Research Paper

Morphometric Analysis of Accessory Sutural Bones Association With Parietal Emissary Foramina

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Citation Jyothi C N, Muraleedharan A, J.P G, Devi. Morphometric Analysis of Accessory Sutural Bones Association With Parietal Emissary Foramina. Anatomical Sciences Journal. 2022; 19(1):33-38.

Article info:
Received: 02 Nov 2021
Accepted: 18 Dec 2022
Available Online: 01 Jan 2022

Keywords:
Interparietal bones, Inca bones, Accessory bones, Sutural bones, Supraoccipital bones, Parietal emissary foramen

ABSTRACT

Introduction: The sutural bones and fontanelle of the skull display unique morphological characters. Sutural bones are also called supernumerary bones, ossicles, or Wormian bones (WBs). These irregularities develop from the independent ossification centers present along the cranial sutures. They appear on periosteal and endosteal surfaces of the skull with variations in size, number, shape, and location. In the current study, we aimed to determine the morphological characteristics of sutural bones and their association with parietal emissary foramina.

Methods: The current study was done on 128 dry human skulls by a convenient sampling method. The skulls were collected from the Department of Anatomy. Many characteristic features of Inca and Wormian bones like shape, number, size, and location were recorded, including abnormal parietal emissary foramen associated with the Wormian and Inca bone, respectively.

Results: Out of 128 dry skulls, the Wormian bones were seen in 13.2% of skulls and the Inca bones in 5.4%. Incorporation of Wormian bones in the lambdoid suture was noted in 12.5% and the sagittal suture at 0.7%, respectively. The Wormian bones were found frequently on the left side (n=12) compared to the right side (n=5). The morphometry of the accessory bones showed quadrilateral as the most common shape (n=9, 37.5%), followed by triangular (n=4, 16.6%). Radiological examination of all 24 skulls with accessory bones showed a zigzag pattern of accessory suture lines. The prevalence of abnormal parietal emissary foramen (bilateral and unilateral absence associated with the Wormian bone was noted at 23.5%. The prevalence of abnormal parietal emissary foramen (unilateral absence and foramen on the sagittal suture) related to the Inca bone was reported at 71.4%.

Conclusion: The presence of Wormian and Inca bones can be easily confused with fractures of the corresponding bony regions. The surgeons must know this to make a proper and accurate diagnosis. Knowledge of these bones benefits the clinician, radiologist, and neurosurgeon highly.

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1. Introduction

Skull is a complex bony structure. In young adults, the skull consists of 28 separate bones, many of which are paired. At an advanced age, the skull is composed of 22 bones. Most of these bones are held together by fibrous joints called sutures. The junction of the sutures undergoes a series of morphological changes from birth to adulthood. The cranial bones are ossified in the membrane, and the ossification is incomplete at birth, marked by the fontanelles and posterior fontanelles. Most of these bones are fused by fibrous or cartilage tissue. During this process, additional ossification centers may appear, potentially sites for developing Wormian bones (WBs) [1, 2].

Between 1460 and 1541 CE Paracelsus first described the WBs. These bones were officially named by Olaus Worm, a Danish anatomist Ossa Wormiana, but are also referred to as intercultural bones, Inca bones, or Goethe's ossicle. WBs are frequently found in the lambdoid suture and near the fontanelles [3]. WBs are commonly seen in the lambdoid suture. The presence and occurrence of WBs in the coronal, sagittal, and squamosal sutures are infrequent [4]. The neurocranium and viscerocranium are the two parts of the human skull. The neurocranium forms the back and base of the skull. The occipital bone consists of a squamosal part, a basilar part, and condyles. The squamous part of the occipital bone consists of an upper membranous part and a lower cartilaginous part; the membranous part is also called inter parietal region, and a cartilaginous part is called as supraoccipital part [5].

The interparietal part lies above the highest nuchal line, is developed in a fibrous membrane, and is ossified from 2 pairs of centers. Each center consists of two nuclei. If these centers fail to fuse, the supraoccipital part may give rise to various accessory bones in the interparietal region [6, 7]. The occurrence of accessory bones can be explained based on an incomplete union of corresponding ossification centers [8]. The accessory bones develop from the separate ossification centers in the interparietal region. The interparietal portion remains separated from the supraoccipital part by a transverse suture, resulting in the occurrence of an Inca bone [9]. The variations in size, shape, number, and position of accessory bones are prevalent [10].

