



Morphological analysis of complete metopism in a brachycephalic skull: a case report

Análise morfológica da persistência completa da sutura metópica em crânio braquicrânio: um relato de caso



Fernando Augusto Pacífico¹  Daniel Rodrigues Lemos Neto¹ 
Mariana Leandro Silva¹  Ismael Felipe Gonçalves Galvão¹ 
Renata Cristinny de Farias Campina² 

¹ Faculdade de Medicina de Olinda. Olinda, Pernambuco, Brazil.

² Universidade Federal de Pernambuco. Recife, Pernambuco, Brazil.

Abstract

The closure of the metopic suture (MS) is clinically relevant and widely debated in the field of neuroimaging. Identifying metopism is crucial to avoid misdiagnoses (e.g., cranial fractures or other pathological conditions). In this study, metopism occurred without signs of craniosynostosis in the major cranial sutures (e.g., coronal, parietal, and lambdoid sutures), indicating lifelong preservation of sutural characteristics. The analyzed skull was classified as brachycephalic, a finding relevant to associated morphological variations. Metopism identification is essential in clinical and imaging evaluations, as it impacts diagnosis and therapeutic approaches.

Keywords: Joints; Skull; Anatomical variations.

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Corresponding author:

Fernando Augusto Pacífico

E-mail: fapacifico@outlook.com

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Resumo

O fechamento da sutura metópica (SM) é amplamente debatido no campo da neuroimagem, especialmente devido à sua relevância clínica. A identificação correta do metopismo é essencial para evitar diagnósticos equivocados, como fraturas cranianas ou outras patologias. A persistência completa da SM observada neste estudo ocorreu sem sinais de sinostose nas suturas cranianas principais, como a coronal, parietal e lambdoide, indicando a preservação das características suturais ao longo da vida. O crânio analisado foi classificado como braquicrânio, achado relevante para a compreensão das variações morfológicas associadas. Reconhecer a persistência completa da SM é, portanto, fundamental durante avaliações clínicas e de imagem, uma vez que sua identificação adequada pode impactar o diagnóstico e a definição de condutas terapêuticas.

Palavras-chave: Articulações; Crânio; Variações anatômicas

INTRODUCTION

Cranial sutures are joints between the skull bones composed of connective tissue. These structures are predominantly observed in younger individuals and evolve to synostosis over time¹. The metopic suture (MS) (i.e., frontal suture) extends from the glabella (the midpoint between the eyes, above the nose) to the bregmatic fontanelle, connecting the halves of the frontal bone during cranial development.² During intrauterine development, MS and its early obliteration are associated with human bipedalism and the challenges of delivery with a narrower pelvis, a distinctive characteristic of our species³.

Literature on the timing of MS closure is controversial. While most authors propose that the closure occurs by approximately two years of age, some studies suggest that it may be delayed until approximately seven years¹. Eventually, the MS may close prematurely in utero, resulting in trigonocephaly (i.e., a triangular malformation of the frontal bone)³.

Also, MS closure may fail to occur, resulting in an anatomical variation known as metopism. The causes of metopism remain unclear; however, studies suggest that it may be associated with hereditary factors, mechanical stress, endocrine dysfunctions, and specific cranial deformities (e.g., plagiocephaly, brachycephaly, scaphocephaly, and hydrocephalus).² Metopism may be classified as complete, extending along the entire original trajectory from the glabella to the bregma, or incomplete, lacking full-length extension. Reported frequencies of metopism range from approximately 1% to 39.4%¹.

Although some studies investigate the isolated presence of metopism, the association with brachycephaly remains underexplored. Emphasizing this association in specific populations may improve understanding of regional cranial anatomy and craniometry, providing valuable insights for clinical and surgical fields (e.g., neurosurgery, radiology, and forensic anthropology). There-

fore, this study aimed to report an anatomical variation characterized by the complete metopism, describe the morphological and morphometric features of this suture, and discuss the main clinical implications.

CASE REPORT

This research was conducted in the laboratory of anthropology and forensic osteology at a higher education institution. During the routine washing and drying of the skeletal collection, a skull with complete metopism was identified (Figure 1). The coronal, parietal, and lambdoid sutures showed no evidence of synostosis. Additionally, the squamous sutures (temporo-parietal) were also observed. No sutural bones were observed within any of the visible sutures. The pterion was classified as stellate on the right side and frontosphenoidal on the left.

