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Original Research Article

Incidence and Morphometrics Analysis of Sutural, Inca and Epipteric Bones in Adult Human Skulls from Central India

Walulkar S.M.[1], Walulkar M.S.[2], Paikrao V. M.[3]

[1,3]Department of Anatomy, NKP Salve Institute of Medical Sciences & Research Centre and Lata Mangeshkar Hospital, Nagpur

[2]Department of Physiology, NKP Salve Institute of Medical Sciences & Research Centre and Lata Mangeshkar Hospital, Nagpur

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Corresponding author: Dr. Sanjay M. Walulkar

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Abstract:

Background: Sutural, Inca, and Epipteric bones are intrinsic components of the cranial structure in various mammals and reptiles. Additional ossification centres may occur in or near sutures, giving rise to isolated sutural bones. Usually irregular in size and shape, and most frequent in lambdoid suture, they sometime occur at fontanelles. There are often only two or three, but they appear in great numbers in hydrocephalic skull.

Aims and Objectives: The study aims to investigate the prevalence, sexual dimorphism, morphological variations, and clinical implications of cranial sutural, Inca, and epipteric bones in adult human skulls from Vidarbha, India.

Methodology: The 430 adult human skulls were collected from various medical colleges in the Vidarbha region, each skull and recording the presence, gross incidence, and distribution of sutural bones, inca, and epipteric bones. The observations were made regarding their occurrence in specific cranial sites, suture locations, and shapes. Anthropometric measurements were taken to determine the maximum length and breadth of each bone. The sexual dimorphism and conducted statistical analyses to identify patterns and trends in the collected data.

Result: In our analysis, Wormian bones were present in 34.18% of the 430 examined skulls, with 38.76% incidence in males and 25.97% in females. These bones were most frequently located in the lambdoid suture and Lambda. Irregular-shaped Wormian bones were predominant. Inca bones were found in 2.33% of skulls, with variations in type, size, and shape. Epipteric bones appeared in 18.37% of skulls, demonstrating sexual dimorphism and a range of symmetry patterns.

Conclusion: In our comprehensive cranial bone study, Wormian bones were most frequent in the lambdoid suture, primarily on the left side, while Inca bones displayed variations in form and incidence, slightly higher in males. Epipteric bones at the pterion can complicate procedures.

Introduction

Sutural bones, also known as Wormian bones, are intriguing cranial anomalies characterized by their irregular shape and location within the sutures of the skull. These bones have garnered attention in anthropological and medical research due to their intriguing nature. Often, they are considered normal morphological variants of the human cranial vault [1].

While the existence of these bones is well-documented, their exact mechanism of formation continues to elude researchers. Some authors have postulated that they may develop in response to external influences [2]. However, despite decades of study, a comprehensive understanding of their origin remains elusive. The prevalence of sutural bones varies in different geographic regions, suggesting that genetic factors may play a role in their occurrence [1]. Inca bones represent a rarer phenomenon in cranial morphology. Inca bones, also referred to as interparietal bones or Goeth's ossicles, result from the failure of fusion between primary and secondary pairs of ossification centers in the occipital bone. Unlike Wormian bones, Inca bones are less common, and their incidence has been less explored in various populations [3].

Furthermore, the pterion, a pivotal landmark on the lateral aspect of the skull, has garnered considerable attention in the field of neurosurgery. Variations in the pterion can have significant implications for neurosurgical procedures. Notably, one such variation involves the presence of an epipteric bone in the pterion region [4].

When found in the vicinity of the pterion, these cranial anomalies are referred to as epipteric ossicles, epipteric bones, or even colloquially as "flower bones" [5-6]. They can be easily mistaken for fractures, particularly in trauma cases, which emphasize the importance of understanding their prevalence and characteristics.

While some research exists on sutural patterns in the pterion region among primates and various human races, there is a notable scarcity of literature on the presence and characteristics of epipteric bones in different populations [7]. The understanding of these variations is of utmost significance for medical professionals, particularly surgeons and radiologists involved in neurosurgical procedures or trauma cases [8].

Furthermore, forensic experts rely on their knowledge of these cranial anomalies when assessing skull fractures, making an accurate diagnosis, and conducting surgical interventions, including burr hole surgeries [9]. Investigating the regional incidence, sexual dimorphism, and variations of these cranial anomalies can help differentiate between these structures and fractures in medicolegal cases. This study will enhance our understanding of the regional occurrence and attributes of sutural, Inca, and epipteric bones within the human skull.

