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Morphometric analysis of mastoid foramen and possible clinical and surgical implications

Análise morfométrica do forame mastóideo e suas possíveis implicações clínicas e cirúrgicas

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Abstract

Introduction: The mastoid foramen (MF) is a narrow fissure in the mastoid process and exhibits considerable anatomical variability. The mastoid emissary vein and the meningeal branch of the occipital artery are important structures that pass through the MF. Despite its anatomical importance, morphological and morphometric analyses of the MF remain scarce. **Objectives:** To investigate the morphological and morphometric aspects of the MF. **Method:** This observational cross-sectional study analyzed 78 human skulls. Measured variables included the diameter of the MF, the presence, number, and the location of MF in relation to the occipitomastoid suture, the position of MF in relation to the Frankfurt plane, and the distances between MF and specific anatomical points. **Results:** All skulls presented at least one MF. However, in 7.69% of the specimens, the MF was absent on one side. MF was present on the right side in 98.72% of specimens and on the left side in 93.59%. The MF pattern most frequently observed was four foramina, independent of laterality, in 23.08% of the skulls. No statistically significant differences were identified across the variables studied. **Conclusion**: This study described relevant morphometric and morphological parameters of the MF.

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Given the importance of the structures passing through this foramen, understanding its anatomic variations and measurements is essential.

Keywords: Anatomy; Mastoid foramen; Clinical relevance; Neurosurgery.

Resumo

Introdução: O forame mastóideo (FM), uma pequena abertura localizada no processo mastoide, pode apresentar diversas variações. Por ali passam estruturas relevantes, como a veia emissária mastoidea e o ramo meníngeo da artéria occipital. Apesar da importância do FM, há na literatura uma relativa escassez de dados morfológicos e morfométricos sobre essa estrutura. **Objetivos:** investigar os aspectos morfométricos e morfológicos do FM, bem como suas repercussões clínico-cirúrgicas. Método: Trata-se de um estudo observacional e transversal. Foram incluídos 78 crânios humanos no estudo, que analisou, em relação ao FM, a presença, a quantidade, a localização em relação à sutura occipitomastoidea, os diâmetros, a posição em relação ao plano de Frankfurt e as distâncias até pontos anatômicos específicos. **Resultados:** Dentre os achados do estudo, destaca-se a prevalência do forame, observado em pelo menos um dos lados de todos os crânios analisados. Em 7,69% observou-se a ausência da estrutura em um dos lados. O forame estava presente no lado direito em 98,72%. No lado esquerdo, estava presente em 93,59%. O padrão encontrado com mais frequência foi de quatro forames, independentemente do lado, em 23,08% dos crânios. Não foram identificadas diferenças estatisticamente significativas em todas as variáveis estudadas. **Conclusão:** O estudo descreve importantes parâmetros morfométricos e morfológicos do FM. Devido à relevância das estruturas que o percorrem, é essencial ter um conhecimento adequado da morfometria e da morfologia do FM.

Palavras-chaves: Anatomia; Forame mastóideo; Neurocirurgia; Relevância clínica.

INTRODUCTION

The temporal bone (TB) exhibits significant morphological complexity due to its various bone accidents, and anomalies and developmental variations are described in the literature[1]. Among these variations, the mastoid foramen (MF) is a small aperture located in the mastoid process (MP) of the TB or along the occipitomastoid suture. However, the MF may be absent or present in a singular or multiple occurrence[1].

The MF variability can also encompass laterality, sex, age, quantity, location, and diameter[2]. These variations are attributed to the structures that pass through the MF, including the mastoid emissary vein (MEV) and the meningeal branch of the occipital artery. From a neurosurgical perspective, understanding the location of these structures is essential as the MF can be a potential source of bleeding during procedures involving the MP, as is the case of retrosigmoid craniotomy[2,3].

Detailed anatomical understanding of the MF and its associated structures remains scarce despite technological advances. Furthermore, the literature offers limited data on the potential clinical and surgical implications related to these structures[1,4,5,6]. Therefore, this study aimed to analyze the morphological and morphometric characteristics of MF using human skulls specimens and discuss potential clinical and surgical implications.

