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Original Research Article

SUTURAL BONES: A STUDY ON INCIDENCE, LATERALITY AND CO-RELATION WITH CEPHALIC INDEX IN DRY CRANIA OF EAST INDIAN ETHNICITY

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ABSTRACT

Background: Sutural bones are supranumary bones occurring along the sutures and completely surrounded by sutures of the skull. Their number, morphology and location in skull vary in skulls. The knowledge of these bones is imperative in surgery, medicolegal cases involving child abuse or fracture of skulls and for anthropologic identification of human populations. This study was undertaken to examine incidence and pattern of distribution of sutural bones in dry skulls from Eastern India and compare the findings with similar studies across the world.

Materials and Method: 180 dry crania were identified as male or female skulls and studied for the incidence and pattern of distribution of sutural bones. Also the Cephalic Index was measured for finding its correlation with the number of sutural bones appearing in a skull.

Results: 124 skulls were identified as male and 56 as female skulls. Overall incidence of sutural bone occurrence was found to be 72.28% which was essentially similar across sexes. The most common sites for sutural bones, in descending order of occurrence, were found to be parieto-occipital suture, asterion, pterion and lambda. Bregma was the least common site where no sutural bone was encountered. A highly statistically significant finding was in regard to laterality of sutural bone occurrence. Sutural bones occurring along coronal, parieto-temporal, parieto-mastoid, occipito-mastoid sutures and pterion exhibited more than 80% tendency towards unilateral occurrence while those occurring at asterion exhibited around 70% tendency towards unilateral occurrence. All these findings, although displayed variable degree of sexual dimorphism, were statistically insignificant for variation among sexes. No correlation between the number of sutural bones with cephalic index was found.

Conclusion: The findings of this study are in agreement with the findings of many similar suitably powered studies across the world.

KEYWORDS: Sutural bones, Cephalic Index, dry crania, parieto-occipital, aterion, pterion, lambda, parieto-temporal, parieto-mastoid, occipito-mastoid.

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INTRODUCTION

Sutural bones, also known as intrasutural or wormian bones are accessory ossicles formed along sutures of calvaria, completely surrounded by sutures. Number, size and shape of the sutural bones vary widely. These miniature

bones are formed because of additional ossification centres which appear along sutures during development [1]. Sutural bones should be differentiated from preinterparietal and interparietal bones, which are the result of incomplete fusion of occipital bone ossification centers, and not surrounded by normal suture lines of skull [2]. Although regarded as normal, non-metric, hypostatic, or epigenetic variants of cranium, their formation have been attributed to sutural stress and gene mutation by some researchers [3].

Generally these intrasutural bones are few in number (0 – 10) and their presence in skull is considered as normal anatomical variant, but unusually more number (>10) of these bones serves as definite marker for diseases like osteogenesis imperfecta, cleidocranial dysostosis, craniosynostosis, rickets and hydrocephalus [4]. In radiological studies sutural bones, especially if these bones are large in size, can mimic signs of trauma or child abuse [5].

The knowledge of sutural bones is imperative for the medical practitioners as well as anthropologists. Important cases where it becomes essential to keep this knowledge in mind are those of skeletal dysplasia, a child with multiple cranial fracture, a medicolegal case with head injuries and a patient who has to undergo a skull surgery [5,6]. Anthropologists on the other hand utilize such knowledge in establishing identification of an individual or a population [7].

This study was undertaken to study incidence and pattern of distribution of sutural bones in the dry crania from Eastern India and to corroborate the findings with such studies across the world.

MATERIALS AND METHODS

Inclusion criteria:

· Adult human crania, in which sutures were well visible, were included for sutural bone observation and Cephalic Index measurement.

· A sutural bone was taken into account, only if it had well demarcated sutures around it.

Exclusion criteria:

· Skulls which were not well preserved or visibly damaged.

· Skulls in which sex could not be determined.

· Sutural bones with faint or obliterated sutures around it were disregarded.

· Interparietal and pre-inerparietal bones (Inca bones) were not counted as sutural bones.

The skulls which showed any feature indicative of skeletal immaturity or sutural separation or fontanelles were excluded.