The findings contribute significantly to the fields of medicine, forensics, and anthropology, facilitating accurate diagnoses and improving surgical interventions.

Through this research, we aim to shed light on the unique characteristics of these cranial anomalies in the Vidarbha region, ultimately advancing our knowledge of cranial morphology and variations within this specific population.

Methodology

The ethical permission was obtained from Institutional Ethical Committee (IEC), the Informed consent also obtained from heads of Anatomy and Forensic departments who provide the skulls before conducting the study.

Sample Collection and Selection

The study was conducted at the Department of Anatomy, N.K.P. Salve Institute of Medical Sciences & Research Centre and Lata Mangeshkar Hospital, Nagpur.

A total of 430 adult human skulls were obtained from Anatomy and Forensic department of various government and private medical colleges in the Vidarbha region.

Selection Criteria for Skulls

Inclusion Criteria: Only skulls that were apparently normal and showed no signs of fracture were included in this study.

Exclusion Criteria: Skulls exhibiting pathological deformities or fractures were excluded from the study.

Data Collection: In the study of 430 skulls, each assigned a unique serial number from 1 to 430, data were recorded separately for male and female skulls. The structural morphology of the skulls was analysed for the presence of sutural bones, Inca, and epipteric bones. Gross incidence and percentage distribution of these bones were documented, including their occurrence in fontanelles and various sutures. Specific sites such as Asterion, Coronal suture, and Lambdoid sutures were examined to identify unilateral or bilateral presence. Various shapes of sutural bones, Inca, and epipteric bones were recorded.

Anthropometric Measurement: To determine the maximum length of each bone, a straight line was drawn between the widest points along the margin of each bone. To determine the maximum breadth; a perpendicular axis was drawn at the point of maximum width of the bone. The distance between these two widest points was measured as the maximum breadth of the bone using measuring tape and vernier caliper.

Sexual Dimorphism Analysis: The selected skulls from both genders were macroscopically observed without any additional aids. Data collected for sexual dimorphism included the incidence and characteristics of sutural bones, Inca, and epipteric bones.

Statistical Analysis: The collected data, including measurements and incidence rates, were subjected to statistical analysis to identify patterns, trends, and sexual dimorphism.

Result

Observations and Results

In this study of 430 adult human skulls, comprising 276 male and 154 female skulls, we conducted a systematic examination of Wormian, Inca, and epipteric bones. Our investigation encompassed several key aspects, beginning with the calculation of gross incidence and percentage frequency of these bones within the sample. We explored sexual dimorphism to identify any variations in bone occurrence between male and female skulls. Our examination extended to assessing the incidence of these bones at specific sites on the skulls and analyzing gender-specific patterns.

Observation: Sutural bones

The study presents essential findings on Sutural bones in 225 skulls, summarized in Tables 1-7 and Figure 1.

It reveals a gross incidence of in Wormian bones among the examined skulls, with variations in male and female skulls. These bones occur predominantly at the lambdoid suture and other sites such as Lambda, Asterion, sagittal suture, and coronal suture. Male skulls exhibit notable occurrences at the Lambdoid suture, Lambda, Asterion, sagittal sutures, and coronal sutures. Female skulls, on the other hand, demonstrate a remarkably high incidence at the lambdoid suture. Wormian bones come in various shapes, with irregular, oval, and triangular shapes. These bones vary in size.

