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Original Article

Morphometric and Anatomic Variations of Foramen Ovale in Human Skull and Its Clinical Importance

Abstract

Objective: There is a paucity of information regarding the specific anatomy and clinical significance of variations of foramen ovale (FO). The present study was undertaken to define this anatomy in more detail and to review the literature regarding these anatomic variations. **Materials and Methods:** A total of 124 adult human dry skulls were analyzed for the variations in appearance and number of FO being noted. The length and width of the FO of both sides were determined using digital vernier calipers and area (A) was also calculated and analyzed. **Results:** Of 82 adult skulls, the values for the right side was 7.64 ± 1.194 mm, 5.128 ± 0.827 mm, and 30.808 ± 7.545 mm^2 and for the left side the values was 7.561 ± 1.123 mm, 5.244 ± 0.950 mm, and 31.310 ± 8.262 mm^2, respectively, for the mean length, width, and area of the FO. The shape of foramen was typically ovale in most of the skulls (56.70%) with some bony variations such as spine, tubercles, bony bridge/bar, and confluence. **Conclusion:** Such variants in the FO could interfere with transcutaneous needle placement into the FO or distort anatomic relationships during approaches to the cranial base.

Keywords: *Anatomic landmarks, foramen ovale, greater wing of the sphenoid, middle cranial fossa, skull base*

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Introduction

Foramina in the floor of middle cranial fossa are very important as they allow passage of as nerves and blood vessels. The greater wing of sphenoid contains three consistent foramina and other small variable foramina. Foramen ovale (FO) is located in the posterior part of the greater wing of sphenoid bone for the transmission of the mandibular nerve, accessory meningeal artery, lesser petrosal nerve, and emissary vein which opens into the infratemporal fossa.[1]

There are few studies documented the abnormal morphology of the FO associated with ossified ligaments of pterygospinous (ligament of Civinini) and pterygoalar (ligament of Hyrtl),[2,3] or its venous part may be compartmentalized by a bony spur resulting in doubled FO.[4] Knowledge of variations of FO will help in distinguishing potentially abnormal foramina from normal during computed tomography and magnetic resonance imaging. Moreover, it is of greater surgical and diagnostic importance in procedures such as percutaneous trigeminal rhizotomy, transfacial fine-needle aspiration technique in perineural spread of tumor, and electroencephalographic analysis for seizure.[5]

The incidence in the anomaly of FO varies in different regions of the world, as reported by various authors. The knowledge of three-dimensional topographic anatomy of skull structures and their morphometric values is needed, but it is not sufficient for performing safe treatment. Therefore, detailed knowledge of morphological variants and morphometric details of the FO in adult human skulls of Indian origin is essential for clinicians who perform various invasive procedures on head and neck.

Materials and Methods

The materials for the present study included 62 (124 sides) dry adult, Indian human skulls of unknown sex and origin were obtained from Bone Bank of the Department of Anatomy. Skulls damaged in the floor of the middle cranial fossa and skulls with gross evident deformities were excluded. Existence of the FO was ascertained bilaterally by observing the

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posterior part of the greater wing of the sphenoid bone, and its patency was confirmed by inserting a probe through each foramen.

The anteroposterior diameter (length) or "L" and transverse diameter (width) or "W" of the FO of both sides are determined using digital vernier calipers.[6] Each dimension was measured, while mean figures were recorded. Area "A" of the FO was calculated using the formula: $(\pi \times L \times B)/4$ or $(3.142 \times L \times B)/4$.[5]

Statistical analysis

Various measurements between the right and left sides were analyzed statistically, using SPSS Statistics Version 16 (IBM, Chicago, USA) by testing student "*t*" test method, and $P < 0.05$ was considered statistically significant.

Results

Morphology

The present study was conducted on a total of 124 sides in 62 dry adult skulls. Various shapes of the FO were observed [Table 1], of which it was typically oval in 75 sides (40 right, 35 left); almond shape in 35 sides (19 right, 16 left), typically round in 10 sides (6 right, 4 left); and irregular shaped in four sides (1 right, 3 left). The incidence of oval-, almond-, round-, and irregular-shaped FO [Figure 1] observed in our study was 60.4%, 28.22%, 6.45%, and 3.22%, respectively [Table 1].

