Original Research Paper

Volume - 15 | Issue - 06 | June - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Anatomy

MORPHOLOGICAL STUDY OF FORAMINA IN THE MIDDLE CRANIAL FOSSA OF THE HUMAN SKULL

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ABSTRACT **Background:** The foramen rotundum, foramen ovale, and foramen spinosum are important openings at the base of the skull that allow nerves and blood vessels to pass. Their shape and size can vary, which is important to know for surgeries and diagnostic imaging. **Objective:** To study and describe the shapes, sizes, and variations of these three foramina in adult human skulls and understand their clinical significance. **Methods:** 50 dry adult human skulls were examined. The foramina on both sides were observed for shape, size, presence of spines or spurs, duplication, or absence using the naked eye and a magnifying lens. Measurements and photos were taken using wire and a mobile camera. Descriptive statistics was used to describe the parameter using Microsoft excel 2019. **Results:** The foramen rotundum was mostly round (around 70% on both sides), followed by oval and pinhead shapes. The foramen ovale had nearly equal numbers of oval and D-shaped forms, with some showing spines or duplication. The foramen spinosum was mainly round and oval, with rare cases of absence or irregular shapes. Some differences were noted between the left and right sides. **Conclusion:** There are significant variations in the morphology of these foramina. Recognizing these differences is important for surgeons and radiologists to avoid complications during skull base procedures. Preoperative imaging should carefully assess these anatomical variations to improve clinical outcomes.

KEYWORDS : Foramen ovale, Foramen rotundum, Foramen spinosum, Skull base anatomy, Anatomical variations

INTRODUCTION

The foramen ovale (FO), foramen rotundum (FR), and foramen spinosum (FS) are important anatomical structures located in the floor of the middle cranial fossa. These foramina serve as key passageways for neurovascular structures and are of significant clinical and surgical relevance, particularly in neurosurgical and radiological procedures. [1] Understanding the anatomical variations in the shape, size, and incidence of these foramina is essential for clinical practice to avoid complications during surgical interventions and diagnostic interpretations. A literature highlights considerable variability in the morphology of these foramina. Aggrawal et al. observed that the foramen rotundum (FR) was bilaterally present in all skulls and round in shape, separated from the superior orbital fissure by a bony bar [2]. Khan et al. described large irregular foramen ovale (FO) with bony spicules dividing it into compartments [3]. Khairnar et al. found duplication and confluence of FO and foramen spinosum (FS) in several cases [4]. Mishra et al. identified diverse shapes, with 66% oval and 22% almond-shaped, and reported asymmetry in FO dimensions in all skulls [5]. Roy et al. found oval FO in 46 skulls and various other shapes, including intercommunicating FO and FS in 40 cases [6]. Zadilla et al. reported significant bilateral differences in FO shape and dimensions [7]. Kumar A. et al. described FO variations ranging from oval to triangular, with bipartite FR in one skull [8]. Tewari et al. found FO shapes ranging from round to pinhole and irregular [9]. Kumar B. et al. observed that oval FO was the most common, while D-shaped foramina were rare [10]. Sophia et al. classified FO shapes based on established criteria, noting accessory foramina and bony growths [11]. Prakash et al. found oval FO in 56.7% of cases, with notable accessory bony features [12]. Finally, Worku et al. emphasized variations in FS morphology and its relation to the spine of the sphenoid [13]. These studies collectively demonstrate that while the foramina of the middle cranial fossa are consistently present, their morphological variations particularly in shape, size, and the presence of accessory bony features are frequent and must be considered during anatomical, surgical, and radiological assessments. Understanding these anatomical variations is crucial for accurate interpretation of radiographs and successful surgical navigation. Therefore, This study aim of the study is to observe and document the morphology and variations of the foramen rotundum, foramen ovale, and foramen spinosum in the middle cranial fossa of the human skull.

Objectives

To analyze the variation in shape, size, and symmetry of the mentioned foramina.