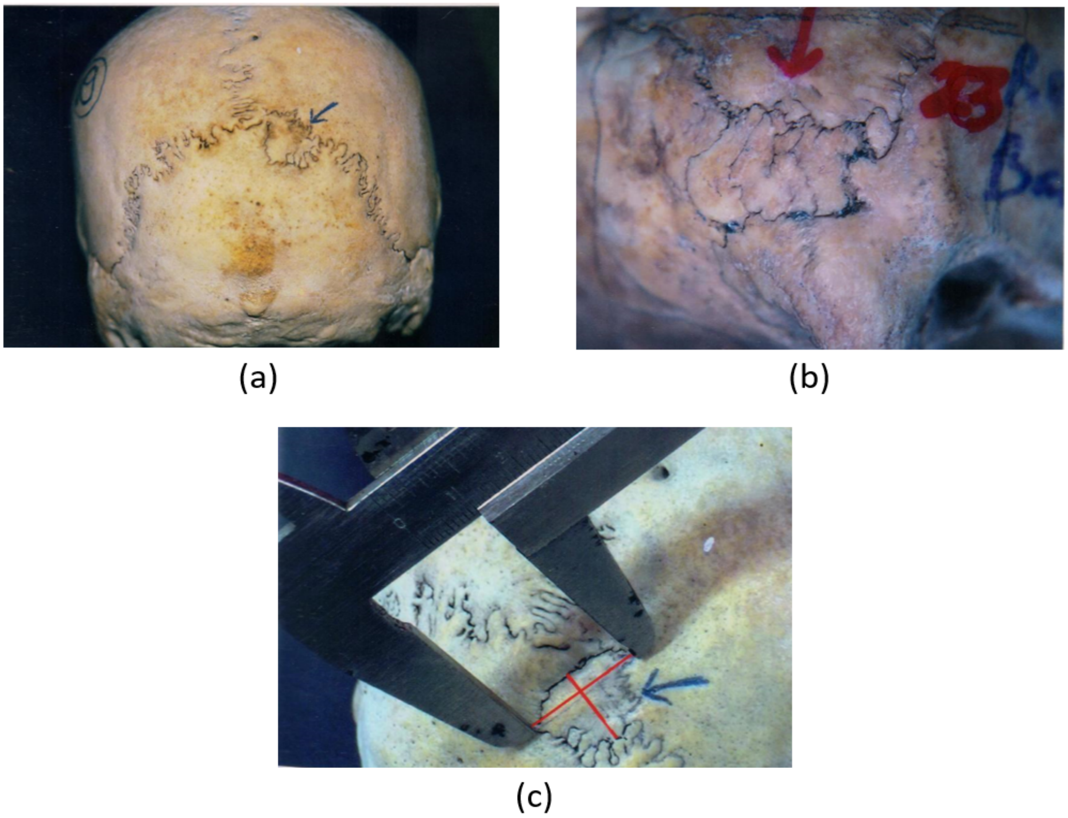

Figure 1 (a): Skull no 38 showing oval sutural bone at lambdoid suture, (b): Skull no 23 showing irregular small Wormian bone at Asterion, (c): The measurement of wormian bone by vernier caliper

Table 1: Gross Incidence and Percentage Frequency of Wormian Bones

Total No. of Skulls Examined	Skulls Showing Wormian Bones	Percentage
430	147	34.18

Table 2: Sexual Dimorphism in Incidence of Wormian Bones

Sex	Skull Examined	Skull Showing Wormian Bones	Percentage
Male	276	107	38.76
Female	154	40	25.97

Table 3: Incidence at Various Sites of Skull

Cranial Sites	No. Of Skulls	Incidence			Total No.	Percentage
		Unilateral		Bilateral		
		Right	Left			
Coronal Suture	147	02	-	-	02	1.36
Sagittal Suture	147	08		-	08	5.44
Lambdoid Suture	147	24	56	25	105	71.42
Bregma	147	-		-	-	-
Lambda	147	17		-	17	11.15
Asterion	147	08	05	02	15	10.20

Table 4: Incidence at Various Cranial Sites in Male Skulls

Cranial Sites	No. Of Skulls	Incidence			Total No.	Percentage
		Unilateral		Bilateral		
		Right	Left			
Coronal Suture	107	02	-	-	02	1.87
Sagittal Suture	107	08		-	08	7.48
Lambdoid Suture	107	19	34	22	75	70.09
Bregma	107	-		-	-	-
Lambda	107	16		-	16	14.95
Asterion	107	03	02	01	06	5.61

Table 5: Incidence at Various Cranial Sites in Female Skulls

Cranial Sites	No. Of Skulls	Incidence			Total No.	Percentage
		Unilateral		Bilateral		
		Right	Left			
Coronal Suture	40	-	01	-	1	2.5
Sagittal Suture	40	02		-	02	5
Lambdoid Suture	40	09	15	08	32	80
Bregma	40	-		-	-	-
Lambda	40	03		-	03	7.5
Asterion	40	02	-	-	02	5

Table 6: Shapes of Wormian Bones

Shapes	Oval	Triangular	Irregular
No. of Wormian Bones (Total 174)	73	22	79
Percentage	41.95	12.64	45.40

Table 7: Range and the Average Sizes (Maximum Length and Maximum Breadth) of Wormian Bones

