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Morphometrric Study of Foramen Ovale in the Human Skulls

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ABSTRACT
The middle cranial fossa is a critical anatomical region housing the foramen ovale, which serves as a conduit for important neurovascular structures. Understanding the morphometric measurements and spatial relationships of the foramen ovale is essential for clinical practice and surgical procedures in this complex area. Sixty dry skulls were meticulously examined for morphometric measurements of the foramen ovale, including anteroposterior diameter and transverse diameter. Bilateral differences and morphological variations were recorded. Statistical analysis was performed using MS Office software, calculating the mean, standard deviation and comparative assessments between right and left sides. The study revealed variations in the average diameter and breadth of the foramen ovale between the left and right sides. The standard deviation values highlighted the degree of variability, emphasizing the importance of individualized anatomical considerations in clinical practice. Additionally, the spatial relationship between the foramen ovale and the mid-sagittal line was examined, providing insights into precise navigational requirements for surgical and interventional procedures. The study's findings offer crucial insights into the complex anatomical characteristics of the middle cranial fossa and the foramen ovale. These insights are invaluable for optimizing outcomes and minimizing risks in neurosurgical and interventional procedures within this region, especially in cases involving the foramen ovale.

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Key Words
Middle cranial fossa, foramen ovale, morphometric measurements, spatial relationship, surgical navigation, anatomical variations

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INTRODUCTION

The human skull contains several cranial fossae, including the anterior, middle and posterior cranial fossae. The middle cranial fossa is situated between the lesser wing of the sphenoid bone in the anterior and the petrous part of the temporal bone in the posterior. It is formed by the combination of three bones, the body and greater wing of the sphenoid, the squamous part of the temporal bone and a portion of the parietal bone. This fossa houses various important structures, including the temporal lobes of the cerebrum, the hypophysis cerebri (pituitary gland), cavernous sinuses, the middle meningeal artery and the trigeminal ganglion[1].

The greater wing of the sphenoid bone, specifically its cerebral or intra-cranial surface, features numerous fissures and foramina, which serve as passage ways for various vessels and nerves. One of these critical foramina is the foramen ovale, which connects the intra-cranial fossa with the infra-temporal fossa located outside and underneath the skull. The foramen ovale is situated in the posterior part of the greater wing of the sphenoid bone and serves as a conduit for four vital structures, the mandibular division of the trigeminal nerve, the accessory meningeal artery, the lesser petrosal nerve and an emissary vein[2]. The foramen ovale is irregularly oval in shape and its proximity to the otic ganglion, an essential peripheral parasympathetic ganglion associated with the parotid salivary gland's secretory function, is notable. Additionally, the emissary and middle meningeal veins connect the cavernous sinus with the pterygoid venous plexus, playing crucial roles in transmitting intra-cranial pressures and infections in various conditions, such as birth injuries, cranial trauma, accidents and cranial infections[3].

The lesser petrosal nerve, which traverses through the foramen ovale, is the general visceral efferent (GVE) component of the glossopharyngeal nerve. It carries parasympathetic preganglionic fibers from the tympanic plexus of the middle ear to the parotid salivary gland, where it synapses in the otic ganglion, from where its postganglionic fibers emerge[4]. Previous studies have suggested the existence of abnormal morphological features of the foramen ovale, such as bony spurs and ossified ligaments, which may divide the foramen ovale into multiple compartments. This compartmentalization of the venous part of the foramen ovale could have clinical implications and requires careful consideration in surgical and diagnostic procedures involving this region[5]. The sphenoid bone is unique in its development, as it undergoes both endochondral and membranous ossification processes. It originates from different primordia, including the orbitosphenoid and basi-posts-phenoid derived from cephalic mesoderm, as well as the alisphenoid and basipresphenoid, which are derived from neural crest cells[6]. This complex developmental origin makes the sphenoid bone susceptible to various anomalies, including chordomas, notochordal tumors and the persistence of the craniopharyngeal canal, resulting in transsphenoidal encephaloceles.

