Morphological investigation of cranial sutures in Indian human adult skulls

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Abstract

Objectives: The goal of the study was to evaluate the gross morphology of the coronal, sagittal and lambdoid sutures in human adult dried skulls and to determine if any difference exists in terms of patency. Materials and Methods: The study included 78 human dry skulls of Indian population. The coronal, sagittal and lambdoid sutures were analyzed using the modified grading scale (Sabini RC and Elkowitz DE, 2006) for quantifying the 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: In coronal suture, the grade 1 suture was seen in 3.9%, grade 2 in 55.1%, grade 3 in 33.3%, and grade 4 in 7.7% of the cases. The sagittal sutures had grade 1 in 2.6%, grade 2 in 46.1%, grade 3 in 37.2%, and grade 4 in 14.1% of the cases. In contrast, the lambdoid suture showed 23.1% grade 1, 55.1% grade 2, 16.7% grade 3, and 5.1% grade 4 sutures. The grade 0 suture morphology was not observed in any of the skulls. Conclusions: When compared with the coronal and sagittal sutures, the lambdoid suture was more likely to be patent. The prolonged patency of the lambdoid suture may be due to external forces acting on it. The greater number of muscles acting on the lambdoid suture compared to coronal and sagittal sutures may be considered as the cause. We believe that, these findings may be helpful to the researchers who are interested in biomedical science and osteopathic manipulative medicine. The findings are also enlightening for the neuroscientists, morphologists, anthropologists and clinicians.

Keywords: coronal, cranial, lambdoid, morphology, sagittal, suture.

Introduction

The cranial sutures are the fibrous tissues uniting the skull bones as they approximate one another during development [1]. It was explained that, during development, these sutures remain patent, allowing the cranial vault to expand for accommodating the growing brain. After cessation of growth, many bones of the skull fuse and the intervening sutures are obliterated by calcified tissue (synostosis). In some cases, complete closure will obliterate any signs of the cranial sutures. If a cranial suture closes prematurely, i.e. before growth of the skull has ceased, this may result in a marked malformation of the skull (craniostenosis) [2]. Maintenance of suture patency depends on various factors, which include tissue interactions, mechanical influences and biochemical signaling [3]. The sutures do not play a substantial role in reducing the total strain within the skull, but probably act in various combinations to allow the skull to respond to different loading conditions by distributing the strain around the skull [4]. In contrast, much remains to be understood regarding the tissue interactions and maintenance of suture patency [5]. The morphology of the skull is influenced by genetic and environmental factors. The muscle function is believed to affect the bone shape and size [6]. It was also reported that, there is a large range of variations in human skull morphology, which is often multifactorial [7]. Although intrinsic factors may have 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, 8]. Determining the presence of morphologic differences among the coronal, sagittal and lambdoid sutures can provide additional details of the cranium. Sabini RC and Elkowitz DE [8] published a paper from the American subjects regarding the significance of differences in patency among cranial sutures. Their ideas and concepts stimulated us to investigate the same, in the Indian population. The goal of the present study was to evaluate the gross morphology of the coronal, sagittal and lambdoid sutures in Indian human adult dried skulls and to determine if any difference exists in terms of patency.

Materials and Methods

The study included 78 human dry skulls of Indian population. The specimens were procured from the Neuroanatomy Laboratories of the Departments of
Anatomy of the Manipal University. There exists an agreement from the Manipal University Ethics Committee where the present study was performed. The skulls, which were deformed, diseased, or fractured, were excluded from the study. The exact ages and sex of the skulls were not determined. The coronal, sagittal and lambdoid sutures (Figure 1) were analyzed using the modified grading scale [8] for quantifying the 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 (Figure 2).

The grading of coronal, sagittal and lambdoid sutures were done after discussing with the co-observers in order to avoid the observation errors. The suture grading scale of the present study is shown in Table 1.