Range of maximum length	Range of Maximum breadth	Average maximum length	Average maximum breadth
5 mm to 25 mm	2 mm to 12 mm	11 mm	6 mm

Observation: Inca bones

The study of Inca bones in 430 adult human skulls yielded several important observations, which are summarized in Tables 8-10 and illustrated in Figure 2. The types of Inca bones observed, categorized according to Kadanoff and Mustafa's [10] classification. These types include Median, Bipartite, Tripartite, and Partial Inca bones. The Inca bones were found in multiple fragmentations, aligning with the previously documented variations in Inca bone structure as described by Pal (1987) [11]. The anatomical details reveal fusion and separation patterns in Inca bone fragments, forming distinct bones from central and lateral pieces.

This study shows variations in Inca bone development, including separation of the right half of the occipital bone from the supraoccipital bone and fusion of the left half with it.

Table 8: Sexual dimorphisms and Gross incidence and percentage frequency

Sex	Skulls Examined	No Skulls showing Inca bones	Percentage
Male	276	7	2.54%
Female	154	3	1.95%
Total	430	10	2.33%

Table 9: Types of Inca Bones (as per Kadanoff &Mutafov 1968[10])

Sr. No.	Type	No. of Fragments	No of skulls showing Inca bone
1	Median	2	4
2	Bipartite	3	3
3	Tripartite	2	1
4	Partial	2	2

Table 10: Size and shape

Types of Inca Bone	Maximum length	Maximum breath
Median	80 mm	42 mm
Bipartite	53 mm	41 mm
	72 mm	45 mm
Tripartite	98 mm	47 mm
Partial	45 mm	38 mm

In our study the Inca bones were found in one, two, three fragments or multiple fragments that coincide with the maximum variations of Inca bone quoted by Pal G.P. (1987) [11].

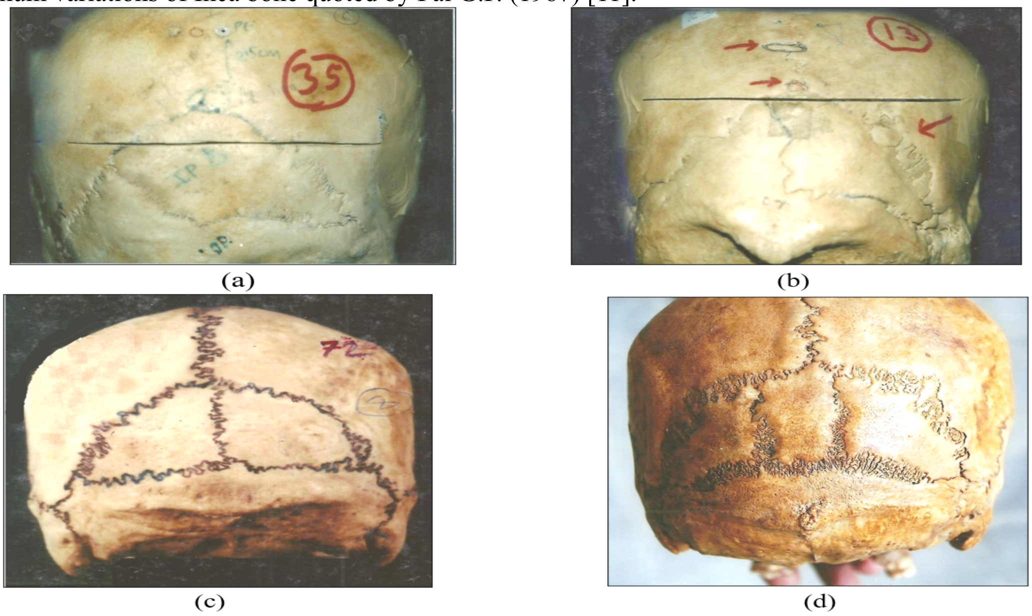

Figure 2(a): Skull no 35 showing Single Median fragment of Inca bone, (b): Skull no 13 showing incomplete lateral asymmetric inca bone (Osincae lateral dextrum), (c): Skull no 72 showing completely symmetric bipartite inca bones (OsIncaeBipartitum), (d): Skull no 59, Incomplete asymmetric tripartite Inca bone

The left piece fuses with the supraoccipital part. Notably, the right half of the occipital bone becomes separate from the rest of the supraoccipital bone, while the left half fuses with it. In cases where the pair of central pieces fails to unite, interparietal bones may develop as two symmetrical halves.

