Significance of Differences in Patency Among Cranial Sutures

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Objective: To evaluate the gross external characteristics of the coronal, lambdoid, and sagittal sutures in human cadaver skulls and determine if a difference exists in terms of patency, sex, and age.

Methods: The coronal, lambdoid, and sagittal sutures were described using a modified grading scale to quantify sutural patency. An open suture was graded as 0, a fused suture as 1, and an obliterated suture as 2, 3, or 4, depending on the extent of obliteration.

Results: Thirty-six skulls were examined, including 17 female and 19 male (age range, 56–101 y). When compared with the sagittal suture, the lambdoid suture was significantly more likely to be patent and least likely to be obliterated. No significant difference in suture grades was found between female and male skulls, and no significant difference was found between age and suture grade.

Conclusion: The prolonged patency of the lambdoid suture may be due to external forces, such as the greater number of muscles affecting the lambdoid suture when compared with the sagittal suture.

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In young humans, cranial sutures are simple and straight.1 As humans age, their cranial sutures undergo increasingly elaborate changes,1–3 becoming more complex and developing interdigitations1–6 through a process of growth and resorption of bone.2,4 Although forensic science correlates obliteration of sutures with age, the morphologic characteristics of sutures are highly variable, making age estimation difficult to determine.3–7,13 However, if suture obliteration is used in conjunction with other skeletal age indicators,14 the accuracy of age estimation increases.15

Because the human body is highly adaptive, and many differences exist among sutures,3–7,9 it would be unreasonable to assume that age is the only factor that contributes to the changes in sutures. Such notions would explain suture morphology solely in terms of intrinsic factors,6 such as genetics. Although intrinsic factors may be an influence, extrinsic or environmental factors such as tensile forces, a growing brain, and active muscle demands, are more likely to affect the characteristics of sutures.1,5,6,9–11,17–20

The effects of extrinsic factors on the morphologic changes in sutures is evident.1–3,6–9,11,17–20 These changes include an increase in complexity, the number and length of bony interdigitations, and a prolongation of time to complete suture obliteration.1–3,6,9,11,17,19 Interdigitations are important in the transmission of forces from one cranial bone to another, because they serve to increase the surface area, thereby displacing larger forces.1,2 It can be inferred that the more complex the interdigitations or the longer a suture remains patent, the greater the force on that particular suture. Conversely, obliteration of a suture is possibly the result of lack of motion or growth.3–7,9

In the absence of obliteration, mechanical stress applied to the rat skull can stimulate activity at the suture to accommodate the forces.20 Studies have demonstrated such adaptability of the cranial sutures. Moss17 found that when sutures of rats were transplanted to different suture locations, the structure conformed to meet the demands of the new location.17 In addition, Washburn18 showed that when the temporal muscle was removed in rats, growth at that location decreased, and the sutures became simpler. These findings seem to indicate that increased stress can modify a basic suture into a complex suture.

With the understanding that external factors, such as muscle activity, may contribute to the maintenance of sutural patency, this study sought to determine if a difference in patency and obliteration of the ectocranial coronal, lambdoid, and sagittal sutures exists. Determining the presence of morphologic differences among these sutures can provide additional understanding of cranial sutures.

Methods

Human cadaver skulls were obtained from the department of anatomy of the New York College of Osteopathic Medicine of New York Institute of Technology in Old Westbury.
Preparation of the skulls involved removing all tissue, including the periosteum, from the surface of the bone to examine the sutures. A pathologist (D.E.E.) conducted a gross evaluation of the ectocranial coronal, lambdoid, and sagittal sutures (Figure 1), and classified them into five categories, according to the extent of sutural patency, using a modified grading scale:

- Grade 0 – open, not fused
- Grade 1 – fused but not obliterated
- Grade 2 – less than 50% obliterated
- Grade 3 – more than 50% obliterated
- Grade 4 – 100% obliterated

Because of the degree of latitude within each grade, non-parametric statistics were used to analyze the data. Analyses included a Spearman rank correlation coefficient, the Friedman test, the Wilcoxon signed rank test in a pairwise comparison, and an analysis of variance. Significance was established at an alpha level of .05.

Results
Thirty-six human cadaver skulls, 17 female and 19 male, were studied. The skulls ranged in age from 56 to 101 years, with a mean±SD age of 82±11 years. Information regarding race was not provided in the death certificate. Characteristics such as body build, skull size, or previous lifestyle were not evaluated in this study.

The observed frequencies of the coronal, lambdoid, and sagittal sutures by grade are shown in Figure 2. No suture was “open,” or graded as 0 (Figure 3).

The Spearman rank correlation coefficient (r) (Table 1) showed that all of the suture grades were correlated with location. Because of this finding, the Friedman test, which allows for ordinal data, was used to confirm a statistically significant difference between the grading of sutures by location ($\chi^2_p = 21.9, P = .028$). To further delineate the difference between the coronal, lambdoid, and sagittal sutures, three pairwise comparisons were performed on the same data, using a Bonferroni adjustment. The significance of the pairwise comparisons was tested at the .0167 level (.05/3) to control for a Type I error at an alpha level of .05. The pairwise comparison was performed using a Wilcoxon signed rank test (Table 2).