Table 1 – Showing the modified grading scale of the cranial sutures [8]

<table>
<thead>
<tr>
<th>Suture grade</th>
<th>Suture status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Open, not fused</td>
</tr>
<tr>
<td>1</td>
<td>Fused, but not obliterated</td>
</tr>
<tr>
<td>2</td>
<td>Less than 50% obliterated</td>
</tr>
<tr>
<td>3</td>
<td>More than 50% obliterated</td>
</tr>
<tr>
<td>4</td>
<td>100% obliterated</td>
</tr>
</tbody>
</table>

Statistical analysis among the suture grades were performed by using the chi-square test. Two-tailed p-values <0.001 (α=0.001) were considered significant. The SPSS 15.0 program was used for statistical analysis.

Results

In coronal suture, the grade 1 suture was observed in 3.9%, grade 2 in 55.1%, grade 3 in 33.3% and grade 4 in 7.7% of the cases. The sagittal sutures had grade 1 in 2.6%, grade 2 in 46.1%, grade 3 in 37.2% and grade 4 in 14.1% of the cases. In contrast, the lambdoid suture showed 23.1%, grade 1, 55.1%, grade 2, 16.7%, grade 3 and 5.1%, grade 4 sutures. The grade 0 suture morphology was not observed in any of the skulls. The observed frequencies of the coronal, sagittal and lambdoid sutures according to grade are analyzed in Figure 3.

The Table 2 shows the numbers and frequencies of the same.

Table 2 – Distribution and frequencies of cranial sutures according to patency grade (n=234)

<table>
<thead>
<tr>
<th>Suture grade</th>
<th>Coronal suture</th>
<th>Sagittal suture</th>
<th>Lambdoid suture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 (3.9%)*</td>
<td>2 (2.6%)*</td>
<td>18 (23.1%)*</td>
</tr>
<tr>
<td>2</td>
<td>43 (55.1%)*</td>
<td>36 (46.1%)*</td>
<td>43 (55.1%)*</td>
</tr>
<tr>
<td>3</td>
<td>26 (33.3%)*</td>
<td>29 (37.2%)*</td>
<td>13 (16.7%)*</td>
</tr>
<tr>
<td>4</td>
<td>6 (7.7%)*</td>
<td>11 (14.1%)*</td>
<td>4 (5.1%)*</td>
</tr>
</tbody>
</table>

Chi-square test value 18.93 18.3 11.6

Statistical significance (chi-square test), *p<0.001.
Among the coronal suture, grade 2 morphology was higher in frequency ($p<0.001$) followed by grade 3 and grade 4. The grade 1 was the least common ($p<0.001$) type observed. In sagittal suture also, the grade 2 was more commonly seen followed by grade 3, grade 4 and the least morphological type was grade 1 ($p<0.001$). Whereas in the lambdoid suture, though the same grade 2 sutures were higher, the second common morphology observed was grade 1 ($p<0.001$). This was followed by the suture grades 3 and 4. The present study observed that the grade 1 suture was more commonly ($p<0.001$) observed in the lambdoid suture (23.1%).