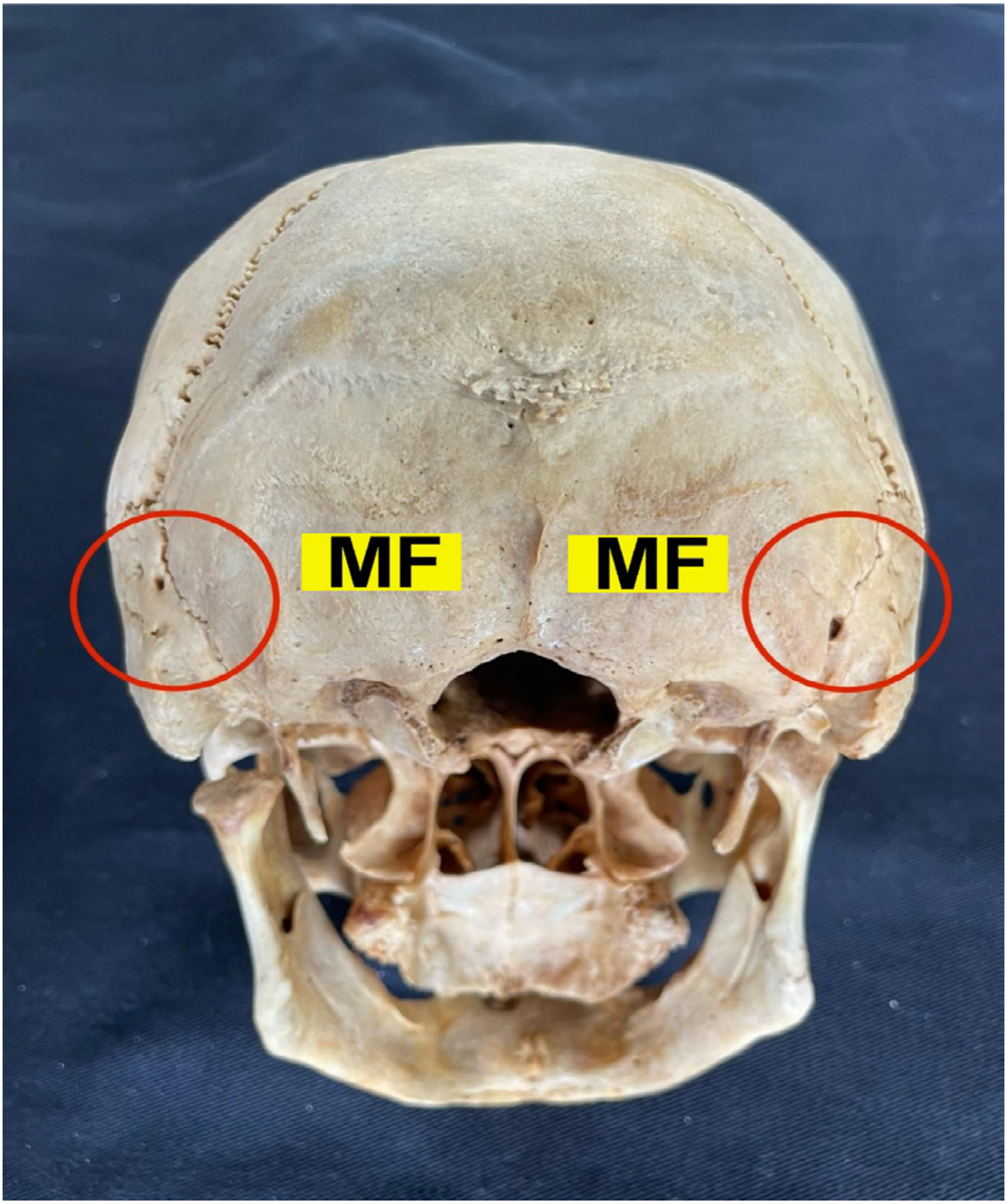
METHOD

Morphological and morphometric measurements of the MF were performed in articulated and disarticulated human skulls from the anatomy laboratory of a higher education institution. Inclusion criteria required human skulls to be cataloged with documented information regarding sex. A total of 100 human skulls were initially considered for analysis, but only 78 met the criteria. Moreover, the remaining skulls were also excluded due to inadequate bilateral visualization of the studied structures or loss of morphological integrity caused by the decomposition process.

The morphometric analysis was conducted using a thickness compass, a Castroviejo type curved dry point compass, and a digital caliper.

