

Estimation of Age of a Person by Cranial Suture Closing Pattern

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Abstract- Age estimation from skeletal remains is a fundamental task in forensic anthropology, bioarcheology, and medico-legal investigations. Cranial suture closure, a long-debated marker of age progression, presents a potential avenue for estimation—particularly in cases where other skeletal indicators are absent or damaged. This study aimed to evaluate the relationship between ectocranial suture closure and chronological age using adult human skulls. Employing the AcsádiNemeskéri scoring system, the degree of closure at selected suture sites (sagittal, coronal, and lambdoid) was quantified across a sample of 15 documented skulls. Statistical analyses, including Pearson's correlation and Chi-square tests, revealed a significant association between suture closure stages—particularly at the Pars Bregmatica region—and advancing age ($p = 0.016$), supporting its value as a supplementary age estimation tool. Results showed that sutures progressively close with age, with early closure (scores 0–1) dominant in individuals aged 20–30 years and complete obliteration (score 3) observed in individuals above 50 years. While inter-individual variability and sample size limit universal applicability, the study confirms that cranial sutures, when scored systematically and interpreted cautiously, can contribute meaningful data in forensic and anthropological contexts. Furthermore, the research highlights the importance of region-specific reference data and advocates for the integration of suture analysis into multifactorial age estimation models. Overall, this dissertation reasserts the relevance of cranial suture closure as a non-invasive, accessible, and contextually valuable method for age estimation.

I. INTRODUCTION

Over the past century, the fields of forensics, archaeology, and paleo demography have grown exponentially. With such expansion has come the development of techniques capable of telling the story

of unknown skeletal remains. Bones contain within themselves a multitude of information, but without the development of techniques for assessing this information, little about the persons to whom skeletons belonged, and the greater cultural and historical context in which they lived, can be discovered. Today, the establishment of biological profiles from unknown skeletal remains helps reveal a detailed picture of past events.

Determination of the age at death of individuals from unidentified skeletal remains is one crucial step in osteological analysis. Numerous studies over the past century have been conducted to assess the accuracy of qualitative and quantitative observations for estimating age at death. As complete skeletons are rarely recovered or preserved, and skeletal material can become easily fragmented, it has become necessary to develop techniques for age estimation from as many different bones bearing age markers as possible. Indeed, the entire skeleton has been canvassed for such markers and with much success. According to İşcan (1989:14), nearly every bone contains an age marker, but it is important that we “know where to look and how to recognize and interpret them.” This pursuit to properly interpret which areas of the skeleton exhibit morphological changes with age has been immense. Some of the most well-documented and utilized age indicators include cranial suture closure, dentition, epiphyses and ossification centers, and the articulating surfaces of the *os coxae* (pubic symphyses and auricular surface).

The oldest and most controversial age indicator is cranial suture closure. Beginning in the sixteenth century, the cranial sutures were believed to change morphologically with age. Since then, cranial suture closure has been widely addressed. Over the years,

many investigators have concluded that suture closure is too variable and does not correlate well.

with age, and should therefore not be used in age estimations (Singer, 1953; Brooks, 1955; Masset, 1989; Hershkovitz et al., 1997), whereas others favor its inclusion (Acsádi & Nemeskéri, 1970; Meindl & Lovejoy, 1985).

Such opposition has not led to a dismissal of interest in cranial suture closure, but has inspired new generations to take up the subject matter in pursuit of explanation. A large reason for this continued quest lies in the lack of definitive knowledge of the structural and functional relationships of sutures. Additionally, the cranium is the most well- preserved part of the human skeleton, necessitating a greater need for it to contain age markers (Brooks, 1955; McKern, 1957; Key et al., 1994). Traditional suture closure studies examined cranial remains of known age in order to develop sequences of suture closure. Sutures were classified into degrees of obliteration and assigned discrete integer scores for each closure stage. Correlations with age were then calculated through rank- order analysis. Though even the earliest authors (19th Century) employed these scoring methods and found contradictory results, methods based on the same framework still persist today, utilized by forensic anthropologists typically as one of many age indicators.