METHODOLOGY

For each cranium, the sex determination was done using the scoring system as described in the book "Standards for data collection from human skeletal remains" [8] in which the morphology of the nuchal crest, mastoid process, supra-orbital margin, supra-orbital ridge and mental eminence are observed and graded. The crania were thoroughly examined with unaided eye as well as with magnifying glass as per requirement for the presence of sutural bones along all the sutures of calvaria and ossified fontanelles. Presence and location of sutural bone was noted. The photographs of the crania positive for sutural bones were taken with a digital camera for record.

Martin's spreading calipers with pointed ends and a least count of 1 mm was used for the measurement of Cephalic Index which was calculated using the formula suggested by Garson [9] as follows:

$$\text{Cephalic Index} = \frac{\text{Maximum breadth of the skull}}{\text{Maximum length of the skull}} \times 100$$

RESULTS

Incidence (Figure 1): Out of the total 180 dry crania studied, 124 were identified as male skulls and 56 as female skulls by the criteria as mentioned in Materials and Methods section.

Overall, 131 (72.28%) were found to be positive for sutural bones. The percentage of positives was similar in male (72.58%) and female (73.21%) skulls wherein 90 out of 124 and 41 out of 56 skulls were positive for sutural bones in the male and female skulls respectively.

Out of the 180 skulls studied, 49 (27.22%) were found to have no sutural bones, 74 (41.11%) had 1 to 3 sutural bones, 45 (25%) had 4 to 10 sutural bones and 12 (6.67%) had more than 10 sutural bones. The gender-wise distribution of these categories was found to be as follows:

• No sutural bones were found 34 (27.42%) of male skulls while 15 (26.79%) of the female skulls had no sutural bones.

• 1 to 3 sutural bones were seen in 57 (45.97%) male and 17 (30.36%) female skulls.

• 4 to 10 sutural bones occurred in 28 (22.58%) male and 17 (30.36%) female skulls.

• More than 10 sutural bones were observed in 5 (4.03%) male and 7 (12.5%) female skulls.

Although noticeable degree of variation in the categorical distribution of sutural bones was observed but overall this variation was not found to be statistically significant (P=0.06063).

Site-wise Incidence (Table 1): In the suture bone positive skulls, the maximum incidence of the sutural bones was found to occur at the parieto-occipital suture (Figure 2) in both the sexes (61.11% and 78.05% in males and females respectively) as well as overall wherein the sutural bones occurred at parieto-occipital suture in 66.41% of suture bone positive skulls. Second most common site for sutural bone occurrence was observed to be asterion (Figure 3) where the overall incidence was 37.4% of all the suture bone positive skulls. Even in both the sexes considered individually, asterion was the second most common site for the occurrence of sutural bones with 37.78% incidences occurring in males and 36.59% in females.

The next most common site for sutural bone occurrence was observed to be pterion (Figure 4) with 28.24% overall incidence in suture positive skulls followed by lambda (Figure 2) where sutural bones were seen in 24.43% of the sutural bone positive skulls.

The least common site for the sutural bone to occur was bregma where not a single sutural bone was come across. Other rare sites were sagittal suture (Figure 2) and parieto-mastoid suture (Figure 5) where the incidence in sutural bone positive skulls was observed to be 6.11% and 6.87% respectively.

Some noticeable sexual dimorphism was observed in the occurrence of sutural bones. There was a noticeable female preponderance for the sutural bones to occur at sites parieto-occipital sutures (78.05% vs. 61.11%), parieto-temporal sutures (26.83% vs. 13.33%) andsagittal suture (12.2% vs. 3.33%). On the contrary, sutural bone occurrence at lambda tended to be greater in males (26.67% vs. 19.51%). Despite such noticeable differences, statistical analysis of these variations failed to show any significant difference in the sexual dimorphism in the sutural bone occurrence at 95% confidence interval level.

Laterality (Table 2):

All the non-median sites exhibited a remarkable and statistically significant predisposition for unilateral occurrence of sutural bones, the only exception being the parieto-occipital sutures. Sutural bones occurring along coronal, parieto-temporal, parieto-mastoid, occipito-mastoid sutures and pterion exhibited more than 80% tendency towards unilateral occurrence while those occurring at asterion exhibited around 70% tendency towards unilateral occurrence. This predisposition for all sites excepting parieto-occipital sutures for unilateral occurrence was highly statistically significant for all these sites.