The analyzed variables were MF presence or absence, number, location relative to the occipitomastoid suture, diameter, position in relation to the auriculo-orbital plane (Frankfurt plane), and distance in relation to the apex of the MP, to the foramen magnum, and the asterion. All variables were analyzed bilaterally (Figures 1 and 2).

Figure 1. Posteroinferior view of the human skull showing the right and left MFs.

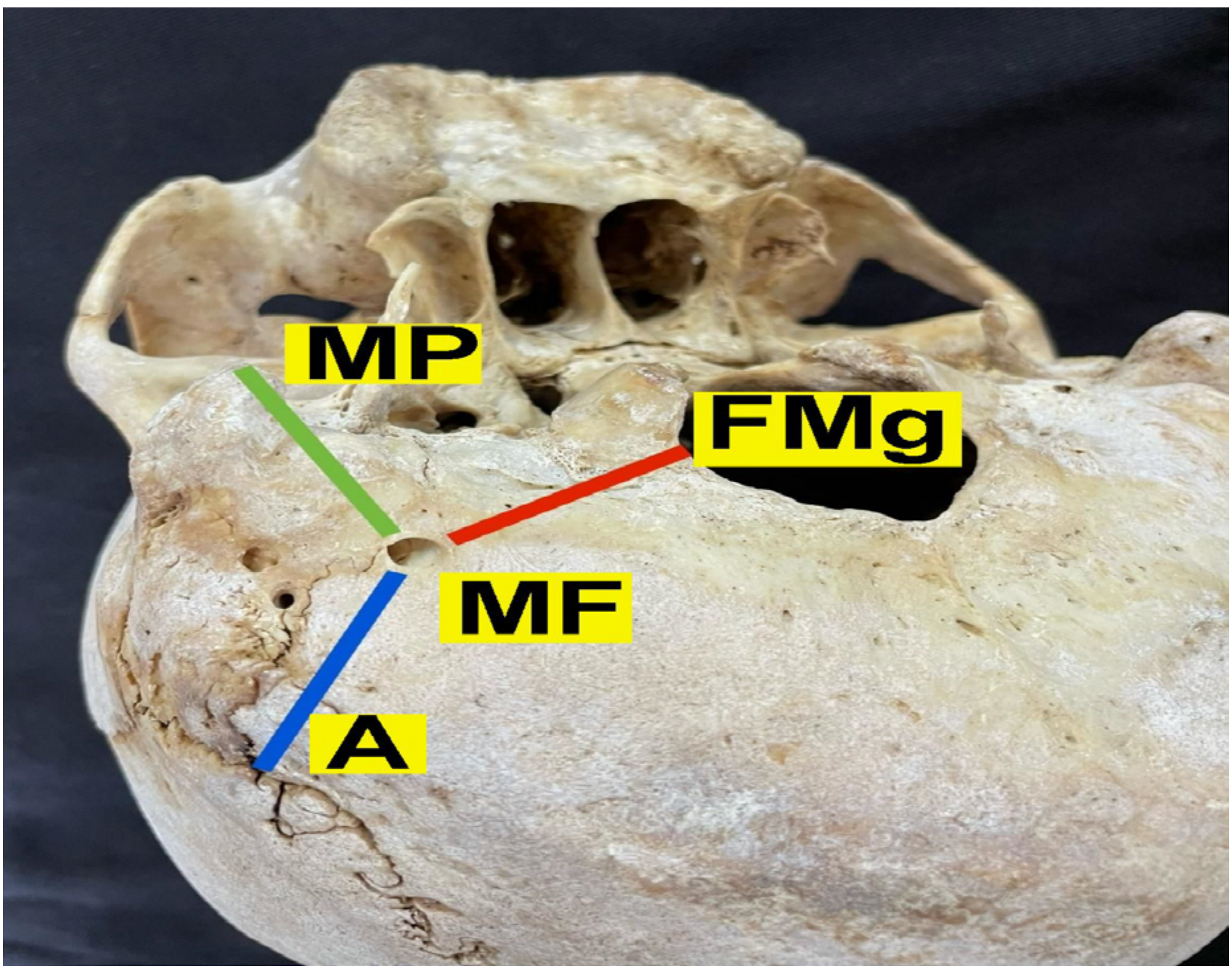


Legend: MF - mastoid foramen.