Recent developments in technology, however, have streamlined the ability to collect and analyze data and opened the door for new and more accurate methods to be created. Though such technologies were not developed specifically for anthropological investigation, their extended application has been very useful. For instance, X-rays and CT scans, primarily used in the field of medicine, have now become tools in the analysis of skeletal material. In another field, dental hygiene, a new laser technology has been developed that can detect tooth decay much earlier than the previous methods of X-rays and probing (KaVo Dental Corporation, 2007). This technology consists of a device, known as the DIdent, which

measures the amount of reflected laser light, or fluorescence, from a tooth surface. Those teeth that exhibit dental caries will reflect lighter than a solid, healthy tooth.

II. MATERIALS AND METHODS

Permission was obtained from the authorities of Mysore medical college, Mysore city for data collection a total 15 skulls were randomly selected, without any pre-existing data such as age, gender, or other personal identifiers each skull was systematically divided into sections, C1, C2, and C3 for the coronal suture, S1, S2, S3, and S4 for the sagittal suture, and L1, L2, L3, for the Lambdoid suture, the degree of suture closure was scored according to the Acsadi-Nemeskeri complex method. Age estimation was carried out based on average closure scores, which were interpreted using the following scale.

- 0.5 = below 20 years
- 0.5 -1.5 = 20 – 30years
- 1.5 – 2.5 = 30 – 40 years
- 2.5 – 3.5 = 40 – 50 years
- 3.5 – 4.0 = above 50 years

For statistical analysis, descriptive statistics (percentage and frequency) Were calculated, The Pearson chi-square test was applied as an inferential statistical tool.

Suture Scoring Scale

System Used: Acsadi-Nemeskeri complex method Scores:

- 0 = Open. There is still little space left between edges of adjoining bones.
- 1 = Incipient closure. Clearly visible as a continuous often zigzagging line.
- 2 = Closure in process. Line thinner, less zigzags, interrupted by complete closure.
- 3 = Advanced closure. Only pits indicate where the suture is located.
- 4 = Closed. Even location cannot be recognized.

TABLE :1 STATISTICAL ANALYSIS

SL No	Coronal suture			Sagital suture				Lambdoid suture			Average estimated age	
	C1	C2	C3	S1	S2	S3	S4	L1	L2	L3		
Skull 1	3	2	2	4	4	4	3	2	3	2	40-50 years	3

Skull 2	2	2	2	2	2	2	1	3	3	3	30-40 years	2
Skull 3	1	1	1	2	2	2	2	3	3	3	30-40 years	2
Skull 4	2	2	1	2	3	2	1	2	2	3	30-40 years	2
Skull 5	2	2	2	2	2	2	3	3	3	3	40-50 years	3
Skull 6	2	2	1	3	3	3	3	1	3	3	30-40 years	2
Skull 7	1	1	1	1	2	3	1	2	1	1	20-30 years	1
Skull 8	2	1	1	1	1	1	1	2	1	1	20-30 years	1
Skull 9	3	3	3	1	1	1	1	1	1	1	30-40 years	2
Skull 10	1	1	1	1	1	1	1	1	1	1	20-30 years	1
Skull 11	4	4	4	4	4	4	4	4	4	4	Above 50 years	4
Skull 12	2	2	2	2	2	2	2	2	2	2	30-40 years	2
Skull 13	2	2	3	2	2	3	3	2	2	2	30-40 years	2
Skull 14	1	1	1	2	2	2	2	2	2	2	30-40 years	2
Skull 15	2	2	2	2	2	2	2	2	2	2	30-40 years	2

Table 1

The table presents the distribution of suture closure scores for the coronal, sagittal, and lambdoid sutures, assessed using the Acsádi–Nemeskéri complex method. Mean values were calculated and subsequently compared with the reference mean score ranges to determine the corresponding average age intervals.