The sutural bones occurring along parieto-occipital suture, however, neither displayed any tendency towards laterality nor towards symmetry. Out of 87 skulls with sutural bones along parieto-occipital suture, 45 (51.72%) had sutural bones bilaterally while 42 (48.28%) had unilateral occurrence.

The overall trends observed for laterality were remarkably similar in both males and females. The statistical analysis for the variations of laterality in the two sexes yielded high P-values thus establishing uniformity of occurrence of the sutural bones across the sexes.

Side Preponderance (Table 3):

The unilaterally occurring sutural bones at various sites did not show any predilection towards any side in particular. The unilateral occurrence of sutural bones in the right side of the skull ranged from 42.86% for sutural bones occurring in right parieto-occipital and parieto-temporal sutures to 51.61% for those occurring at right pterion while the complimentary figure ranges were observed for the left side. On statistical analysis, these results were statistically very insignificant thus establishing that unilateral occurrence of sutural bones is randomly distributed in the population and no sutural bone has any side predilection.

When the unilateral sutural bones were studied in the two sexes, there was a noticeable difference in the distribution. In males, the unilateral sutural bones at pterion (60%) and asterion (60%) occurred more towards right side and those along parieto-temporal suture (66.67%) occurred more towards left side. In females however, the unilateral sutural bones at pterion (63.64%), asterion (77.78%) and along parieto-occipital suture (62.2%) had a left predilection while those at coronal suture (60%) had a right predilection. These variations in the genders, when analyzed statistically, turned out to be insignificant indicating that no side predilection exists for unilateral sutural bones in either of the sexes.

Fig. 1: Frequency distribution of sutural bones in dry crania (n=180). Blue part of the bar depicts frequency distribution in male skulls (n=124) while red part depicts frequency distribution of female skulls (n=56). Overall genderwise frequency distribution was not found to be statistically significant (P=0.06063).

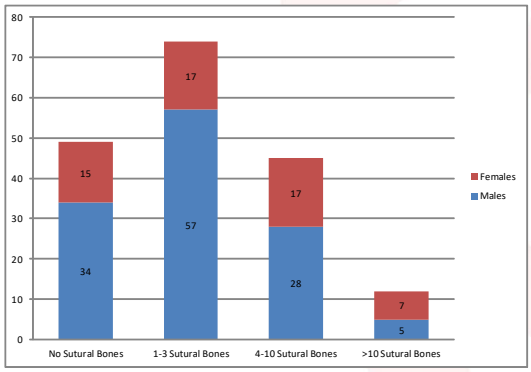
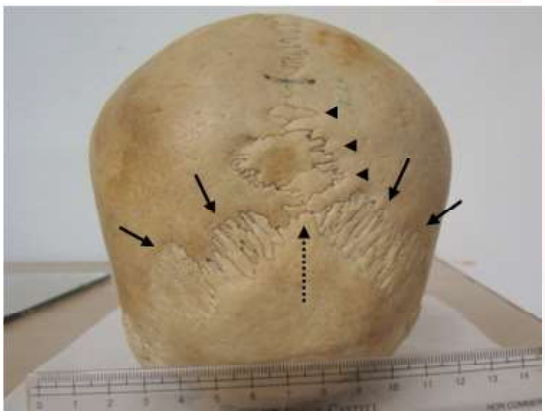


Fig. 2: Multiple sutural bones seen at parieto-occipital suture (solid arrows), lambda (dotted arrow) and sagittal suture (arrow heads).



Correlation of No. of Sutural Bones with Cephalic Index (Figure 6): Cephalic Indices (as described in Materials and Methods section) of the skulls were plotted against the number of sutural bones present in the same skulls to analyze and observe any correlation between these two parameters and the correlation coefficient was calculated. No correlation was observed from the plot and a very small value for correlation coefficient (r=0.044333) confirmed the same.

Fig. 3: Sutural bone at asterion (arrow).

Fig. 4: Sutural bone at pterion (arrow).

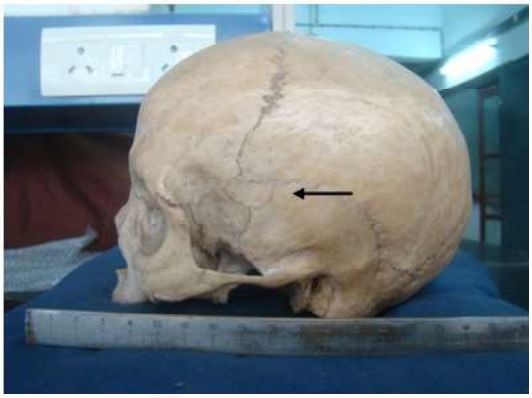


Fig. 5: Sutural bone at parietomastoid suture (arrow).

