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**Research Article**

# Forensic Investigation Of Wormian Bones In Northwest Indian Population- A CT Scan Based Study

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**ABSTRACT**

Skeletal remains play a significant role in the process of personal identification. These remains may indicate an important lead in investigation.Wormian bones are the bones developed within the cranial sutures. These bones are small and irregular in shape and size. In forensic scenario, if studied carefully, may prove an important collaborative evidence but very little research on this aspect has been published. Therefore, the main objective of the present study was to investigate the prevalence of wormian bone in contemporary Northwest Indian population, their topographic distribution, possible correlations with sex and age through CT scan data of skull. The sample size for the current study was 1248 CT scans of Northwest Indian population (636 male and 612 female) between the age group of 20 to 80 years. Total six parameters were under investigation for the present study. The percentage of subjects with the presence of wormian bone, location, type, direction, shape, vertical and transverse diameter of wormian bone were analysed. The percentage of incidence of wormian bone was 30.4% in the collected sample, with males having 18.6% and females with 11.7%. As per the analysis of the samples, the highest percentage of wormian bones was present on the centre with 48.9%. All the types of wormian bones were present in the present study except type 11 and type 12. Male exhibits higher values of vertical and transverse diameter than female. But there was no statistically difference in vertical and transverse diameter of male and female wormian bone, according to p-value (VD-0.403 and TD- 0.914). It was evident from the present study, that the incidence of wormian bone is very less in the present population as compared with other population. Therefore, it can be used in identification of an individual and for the estimation of an ancestry for the present population group. Radiologists may find the wormian bone's insights to be helpful in distinguishing between fractured and normally sutured bones. Wormian bones can be used in identification of an individual and for the estimation of an ancestry for the present population group.

**Keywords:** Wormian bone, Os incae, CT scan, Lambda, Lambda suture

## Introduction

Wormian bones are the bones developed within the cranial sutures. These bones are small and irregular in shape and size. Cranial sutures are the fibrous type of joints present between the bones of skull. These sutures provide the room for expansion during the growth of skull bones. Wormian bones develop from the extra ossification centers within the cranium. This term, wormion bone, was historically coined by Thomas Bartholin in honor of Olaus Wormious, a Dutch anatomist [1, 2]. Intercalary, intrasutural bones are the alternative nomenclature of wormian bone [3]. The actual reason for the formation of wormian bones is not known till date. A number of theories have been suggested by different scientists but not a single one was accepted universally. They have drawn different explanations such as incidence of these bones is normal, may be hereditary or due to external factors which are responsible for the same [4-6]. Earlier studies suggest that these bones are identified on lambdoid suture, coronal suture and lambda, mostly on the right side of the

skull [7-8]. These bones are also found at other locations such as bregma, pterion, saggital suture, occipitomastoid suture and parietomastoid suture [9]. Wormion bones are present in normal individual but their presence also has pathological and diagnostic indications [10]. A number of factors such as location, shape, number and size are responsible for differentiating normal wormion bones from pathology [11]. Presence of wormion bone is an indicative of different disorders like osteogenesis imperfecta, pycnodysostosis, rickets, kinky hair syndrome, hypothyroidism and otopalatodigital syndrome [7, 11]. Anthropologists suggest that environmental factor also plays an important role in formation of wormion bones on posterior side as compared to anterior part of skull [7]. Incidence of wormion bones in Chinese population is highest. It is approximately 80% as compared to other population of the world, due to the environmental factors responsible for the same [12]. Traditionally, Chinese infants have supine sleeping position which puts an extra pressure on posterior cranial vault and results in the expansion of posterior cranial sutures [13]. Finally this results in wider cranial base and foreshortened wider face in Chinese [7].
The main objective of the present study was to investigate the prevalence of wormion bone in contemporary Northwest Indian population, their topographic distribution, correlations with sex and age through CT scan data of skull.

## Material and Methods

The present study is based on retrospective CT scan of skull, collected from the Department of Radio-Diagnosis and Imaging. The study was conducted after obtaining the approval from institutional ethical committee (IEC). The sample size for the current study was 1248 CT scans of Northwest Indian population (636 male and 612 female) between the age group of 20 to 80 years.

### Inclusion and Exclusion criteria

The subjects with previous history of fracture, trauma, any pathology or congenital disorders which can alter the dimensions of the skull bones were excluded from the current study.
Ten subjects with history of skull fracture at occipital bone along with presence of wormian bone were included in the present study to differentiate between the fracture and wormian bone.
The equipment used for the acquired scans was 128 slice CT scanner of GE company with single source (X ray tube).
After the collection of raw data, scans were reconstructed using the 3-D volume rendering technique for the visualization of wormian bones. This was done by Radiant DICOM viewer (64 bit) software version 2021.2.2, manufacturer Medixant.
The parameters under investigation were as follow:

1) The percentage of subjects with presence of wormian bone.
2) The location of wormian bones in relation with sutures of skull.
3) The types of wormian bone as per the classification drafted by Kadanof and Mutafov 1964 [14].
4) Direction of the wormian bone present on the skull (right, left, centre or on bilateral side).
5) The shape of the wormian bone present on the skull (round, oval, triangular, quadrangular or irregular).
6) The vertical and transverse diameter of wormian bone.
7) Correlation of wormian bone with sex and age.

### Statistical analysis

The acquired data was statistically analysed by using IBM SPSS (Statistical Package for Social Science, version 23.0).
All the measured values of vertical diameter, transverse diameter, area and perimeter of wormian bones were subject to descriptive statistics to calculate mean, minimum, maximum values and standard deviation (SD). Data was
statistically analysed by applying chi square test to report the association between sex and incidence of wormian bones.

## Results

### Incidence of wormian bone

The sample size for the current study was 1248 (636 male and 612 female). The subjects with the presence of wormian bone were 380 (233 male and 147 female). The percentage of incidence of wormian bone was 30.4% in the collected sample, with males having 18.6% and females with 11.7% (Table1).

As per the results of chi square test, there was close association of incidence of wormian bone with sex, as the values were statistically significant ($\chi^2$= 22.802 and p-value<0.05).
The number of wormian bones present on skull was categorized into one, two, three, four and more than four bones as multiple bones. The number of subjects with the presence of one wormion bone was 164 (102 male and 62 female). Two wormian bones were present in 82 subjects (41 male and 41 female). Three wormian bones were present in 42 subjects (25 male and 17 female). The numbers of subjects with four wormian bones were 22 (11 male and 11 female). More than four wormian bones were categorized under multiple bones. And total number of subjects with multiple wormian bones were 70 (54 male and 16 female) (Table 2).

### Location and direction of wormian bone

The total numbers of wormian bones present on lamdoid suture (LS) were 223 (58.6%), 164 bones were found on lambda (43.1%), number of bones present on saggital suture were 30 (7.8%), bones on parietomastoid suture (PMS) were 8 in number (2.1%) and number of wormian bones present on occipitomastoid suture (OMS) were 5 (1.31%) respectively (Table 1). As per the analysis of the samples, there were 186 (48.9%) wormian bones present on the centre, 165 (43.4%) on bilateral sides, 65 (17.1%) on the left side and 48 (12.6%) on the right side. There was statistical insignificant difference on the incidence of wormian bone on centre, bilateral, left and right side ($\chi^2$= 3.555 and p-value>0.05) (Table 3). This signifies that, there was symmetrical distribution of wormian bones.

### Shape and types of wormian bones

All the wormian bones present in the sample were categorized into different shapes such as round, oval, triangular, quadrangular and irregular (Table 4).