The openings and foramina in the sphenoid bone begin to appear after the 8th gestational week as part of the skull base ossification process, which occurs near preexisting neurovascular bundles. Variations in the size and shape of the foramen ovale can be attributed to the dual ossification types (intra membranous and endochondral) involved in sphenoid bone development[7]. Observing foramen ovale formation, it can either manifest as a single main foramen ovale or as a foramen ovale divided by thin osseous trabeculae. This study aims to explore the diverse morphological and morphometric features of the foramen ovale, shedding light on its anatomical variations and clinical significance. The intricate development of the sphenoid bone, which houses the foramen ovale, plays a crucial role in shaping its structure and function. By examining the formation and characteristics of the foramen ovale, we can gain a deeper understanding of the complex anatomy of the middle cranial fossa and its implications for surgical and diagnostic procedures.

MATERIALS AND METHODS

Sample collection: A total of 60 dry skulls were procured for this study. These specimens were sourced from two medical institutions in Srikakulam town, specifically, the Government Medical College, Srikakulam and the Great Eastern Medical School and Hospital, Srikakulam. Careful selection was employed and only intact skulls devoid of damage to or around the foramen ovale were included in the study.

Morphometric measurements: The study involved the measurement of two key parameters of the foramen ovale in each skull specimen:

- **Anteroposterior diameter (maximum length):** The maximum length of the foramen ovale was measured using vernier calipers. This measurement was taken once for each skull specimen
- **Transverse diameter (maximum width):** The maximum width of the foramen ovale was also measured using vernier calipers. Similar to the antero-posterior diameter, this measurement was recorded once for each skull specimen

December 20, 2023Bilateral comparison: To evaluate potential bilateral differences, measurements of the foramen ovale were performed separately for the right and left sides of each skull specimen. These bilateral differences, if present, were documented.

Assessment of morphological variations: The study also included an examination for any morphological variations in the foramen ovale, such as septation or partitions. These variations, when observed, were carefully noted.

Data validation: All measurements and observations were conducted meticulously and to ensure accuracy, each reading was recorded twice. The final figures for analysis were determined by calculating the mean of the duplicate measurements. This approach aimed to minimize errors and enhance the reliability of the data collected.

Statistical analysis: The collected data, including measurements of the foramen ovale, were subjected to thorough analysis to derive meaningful insights. This analysis was carried out utilizing MS Office software (version 2017). Key statistical parameters, namely the mean and standard deviation, were calculated to summarize and describe the data-set effectively. Moreover, a comparative assessment between the right and left sides was conducted to discern any potential differences or variations in the measurements. This comparison aimed to provide a comprehensive understanding of the bilateral characteristics of the foramen ovale.

RESULTS

Table 1: data on foramen ovale: This table 1 presents detailed measurements and comparative analysis of the foramen ovale, focusing on length and breadth, for both the left and right sides. Additionally, the table provides information on the range of differences between the measurements for the two sides.

Averaged diameter: The average diameter of the foramen ovale was found to be 8.61 mm on the left side and 8.15 mm on the right side. This measurement reflects the mean size of the foramen ovale for the respective sides.

Breadth: The breadth, or width, of the foramen ovale was measured at 4.6 mm on the left side and 3.99 mm on the right side. These values represent the maximum width of the foramen ovale.

Difference range: The difference range indicates the variability between the right and left sides in terms of length and breadth. The maximum difference in length observed was 9.21 mm, while the minimum difference was 3.54 mm. For breadth, the maximum difference was 10.12 mm and the minimum difference was 3.33 mm.

Standard deviation: The standard deviation provides a measure of the spread or dispersion of the data. In this case, the standard deviation for length was 1.15 on the left side and 1.10 on the right side. For breadth, the standard deviation was 1.4 on the left side and 1.8 on the right side. These values indicate the degree of variability in measurements for each parameter. The data in Table 1 offers valuable insights into the dimensions and bilateral differences of the foramen ovale. It allows for a comprehensive understanding of the variability in size and shape, which can have clinical implications in various medical and surgical contexts. Additionally, the standard deviation values provide information about the degree of consistency or heterogeneity in the measurements, aiding in the interpretation of the data-set. This table 2 provides crucial data on the average length between the foramen ovale and the midsagittal line for both the right and left sides.