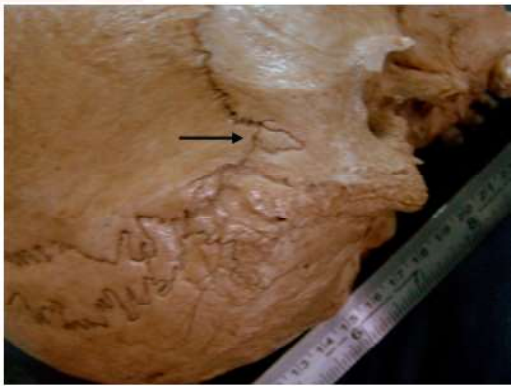


Fig. 6: Co-relational scatter plot between Number of Sutural Bones and Cephalic Index. No significant correlation is observed (r=0.04433)

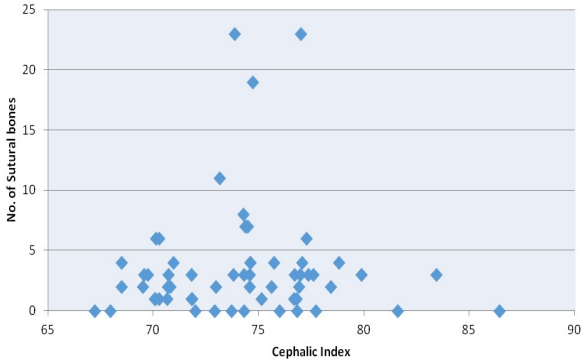


Table 1: Site wise sutural bone distribution in the skulls positive for sutural bone: overall and across the sexes in the studied dry crania. Figures in parentheses show actual numbers.

	All Positive	Males	Females	P-value^
Coronal	10.69% (14)	8.89% (8)	14.63% (6)	0.3659*
Pterion	28.24% (37)	26.67% (24)	31.71% (13)	0.5523
Parieto-temporal	17.56% (23)	13.33% (12)	26.83% (11)	0.05947
Parieto-mastoid	6.87% (9)	7.78% (7)	4.88% (2)	0.7193*
Asterion	37.4% (49)	37.78% (34)	36.59% (15)	0.8959
Occipito-mastoid	16.79% (22)	14.44% (13)	21.95% (9)	0.2865
Parieto-occipital	66.41% (87)	61.11% (55)	78.05% (32)	0.057
Lambda	24.43% (32)	26.67% (24)	19.51% (8)	0.3768
Sagittal	6.11% (8)	3.33% (3)	12.2% (5)	0.1073*
Bregma	0% (0)	0% (0)	0% (0)	NA

^ P-values for variation in gender wise distribution of sutural bones at different sites. All p-values except starred calculated using Chi-Square test.

* P-value calculated using Fisher's Exact test due to sparse data.

Table 2: Site wise laterality in the skulls positive for sutural bone: overall and across the sexes in the studied dry crania. Figures in parentheses show actual numbers.

	Overall			Male		Female		*P-value
	Bilateral	Unilateral	^P-value	Bilateral	Unilateral	Bilateral	Unilateral	
Coronal	14.29% (2)	85.71% (12)	0.0065	12.5% (1)	87.5% (7)	16.67% (1)	83.33% (5)	1
Pterion	16.22% (6)	83.78% (31)	0.000021	16.67% (4)	83.33% (20)	15.38% (2)	84.62% (11)	1
Parieto-temporal	8.7% (2)	91.3% (21)	0.000033	0%	100% (12)	18.18% (2)	81.82% (9)	0.2174
Parieto-mastoid	11.11% (1)	88.89% (8)	0.01953	14.29% (1)	85.71% (6)	0%	100% (2)	1
Asterion	30.61% (15)	69.39% (34)	0.0047	26.47% (9)	73.53% (25)	40% (6)	60% (9)	0.5022
Occipito-mastoid	18.18% (4)	81.82% (18)	0.002172	15.38% (2)	84.62% (11)	22.22% (2)	77.78% (7)	1
Parieto-occipital	51.72% (45)	48.28% (42)	0.4152	52.73% (29)	47.27% (26)	50% (16)	50% (16)	0.8275

^ P-values for overall variation in symmetry. All p-values calculated using Binomial Exact test.