Detected wormian bones were categorized into different types as per the classification of Kadanof and Mutafov 1964 [14] (Table 5). The following types of wormian bones were detected in the present study:

1) Type 1: Os Incae totum (Fig. 1)
2) Type 2: Os Incae bipartitum (Fig. 2)
3) Type 3: Os Incae tripartitum (Fig. 3)
4) Type 4: Os Incae quadripartitum (Fig. 4)
5) Type 5: Os Incae multipartitum (Fig. 5)
6) Type 6: Os Incae laterale sinistrum (Fig. 6)
7) Type 7: Os Incae central (medianum) (Fig.7)
8) Type 8: Os Incae laterale dextrum (Fig. 8)
9) Type 9: Os Incae duplex symmetricum (Fig. 9)
10) Type 10: Os Incae duplex asymmetricum (Fig. 10)

Type 11, pars incoidea squamae occipitalis (processus sagittalis squamae occipitalis and type 12, remnant of sutura mendosa were not detected in the present study.

### Size of the wormian bone

Descriptive statistics was used for the calculation of mean, standard deviation (SD), maximum and minimum values of the vertical diameter (VD) and transverse diameter (TD) of wormian bone. The largest wormian bone among all the detected wormian bones on each sample was selected for taking vertical and transverse measurements. The mean values of vertical diameter were 2.29cm (male) and 2.21cm (female) and mean values of transverse diameter were recorded as 2.54cm (male) and 2.52cm (female) (Table 6). Male exhibits higher values of vertical and transverse diameter than female. But there was no statistically difference in vertical and transverse diameter of male and female wormian bone, according to p-value (VD-0.403 and TD-0.914).

### Skull fracture Vs Wormian bone

Wormian bones show as little, spherical, or irregularly shaped bones within the sutures like zig-zag pattern and can be observed on imaging examinations such as CT scans or X-rays. On imaging, skull fractures may show up as distinct cracks or abrupt discontinuities in the bone (Figure 11a, 11b, and 11c). Wormian bones are changes that occur naturally rather than as a result of trauma. Trauma or external pressures applied to the head are frequently linked to skull fractures.

## Discussion

The present study was conducted to examine the variation, frequency, topography, shape, type and size of wormian bone in the contemporary Northwest Indian population. As per the review of literature there are very less number of studies conducted on wormian bone for Indian population through CT scan. Moreover literature is very limited on wormian bone analysis through radiological modalities. Incidence of wormian bones is not so common and percentage of these bones detected in the present study was 30.4%. A small percentage often hints at something being unique or uncommon. Whether it's a rare trait, an unusual occurrence, exclusivity, or distinctive elements, a low percentage suggests that whatever is being measured stands out in some way from the majority. This study establishes that there was close association between the incidence of wormian bone and sex (p-value, less than 0.05). This study reported that, subjects with the presence of single wormian bone were maximum, as compared with two, three, four and multiple bones (Table 2). The highest percentage of wormian bone was found at lambdoid suture (58.6%), followed by lambda with 43.1%. Direction of wormian bone placement was highest at centre with 48.9%, followed by bilateral side with 17.1%. It has been reported from the previous studies that wormian bone was frequently observed on lambdoid suture for most of the population across the globe [15- 25].

Another important finding of the study was that, type 7 categories of wormian bones were highest with 28.1%, followed by type 9 (25%). But, type 11 and type 12 wormian bones were not found in the present population

selected for the analysis. As per the review of literature wormian bones of type 6, 8 and 10 are not found frequently and type 9 is considered very rare [16]. The average diameter of vertical and transverse dimensions of wormian bone was higher for males as compared to females. But this difference was not statistically significant as p-value is greater than 0.05. In contrast with the study conducted by Ogut et al., (2023) where average vertical diameter of female wormian bone was at higher end as compared with male [16]. The present study concluded with a distinctive pattern.

Incidence of wormian bone is also closely related with population. Recently a study was conducted by Ogut et al., (2023) on Turkish population and frequency of wormian bone occurence was 52.7% [16]. The frequency was quite high as compared to the present study. This study highlights substantial variations in the distribution of Wormian bones and their unilateral asymmetrical types in Turkish skulls. These differences may be influenced by factors such as clinical syndromes, developmental deficiencies, and population characteristics. The findings contribute valuable insights into understanding cranial morphology, offering potential applications for clinical diagnoses and population-based studies. It has been reported from the previous studies that wormian bone was present on lambdoid suture for most of the population across the globe [15- 25]. As per the reports of previous conducted study in India, there is a wide disparity of incidence of wormian bone among population across different part of India [17, 23]. This may be attributed to different physical, environmental and genetic variations among Indian population [26]. There are studies available for Indian population which is in almost perfect agreement with the present study in terms of frequency of occurrence of wormian bone [15, 19]. Therefore, it is concluded that population has a great impact on occurrence of wormian bone. Moreover, presence of wormian bone and its variation may provide the valuable insights of ancestry and population history.

Ghosh et al., conducted a study on eastern part of India for the incidence, frequency and topographic distribution of wormian bone. It has been observed that 45% of skull was found with the presence of wormian bone [23]. The study reflected higher percentage of wormian bones at lambdoid suture (53.33%). Bilateral symmetry of wormian bones were observed in 12.5% samples. The authors are of the view that genetic variation mainly influenced the morphology of wormian bone. Another study conducted for Western India population by Walulkar et al., on wormian bones [19]. The gross percentage of wormian bone present in the study was 34.22%. The results from the studies conducted earlier found most of the wormian bones present on the left side of the skull. However, the present study found most of the wormian bones at the centre of the skull.

The shape of the bone encountered in the present study with maximum percentage was irregular shape followed by triangular (Table 4). These results were in perfect agreement with the study conducted previously by Walukar et al., for Indian population [19].

Goyal et al., conducted a study for North Indian population (Haryana) on incidence and medicolegal significance of wormian bone [15]. The overall incidence of wormian bone was 35.3%. The authors have concluded that there was no association between sex and incidence of wormian bone. But the current study concluded that sex and incidence of wormian bone was closely related. As per the review of literature, most of the studies conducted for Indian population does not categorized the type of wormian bone as per the classification of Kadanof and Mutafov 1964 [14]. But, the present study classifies the wormian bone into different categories.. But in the current study these types were also found in appropriate numbers.

Recently, Singh (2023) conducted a study on 200 adult dry skulls for Indian population [27]. The wormian bone was found in 190 skulls. The right side showed a higher frequency with 186 occurrences, while the left side had 108 instances. The lambdoid suture emerged as the most prevalent location for these sutural bones, followed by the sagittal suture. On the other hand, the lambda displayed the lowest incidence of Wormian bones. These findings shed light on the distribution patterns of Wormian bones across various sutures, emphasizing the lambdoid suture as the most commonly affected site. Rizvi et al., reported a case where wormian bones were found in the orbit [28]. This location is very rare as per the previous literature available. This can present challenges in clinical situations, as these bones may resemble fractures in imaging studies and could dislodge during surgery, potentially causing harm to surrounding structures. But, present study has not been encountered with wormian bone present in the orbit. In the study of anatomy, images play a crucial role, and it's undeniable that the accuracy of describing observed structures depends heavily on the quality of these images. Employing computerized image processing and analyzing CT scans facilitates the reconstruction of the spatial organization of biological entities. This process, utilizing volume rendering algorithms, allows the creation of lifelike 3D models, contributing significantly to our comprehension of anatomical structures [29].

It was evident from the present study, that the incidence of wormian bone is very less in the present population. Therefore, it can be used in identification of an individual and for the estimation of an ancestry for the present population group. Although wormian bones may not have a definite purpose, their significance is clear given their links to forensic, medicinal, anthropological, and genetic facets of human biology. Their research advances our understanding of skeletal diversity, health, and development in general.

Significant variations in prevalence between the current study and previous research highlight the need for more thorough studies that take into account a variety of contributing factors and include a wide range of groups. Wormian bones are also very important as indicators for skeletal identity. Understanding their evolution has broader implications for clinical and forensic applications in addition to aiding in the

identification and characterization of individuals in skeletal investigations. It enhances the accuracy of skeletal assessments made during forensic investigations and provides a foundation for understanding linked illnesses.