WBs can be found in healthy individuals with congenital disorders, such as osteogenesis imperfecta, cretinism, cleidocranial dysostosis, and enlarged parietal foramina [3]. Knowledge of the normal anatomy, development, and timing of sutural closure is also essential in evaluating fractures. The presence of intercultural bones can be misdiagnosed as skull bone fractures [11]. It may also affect posterior craniotomy approaches to the skull. Awareness of morphology, morphometry, and prevalence of accessory sutural bones is essential in medicolegal cases and neurosurgery. The current study aimed to report the prevalence and morphology of additional sutural bones in dry human skulls.

2. Materials and Methods

Out of 128 adults, dry human skulls of unknown sex and age were included in the study. Each skull was observed for the presence of WBs and Inca bones. The morphology and morphometry of the accessory bones were also noted. Along with the occurrence of the WBs and Inca bones, associated parietal emissary foramen abnormalities were noted. All the skull sutures were examined, and findings were recorded. All adult skulls were included in this study, and fetal or damaged skulls were excluded.

3. Results

Of the 128 dry skulls examined, WBs were seen in 17 (13.2%) skulls and Inca bones in 7 (5.4%). Incorporation of WBs in lambdoid suture was noted in 16 skulls (12.5%) and incorporation in sagittal suture in one skull (0.7%), respectively, as shown in (Figures 1A,B,C,D). The WBs were found more frequently on the left side (n=12) than on the right side (n=5). The parietal emissary foramen variations were noted in most skulls with accessory bones. The commonly reported variations were the bilateral absence of parietal foramen (Figures 1A,B) and unilateral presence (Figure 1D, E, F), presence on the sagittal suture (Figure 1G), and multiplicity (Figures 1H).

The morphometry of the WBs and Inca bones showed quadrilateral (Figure 2, 2B) as the most common shape (n=9, 37.5%), followed by triangular (n=4, 16.6%). The majority of the bones were large. The chief morphometric features are depicted in (Figure 3). Radiological examination of all 24 skulls with accessory bones showed a zigzag pattern of accessory suture lines (Figures 1B, 2).

The prevalence of abnormal parietal emissary foramen (bilateral and unilateral absence) associated with the Wormian bone was 23.5% (Figures 1A,B,D). The prevalence of abnormal parietal emissary foramen (unilateral

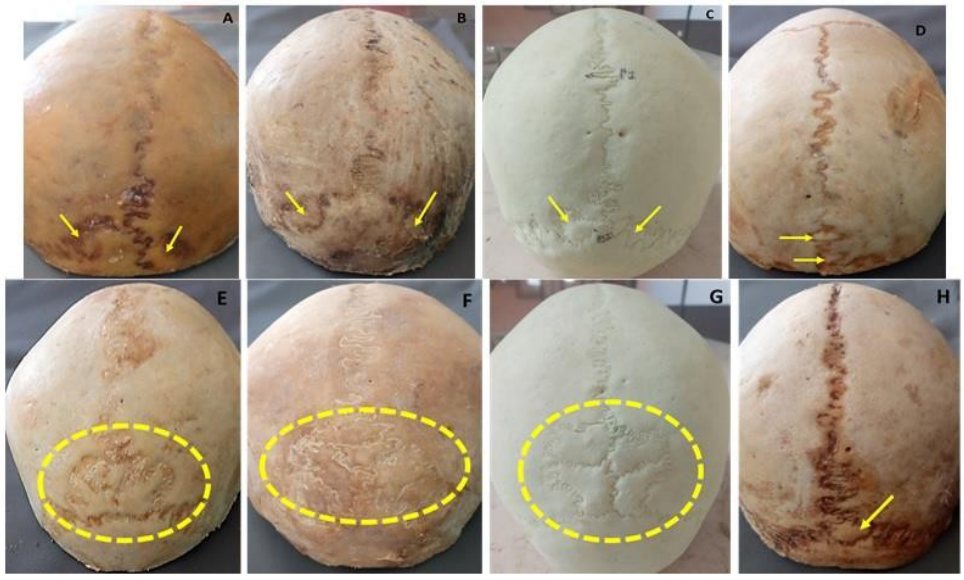

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Figure 1. A, B, C arrows showing bilateral WBs in the lambdoid suture, C arrow showing WBs in sagittal suture E, F, G circle showing Inca bones, A, B skulls showing bilateral absences of Parietal foramen, and D, E, F, H skulls showing unilateral Parietal foramen, C skull showing left Parietal foramen on the sagittal suture.