* P-value for gender wise variation in symmetry. All p-values calculated using Fisher's Exact test.

Table 3: Site wise side preponderance in the skulls positive for unilateral sutural bone: overall and across the sexes in the studied dry crania. Figures in parentheses show actual numbers.

	Unilateral: Overall			Unilateral: Male		Unilateral: Female		*P-value
	Right	Left	^P-value	Right	Left	Right	Left	
Coronal	50%(6)	50%(6)	0.6128	42.86%(3)	57.14%(4)	60%(3)	40%(2)	1
Pterion	51.61%(16)	48.39%(15)	0.5	60%(12)	40%(8)	36.36%(4)	63.64%(7)	0.2734
Parieto-temporal	42.86%(9)	57.14%(12)	0.3318	33.33%(4)	66.67%(8)	55.56%(5)	44.44%(4)	0.3964
Parieto-mastoid	50%(4)	50%(4)	0.6367	50%(3)	50%(3)	50%(1)	50%(1)	1
Asterion	50%(17)	50%(17)	0.5679	60%(15)	40%(10)	22.22%(2)	77.78%(7)	0.1175
Occipito-mastoid	44.44%(8)	55.56%(10)	0.4073	45.45%(5)	54.55%(6)	42.86%(3)	57.14%(4)	1
Parieto-occipital	42.86%(18)	57.14%(24)	0.2204	46.15%(12)	53.85%(14)	37.5%(6)	62.5%(10)	0.7501

^ P-values for overall variation in side preponderance. All p-values calculated using Binomial Exact test.

* P-value for gender wise variation in side preponderance. All p-values calculated using Fisher's Exact test.

DISCUSSION

Sutural bones, when present without any clinical findings, are considered as normal variants in human cranium [10]. However, their presence may pose challenges, both diagnostic, as in radiology where they may be confused with fractures or signs of child abuse in skull radiographs [11], and therapeutic as in surgeries involving skull bones where they may pose difficulties in landmark identification [12] or may induce complications by breaking away during the procedure [13].

The above mentioned clinical importance assumes greater significance if the incidence of the sutural bones in the normal local population is high.

The incidence of sutural bones in the normal population varies with the population under study and is considered a population characteristic [14]. The worldwide incidence has been reported from as low as 10% in Caucasians to as high as 80% in the Chinese population [15].

The Indian population is quite varied and it is no surprise that the reported sutural bone incidence from the Indian population is quite varied too. William F. Masih [16] , from his study in Rajasthan, reported a incidence of 4.7%. On the other hand, Muralimanju BV et al, [17] who also studied dry skulls from the Indian population, reported a incidence of 73.1%.

In this study done on 180 dry skulls, 131 skulls were found positive for sutural bones thus presenting a incidence of 72.28% which is quite similar to that reported by Muralimanju BV et al [17].

Generally, the normal population is considered to exhibit zero to three sutural bones [1] and this study was no exception to this statement as 123 skulls out of 180 (68.33%) fell in the category of 0-3 sutural bones (Figure 1).

Gender-wise incidence was similar across the male and female skulls in this study with incidence in males being 72.58% and in females being 73.21% . The categorical incidences in this study, too, showed similar trends and the differences observed in the categories between the sexes were statistically non-significant (P=0.06063). The reported incidence in males and females is quite varied with some studies reporting a preference for sutural bone incidence in males [16] while others have reported this preference for females [18] and still others have reported no preference [19]. However, the common agreement between all these studies is that even those authors, who have reported sexual dimorphism, agree that this dimorphism, if any, is statistically insignificant and this fact is, conceptually, a fundamental requirement for anthropological population studies on sutural bones.

This study indicates that the most common site for sutural bone incidence is parieto-occipital (lambdoid) suture followed by asterion, pterion and lambda where the incidence was 66.41%, 37.4%, 28.24% and 24.43% respectively in the suture bone positive skulls (Table 1). Less common sites of occurrence are the coronal (6.11%) and sagittal (6.87%) sutures while least common is bregma at which not a single sutural bone was found. These results, in general, in agreement with the works of many researchers wherein many have reported most common occurrence at lambdoid suture [1,2,17,18,20,21]. Asterion, pterion and lambda have been reported to be common sites of sutural bone occurrence and some studies reported them to be the most common site of occurrence according to their findings [22,23]. The least common site has been reported to be the bregma by almost all the researchers[17,18,21,24].