In the present study, the mean length of FO was 7.74 ± 1.94 mm on the right side and 7.60 ± 1.25 mm on the left side, whereas the observed maximum and minimum length on the right side was 12.5 mm, 4.95 mm and on the left was 12.1 mm, 4.3 mm, respectively [Table 2 and Figure 2]. However, the difference between the length of right and left sides was not statistically significant [Table 3]. The maximum and minimum width of FO was 8.0 and 3.5 mm on the right and 8.8 and 3.5 mm on the left side [Table 2], and the mean width on the right side was 5.18 ± 0.98 mm and on the left side was 5.4 ± 0.85 mm [Table 2] with no significant difference between the sides [Table 3]. When the mean area (A) of FO was calculated, based on the formula obtained by previous studies, it was found 32.54 ± 7.54 mm^2 (55.73–14.5 mm^2) on the right side and 31.07 ± 9.54 mm^2 (58.3–15.1 mm^2) on the left side [Table 2 and Figure 3], with no statistically significant difference between the two sides [Table 3]. Other features noted are bony spicule, spur, bony bridge, confluence etc as shown in Figures 3 and 4.

Table 1: Variations in appearance of foramen ovale

Shape	Right (*n*=62), *n* (%)	Left (*n*=62), *n* (%)	Total (*n*=124), *n* (%)
Oval	40 (64.5)	35 (56.4)	75 (60.4)
Almond	16 (25.8)	19 (30.6)	35 (28.22)
Round	5 (8.0)	5 (8.0)	10 (6.45)
Irregular	1 (1.62)	3 (4.8)	4 (3.22)

There was a positive correlation between lengths, breadths and areas between right and left sides of the FO [Table 4].

Discussion

The skull foramina exist as the ossification of the skull base occurs around preexisting vessels and cranial nerves. After

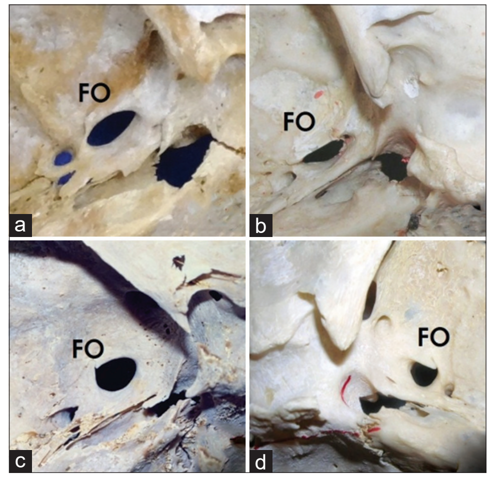

Figure 1: Types of FO shape, (a) oval type, (b) almond-type, (c) round-type, and (d) irregular-type. FO – Foramen ovale

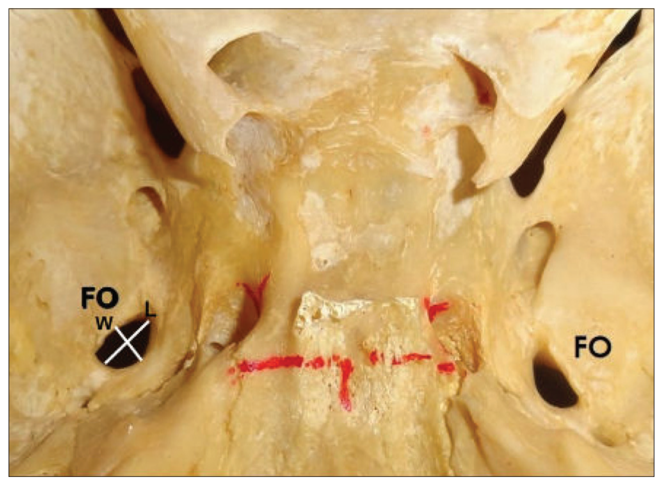

Figure 2: FO anteroposterior length (L) and transverse width (W). FO – Foramen ovale

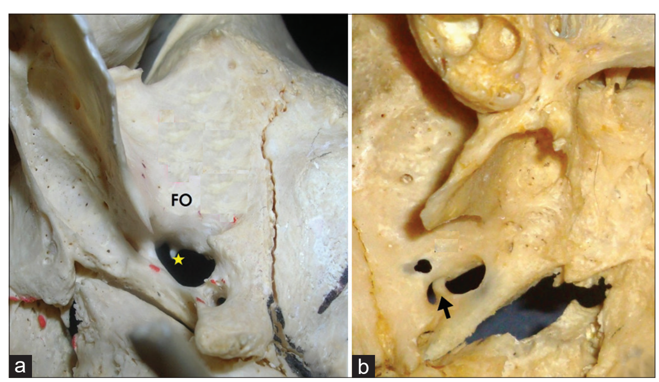

Figure 3: FO spur/tubercle (yellow star) (a), osseous bridging (black arrow) (b). FO – Foramen ovale