The data were tabulated, processed, and statistically analyzed using the SPSS® software (IBM, Chicago, USA). The Kolmogorov-Smirnov test evaluated the normality and homogeneity of the data. For non-normal data, descriptive statistics were expressed using measures of central tendency (mean, minimum, and maximum) and dispersion (standard deviation). The significance level was set as 5%, with a 95% confidence interval and a maximum variability of 0.5.

In this study, the chi-square test of independence evaluated potential associations between categorical variables, such as the presence of MF on the right and left sides and differences in its location in relation to the mastoid suture and the auriculo-orbital plane, which may differ by antimere. The paired Wilcoxon test investigated differences in the number of foramina on the right and left sides and in their diameters and distances.

Figure 2. Defined surface landmarks and their distances from the MF: green, apex of the MP-MF; red, foramen magnum-FMg; blue, asterion-MF.



Legend: asterium (A); foramen magnum (FMg); mastoid foramen (MF); and mastoid process (MP).

RESULTS

The MF was present in all analyzed human skulls (n = 78). However, 7.69% (n = 6) of the sample exhibited a unilateral MF. Of the total sample, the MF was present on the right side in 98.72% (n = 77) of specimens, whereas in only 1.28% (n = 1) of absence was observed. The MF was present on the left side in 93.59% (n = 73) specimens, whereas 6.41% (n = 5) of absence was observed. No statistically significant difference was found in the presence of MF between the right and left sides (p = 0.105).

The most frequent MF pattern across the skull sample was four foramina, irrespective of side, observed in 23.08% (n = 18) of the specimens. Both right and left sides presented two foramina in 38.46% (n = 30) and 34.62% (n = 27) of specimens, respectively. The findings enhance the understanding of the variability of this morphological feature of MF, emphasizing the most common patterns identified in the study. No statistically significant difference was observed in the number of MFs between the right and left sides (p = 0.534).

When present on the right side, the MF was located laterally to the occipitomastoid suture in 55.84% (n = 43) of the specimens, medially in 14.29% (n = 11), and at the suture in 29.87% (n = 23). When present on the left side, the MF was lateral to the suture in 57.53% (n = 42) of the specimens, medial in 8.22% (n = 6), and at the suture in 34.25% (n = 25). No statistically significant difference was observed in the location of the MF relative to the occipitomastoid suture between the right and left sides (p = 0.482).

The MF diameter was measured on both sides. For the MFs on the right side, the mean upper-bottom diameter (UBD) was 0.23 cm (SD ± 0.23), and the laterolateral diameter (LLD) was 0.18 cm (SD ± 0.12). For the MFs on the left side, the mean UBD was 0.25 cm (SD ± 0.24), and the LLD was 0.22 cm (SD ± 0.16). Although the UBD was slightly smaller on the right side and the LLD was slightly larger on the left side, no statistically significant differences were found between the right and left sides (p = 0.310 for UBD and p = 0.155 for LLD).

The MF position was classified as below, on, or above in relation to the auriculo-orbital plane (Frankfurt plane). A below MF was found in 94.8% (n = 73) of the specimens on the right side and 97.3% (n = 72) on the left side. No statistically significant differences were found in the MF position in relation to the auriculo-orbital plane between the right and left sides (p = 0.192).

In relation to other anatomical measurements, the distance between the MF and the apex of the MP (MF-MP) had mean values of 3.05 cm (SD ± 0.52 cm) on the right side and 3.03 cm (SD ± 0.59 cm) on the left side. Furthermore, the distance between the MF and the foramen magnum (MF-FMg) had a mean of 4.02 cm (SD ± 0.60 cm) on the right side and 4.00 cm (SD ± 0.52 cm) on the left side. Lastly, the distance between MF and asterion (MF-AA) had a mean of 2.01 cm (SD ± 0.53 cm) on the right side and 2.02 cm (SD ± 0.60 cm) on the left side. No statistically significant differences were found in the distances between the MF and MP (p = 0.533), foramen magnum (p = 0.584), or asterion (p = 0.781).

