Review Article

Evaluation of spheno-occipital synchondrosis: A review of literature and considerations from forensic anthropologic point of view

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Abstract

Cranial sutures and synchondrosis have long been studied by forensic scientists, human anatomists, and anthropologists for estimation of age in different population groups. Observation of the closure of spheno-occipital synchondrosis has an important role to play in the estimation of age in the examination of unknown human remains when a skull is brought for examination. The present article reviews the studies conducted on the closure of spheno-occipital synchondrosis and presents a few valuable considerations that would be essential for carrying out research related to closure of spheno-occipital synchondrosis in humans.

Key words: Age estimation, forensic anthropology, human remains, medicolegal examinations, spheno-occipital synchondrosis

Introduction

Synchondroses in the cranial base are important growth centers of the craniofacial skeleton. Spheno-ethmiodal synchondrosis, intersphenoid synchondrosis, and spheno-occipital synchondrosis are the three synchondroses present along the midline in the cranial base.[1] Spheno-occipital synchondrosis is a cartilaginous union between the body of the sphenoid and the basilar part of the occipital bone. Thus, it in fact is a "synchondrosis" and not a "suture" as is sometimes called. Cranial base synchondroses essentially contribute to the craniofacial development. Growth at the spheno-occipital synchondrosis carries the maxilla upward and forward relative to the mandible resulting in an increased facial height and depth. Spheno-occipital synchondrosis is related to dento-alveolar development and is of significance in orthodontic practices. A rapid maxillary expansion is shown to cause a small immediate widening of spheno-occipital synchondrosis in young individuals.[2]

Spheno-occipital synchondrosis is of particular significance in forensic anthropology case work due to its late closure in adolescent age groups. Estimation of age has been considered as one of the essential parameters in forensic anthropology. During the examination of unknown human remains, observation of the closure of spheno-occipital synchondrosis can help in the estimation of the age of a skull brought for examination. The present review of literature addresses some of the important technical observations, which would be essential for carrying out research related to closure of spheno-occipital synchondrosis in humans.

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Ossification centres and pattern of closure of spheno-occipital synchondrosis

Okamoto *et al*.[3] based on a high resolution computed tomography (CT) analysis noticed the presence of an ossification center in the midline in patients aged between 8 and 13 years. They also reported the presence of additional symmetric ossification centers on either side of the midline in girls. Fusion of the spheno-occipital synchondrosis

begins at the endocranial surface and progresses to the ectocranial surface.[4] According to Melsen[5] the closure of synchondrosis was noted to start at the internal surface of the cranial base. Bassed *et al*.[6] in a CT-based analysis observed that the fusion begins superiorly and progresses inferiorly. Their observations are similar to that of Irwin[7] who found that the ossification began at the superior border of the synchondrosis and progressed inferiorly.

This closure usually occurs about 2 years earlier in girls than in boys; this may be attributable to the early growth process or maturity of girls.[8,9] Shirley and Jantz[10] in this regard, observed that the fusion of synchondrosis in females occurs 4 years before males. Bassed *et al*.[5] in a recent research, however, did not find any significant differences in progress of fusion between males and females after the age of 16 years.

Review of literature on closure of spheno-occipital synchondrosis

Gray's anatomy[11] mentions that the sphenoid and occipital bones are completely fused by the 25th year. The Human Skeleton in Forensic Medicine by Krogman and Iscan[12] mentions that the closure of spheno-occipital synchondrosis occurs sometime between 18 and 23 years. Researchers have had varying opinions as regards the time of closure of the spheno-occipital synchondrosis. Findings of various studies in this regard are detailed in chronologic order of their publication.

Ford[13] in a study on human dry skulls reported that the closure of spheno-occipital synchondrosis takes place somewhere between 17 and 25 years. Irwin observed that the ossification of the synchondrosis was generally completed by 18 years.[7] Powell and Brodie[14] based on midsagittal laminagraphy study of the spheno-occipital synchondrosis concluded that the closing age for the synchondrosis in males was between 13 and 16 years, and in females between 11 and 14 years. Melsen[15] related the closure of spheno-occipital synchondrosis with the time interval between eruption of 2nd and 3rd molars. Melsen[5] found that the spheno-occipital synchondrosis was closed completely between the age of 12 and 17 years. Ingervall and Thilander[8] studied the spheno-occipital synchondrosis macroscopically. The material studied consisted of the major part of the clivus and dorsum sellae, which were decalcified and serially sectioned in the sagittal plane. They observed that the synchondrosis was never completely open in any of the females above 13 years 9 months, the corresponding age for the boys was 16 years.