TABLE 2: AGE DISTRIBUTION

Suture name		Age distribution				
			20-30Y	31-40Y	41-50Y	50+Y
Coronal suture	C1	Pars bregmatica	3	9	2	1
	C2	pars complicata	3	9	2	1
	C3	pars pterica	3	9	2	1
Sagittal suture	S1	Pars bregmatica	3	9	2	1
	S2	Pars verticis	3	9	2	1
	S3	Pars obelica	3	9	2	1
	S4	Pars lambdica	3	9	2	1
Lambdoid suture	L1	Pars lambdica	3	9	2	1
	L2	Pars intermedia	3	9	2	1
	L3	Pars asterica	3	9	2	1

Table -2

The analysis of 15 skulls, suture closure patterns revealed that 3 skulls belonged to the age group of 20-30 years, 9 skulls to the 31-40 years, 2 skulls to the 41-50 years, and 1 skull to the 50+ age group.

TABLE 3: PEARSON CHI-SQUARE DISTRIBUTION

SUTURE NAME		Pearson chi-square			
			value	df	asympt sim(2 sided)
Coronal suture	C1	Pars bregmatica	20.313	9	0.016
	C2	Pars complicata	23.25	9	0.006
	C3	Pars pterica	22.571	9	0.007
Sagittal suture	S1	Pars bregmatica	20.729	9	0.014

	S2	Pars verticis	15.868	9	0.07
	S3	Pars obelica	17.004	9	0.049
	S4	Pars lambdica	25.833	9	0.002
Lambdoid suture					
	L1	Pars lambdica	17.257	9	0.045
	L2	Pars intermedia	29	9	0.002
	L3	Pars asterica	25.333	9	0.003

Table-3

All parts of the coronal suture show significant association with age progression, I.e, (p<0.05).

Most of the regions of sagittal suture show significant association with age progression except S2 (pars verticis) since (p>0.05), all lambdoid suture shows significant association with age, I.e, (p<0.05).

TABLE 4: ACSADI NEMESKERI SCALE DISTRIBUTION

SUTURE NAME			SCALE OF ACSADI NEMESKERI			
			1	2	3	4
Coronal suture						
	C1	Pars bregmatica	4	8	2	1
	C2	Pars complicata	5	8	1	1
	C3	Pars pterica	7	5	2	1
Sagittal suture						
	S1	Pars bregmatica	4	8	2	1
	S2	Pars verticis	3	8	2	2
	S3	Pars obelica	3	7	3	2
	S4	Pars lambdica	6	4	4	1
Lambdoid suture						
	L1	Pars lambdica	3	8	3	1
	L2	Pars intermedia	4	5	5	1
	L3	Pars asterica	4	5	5	1

Table 4

In the pars bregmatica region of the coronal suture, incipient closure was observed in 4 skulls, closure in process in 8 skulls, advanced closure in 2 skulls, and complete closure in 1 skull.

In the pars complicata region of the coronal suture, incipient closure was observed in 5 skulls, closure in process in 8 skulls, advanced closure in 1 skull, and complete closure in 1 skull.

In the pars pterica region of the coronal suture, incipient closure was observed in 7 skulls, closure in process in 5 skulls, advanced closure in 2 skulls, and complete closure in 1 skull. In the pars bregmatica region of the sagittal suture, incipient closure was observed in 4 skulls, closure in process in 8 skulls, advanced closure in 1 skull, and complete closure in 2 skulls.

In the pars verticis region of the sagittal suture, incipient closure was observed in 3 skulls, closure in

process in 8 skulls, advanced closure in 2 skulls, and complete closure in 2 skulls.

In the pars obelica region of the sagittal suture, incipient closure was observed in 3 skulls, closure in process in 7 skulls, advanced closure in 3 skulls, and complete closure in 2 skulls.

In the pars lambdica region of the sagittal suture, incipient closure was observed in 6 skulls, closure in process in 4 skulls, advanced closure in 4 skulls, and complete closure in 1 skull.

In the pars lambdica region of the lambdoid suture, incipient closure was observed in 3 skulls, closure in process in 8 skulls, advanced closure in 3 skulls, and complete closure in 1 skull.