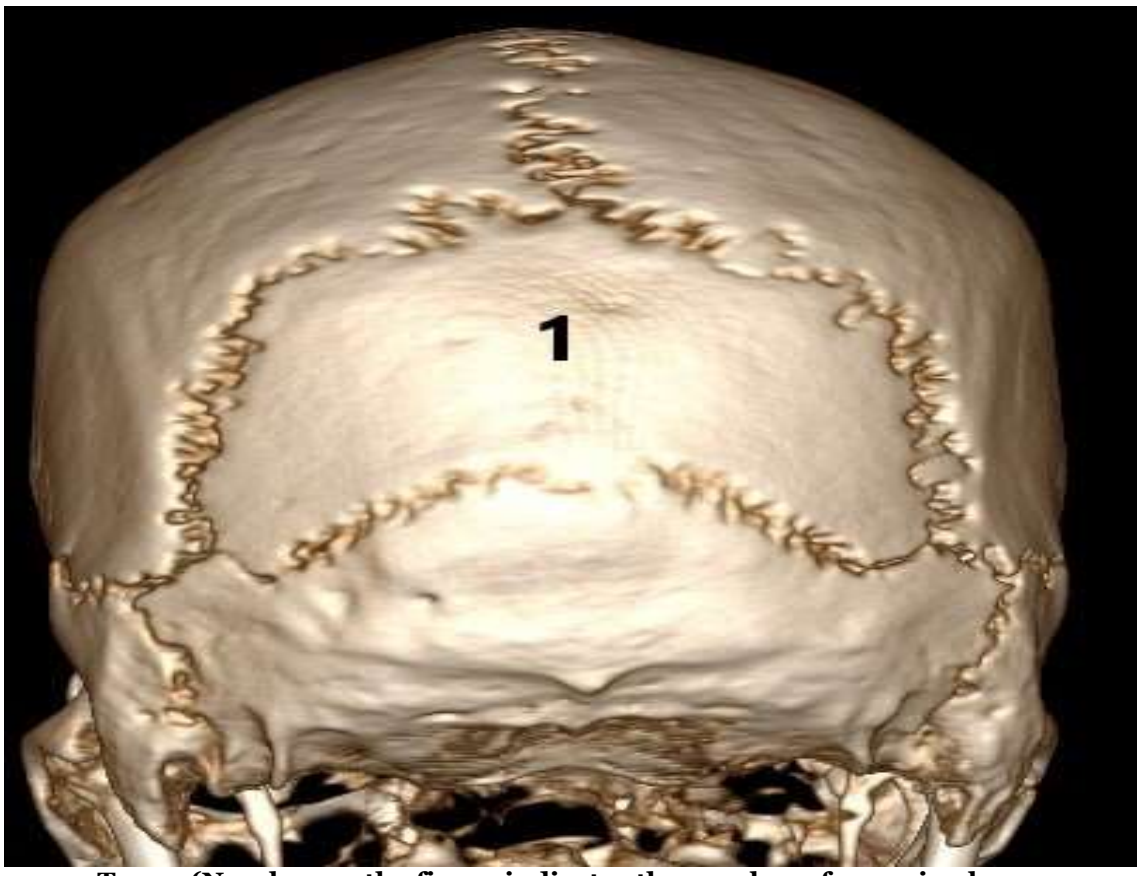


**Figure 1. Type 1 (Number on the figure indicates the number of wormian bones present)**

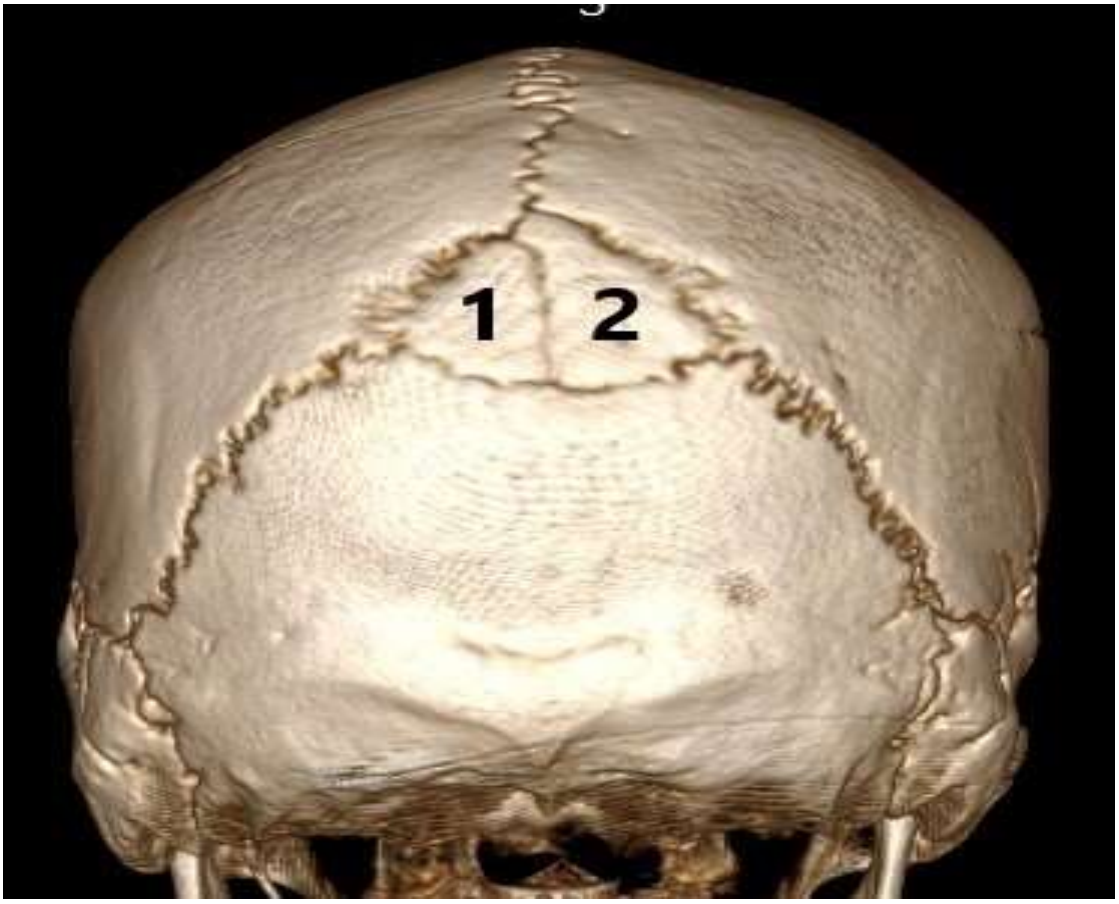

**Figure 2. Type 2 (Number on the figure indicates the number of wormian bones present)**

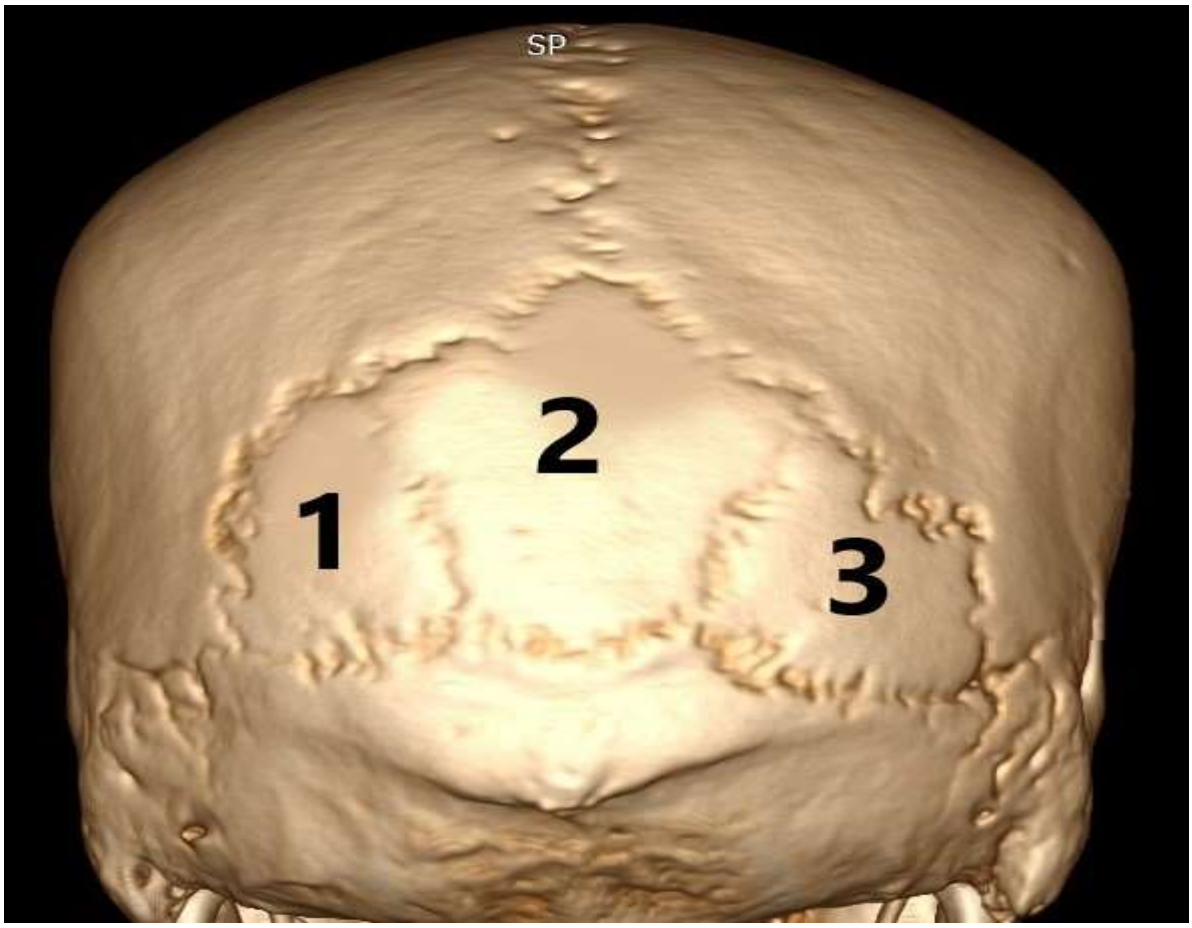