Figure 1. Skull with complete metopism observed from anterior and anterosuperior angles.



Source: Authors

The Horizontal Cranial Index (HCI) was measured using a spreading caliper based on two linear measurements: the maximum cranial width (measured between the two euryon points) and the maximum cranial length (measured from the glabella to the opisthocranium). The obtained measures were 190 mm for maximum length and 154.10 mm for maximum width. Skull classification was conducted using the HCI formula ($[\text{maximum skull width} \times 100] / \text{maximum skull length}$), which classifies skulls as dolichocephalic (70-74.9 mm), mesocephalic (75-79.9 mm), or brachycephalic (80-84.9 mm). In the present case, the HCI was calculated as follows:

$$\text{ICH} = \left(\frac{(\text{maximum skull width})}{(\text{maximum skull length})} \right) \times 100$$

$$\text{ICH} = \left(\frac{154,10}{190,00} \right) \times 100 = 81,10$$

Based on the calculated HCI, the skull was classified as brachycephalic.

Regarding morphometry, metric parameters of the cranial sutures were measured using a spreading caliper. The results were as follows:

1. Length of the MS: 114.80 mm.
2. Length of the sagittal suture: 113.10 mm.
3. Distance between the junction of the MS and frontal suture and the right pterion: 104.60 mm.
4. Distance between the junction of the MS and frontal suture and the left pterion: 105.90 mm.

DISCUSSION

Literature shows divergent perspectives on the etiology and implications of metopism.

Several studies explored the variation in metopism prevalence among populations, suggesting a significant genetic influence. Ajmani *et al.* (1983)⁴ found differences in metopism frequency between skulls from different population groups. Similarly, Agarwal *et al.* (2021) documented the metopism prevalence ranging from 1% to 10%, depending on the ethnic group⁵.

Also, Barbosa *et al.* (2013)⁶ reported metopism prevalence ranging from 1% to 39.4% among different populations. This variability may be influenced by genetic, geographic, and methodological factors across studies. Variations in the criteria used to define complete versus incomplete metopism represent a methodological inconsistency that may contribute to the wide range of reported frequencies⁷. In the present study, metopism was classified as complete, with no evi-

dence of synostosis in other sutures (coronal, parietal, and lambdoid), suggesting preservation of sutural integrity in the lifespan of the individual.

Brachycephaly, characterized by a skull with a predominant transverse width relative to its length, has been identified in some studies as a possible factor associated with metopism^{8,9}. The spatial configuration of a brachycephalic skull may influence biomechanical tensions during cranial development, affecting the MS fusion. Complete metopism in a brachycephalic skull, without other premature synostoses, reinforces the need for further investigation into this morphological relationship. The analysis may provide insights into both normal anatomical variation and the differential diagnosis of craniosynostosis. The present study lacks data on the skin color or race of the individual, which represents a limitation that prevents further exploration of specific ancestral influences in this case. Although the specimen is presumably Brazilian, based on the institutional context of the collection, the high degree of genetic admixture in the Brazilian population complicates ancestry inference in the absence of genetic or self-reported data. The observed association between the brachycephalic cranial type and metopism remains the central focus of the morphological analysis.

Despite the relatively low frequency of complete metopism in adulthood reported in many populations^{5,6}, literature shows several studies on the topic. This apparent contradiction, being both “rare” and frequently investigated, highlights the clinical and anthropological relevance of metopism. The present report of a brachycephalic skull from a 69-year-old male with complete MS persistence contributes to this discussion. Identifying the sex and age of the specimen facilitates precise contextualization within epidemiological data and enhances discussions regarding suture persistence in advanced age groups. Also, examining the correlation between brachycephalic cranial type and metopism in this individual may provide insights into the stability of this variation across the lifespan and the potential interaction with cranial aging processes. This aspect remains relatively underexplored, as many studies focus on prevalence or genetic factors without detailing specific age ranges in older adults.

Our study corroborates the literature showing that metopism generally occurs in isolation, without interference in synostosis of other main cranial sutures (i.e., coronal, sagittal, and lambdoid sutures). However, literature still lacks consensus on this matter. A study by Nikolova *et al.* (2022)¹⁷, concluded that sagittal suture closure in skulls with metopism is significantly delayed compared to control skulls. The authors propose that, in individuals with metopism, the sagittal suture represents a less reliable marker for age-at-death estimation¹⁷. This perspective contrasts with the reported independence between metopism and the behavior of other sutures, highlighting the complexity of cranial development and warranting further investigation.