MATERIAL AND METHOD

Study Design: Cross sectional observational study

Study Area: The study was conducted in the Department of Anatomy, Era's Medical College & Hospital, Lucknow in the collaboration with King George Medical University, Lucknow. All skulls were studied from the floor and base of the skulls. Each skull has foramen rotundum, foramen ovale and foramen spinosum two in number except one skull. In which one Foramen rotundum found absent on right side.

Study Duration: 6 months.

Materials: 50 well preserved dry adult human skulls.
12mp. Mobile Camera
Wire/Thread
Lens

Method: Fifty dry adult human skulls of unknown sex were collected. All the skulls were examined by necked eyes. Shape of the foramen, Presence of spine, spur and plate, Duplication of Foramina, Absent foramina and margins of foramen were also inspected by the help of lens. Wire and thread were inserted in foramen, to take photos.

Sample Size: Sample size is calculated by using the formula:

$$n=\frac{(Z\alpha+Z\beta)^2}{\{ln(1-e)\}^2}\left[\frac{1-p_1}{p_1}+\frac{1-p_2}{p_2}\right]$$

Where, p1 =0.17% (foramen of Vesalius unilateral)
p2 =0.12 (12% foramen of Vesalius bilateral) [14]
type I error α=5%
Type II error β=20%
Point 1 study =80%
The samples are n=50

Inclusion Criteria: Dry adult skull, well defined foramen ovale, foramen rotundum, foramen spinosum.

Exclusion Criteria: Damage skulls with non-identifying features of foramen rotundum, foramen ovale and foramen spinosum were excluded.

RESULT

A total of 50 adult human skulls of unknown sex were examined, the study focused on the morphology and variations of the foramen rotundum, foramen ovale, and foramen spinosum observed on the floor and base of the skulls as showed in figure 1.

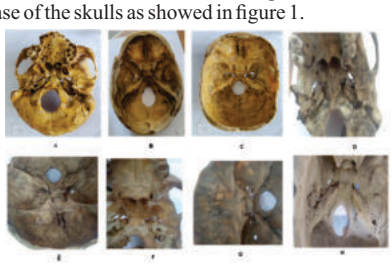

Figure 1: A) Right-foramina seen from the base of skull left foramen seen in floor of skull, B) Right skull – D shape foramen Ovale , C) Left

skull - Bilateral oval shape foramen Oval D) Bilateral D-shape Foramen, E) Left D-shape with spine, F) Left Duplicated Foramen Rotundum G) By lateral Ovale Foramen Ovale, H) Foramen Ovale Irregular.

Table 1 predominantly exhibited a round shape on both sides, with 72.0% (36/50) on the left and 70.0% (35/50) on the right. Oval-shaped foramina were the second most common, accounting for 18.0% on the left and 22.0% on the right side. Pinhead-shaped foramina were less frequent, observed in 10.0% (left) and 8.0% (right), while duplicated (multiple) foramina were rare, found equally (2.0%) on both sides.

Table 1: Morphological Variations in Foramen Rotundum (n=92)

Shape	Left (n, %)	Right (n, %)	Total (n)
Round	36 (72.0%)	35 (70.0%)	61
Oval	9 (18.0%)	11 (22.0%)	20
Pinhead	5 (10.0%)	4 (8.0%)	9
Multiple	1 (2.0%)	1 (2.0%)	2
Total	50 (100%)	50 (100%)	92

Table 2 showed a roughly equal distribution between oval and D-shaped forms. On the left side, oval-shaped foramina accounted for 52.0%, and D-shaped for 46.0%, whereas on the right side, D-shaped foramina were slightly more frequent at 52.0% compared to 44.0% oval. Variations including the presence of a spine, irregular, round, and duplicated foramina were noted but were less common overall.

