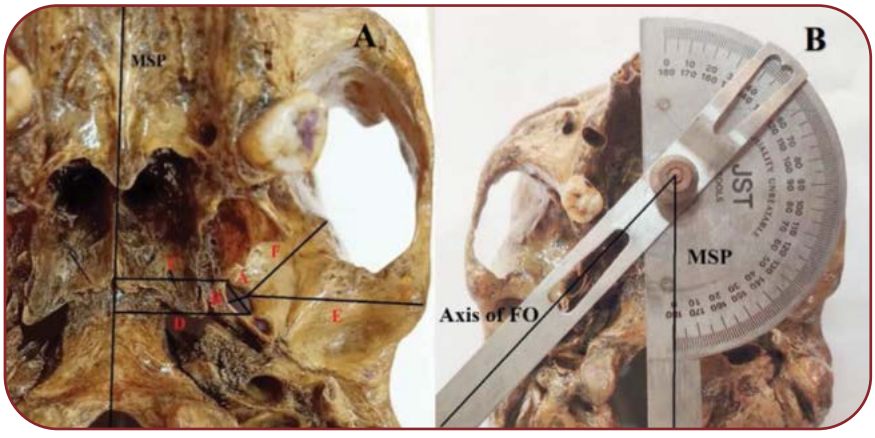

FIGURE 1. Metric parameters of foramen ovale (FO). A: anteroposterior diameter; B: transverse diameters; C: distance of anterior from midsagittal plane; D: distance between the posterior end and midsagittal plane (MSP); E: lateral border to posterior end of zygoma; F: lateral border to infratemporal crest; 1 B: measurement of angle between the long axis of FO and MSP

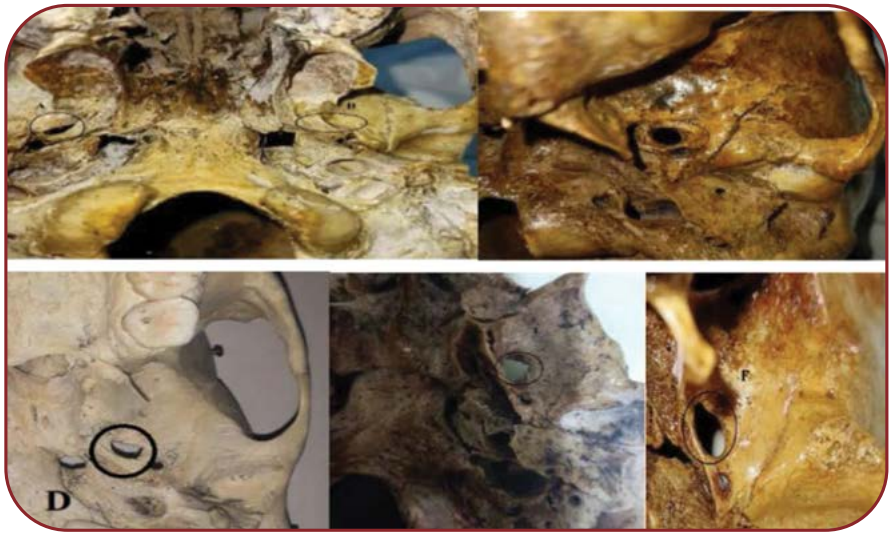

FIGURE 2. Shapes of foramen ovale.
A: almond; B: slit-like; C: round; D: D-shaped; E: triangular; F: pear shaped

Q in Figure 1; 7) angle between axis of foramen ovale and MSP (Figure 2).

Statistical analysis

Morphological and morphometric data collected was analyzed using SPSS 18 and Excel 2010. The mean, standard deviation (SD) and range were calculated. P value was collected by using student's t test and it was considered significant if less than 0.05. ❑

RESULTS

The number of FO was observed and there were single foramen present on both sides in all specimens. Oval shapes were predominantly observed. Oval shaped FO was seen in 68% of skulls on the right side and in 72% on the left side, while almond shaped FO in 20% of skulls on the right side and 18% on the left side (A in Figure 2). Slit-like shaped FO was seen in 1% of skulls bilaterally (B in Figure 2), and round shaped FO in 4% and 2% of skulls on the right and left sides, respectively (C in Figure 2). Also, D-shaped FO was observed in 6% each on the right and left sides (D in Figure 2), triangular shaped in 1% on the right side and pear shaped in 1% on the left side (E and F in Figure 2, respectively).