A statistically significant difference was found in the average grade of lambdoid sutures when compared with...
sagittal sutures ($P = 0.007$). No statistically significant difference was found in the average grade of the lambdoid sutures when compared with coronal sutures ($P = 0.044$) or when comparing coronal and sagittal sutures ($P = 0.499$). No statistically significant difference was found in suture location between female and male skulls (coronal, $P = 0.059$; sagittal, $P = 0.034$; and lambdoid, $P = 0.946$) (Table 3).

In establishing the significance of age in the grading of the ectocranial sutures, an analysis of variance was used, with the grade of the suture as the independent variable and age as the dependant variable. Table 4 shows the results for the coronal ($P = 0.201$), sagittal ($P = 0.473$), and lambdoid ($P = 0.442$) sutures. No significant difference was found in age by grade at any of the suture locations.

**Comment**
The results show that the lambdoid suture was significantly more likely to be patent and least likely to be obliterated when compared with the sagittal suture. Bolk\(^2\) found a delay in the obliteration of the lambdoid suture in a study population of 1820 skulls, primarily ranging in age from 3 to 11 years, with a small percentage (58 [3.2%]) of skulls aged 13 to 20 years. The frequency of suture obliteration was 0.65% for the coronal, 0.27% for the lambdoid, and 3.9% for the sagittal suture.\(^2\)

Patency or obliteration of sutures can be attributed to the presence or lack of physical force on the bones of the skull, respectively.\(^1,5,6,9-11,17,18\) The stress exhibited by muscle tension is one of several external factors that is believed to impose changes on the sutures.\(^1,6,7,9-11,17,18\) Hence, the muscles and ligaments that attach to the occipital bone and confer mobility to the cervical spine can contribute to the lambdoid suture being under more stress and, therefore, more patent than the sagittal suture. This concept is also known as **myofascial continuity**, where origins of muscles that begin in one location and cross joints to reach different and distant regions for attachment can exert their actions onto those areas.\(^2\)

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**Figure 3.** Gross image of cadaver skulls showing suture grade: 1=fused but not obliterated (A); 2=less than 50% obliterated (B); 3=more than 50% obliterated (C); 4=100% obliterated (D).
Significantly more muscles affect the occipital than the parietal bones. The occipital bone is affected by forces from the obliquus capitis superior, rectus capitis posterior major and minor, rectus capitis anterior and lateralis, semispinalis capitis, splenius capitis, longissimus capitis, occipitalis, and sternocleidomastoid. The ligamentum nuchae can also be a source of force on the occiput because it inserts on the external occipital protuberance and attaches to the tip of vertebra prominens. In addition, it also forms aponeurotic attachments to the trapezius (attaching as far as the T12 vertebra), rhomboideus minor, splenius capitis, and serratus posterior.

The theory that external forces maintain suture patency and complexity can be supported by the morphologic characteristics of facial sutures, which are more serrated and interdigitated than cranial sutures and remain patent for longer periods of time. This difference can be presumed to correlate with facial muscles necessary for speaking, mastication, and facial expression.

Relative to the lambdoid suture, the sagittal suture is affected by far fewer associated muscular attachments: temporalis and occipitalis muscles. The smaller amount of force imposed on the sagittal suture may explain its tendency to be more obliterated than at the lambdoid suture. Also, the stresses imposed on the sagittal suture may be displaced and transmitted to the coronal and lambdoid sutures, thereby maintaining or prolonging their patency. When establishing a difference between the coronal and lambdoid sutures, a greater number of cadaver skulls needs to be examined.

Although the current study only evaluated the ectocranial sutures, the question remains whether the patency or obliteration found at the ectocranial surface is found through the depth of the suture. We did not evaluate the endocranial sutures nor was microscopic visualization performed—additional studies that could have further elucidated the findings. In addition, the cadavers had been embalmed in a formalin solution. The possibility that the embalming process affected the sutures was considered; however, any morphologic change in the sutures secondary to the formalin would most likely be appreciated at a microscopic level.

The prolonged patency of the lambdoid suture may have clinical significance in the field of osteopathic medicine. Myofascial continuity demonstrates that muscles exert forces in different areas of the body, reaffirming the osteopathic concept that the body is a unit. Therefore, muscle dysfunctions of the cervical and thoracic spine that attach to the occiput, can increase strain to that region, making it vital to examine and treat joints and muscles that are interrelated.
In addition, the presence of strains in the region of the occipital bone and subocciput are vital in diagnosis and treatment because of their relationship to the autonomic nervous system. For instance, once the vagus nerve exits the skull through the jugular foramen, dysfunction at the point where it courses through the head (jugular foramen compression), neck (occipitotransatlantal and atlantoaxial dysfunctions), and thorax can affect autonomic function.24 Therefore, the finding that the lambdoid suture is the most patent suture in cadaver skulls may support its role in the maintenance of motion and proper autonomic function. How certain forces and stresses, whether internal or external, act on the sutures and how the resultant structure may correlate with the structure and function of individuals requires further investigation.

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References