**Figure 3. Type 3 (Number on the figure indicates the number of wormian bones present)**

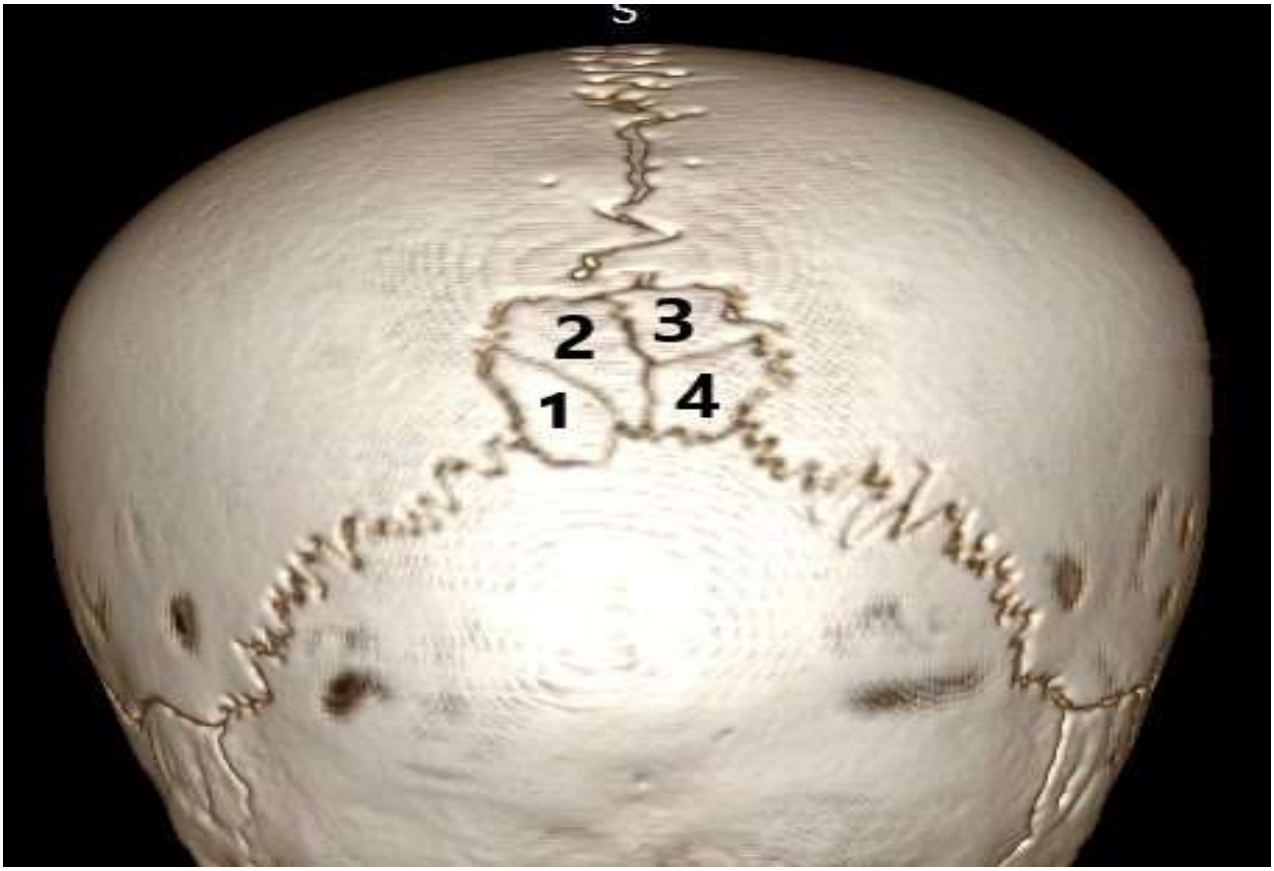

**Figure 4. Type 4 (Number on the figure indicates the number of wormian bones present)**

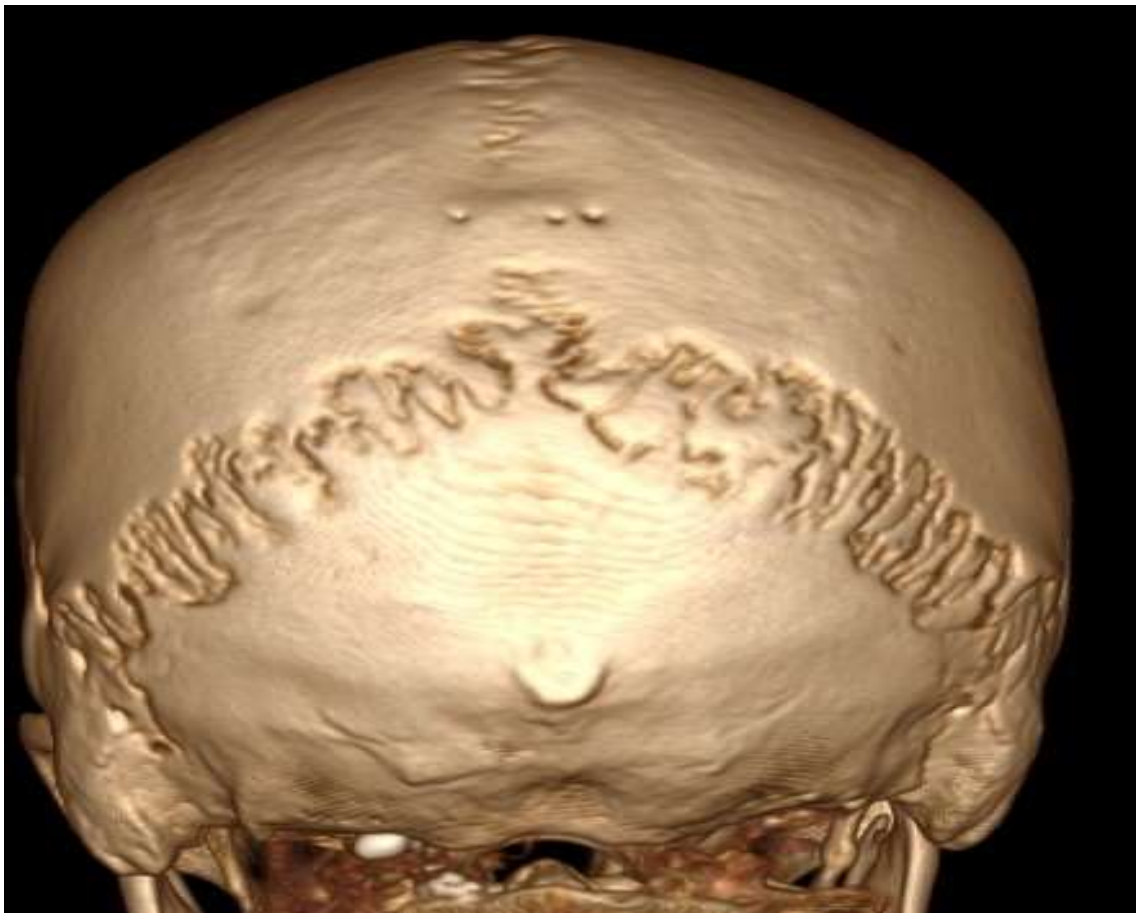

**Figure 5. Type 5 (Number on the figure indicates the number of wormian bones