absence and foramen on the sagittal suture) associated with the Inca bone was noted at 71.4% (Figure 1E, F, H).

Figures 1A,B,D show abnormal parietal emissary foramen (bilateral and unilateral absence associated with the Wormian bone. Figure 1E, F, H shows abnormal parietal emissary foramen (unilateral absence and foramen on the sagittal suture) related to the Inca bone.

4. Discussion

The current study aimed at identifying the presence of WBs and Inca bones and their morphology and morphometry association with the abnormal parietal emissary foramen. WBs can be seen in normal and pathological crania. Their etiology is still unclear if it could be related to genetics [12]. Studies have reported

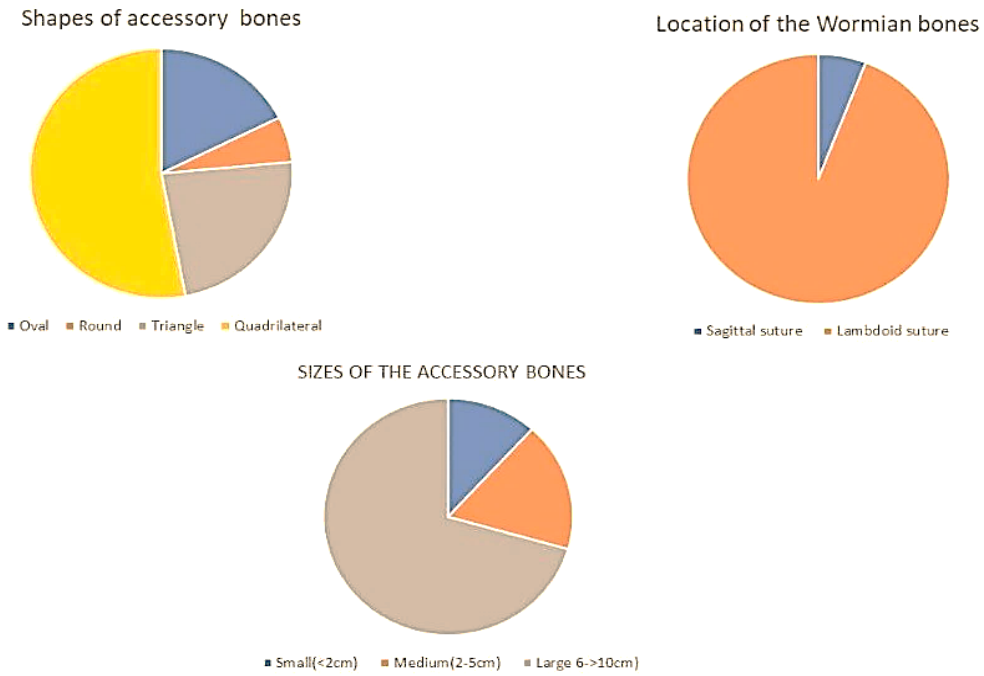

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Figure 2. B1 Plain skull X-Ray showing a zigzag pattern of accessory suture lines and B2 photograph of the radiographed skull.