Metopism prevalence by sex remains unclear in the literature. While some studies^{8,9} indicate a higher frequency in males, others report a slightly greater prevalence in females or an even

distribution. Silva (2024)¹⁸ identified six cases of complete MS persistence in Brazilian skulls, divided between female and male individuals. These findings suggest considerable variability in sex-related prevalence across populations and study samples, discouraging definitive conclusions regarding sex-based susceptibility. The chronology of cranial suture closure must also be considered. Zdilla *et al.* (2018)² reported that sagittal suture closure typically begins around 22 years of age, and coronal suture closure near 24 years. Usually, the MS closes between five and seven months of age. However, metopism in adulthood, as observed in the present case, may not indicate an altered timeline for the closure of other sutures. In this study, patent coronal, sagittal, and lambdoid sutures alongside complete metopism were observed. This finding might highlight an isolated anatomical variation rather than an indicator of broader cranial suture dysregulation.

The MS typically fuses during infancy. However, failure of the fusion process may represent an anatomical variation without clinical consequence. Grine *et al.* (2024)¹⁰ proposed that metopism may be associated with other sutural variations, although such associations may not indicate pathological significance. In this study, no additional sutural anomalies were observed. Furthermore, in the presence of metopism, other cranial sutures (e.g., coronal, parietal, squamous, and lambdoid) commonly remain unfused in the absence of premature synostosis⁸. These findings support the interpretation of metopism as an isolated persistence of MS, with no significant impact on the physiological ossification of other cranial sutures.

The clinical relevance of metopism remains widely debated, particularly in the context of neuroimaging. Maskey *et al.* (2020)¹¹ emphasize the importance of clinical awareness to prevent misdiagnosis of metopism as cranial fractures or other pathologies. The authors also highlight the need for disseminating information for clinicians to cautiously consider anatomical variations when interpreting imaging studies in patients with head and neck trauma¹¹. Additionally, MS persistence has been associated with craniofacial conditions, such as trigonocephaly, where early suture fusion results in a triangular deformation of the frontal bone¹². However, in many cases, metopism has no negative impact on individual health and correlates with significant differences in neurocranial dimensions, particularly in specific regions (e.g., reduced frontal sinus volume, a shorter lateral lamella, and a shallower olfactory fossa)¹³.

From an evolutionary perspective, the MS plays an important role in cranial development. Vinchon (2019)³ suggests that metopism may be associated with evolutionary adaptations related to bipedalism and human childbirth. Early fusion of the MS is considered an adaptation to the narrow human pelvis, facilitating parturition, whereas its persistence may represent a normal variation without adverse effects. An alternative hypothesis, proposed by White *et al.* (1994), suggests that metopism may be related to human cranial growth, enabling greater morphological variation, which may provide evolutionary advantages in specific contexts¹⁴.

The morphometric measurements obtained in the present study, including the HCI, provide

a foundation for comparisons with other studies. Roosenboom *et al.* (2018) report that HCI variations may be associated with distinct cranial morphologies, potentially influenced by both genetic and environmental factors¹⁵. Although no additional cranial anomalies associated with metopism were identified in the case, Sakamoto *et al.* (2024) suggested that morphometric variations may be indirectly linked to specific craniofacial conditions¹⁸.

In the present study, the brachycephalic characteristic corroborates previous findings associating this cranial type with metopism. While no additional sutural anomalies were identified, the complete metopism may reflect developmental variations in cranial morphology, as reported by Atalay *et al.* (2021), who described differences in frontal sinus volume in similar cases¹³.

Metopism may be misinterpreted as cranial fractures in imaging studies, particularly in cases of trauma to the frontal bone¹¹. Accurate identification of this anatomical variation is essential to prevent diagnostic errors and to ensure the safe planning of surgical interventions.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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AUTHOR CONTRIBUTIONS

FAP: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing – original draft, Supervision, and Writing – review and editing. **DRLN:** Writing – original draft and Writing – review and editing. **MLS:** Writing – original draft and Writing – review and editing. **IFGG:** Writing – original draft and Writing – review and editing. **RCFC:** Writing – review and editing. All authors read and agreed with the final version of the manuscript.

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