present)**

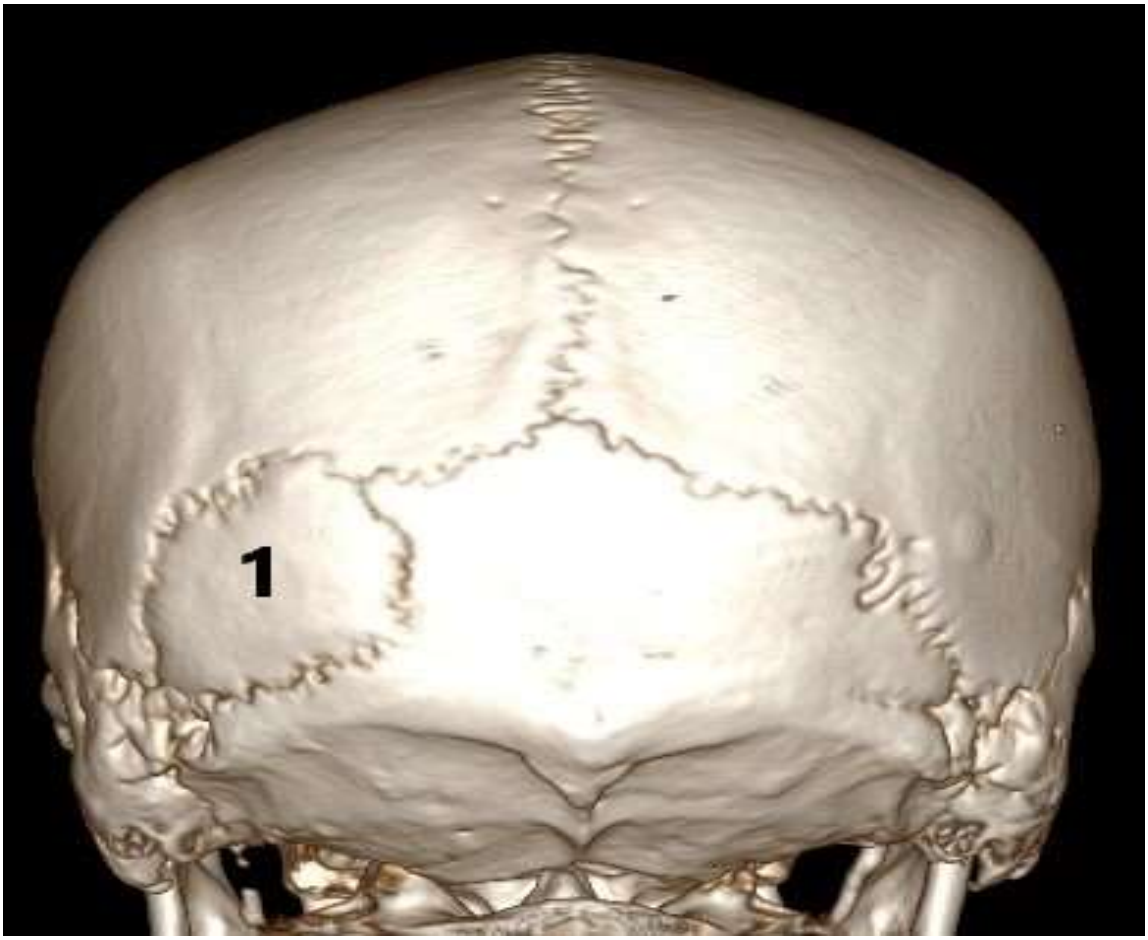


**Figure 6. Type 6 (Number on the figure indicates the number of wormian bones present)**

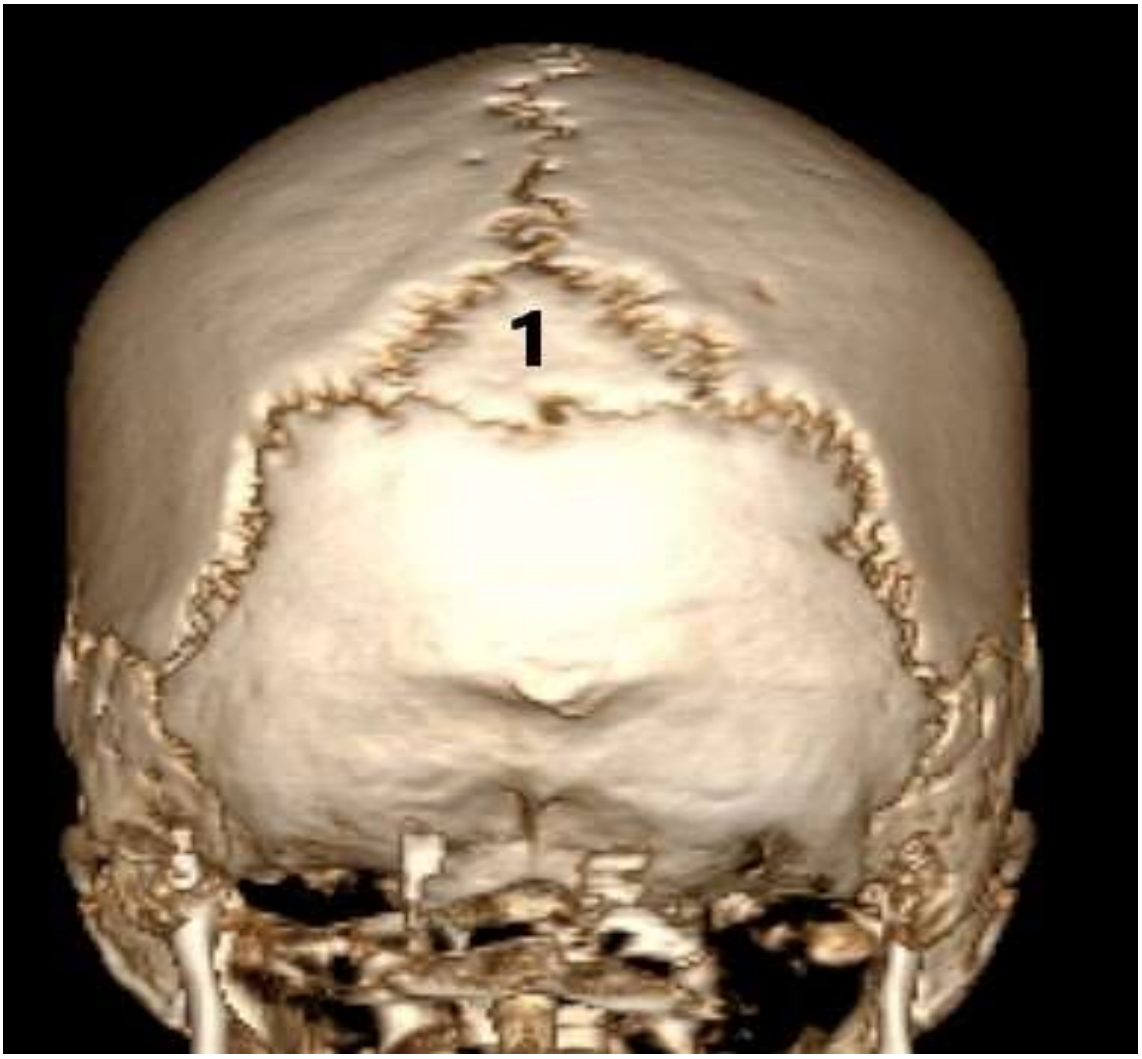


**Figure 7. Type 7 (Number on the figure indicates the number of wormian bones present)**

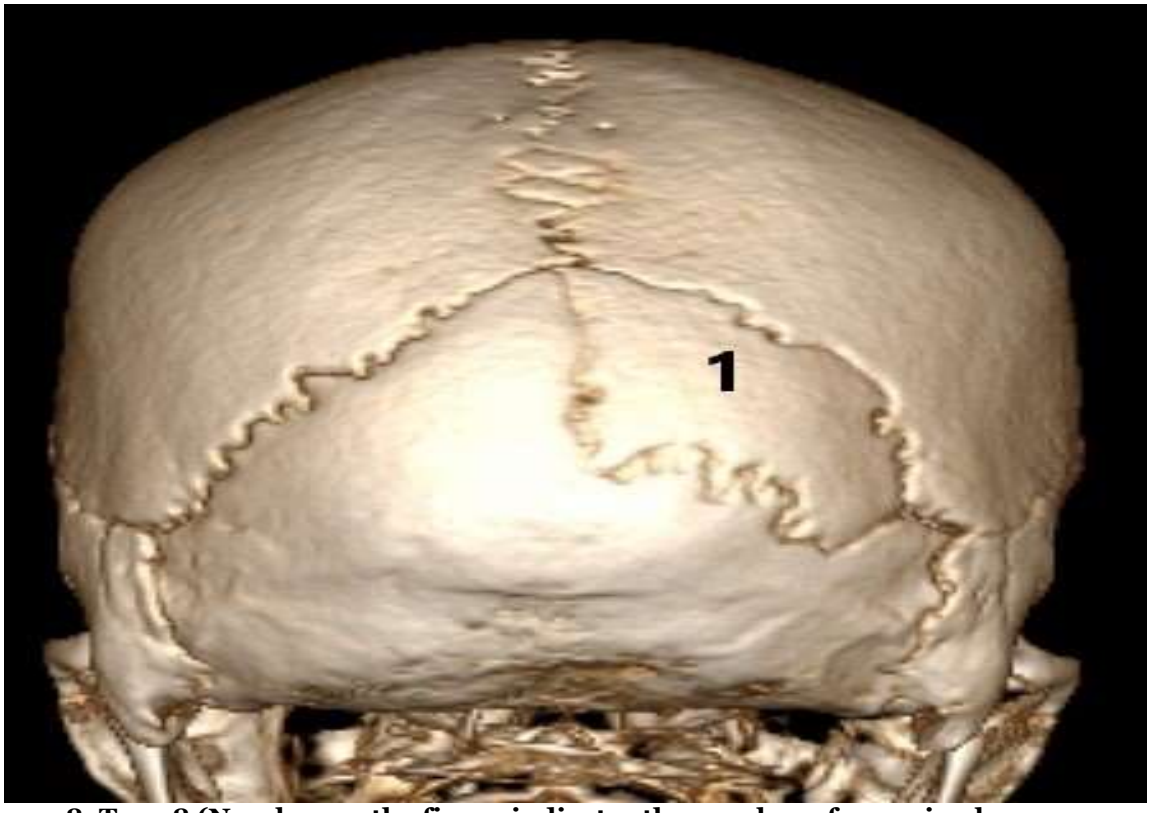