Table 2: Dimensions of foramen ovale

	Length (mm)		Breath (mm)		Area (mm²)	
	Left	Right	Left	Right	Left	Right
Mean±SD	7.60±1.25	7.74±1.94	5.4±0.85	5.18±0.98	32.54±7.54	31.07±9.54
Minimum	4.3	4.95	3.8	3.5	15.1	14.5
Maximum	12.1	12.5	8.8	8.0	58.3	55.73

SD – Standard deviation

Table 3: Side comparative results of foramen ovale

Parameters	Mean±SD		*P*
	Left side	Right side	
Length (mm)	7.60±1.25	7.74±1.94	0.428
Breadth (mm)	5.4±0.85	5.18±0.98	0.455
Area (mm²)	32.54±7.54	31.07±9.54	0.234

Student's *t*-test; *P*<0.05 considers significant. SD – Standard deviation

Table 4: Comparison between length, breadth, and area on the right and left sides of the foramen ovale

Right and left asymmetry	*n*	Correlation coefficient (*r*)	*P*
FO breadth	62	0.803	0.035*
FO length	62	0.758	0.026*
FO area	62	0.643	0.013*

*Significance at level of *P*<0.05. *r* – Pearson's correlation coefficient; FO – Foramen ovale

the 8th week of gestation, the cartilage development begins around the already apparent vessels and nerves.[7] The cartilaginous ossification of the greater sphenoidal wing begins at the 15th gestational week and until the 22nd week; the FO appears in the greater wing of the sphenoid.[8,9]

The FO is an important landmark for middle cranial fossa surgery as well as diagnostic procedures, such as electroencephalographic analysis of the seizure for patients undergoing selective amygdalohippocampectomy,[10] microvascular decompression by percutaneous trigeminal rhizotomy for trigeminal neuralgia,[11] and percutaneous biopsy of cavernous sinus tumors.[12] The technique of computed tomography-guided transfacial fine-needle aspiration technique through the FO is used to diagnose squamous cell carcinoma, meningioma, Meckel, etc.;[13] Other than CT- guided transfacial fine-needle aspiration technique, several key landmarks that could be used radiologically and surgically to guide an endoscopic, endonasal, transzygomatic, transmaxillary, transpterygoid approach to the infratemporal fossa, to access pathologies arising in and around the FO of middle cranial fossa and thus helping to decrease patient morbidity and significantly decrease the cost involved.[14]

In the present study, the most common variations in the shape of FO were oval shape (60.4%), followed by almond shape (28.22%), round shape (6.4%), and irregular shape (3.2%), similar to the studies conducted in the past.[15,16] Further, various bony outgrowths of the FO such as spine on the margin of FO, tubercle protruding from its

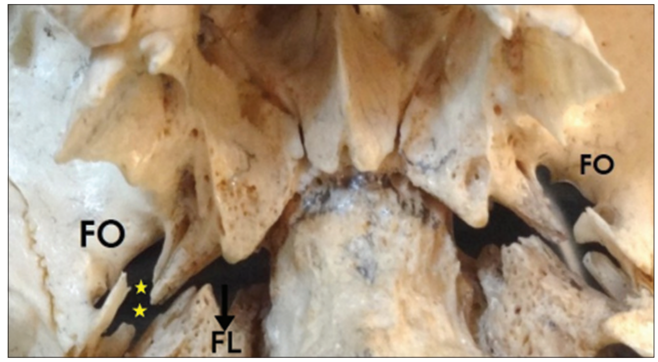

Figure 4: Confluence (yellow star) between FO and FL. FO – Foramen ovale, FL – Foramen lacerum

margin, and bony bar extending to divide the foramen into two complete compartments were noticed in the present study [Figure 2].

Mean length of FO in our study was 7.74 ± 1.94 mm on the right and 7.60 ± 1.25 mm on the left side, and however, the difference was not significant similar to various other studies, i.e., the mean length of FO was 7.46 ± 1.41 mm on the right and 7.01 ± 1.41 mm on the left side.[3] In addition, according to Lang *et al*.,[17] the mean length of FO is 7.2 mm, whereas in a fluoroscopically-assisted laser-targeting of the FO, it was 6.9 mm on the right side and 6.8 mm on the left, less than the present values. In our study, the maximal length of FO was 12.1 mm and its minimal length was 4.3 mm, whereas these values in previous studies such as Arun[18] and Osunwoke *et al*.[6] were 9.8 and 2.9 mm and 9.5 and 5.0 mm, respectively.