Table 2: Morphological Variations in Foramen Ovale (n=106)

Shape/Type	Left (n, %)	Right (n, %)	Total (n)
Oval	26 (52.0%)	22 (44.0%)	48
Oval + Spine	1 (2.0%)	1 (2.0%)	2
D-Shape	23 (46.0%)	26 (52.0%)	49
D-Shape + Spine	1 (2.0%)	1 (2.0%)	2
Irregular	0 (0.0%)	1 (2.0%)	1
Round	1 (2.0%)	1 (2.0%)	2
Multiple D-Shape	1 (2.0%)	1 (2.0%)	2
Total	53 (100%)	53 (100%)	106

Table 3 was mainly round-shaped on sides, comprising 58.0% on the left and 60.0% on the right. Oval shapes constituted 40.0% (left) and 36.0% (right). Occasional variants such as absent, irregular, and triangular shapes were identified but were rare.

Table 3: Morphological Variations in Foramen Spinosum (n=100)

Shape	Left (n, %)	Right (n, %)	Total (n)
Oval	20 (40.0%)	18 (36.0%)	38
Round	29 (58.0%)	30 (60.0%)	59
Absent	0 (0.0%)	1 (2.0%)	1
Irregular	1 (2.0%)	0 (0.0%)	1
Triangular	0 (0.0%)	1 (2.0%)	1
Total	50 (100%)	50 (100%)	100

DISCUSSION

This study investigated the morphological variations of the foramen rotundum, foramen ovale and foramen spinosum in 50 adult human skulls. A range of shapes and anomalies were observed across all three foramina, with some similarities and differences compared to previously reported findings. The majority of the foramen rotundum were round in shape (72% left, 70% right), followed by oval (18% left, 22% right), and a few cases of pinhead-shaped (10% left, 8% right). Duplicated foramina were rare (2% on both sides). These findings are consistent with Aggrawal et al. [2], who reported bilateral presence and predominantly round-shaped FR in all skulls. Our observation of a small proportion of oval and pinhead-shaped foramina is also supported by previous studies noting minor morphological variations [8]. The presence of rare duplicated foramina, while uncommon, is in line with Kumar A. et al. [8], who documented bipartite FR in one skull, indicating developmental anomalies or ossification irregularities.

In our study, FO showed nearly equal distribution between oval (52% left, 44% right) and D-shaped (46% left, 52% right) foramina. Less common shapes included oval or D-shaped foramina with spines (2% each side), irregular (2% right), round (2% both sides), and duplicated D-shaped foramina (2% both sides). The high occurrence of both oval and D-shaped FO in our study is partially consistent with Mishra et al. [5], who reported 66% oval and 22% almond-shaped FO. However, we observed a higher proportion of D-shaped and other irregular forms. The presence of spines and duplication aligns with the findings of Khan et al. [3], who described FO with bony spicules, and Khairnar et al. [4], who noted duplication and confluence with adjacent foramina. Sophia et al. [11] also reported the presence of bony growths and accessory foramina, which supports our observation of variant FO forms. The asymmetry observed between sides is consistent with previous literature [5,7]. These variations may result from differences in ossification patterns during skull development and are significant in neurosurgical planning and interpreting imaging studies [6, 12].

Most FS were round (58% left, 60% right) or oval (40% left, 36% right). Rare variants included absent FS (2% right side), irregular (2% left), and triangular shapes (2% right). Our results are largely consistent with Worku et al. [13], who emphasized variability in FS morphology, including its shape and relation to the sphenoid spine. Roy et al. [6] and Kumar B. et al. [10] also found oval to round FS shapes as common, with D-shaped or irregular ones being rare, supporting our findings. The unilateral absence of FS in one case corresponds to earlier observations where FS was occasionally missing, especially when the middle meningeal artery entered through the FO [4,13].

CONCLUSION

This study of foramen rotundum, foramen ovale, and foramen spinosum showed that foramen rotundum was mostly round on both sides. The foramen ovale showed both oval and D-shapes almost equally. The foramen spinosum was mostly round, with a few unusual shapes. Some small differences were found between the left and right sides. This notable anatomical variation is crucial for avoiding complications during procedures involving the skull base. It is recommended that Preoperative imaging should be carefully reviewed to identify any anatomical anomalies that may impact clinical outcomes.

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