Metric values were summarized in Table 1, showing that all parameters have been found to a greater extent on the right side than the left side. ❑

DISCUSSION

Foramen ovale lies in the greater wing of sphenoid and it is of immense clinical and surgical importance. Therefore, its anatomical study holds

TABLE 1. Results of the present study

Sr. No.	Parameter	Mean and SD (mm)		Range (mm)		P value
		Right	Left	Right	Left	
1	AP diameter	8.16±1.560	7.68±1.253	4.8-13.01	4.49-10.72	0.0194
2	TV diameter	4.97±1.164	4.74±1.206	2.01-8.67	2-8.54	0.1756
3	Distance between anterior end and MSP	22.69±1.881	22.18±1.906	19.28-27.91	18.67-27.87	0.0616
4	Distance between posterior end and MSP	28.92±2.185	22.66±2.398	23.44-34.65	22.37-33.76	0.4194
5	Distance between lateral border and zygoma	30.65±2.984	30.30±2.596	23.28-37.58	23.04-35.29	0.5182
6	Distance between lateral border and infratemporal crest	21.05±2.832	20.87±3.015	14.21-27.85	14.17-27.2	0.6567
7	Angle between the axis of FO and MSP	45.44°±8.794	45.78°±8.32	30°-65°	29°-65°	0.7829

AP=anteroposterior; TV=transverse; SD=standard deviation; FO=foramen ovale; MSP=midsagittal plane

TABLE 2. Comparison of foramen ovale shapes with those described by other studies

Study authors	Incidence of various shapes (%)															
	Oval		Almond		Round		D-shaped		Slit-like		Irregular		Triangular		Pear shaped	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Burdan *et al*, 2011	62.8	60	31.4	34	2.8	2.8	-	-	2.8	-	-	-	-	-	-	-
Daimi *et al*, 2011	29.87		10.41		12.52		46.16		1.04		-		-		-	-
Somesh *et al*, 2011	56.70		28.65		10.97		-		-		3.65		-		-	-
Desai *et al*, 2012	62.8		23.2		11.81		-		-		2.91		-		-	-
Nirupma *et al*, 2013	54.29		35.71		8.57		-		1.43		-		-		-	-
Khairnar and Bhusari, 2013	76.5		10.5		7		-		6		-		-		-	-
Magi *et al*, 2014	69		29		2		-		-		-		-		-	-
Patel *et al*, 2014	59.5		12		27.5		-		1		-		-		-	-
Deepti *et al*, 2015	80		11.67		6.67		1.67		-		-		-		-	-
Naqshi *et al*, 2017	70		17.5		10		2		-		-		-		-	-
Poornima *et al*, 2017	60		25		13		2		-		-		-		-	-
Kumar B, 2018	60		28.75		10		1.25		-		-		-		-	-
Sophia *et al*, 2018	68.46		5.85		8.55		15.31		0.9		-		-		-	-
Das *et al*, 2019	53.94		21.05		-		3.94		-		-		-		-	-
Present study, 2021	68	72	20	18	4	2	6	6	1	1	-	-	1	-	-	1

a great significance. Unfortunately, not much literature regarding various parameters explored in the present study could be accessed.

In our study, single FO was observed in all specimens. Skrzat reported absent FO in one specimen on the left side (4), whereas bilateral absence was reported by Sophia *et al* (6). Oval FO was the most commonly seen shape in the present study. Incidences of different shapes found by us and comparisons with those described by other studies are summarized in Table 2, which clearly shows that our findings were compatible with those reported by authors of previously published studies (6-8).

In the present study, variant FO was seen in 18% of skulls, bony spine in four specimens along the lateral margin, one specimen along the anterior margin and one specimen along the posterior margin (three on the right side and three on the left side). Medial margin was raised in five specimens (one on the right side and four on the left side). Posterior margin was raised in one specimen on the left side. A small foramen was found along the lateral margin on the right side in one specimen. Tubercles were found in

FIGURE 3. Variants of foramen ovale. A: spine; B: raised margin; C: tubercles; D: foramen; E: bony bars; F: ridge

two specimens on the left side. Bony bars were seen in two specimens and in one specimen on the medial margin. In another triangular shaped foramen, two bars were present: one on the anterolateral aspect and one from the posterior margin which were projecting towards the FO, leading to obstruction of the foramen. In one specimen there was a bony ridge along the lateral margin. Interestingly, no spine was found along the medial margin and raised margins were more common on the left side. Such type of structures may be an underlying cause of compression disorders of neurovascular structures or these may pose obstruction in the course of their treatment.

Ray *et al* (3) reported the following variants of FO: spine in two specimens on the right side and one specimen on the left side, tubercle in one specimen on the right side and two specimens on the left side, bony plate in one specimen on each side. Chauhan *et al* (9) also found spine in 18 (12 on anterior margin and six on posterior margins), tubercle in five, bony plate in 1.21% and raised margin in 1.21% of skulls.

Theses variations can be explained on the basis of embryology that is due to overgrowth of the surrounding bones. Intrauterine position of fetus, damage to skull or muscle associated, partially atrophied skull, congenital anomalies of sphenoid, mandible or temporal bone are a few factors that cause such variant features (1).