**Figure 8. Type 8 (Number on the figure indicates the number of wormian bones present)**

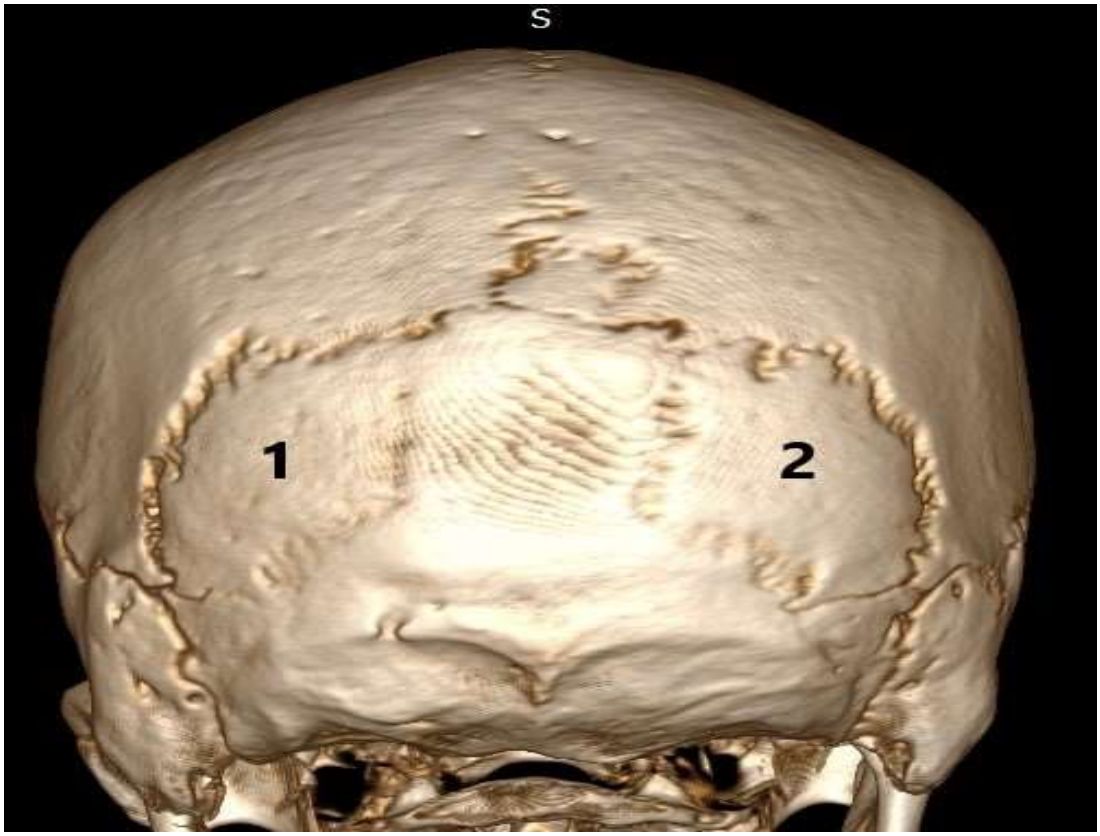


**Figure 9. Type 9 (Number on the figure indicates the number of wormian bones present)**

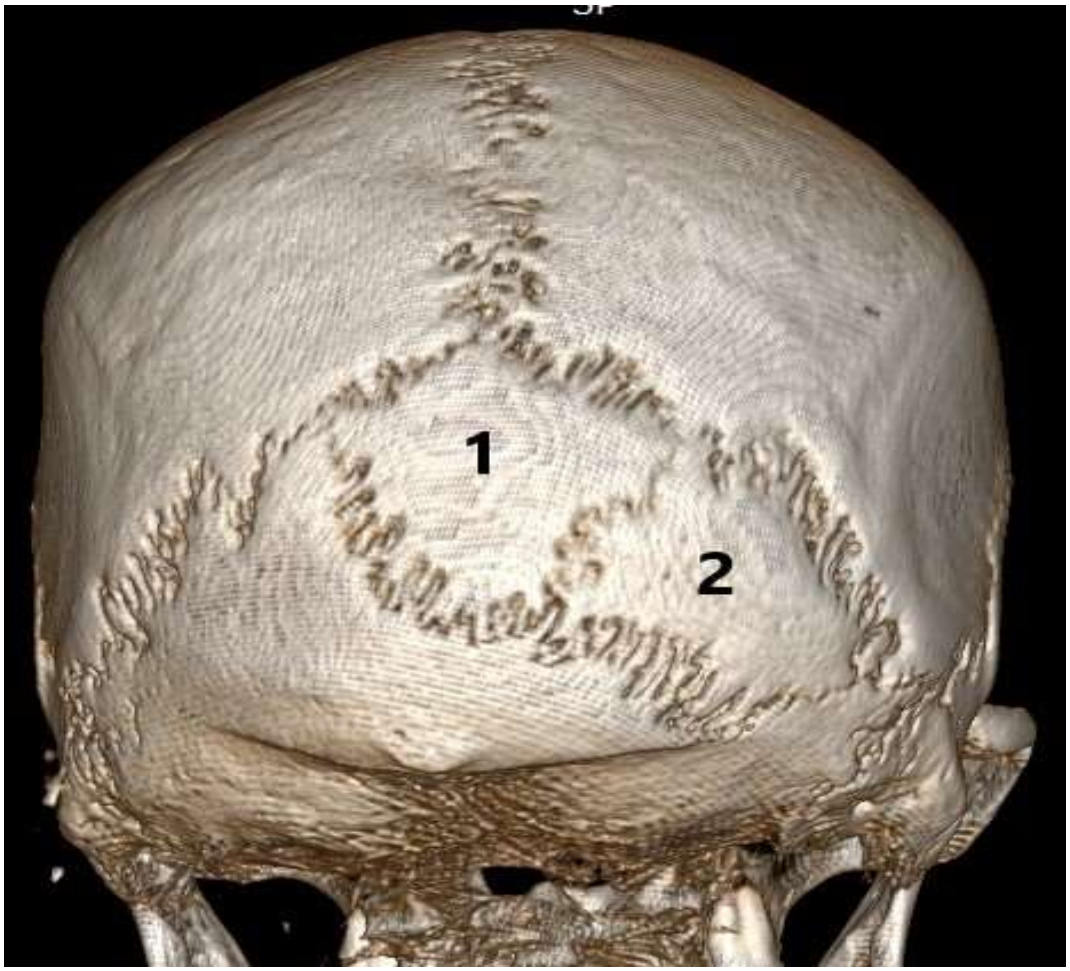


**Figure 10. Type 10 (Number on the figure indicates the number