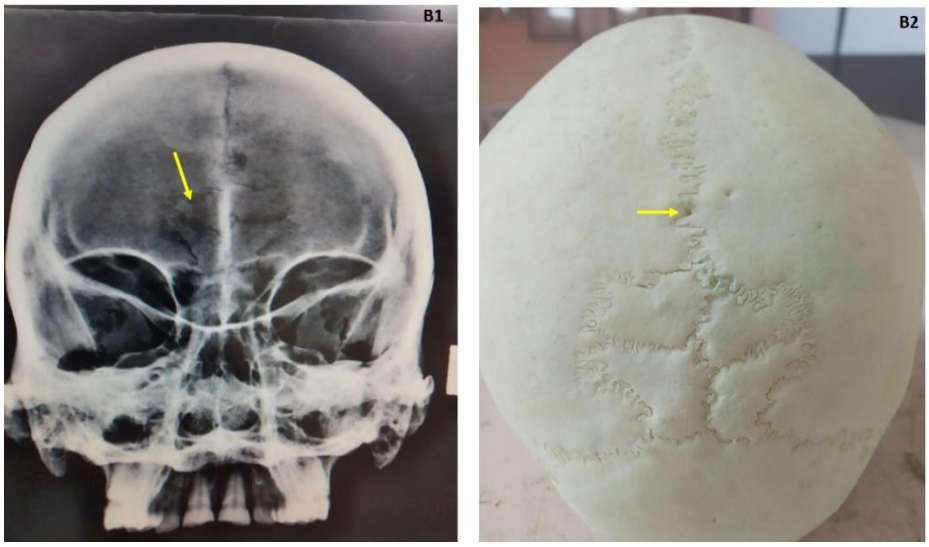

Figure 3. The chief morphometric features of accessory bones are depicted in a pie chart

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that WBs are under the genetic influence and may be inherited as an autosomal dominant trait with about 50% variable expression [13]. The different shapes and sizes of the WBs have been reported in the literature. Frequently encountered shapes are triangular and quadrilateral, consistent with the current study's findings [14]. In the current study, 50% of the accessory bones are between 5-10cm, and these bones articulate with the surrounding bones by sutures.

The prevalence of WBs has been estimated as 52.99% in the lambdoid suture, and multiple WBs were seen in lambdoid suture at 0.01% [15]. In the occipital region, the accessory bones can be numerous and bilateral [16]. In the current study, the prevalence of WBs is approximately 13.2%, out of which numerous bilateral WBs were seen in the lambdoid suture. The occurrence of interparietal bone or Inca bone at the lambda has been reported in previous literature, but these are associated with other cranial and central nervous system abnormalities [17, 18].

The current study found Inca bones that could be associated only with parietal emissary foramen abnormalities. Multiple studies are available about accessory bones at the lambda, lambdoid suture, sagittal suture, and the pterion. In a unique case reported by Satheesha Nayak, the presence of accessory bone at the bregma may occur because of an abnormal ossification center in the fibrous membrane at the anterior median fontanelle in fetal life [19].

The presence of multiple WBs can be misdiagnosed as skull fractures [20]. The salient features that differentiate skull fracture and accessory sutures are tabulated as shown in Table 1. The radiologic appearance of accessory bone and fracture is different. The radiologic pattern of simple skull fractures can be demonstrated as non-sclerotic edges, in sutural bones show a zigzag pattern with sclerotic borders [21]. The salient

Table 1. Salient features of the differentiated skull fractures and accessory sutures

Row	Parameters	Skull Fracture	Accessory Suture
1	Radiologic pattern	Non-sclerotic borders	Sclerotic borders
2	Appearance	Sharp lucency	Zig-Zag
3	Laterality	Often unilateral	Often bilateral
4	Soft tissue reaction swelling/hematoma	Yes	No
5	Relation with suture lines	Crosses adjacent suture line	Merges with adjacent line
6	Diastasis	Yes	No

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features of the differentiated skull fractures and accessory sutures are tabulated in Table 1 [22].

Piagku et al. reported an association between sizeable parietal emissary foramen and multiple Wormian bones in all the sutures of a single skull [23]. In our study, we observed that abnormal parietal emissary foramen associated with the Wormian bone was noted in 23.5%, and abnormal parietal foramen related to the Inca bone was noted in 71.4%.

5. Conclusion

The current study highlights the presence of Wormian and Inca bone association with the abnormal parietal foramen. Knowing the existence, number, and location of WBs is essential for anthropologists, radiologists, and neurosurgeons in diagnosing and treating skulls. The presence and number of WBs should always be reported and distinguished from fracture. Concerning our results, it is essential to remember that accessory sutural bones are joint in an average population before diagnosing such findings.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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