Observation: Epipteric Bone

The study of epipteric bones revealed significant findings, as summarized in Tables 11 and 12. Among the 154 female skulls, 27 exhibited epipteric bones, with a percentage incidence of 17.53%. Collectively, out of the total 430 skulls examined, 79 demonstrated the presence of epipteric bones, resulting in an overall percentage incidence of 18.37%.Among male skulls showing epipteric bones, 16 exhibited unilateral epipteric bones on the right side, while 21 displayed unilateral epipteric bones on the left side. Additionally, 15 male skulls showcased bilateral epipteric bones.

Among female skulls with epipteric bones, 7 displayed unilateral epipteric bones on the right side, 8 had unilateral epipteric bones on the left side, and 10 showed bilateral epipteric bones (Table-12).

The study systematically classified each pterion into one of four types—sphenoparietal, front temporal, stellate, or epipteric—based on established criteria outlined by Murphy [12]. The illustrative representation in Figure 3 highlights the morphological variations observed in epipteric bones, such as irregular and triangular configurations, at the pterion sites on the skulls.

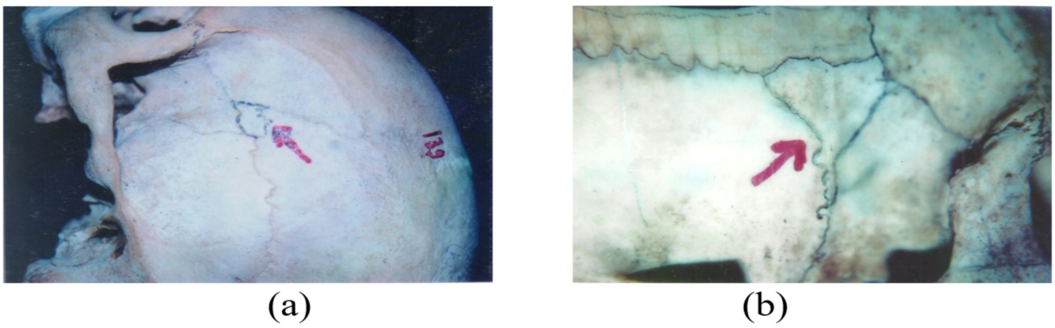

Figure 3: (a): Irregular Epipteric bone at the pterion on left side of skull, (b): Triangular Epipteric bone at pterion on right side of skull

Table 11: Sexual dimorphisms and Gross incidence and percentage frequency

Sex	Skulls Examined	No Skulls showing Epipteric bones	Percentage
Male	276	52	18.84%
Female	154	27	17.53%
Total	430	79	18.37%

Table 12: The incidence of Epipteric Bones with reference to Symmetry

Sex	No. Skulls showing Epipteric bones	Incidence Rate and Percentage					
		Unilateral				Bilateral	
		Right	%	Left	%	Incidence	%
Male	52	16	30.77	21	40.38	15	28.85
Female	27	7	25.93	8	29.63	10	37.04

Discussion

This study conducted in the Vidarbha region focus on the anatomical variations and prevalence of sutural bones (Wormian bones), Inca bones, and epipteric bones

Sutural bones, also known as Wormian bones, are small, irregularly shaped bones found within the cranial sutures. These bones develop as additional islands of bone within the calvarial sutures, representing independent centers of ossification.

One of the critical findings in this study is the common sites of occurrence for Wormian bones. The Lambdoid suture emerges as the most frequent location, followed by Lambda, Asterion, the sagittal suture, and the coronal suture, which shows the least incidence. Remarkably, no Wormian bones were encountered at bregma. These findings suggest a clear preference for certain suture locations, shedding light on the factors influencing their development.

These small, irregularly shaped bones develop within cranial sutures, with a relatively common occurrence in human crania. Goyal et al. [13] found an overall incidence of Wormian bones in 35.3% of skulls, with variations between males (23.8%) and females (11.5%). Natsis et. al. [14] reported a high incidence of 74.7% in Greek adult skulls, with no significant gender or age-related differences. Basnet et al. [15] observed a remarkable 88.57% incidence in skulls, with variations based on cranial sutures and head shape. Marti et al. [16] focused on a pediatric population and found Wormian bones in 53% of children, with varying numbers in different individuals. This study also examined sexual dimorphism and the shapes of Wormian bones. It is important to note that the presence of Wormian bones aids in differentiating normal sutures from fractures or gunshot wounds. This study also delves into sexual dimorphism, revealing differences in the incidence of Wormian bones between male and female skulls.