of wormian bones present)**


**Figure 11a. Axial section of CT scan of skull showing fracture with arrow head 'a' and wormian bone with arrow head 'b'.**

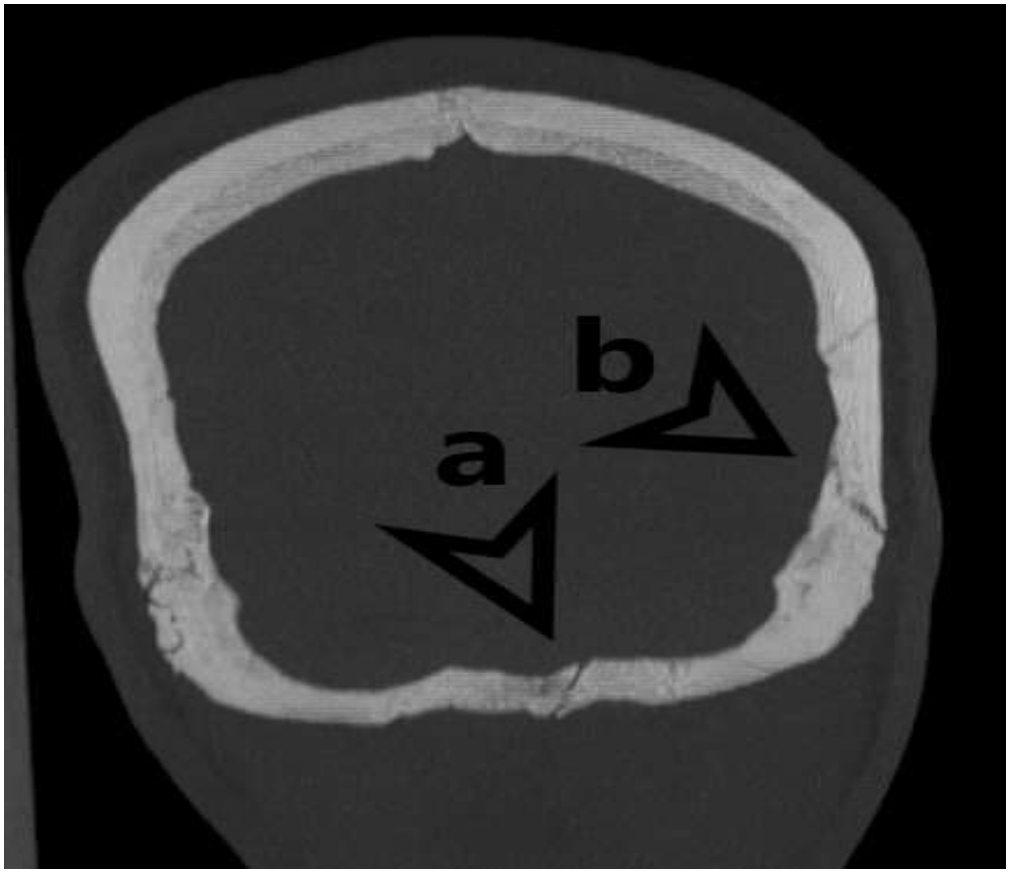


**Figure 11b. Coronal section of CT scan of skull showing fracture with arrow head 'a' and wormian bone with arrow head 'b'.**