Some degree of variation in sutural bone occurrence in males and females was observed in this study (Table 1). Sutural bone occurrence at parieto-occipital, parieto-temporal and sagittal sutures was noticeably more in females while that at lambda was noticeably more in males. However, these findings failed to demonstrate any statistical significance. Similarly, many workers have noticed sexual dimorphism in the occurrence of sutural bones at various sites but have failed to demonstrate statistical significance for the sexual dimorphism [18,20,25]. On the contrary, few workers have indeed reported significant sexual dimorphism for sutural bones at some sites [19]. The applied aspect of such reported sexual dimorphism is currently unknown.

A highly statistically significant observation in this study was the tendency towards unilaterality for all non-median sutural bones with the only exception being the sutural bones at parieto-occipital suture which occurred bilaterally and unilaterally with almost equal predisposition (Table 2). This general trend was maintained in males and females and any statistical difference between the sexes for unilaterality was not observed (Table 2). Such significant differences in lateralilty have been reported by various workers viz. AA Khan [26], Rajani Singh [25], and R Sudha [22] reported unilaterality at asterion while Murlimanju BV et al [17] and R Sudha [22]

reported at pterion. The reports for unilaterality at other sites seem to be very sparse as these could not be located and neither could any literature on sexual dimorphism in laterality come across.

Since many sites of sutural bone occurrence had tendencies towards unilaterality, a study of side wise distribution for these sutural bones was undertaken in skulls with unilateral sutural bones. The distribution on both sides was found to be similar and statistically very insignificant thus implying no side preference for any sutural bone occurrence (Table 3). This is in unison with the works of GP Pal [20] who also noticed no significant side predilection for sutural bones in general, Rajani Singh [25] whose work on asterion showed unilaterality but no side preponderance and also R Sudha [22], whose work on pterion showed no side predilection. These results, in general, were applicable across the sexes also. However, a few noticeable differences were noted such as asterion and pterion tended to occur more on right side in males while on the left side in females (Table 4). Since the absolute number of skulls in the male and female groups was quite small, hence this observation could not translate into statistical significance. Prabha Antony Mary [27] also reported difference in side preponderance for pterion in males and females which was opposite to that of our study but did not report any statistical significance. Since, the absolute number of skulls with sutural bone at pterion in male and female group in their study was even smaller than that in our stud, their result too can logically be assumed to be statistically insignificant as in our study. Further literature on sexual dimorphism for side preponderance is lacking in all probability.

In this study, the correlation between the number of sutural bones with cephalic index was determined. It turned out that there was essentially no relation between these two parameters as correlation coefficient (r) was calculated to be 0.044333 (Figure 6). E. Gumusburun et al [28], too, in their study of 302 skulls found no such correlation as neither did GP Pal [29] in his study. However, on the contrary, Sanchez Lara PA et al [30] reported that there was a tendency for the sutural bones to increase as the skulls became more brachycephalic. However, this observation could likely be due to chance as their study included only 20 skulls. A non-relation between number of sutural bones and cephalic index, as indicated by better statistically powered studies as by E. Gumusburun [28] and present study, is more probable.

CONCLUSION

This study concludes the following:

Most of the persons have zero to three sutural bones in their cranium and are essentially normal variations.

Commonest site of sutural bone occurrence is the lambdoid suture. Other sites of common sutural bone occurrence are asterion, pterion, lambda, parieto-temporal suture and occipito-mastoid suture. Rarer sites are coronal and sagittal sutures. Rarest site is bregma.

Except for the sutural bones occurring at lambdoid suture, which have an equal tendency of occurring bilaterally or unilaterally, all other non-median sutural bones have a very strong tendency to occur unilaterally. However, there is no side predilection for unilaterally occurring sutural bones and these can safely be considered to be distributed randomly on the right or left side in the human population.

The males and females populations exhibit the same general patterns mentioned above and there is no statistically significant difference between the sexes. Hence, any population study on sutural bone occurrence may be undertaken without regard to gender.

Conflicts of Interests: **None**

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