Inca bones represent a distinct type of sutural bone, characterized by their presence at the interparietal portion of the occipital bone. These bones are formed due to a failure of fusion between primary and secondary pairs of ossification centers. Unlike Wormian bones, Inca bones are relatively rare.

Marathe et al. [3] reported an incidence of 1.315% in central India, with a slightly higher occurrence in male skulls (1.428%) compared to female skulls (1.176%). Donapudi and Vijayanirmala [17] found a 2.6% incidence of Inca bones in a southern Indian district, with a notable male bias (3.4% in males compared to 1.2% in females). Hanihara and Ishida [18] extensive research revealed variations in Inca bone frequency among major human population groups, with higher frequencies in New World populations and isolated groups derived from eastern Asian population stock. In contrast, Central and West Asia, as well as Europe, showed relatively low Inca bone frequencies. The study explores Inca bone incidence, sexual dimorphism, and variations in the Vidarbha region, including the number of fragments of Inca bones and the clinical significance of these bones in relation to ossification defects and pathologies. This study on Inca bones aimed to uncover their gross incidence, sexual dimorphism, and variations in formation in the Vidarbha region. One significant finding was the variability in the number of fragments of Inca bones, ranging from one to multiple fragments. This suggests that Inca bones can manifest in different forms and sizes within the population.

It was noted that the incidence of Inca bones was slightly higher in male skulls compared to female skulls, further highlighting the variations in occurrence based on gender. These findings contribute to a better understanding of Inca bones' prevalence and diversity in the Vidarbha region.

The study also acknowledged the clinical significance of Inca bones. They can be related to various conditions, such as defects in ossification, metabolic disorders, and underlying central nervous system pathologies like hydrocephalus. Additionally, the presence of Inca bones may impact radiological interpretations and forensic investigations, as they can be mistaken for skull fractures.

Epipteric bones, found near the pterion on the lateral aspect of the skull, were the focus of the third study. The pterion is an essential neurosurgical landmark, and the presence of epipteric bones can impact surgical procedures and radiological interpretations.

The study aimed to explore the variations in the occurrence of epipteric bones in different populations. The research revealed that nearly 40% of skulls had sutural bones near the lambdoid suture, with epipteric bones being the next most common. This underscores the importance of understanding the variations in pterion anatomy for surgeons operating in the field.

Epipteric bones are crucial in differentiating between cranial fractures and the presence of sutural bones. Misinterpretation of these bones as fractures can have significant implications in both clinical and forensic settings. Matsumura et al. [19] conducted a comprehensive study on 614 Japanese skulls, including fetuses, juveniles, and adults, finding epipteric bones in over 10% of juvenile and adult pteria. Khatri et al. [20] conducted a study in Gujarat, India, focusing on the Pterion and epipteric bones in dry human skulls. They discovered the sphenoparietal variety of pterion as the most prevalent and found epipteric bones in 11.73% of the skulls. Sreekanth (2017) [21] conducted an anatomical study on 120 dry adult human skulls and found that 5% had unilateral epipteric bone occurrences, with varying placements.

Understanding the prevalence and locations of these bones is crucial for surgeons, radiologists, and clinicians, as it can impact surgical procedures, radiological interpretations, and the diagnosis of various cranial conditions. The presence of sutural bones, Inca bones, and epipteric bones can complicate forensic investigations. Accurate identification of these bones is essential to avoid misinterpretation as fractures.

This study contributes to the broader field of anthropology by providing data on the prevalence of these bones in different populations. This information can aid in population studies and evolutionary research. Wormian and Inca bones highlight the role of genetics in the development of these anatomical variations. Understanding the genetic factors involved can have broader implications for genetic research. The knowledge of the variations in pterion anatomy, including the presence of epipteric bones, is crucial for neurosurgeons and orthopedic surgeons. It helps in planning surgical interventions accurately.

Conclusion

In conclusion, these studies provide valuable contributions to our understanding of cranial anatomy and its variations.

They emphasize the importance of considering anatomical diversity in medical, forensic, and anthropological contexts, ultimately improving the accuracy of diagnoses, surgical procedures, and research in the field of cranial morphology. Further research in this region and in other populations can continue to enhance our knowledge of these anatomical features and their implications

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