- **Right side:** The average length between the foramen ovale and the midsagittal line on the right side was measured to be 22 mm
- **Left side:** On the left side, the average length between the foramen ovale and the midsagittal line was found to be 21.95 mm

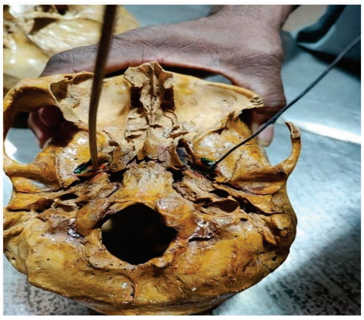

Fig. 1: Foramen ovale in a skull specimen

Fig. 2: Measuring the foramen ovale with digital calipers

Table 1: Morphometric Measurements and Bilateral Differences of the Foramen Ovale

Foramen Ovale	Length(mm)		Breadth(mm)		Difference range (mm)	
	Left	Right	Left	Right	Right side	Left side
Average diameter	8.61	8.15	4.6	3.99	Max- 9.21 Min-3.54	Max-10.12 Min-3.33
Standard deviation	1.15	1.1	1.4	1.8		

Table 2: Length between Foramen Ovale and Midsagittal Line

	Average length
Right side	22 mm
Left side	21.95 mm

This table's data is significant for understanding the spatial relationship between the foramen ovale and the midsagittal line. These measurements can have clinical relevance in various medical and surgical contexts, providing insights into the positioning of the foramen ovale within the cranial anatomy. The image displays a close-up view of a skull specimen being examined with probes pointing to the foramen ovale. The image presents a skull specimen with digital calipers being used to measure the foramen ovale.

DISCUSSION

The present study shows the morphometric measurements and spatial relationship of the foramen ovale provides valuable insights into the anatomical characteristics of this critical structure within the human skull. The middle cranial fossa, housing the foramen ovale, is a region of great neuroanatomical importance and understanding its dimensions and variations is essential for clinical practice and surgical procedures. Results of the present study shows the measurements of the foramen ovale's average diameter, breadth and the range of differences between the left and right sides. These findings are consistent with the complexity of cranial anatomy, where bilateral differences are not uncommon. Such variations can have clinical implications, especially in procedures involving the foramen ovale, such as percutaneous interventions, where knowledge of the foramen's dimensions aids in minimizing risks and ensuring successful outcomes.

The observed differences in the average diameter and breadth between the left and right sides highlight the importance of careful preoperative assessment and patient-specific planning. Surgical and interventional procedures in the middle cranial fossa require a precise understanding of these variations to avoid complications and optimize outcomes[8]. CCResults of our study focus on the length between the foramen ovale and the midsagittal line. While the difference in average length between the right and left sides is minimal, it provides valuable information about the spatial relationship of the foramen ovale within the cranial anatomy. This knowledge is crucial for ensuring the accuracy of procedures that involve navigating through this region, such as percutaneous rhizotomy for trigeminal neuralgia. The clinical relevance of these findings is further highlighted by previous studies that have explored the variations and anatomical intricacies of the middle cranial fossa. Laleva *et al.* emphasized the importance of understanding the middle cranial fossa's neurovascular relationships for safe surgical approaches. Additionally, Rhoton extensively described the microsurgical anatomy of the middle cranial fossa, providing critical insights for neurosurgeons[9]. Comparing these findings with data from previous studies[10], it becomes evident that there is variability in the morphometric measurements of the foramen ovale across different populations and studies. For instance, Somesh *et al*. reported an average length of 7.6 mm and a width of 5.12 mm[11], while A. Mishra *et al*. found an average length of 7.05 mm and a width of 3.99 mm[12]. Punitha Rani and Nsa *et al*. also reported different measurements for the foramen ovale. These variations could be attributed to factors such as population differences, measurement techniques and sample sizes.

Furthermore, these measurements and spatial relationships can be of particular importance in the context of minimally invasive procedures. For instance, percutaneous rhizotomy for trigeminal neuralgia requires precise navigation through the foramen ovale [15]. Knowledge of the foramen's dimensions and its proximity to the midsagittal line can significantly impact the success and safety of such procedures.

CONCLUSION

In conclusion, the study's findings regarding the morphometric measurements and spatial relationship of the foramen ovale offer valuable insights into the complex anatomical characteristics of the middle cranial fossa. These insights are critical for clinical practice and surgical procedures, particularly those involving the foramen ovale. The study underscores the importance of considering anatomical variations and individual patient anatomy to optimize outcomes and minimize risks in neurosurgical and interventional procedures within the middle cranial fossa.

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