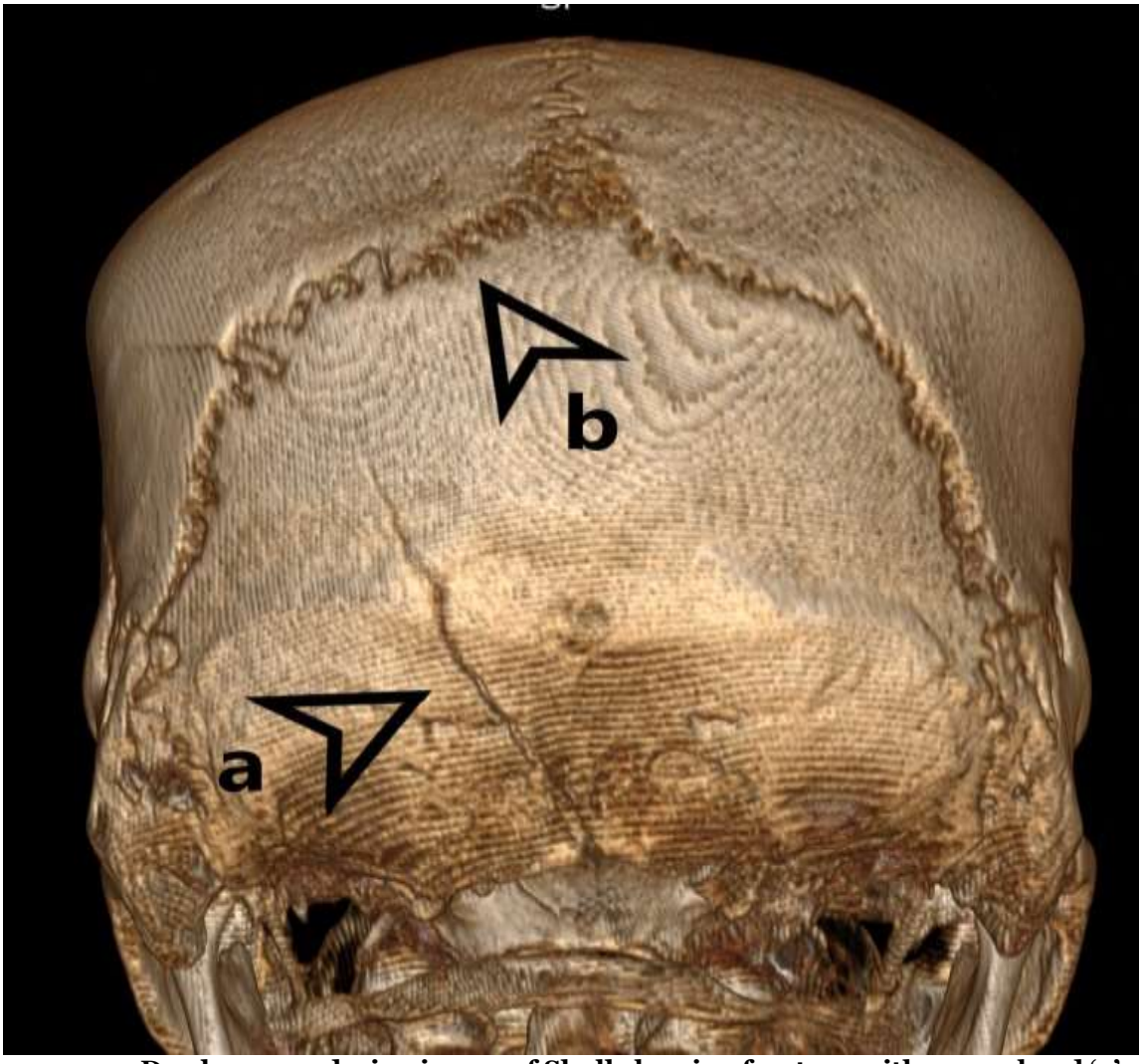


**Figure 11c. 3-D volume rendering image of Skull showing fracture with arrow head 'a' and wormian bone with arrow head 'b'.**

**Table 1 Overall incidence of wormian bone in male, female and at different locations on the skull**

| Wormian bone | Male | Female | Total |
|---|---|---|---|
| Overall | 233 (18.6%) | 147 (11.7%) | 380 (30.4%) |
| Lambda | 99 (26%) | 65 (17.1%) | 164 (43.1%) |
| LS | 125 (32.8%) | 98 (25.7%) | 223 (58.6%) |
| Saggital | 16 (4.2%) | 14 (3.6%) | 30 (7.8%) |
| PMS | 05 (1.3%) | 03(0.7%) | 08 (2.1%) |
| OMS | 02 (0.5%) | 03 (0.7%) | 05 (1.3%) |

**Table 2 Number of wormian bones present in male and female**

| Number of Wormian bone | Male | Female | Total |
|---|---|---|---|
| 01 | 102 (26.8%) | 62 (16.3%) | 164 (43.2%) |
| 02 | 41 (10.7%) | 41 (10.7%) | 82 (21.5%) |
| 03 | 25 (6.5%) | 17 (4.5%) | 42 (11%) |
| 04 | 11 (2.9%) | 11 (2.9%) | 22 (5.8%) |
| Multiple | 54 (14.2%) | 16 (4.2%) | 70 (18.4%) |

**Table 3 Presence of wormian bone on different sides ( left, right, bilateral and centre)**

| Location | Male | Female | Total |
|---|---|---|---|
| Centre | 111 (29.2%) | 75 (19.7%) | 186 (48.9%) |
| Bilateral side | 99 (26%) | 66 (17.4%) | 165 (43.4%) |
| Right side | 34 (8.9%) | 14 (3.7%) | 48 (12.6%) |
| Left side | 44 (11.6%) | 21 (5.5%) | 65 (17.1%) |

**Table 4 Number of different shapes of wormian bones observed in male and female**

| Shape | Male | Female | Total |
|---|---|---|---|
| Round | 18 (4.7%) | 12 (3.2%) | 30 (7.9%) |
| Oval | 40 (10.5%) | 29 (7.6%) | 69 (18.2%) |
| Triangular | 42 (11%) | 30 (7.9%) | 72 (18.9%) |
| Quadrangular | 28 (7.4%) | 22 (5.8%) | 50 (13.2%) |
| Irregular | 105 (27.6%) | 54 (14.2%) | 159 (41.8%) |

**Table 5 Different categorization of wormian bone in male and female**

| Type | Male | Female | Total |
|---|---|---|---|
| 1 | 03 (0.7%) | 03 (0.7%) | 06 (1.5%) |
| 2 | 01 (0.3%) | 00 (0%) | 01 (0.3%) |
| 3 | 02 (0.5%) | 05 (1.3%) | 07 (1.8%) |
| 4 | 06 (1.5%) | 03 (0.7%) | 09 (2.4%) |
| 5 | 36 (9.5%) | 10 (2.6%) | 46 (12.1%) |
| 6 | 41 (10.8%) | 17 (4.5%) | 58 (15.3%) |
| 7 | 62 (16.3%) | 45 (11.8%) | 107 (28.2%) |
| 8 | 28 (7.4%) | 13 (3.4%) | 41 (10.8%) |
| 9 | 49 (12.9%) | 46 (12.1%) | 95 (25%) |
| 10 | 02 (0.5%) | 01 (0.3%) | 03 (0.7%) |
| 11 | - | - | - |
| 12 | - | - | - |

**Table 6 Descriptive statistics showing mean, standard deviation (SD), minimum and maximum values**

| Descriptive Statistics | | | | | | |
|---|---|---|---|---|---|---|
| Gender | | N | Minimum | Maximum | Mean | Std. Deviation |
| Male | Size VD | 233 | 1.02 | 6.17 | 2.29 | 0.941 |
| | Size TD | 233 | .400 | 9.450 | 2.54 | 1.52 |
| | Valid N (listwise) | 233 | | | | |
| Female | Size VD | 147 | .90 | 5.49 | 2.21 | 0.98 |
| | Size TD | 147 | .60 | 8.55 | 2.52 | 1.56 |
| | Valid N (listwise) | 147 | | | | |

## Conclusion

The prevalence and distribution of wormian bones in the Northwest Indian population were extensively examined in this study. Wormian bone research has applications in both forensics and anthropology. These bones' existence and properties can shed light on migration trends, population genetics, and other facets of human evolution. Radiologists may find the wormian bone's insights to be helpful in distinguishing between fractured and normally sutured bones. Overall, this study highlights the complex interactions between genetic, developmental, and environmental factors and offers important new information about the prevalence and distribution of Wormian bones. It emphasizes how crucial it is to carry out larger, more comprehensive research to improve our understanding of these cranial characteristics and the relationships between them.

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