DISCUSSION

Our results indicate that the mastoid foramen is typically located in the mastoid process of the temporal bone. However, Patel et al. reported that the MF was in the occipitomastoid suture in 40% of the sample[7]. The authors analyzed 100 human skulls and also observed the presence of two MF of the specimens, 2% on the right side and 16% on the left side. Lastly, they observed a single MF on the left side in 26% of the specimens and in 16% on the left[8]. In another study conducted in 96 human skulls, three MFs were found in 6.2% of the cases. In one case described by Sehmi S., four MFs were observed on the right side[10].

Tsutsumi et al. analyzed magnetic resonance images of the skulls of 96 individuals, demonstrating that the MF was located at an average distance of 21.44 mm from the asterion and 33.65 mm from the tip of the MP[6]. Furthermore, another study, including a sample of 103 human skulls, measured the MF diameter and showed that the widest diameters were found in males, with an average value of 1.2 mm[11].

The MF can be classified into five types, differentiated by the number of external openings (types I to IV, with type 0 representing the absence of MF). In an analysis of 22 human skulls conducted by Chaiyamoon *et al.*[12], type I was the most prevalent (50%)[12]. In contrast, Hampl et al. found a higher frequency of type II (41.2%) in an analysis of 295 human skulls[7].

Although there is an apparent predominance of MF types I, II, III, and IV on the right side and a significantly higher absence of MF on the left side, further elucidation on the reasons behind these differences is needed[12]. For example, some authors suggest that laterality and sex may be related to MF types[12].

The MF is the means by which the meningeal branch of the occipital artery is transmitted to the dura mater and the MEV to the sigmoid sinus, connecting it to the suboccipital venous plexus, extending posteriorly to MP[13,14]. The sigmoid sinus drains the vertebral plexus in the upright position and the internal jugular vein in the supine position[14].

However, the vein extending into the sigmoid sinus has no valve structures and receives slow blood flow, which enhances its role in drainage. When this vein is dilated, as is the case in patients with intracranial hypertension and aplasia or hypoplasia of the internal jugular vein, it leads to high-flow vascular malformations in the venous connections. In certain procedures, these malformations can become an important hemorrhagic source[14].

In addition, the MEV is responsible for blood drainage from the posterior cranial fossa, particularly during otological and neurological procedures (e.g., mastoidectomy, epithympanectomy, and retrosigmoid craniotomy)[7,14,15]. Veins of this type are also a source of bleeding during ear surgeries and skull base operations, especially in the lateral and retrosigmoid approaches[16]. Surgical procedures in the mentioned areas can also lead to thrombosis and embolization due to the bidirectional blood flow near the sigmoid sinus[16].

A better understanding of the MEV can help to prevent surgical complications. For example, in craniofacial surgeries (e.g., craniosynostosis), the MEV may be the only drainage pathway for the brain[16]. In this procedure, the volume of bleeding in lesions in the MEV depends on its diameter and, consequently, on the MF diameter, i.e., smaller bleedings occur in smaller MF[14]. Small bleeding can be managed using electrocautery or bone wax. However, larger MF diameters can lead to significant bleeding, which is challenging to control and increases the risk of sigmoid sinus rupture, shock, infection, and thrombosis[5]. Of note, larger diameters of the MEV can be found in cases of otitis and labyrinthine dysplasia, primarily due to vascular malformations in the internal jugular vein and sigmoid sinus[15].

A detailed study of the morphology and morphometry of the MF during the preoperative period of specific surgical procedures may reduce the risk of damage to the anatomical structures in the region, thus mitigating the occurrence of complications.

CONCLUSION

The present study described the morphometric and morphological parameters of the mastoid foramen. Given the relevance of the anatomical structures passing through this foramen, an adequate understanding of its morphology and morphometry is essential for improved outcomes in surgical interventions, in addition to potentially reducing the risk of perioperative and postoperative complications.

CONFLICT OF INTEREST

Nothing to declare.

CONTRIBUTIONS OF THE AUTHORS

IFGG - conceptualization, investigation, manuscript writing and writing – revision and editing; **MMV -** writing – revision and editing; **TJMBSV -** conceptualization, investigation, manuscript writing and writing – revision and editing; **JMSD -** writing – revision and editing; **AAISG -** writing – revision and editing; **RCFC** - resources, writing – revision and editing; **FAP** - conceptualization, data curation, investigation, methodology, project administration, resources, manuscript writing, supervision and writing – revision and editing. All authors approved the final version to be published.

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