**Discussion**

The word suture is derived from Latin word sutura, which means seam like or series of stitches. Sutures are formed during the embryonic development at the sites of approximation of membranous bones of craniofacial skeleton [1]. During mid to late gestation, the cranial bone fronts approximate one another and either abut or overlap, with the creation of a suture between them [1]. The sutures form an integral part of the skull, but their role has long been debated among vertebrate morphologists and paleontologists [4]. Their role in cranial biomechanics has interested many morphologists for decades, but there are many unanswered questions [4]. It was reported that the growth and morphology of craniofacial sutures are thought to reflect their functional environment [7]. The more complex the interdigitations or the longer a suture remains patent, the greater the force on that particular suture [8]. Previous work has shown that some cranial sutures experience large strains during mastication [9]. Gratiolet observed that ectocranial suture closure progressed sequentially: sagittal, lambdoid, and then coronal [10]. Parsons and Box suggested that less serrated (simple) sutures closed before all other sutures, and that there were no differences in closure periods for the left or right side of the skull. They proposed that the lambdoid was the last of the vault sutures to reach complete closure [10]. Following Broca, Frederic introduced his own rating scale of 0 to 4 (open, less than one half closed, half closed, more than one half closed, and totally closed). Examining endocranial sutures, he found that the lambdoid closed after the sagittal and coronal [10]. In the present study, the guidelines of Sabini RC and Elkowitz DE [8] was followed and we observed that the lambdoid suture was more likely to be patent compared with the other sutures. This is similar to the observations of Sabini and Elkowitz [8] and our observations confirm their findings. Sabini and Elkowitz [8] reported that Bolk also noted a delay in the obliteration of the lambdoid suture, the frequency of suture obliteration was 0.65% for the coronal, 0.27% for the lambdoid and 3.9% for the sagittal suture. Patency or obliteration of sutures can be attributed to the presence or lack of physical forces acting on the skull [1, 11]. The stress exhibited by muscle pull is one of several external factors that is believed to impose changes on the sutures [8, 11]. The muscles and ligaments that have attachment to the occipital bone and those confer mobility to the cervical spine can cause stress on the lambdoid suture and may be the reason for increased patency of the sagittal suture [8]. This concept is known as myofascial continuity, where origins of muscles, which begin in one location, cross the joints to reach distant regions for insertion and exert their actions on those areas [12]. It is obvious that more muscles affect the occipital bone than the frontal and parietal bones. The occipital bone is affected by muscles like obliquus capitis superior, rectus capitis posterior major and minor, rectus capitis anterior and lateralis, semispinalis capitis, splenius capitis, longissimus capitis, occipitalis and sternocleidomastoid [13]. The ligamentum nuchae can also be a source of force on the occiput since it inserts on the external occipital protuberance. It also forms aponeurotic attachments to the trapezius, rhomboideus minor, splenius capitis and serratus posterior [13]. The concept of external forces maintaining suture patency and complexity can be supported by the morphologic characteristics of facial sutures, which are more serrated and interdigitated than the cranial sutures and remain patent for longer time [11]. This is presumed to correlate with facial muscles necessary for speaking, mastication and facial expression [8]. Relative to the lambdoid suture, the coronal and sagittal sutures are affected by far fewer associated muscular attachments like frontalis, temporalis and occipitalis [8]. The smaller amount of forces exerted on the coronal and sagittal sutures may explain their tendency to be more obliterated than the lambdoid suture. Just like Sabini and Elkowitz’s study [8], we have also evaluated only 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.

The knowledge of suture patency of the cranial bones may have clinical implications in the field of biomedical science and osteopathic medicine [8]. The muscles of the cervical and thoracic spine that attach to the occiput, can increase the strain, making the occipital region vital to examine. The joints and muscles will need treatments accordingly that are interrelated [8]. In addition, the presence of strains in the occipital region and subocciput are vital in the clinical diagnosis and therapeutics as they are related to the autonomic nervous system. For example, compression of the vagus nerve while passing through the jugular foramen, joint involvements like atlanto-occipital and atlanto-axial dysfunctions can affect the autonomic function [14]. Sabini RC and Elkowitz DE [8] opined that, how exactly the forces and stresses act on the sutures and how the resultant suture structure may correlate with structure and function of individuals, may require further investigation. Washburn SL [15] showed that, when the temporalis 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 [8]. Keeping view of these facts, we may conclude that the external factors, such as muscle
activity, may contribute to the maintenance of the sutural patency. The greater number of muscles acting on the lambdoid suture might be considered as the cause. We believe that, this study might be of help to the researchers who are interested in biomedical sciences and osteopathic manipulative medicine. The findings are also enlightening to the neuroscientists, morphologists, anthropologists and clinicians.

The present study has few limitations; there is the fundamental problem of using a method based on a structure, which as yet is simply poorly understood. But, whatever the underlying biological factors are for suture closure, and even if these in the future should be better quantifying these structures, in order to render the methods of quantification as unbiased as possible. For a more accurate and better assessment of suture closure various other modalities like radiology (X-ray, CT-scan, MRI), histology may have to be combined with the present osteological study. In the present study age distribution and sex is not determined. Hence, this has to be taken into consideration in future studies and there are only 78 cases, which may not be the representation of whole population. Hence, the study population (sample size) has to be increased in future studies.

Conclusions

The lambdoid suture is the most patent suture among the cranial sutures and its prolonged patency might be because of external forces acting on it. The present investigation from the Indian subjects confirms the findings of Sabini and Elkowitz, as the same conclusion was drawn.

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References


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