In the pars intermedia region of the lambdoid suture, incipient closure was observed in 4 skulls, closure in process in 5 skulls, advanced closure in 5 skulls, and

complete closure in 1 skull.

In the pars asterica region of the lambdoid suture, incipient closure was observed in 4 skulls, closure in

process in 5 skulls, advanced closure in 5 skulls, and complete closure in 1 skull.

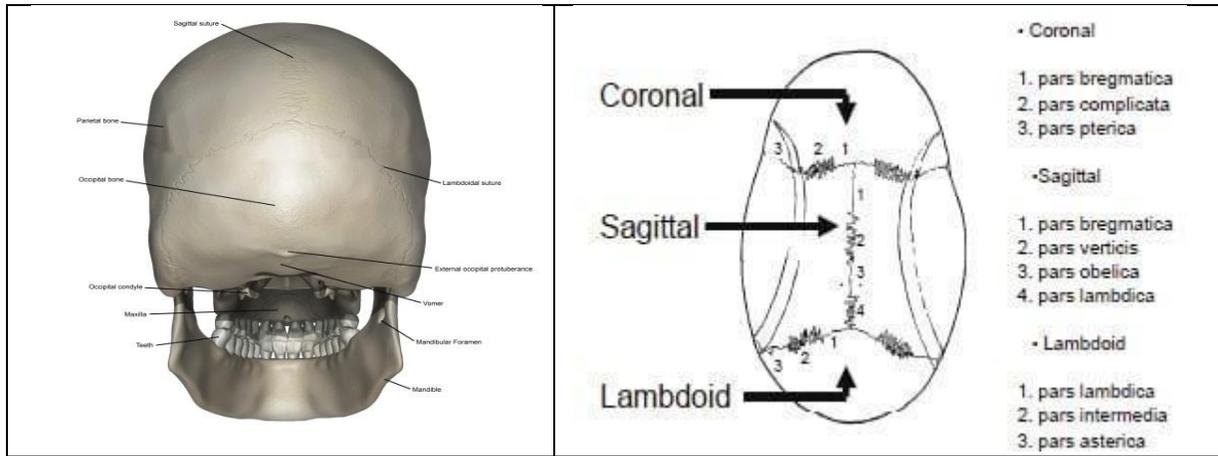


Figure 1: Distribution of different sutures in human skull

III. DISCUSSION AND SUGGESTION

Cranial suture closure has always been a point of debate in forensic and anthropological studies. Many researchers have considered it to be unreliable because the degree of closure does not always match well with a person's age. In this study, however, the findings show that even with its limitations, suture closure can still be a useful supportive tool for estimating age, especially in situations where other skeletal features are missing or too damaged to study.

The statistical analysis in this research showed a clear positive correlation between suture closure—particularly at the *pars bregmatica* of the coronal suture—and chronological age. Closure scores were found to increase steadily with age, and complete obliteration was mostly seen in individuals above 50 years. These results are in line with the classic works of Todd and Lyon, Meindl and Lovejoy, and several others who also noted similar age-related patterns in cranial sutures.

The results further suggest that cranial suture closure is more reliable when applied to middle-aged and older individuals (30–50 years and above). In younger individuals, however, the closure pattern is too variable to provide an accurate estimate. For this reason, in forensic cases where the remains are of older individuals and other key features such as the pubic symphysis or epiphyseal plates are unavailable, cranial

sutures can still be used as an important age estimation criterion.

IV. SUGGESTIONS FOR FUTURE RESEARCH

1. A larger sample size with individuals from different populations should be studied to check for consistency and population-specific differences.
2. Suture closure should be combined with other skeletal and radiological methods to improve the overall accuracy of age estimation.
3. Each sutural region should be studied separately (for example, sagittal or lambdoid) as they may close at different rates.
4. Modern techniques like CT scans can be used to study closure more objectively and reduce observer bias.

To conclude, cranial suture closure alone should not be considered a fully reliable method, but when used alongside other indicators, it becomes an important supplementary tool—especially for middle-aged and elderly individuals in forensic cases.

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