The mean of anteroposterior diameter found in the present study was 8.16±1.560 mm on the right side and 7.68±1.253 mm on the left side; its P value was 0.0194, which was statistically significant. So, the surgeon has to be careful about this difference. Table 3 clearly shows that anteroposterior diameter in our study is in accordance with findings reported by Desai *et al* (10).

The mean of transverse diameter found in the present study was 4.97±1.164 mm on the right side and 4.74±1.206 mm on the left side. P value was 0.1756, so the difference between the right and left sides was statistically insignificant.

Regarding the distance from anterior and posterior ends of FO to MSP, the mean value of the distance of anterior end of FO was 22.69±1.881 mm on the right side and 22.18±1.906 mm on the left side, with P value 0.0616. On statistical analysis, the difference of both sides was found insignificant. Teul *et al* (1) measured it in mediaeval and contemporary skulls and found it to be 35.0 mm on the right side and 34.5 mm on the left side in both types, which was much higher than results found in present study. However, our findings were in ac-

Author	A-P diameter		TV diameter	
	Right	Left	Right	Left
Osunwoke *et al*, 2010	7.01±0.1	6.89±0.09	3.37±0.07	3.33±0.07
Somesh *et al*, 2011	7.64±1.194	7.56±1.123	5.128±0.827	5.244±0.950
Desai *et al*, 2012	8.14±1.42	7.98±1.89	5.26±0.93	5.88±1.01
Nirupma *et al*, 2013	7.2±1.1	6.4±1.3	3.5±0.7	3.5±0.7
Magi *et al*, 2014	8.9±1.6	8.5±1.3	3.7±1.0	3.9±0.9
Ashwini *et al*, 2017	6.59±2.21	6.38±2.52	4.83±0.97	4.97±0.97
Karthikeyan *et al*, 2017	7.45±1.1	7.61±1.15	3.99±1.8	4.6±1.4
Poornima *et al*, 2017	6.5±1.398	6.4±1.47	3.54±0.569	3.73±0.83
Rao B *et al*, 2017	7.24±0.84	7.11±1.00	3.75±0.71	3.75±0.67
Zahira *et al*, 2017	7.04± 1.08	7.18±1.14	4.15±0.92	3.99±0.86
Binod *et al*, 2018	6.8±1.2	6.8±1.3	3.5±0.5	3.5±0.5
Kumar B, 2018	6.86±1.26	6.84±1.3	3.3±0.59	3.51±0.58
Sophia *et al*, 2018	7.57±1.55	7.39±1.53	4.28±0.9	4.57±1.1
Das *et al*, 2019	7.17±1.31	7.26±1.91	3.49±0.54	3.73±0.83
Present study, 2021	8.16±1.560	7.68±1.253	4.97±1.164	4.74±1.206

TABLE 3. Comparison of anteroposterior and transverse diameters with those reported by previous studies

cordance with those reported by Sharma *et al* (11), who found it to be 22.31 mm on the right side and 21.71 mm on the left side.

The mean of distance of posterior end of FO was 28.92±2.185 mm on the right side and 22.66±2.398 mm on the left side. P value of the mean of distance of posterior end from MSP on the right and left sides was 0.4194, which was statistically insignificant. Unfortunately, no data could be traced for comparison in the accessible literature.

Regarding the distance between lateral border of FO and posterior end of zygoma, we found 30.65±2.984 mm and 30.30±2.596 mm on the right and left sides, respectively. P value was 0.5182. So, the difference was considered statistically insignificant. Our results were close to those reported by Srivastava *et al* (12) in 2021 (31.75±3.02 mm).

Regarding the distance between the lateral border of FO and the midpoint of infratemporal crest, its mean value found in our study was 21.05±2.832 mm and 20.87±3.015 mm on the right and left sides, respectively. P value was calculated to compare mean values of right and left and it was found to be 0.6567, which was statistically insignificant. No data could be found for comparison in the accessible literature.

In the present study, the mean of angle of FO with MSP was 45.44°±8.794 on the right side and 45.78°±8.32 on the left side. P value was 0.7829, which was considered not statistically significant. Knowledge about angle is important to avoid any injury to accompanying or nearby vascular structures during treatment of trigeminal neuralgia. ❑

CONCLUSION

Although FO is a very important foramen in the skull base, a limited number of studies on this topic have been published so far. Therefore, the present study is providing baseline data for neurosurgeons, radiologists and future researchers. We found a significant difference in the mean of anteroposterior diameter on the right and left sides, which is the key point to be taken care of while operating in this region. Measurements of other parameters showed higher values on the right side but the difference from the left side was statistically insignificant. All measured parameters are important for approaching the foramen ovale to access mandibular nerve in various procedures. ❑

Conflicts of interest: none declared.
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