According to a study conducted by fluoroscopically-assisted laser-targeting of FO, the mean width was 3.4 mm on the right side and 3.8 mm on the left side.[13] In this study, the maximum and minimum width of FO on the right side was 8.0 and 3.5 mm whereas on the left side was 8.5 mm and 3.8 mm. Further, the mean width on the right side was 5.18 ± 0.98 mm and on the left side was 5.44 ± 0.85 mm, and this difference was not statistically significant. The mean area of FO calculated in the present work was 31.07 ± 9.54 mm² (55.3–14.5 mm²) and 32.54 ± 7.54 mm² (55.73–14.5 mm²) on the right and left sides, and in a previous study, the combined area of FO ranged from 25.99–67.40 mm² in adult male skulls to 19.58–67.40 mm² in case of female skulls.[5]

Conclusion

Variations in the shapes of the FO are found due to developmental reasons, which may seriously hamper clinical and diagnostic procedures. The detailed knowledge of anatomy and morphology including variations of FO, as observed in the current study, is of great importance to the clinicians in diagnosis and management of various conditions where microneurosurgical and microvascular approach is a requisite.

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Conflicts of interest

There are no conflicts of interest.

References

1. Reymond J, Charuta A, Wysocki J. The morphology and morphometry of the foramina of the greater wing of the human sphenoid bone. Folia Morphol (Warsz) 2005;64:188-93.
2. Emril DR, Ho KY. Treatment of trigeminal neuralgia: Role of radiofrequency ablation. J Pain Res 2010;3:249-54.
3. Tubbs RS, May WR Jr., Apaydin N, Shoja MM, Shokouhi G, Loukas M, *et al*. Ossification of ligaments near the foramen ovale: An anatomic study with potential clinical significance regarding transcutaneous approaches to the skull base. Neurosurgery 2009;65:60-4.
4. Freire AR, Rossi AC, Souza de Oliveria VC, Prado FB, Ferreira Caria PH, Botacin PR. Emissary foramens of the human skull: Anatomical characteristics and its relations with clinical neurosurgery. Int J Morphol 2013;31:287-92.
5. Gerber AM. Improved visualization of the foramen ovale for percutaneous approaches to the gasserian ganglion: Technical note. J Neurosurg 1994;80:156-9.
6. Osunwoke EA, Mbadugha CC, Orish CN, Oghenemavwe EL, Ukah CJ. A morphometric study of foramen ovale and foramen spinosum of the human sphenoid bone in the Southern Nigerian population. J Appl Biosci 2010;26:1631-5.
7. Di Ieva A, Bruner E, Haider T, Rodella LF, Lee JM, Cusimano MD, *et al*. Skull base embryology: A multidisciplinary review. Childs Nerv Syst 2014;30:991-1000.
8. Nemzek WR, Brodie HA, Hecht ST, Chong BW, Babcook CJ, Seibert JA. MR, CT, and plain film imaging of the developing skull base in fetal specimens. AJNR Am J Neuroradiol 2000;21:1699-706.
9. Padget DH. The development of the cranial venous system in man, from the viewpoint of comparative anatomy. Contrib Embryol 1957;36:79-140.
10. Wieser HG, Siegel AM. Analysis of foramen ovale electrode-recorded seizures and correlation with outcome following amygdalohippocampectomy. Epilepsia 1991;32:838-50.
11. Gözil R, Keskil S, Calgüner E, Tunç E, Kadioğlu D, Sevim A, *et al.* Neurocranial morphology as determined by asymmetries of the skull base. J Anat 1996;189:673-5.
12. Sindou M, Chavez JM, Saint Pierre G, Jouvet A. Percutaneous biopsy of cavernous sinus tumors through the foramen ovale. Neurosurgery 1997;40:106-10.
13. Barakos JA, Dillon WP. Lesions of the foramen ovale: CT-guided fine-needle aspiration. Radiology 1992;182:573-5.
14. Kantola VE, McGarry GW, Rea PM. Endonasal, transmaxillary, transpterygoid approach to the foramen ovale: Radio-anatomical study of surgical feasibility. J Laryngol Otol 2013;127:1093-102.
15. Chimmalgi M, Kulkarni Y, Sant SM. Sexing of skull by new metrical parameters in west India. J Anat Soc India 2007;56:28-32.
16. Wadhwa A, Sharma M, Kaur P. Anatomic variations of foramen ovale – Clinical implications. Int J Basic Appl Med Sci 2012;2:21-4.
17. Lang J, Maier R, Schafhauser O. Postnatal enlargement of the foramina rotundum, ovale et spinosum and their topographical changes. Anat Anz 1984;156:351-87.
18. Arun SK. Some observations of the foramina ovale and spinosum of human sphenoid bone. J Anat Soc India 2006;55:100-1.