Madeline and Elster[16] based on CT assessment found that the spheno-occipital synchondroses remained partially open into the teenage years and concluded that the complex process of skull base development is chronicled. Okamoto *et al*.[3] found that no sphenooccipital synchondrosis persisted beyond the age of 13 years in males and females. They concluded that high-resolution CT scans can recognize and predict the progressive ossification of spheno-occipital synchondrosis. Sahni *et al*.[17] in a study on Indian subjects, observed complete fusion of spheno-occipital synchondrosis in all males and females at 19 and 17 years, respectively. They observed that complete fusion occurred between 13 and 17 years in females and between 15 and 19 years in males. Mann *et al*.[18] stated that the spheno-occipital synchondrosis began to fuse at around 8 years, and the fusion was essentially complete by 16 years in girls and 18 years in boys. Kahana *et al*.[19] assessed the state of fusion of the spheno-occipital synchondrosis and investigated the correlation between the degree of closure and chronologic age. They concluded that fusion of the basilar synchondrosis is not a good age indicator in male cadavers. They, however, found it to be useful criteria for the estimation of age in females.

El-Sheikh and Ramadan[20] in a CT examination for analysis of the age of closure of the spheno-occipital synchondrosis in the Arabian Gulf Region observed that complete closure of the spheno-occipital synchondrosis was observed as early as 11 years in females and 12 years in males. All males above the age of 18 years and females above 16 years exhibited complete closure of synchondroses. Akhlaghi *et al*.[21] on direct inspection of male skulls endocranially during autopsy concluded that closure of spheno-occipital synchondrosis can be used as a good indicator for age estimation in males. Bassed *et al*.[6] in a CT analysis of the spheno-occipital synchondrosis in a modern Australian population observed that the closure of synchondrosis was complete by the age of 17 years in both males and females. Akhlaghi *et al*.[22] in a recent communication on macroscopic analysis of spheno-occipital synchondrosis endocranially in an autopsy sample concluded that the closure degree of the synchondrosis can be a good indicator for age in males and females. We observe that the inferences drawn by the authors[22] are debatable. In view of the large variations and overlapping in ages and stages of suture closure in the study, the conclusions drawn by the authors that the spheno-occipital sutures can be a good indicator of the age estimation appear inappropriate.

Shirley and Jantz[10] based on the direct inspection of the ectocranial site of the synchondrosis stated that the fusion of basilar synchondrosis reflect sexual dimorphism and that complete fusion at the spheno-occipital synchondrosis occurs well before 25 years of age. They observed that the onset of fusion corresponded closely with the onset of puberty.

Methodologic issues, technical observations, and statistical analyses

Various studies thus, are conducted to analyze the age of closure of spheno-occipital synchondrosis. There is,

however, no universal agreement on the age of closure of spheno-occipital synchondrosis primarily owing to the different methodologies followed by the researchers, variations between populations, variations in sample sizes and age ranges of the sample, and differences in statistical analysis employed in previous studies.

Methodologies employed in analysis of spheno-occipital synchondrosis

A possible reason for the variation in results of earlier studies on closure of spheno-occipital synchondrosis is the differences in the methods of analysis employed by different researchers. Macroscopic, histologic, radiographic and high-resolution CT investigations have been carried on for the estimation of age from the closure of spheno-occipital synchondrosis. So while a few examiners had a full vision of the synchondrosis from the CT scans or on using radiologic investigations, others relied on macroscopic examination of the synchondrosis by direct inspection either ectocranially or endocranially. The examination of autopsy specimens, dry skulls, histologic sections, and use of radiography, and CT scans may be interpreted differently. CT scans and radiographs can detect the state of fusion earlier than direct inspection method. Although imaging procedures appear to be superior in examining the sutures than the direct inspection methods, direct inspection methods are used most frequently in forensic anthropology case work. Direct inspection methods are considered as a fast and cost-effective method.[10] Shirley and Jantz[10] suggest that the synchodrosis should be scored via direct inspection ectocranially. A study by Sahni *et al*.[17] is distinct in this regard as the authors analyzed 50 male and 34 female autopsy samples where the basi-sphenoid region was X-rayed and macerated and also the CT scans in 46 male and 27 female living subjects from the same population. They however, neither presented the findings on live subjects and autopsy samples individually nor the observations made in CT scans, X-rays, or direct inspection separately.

With regard to different methodologies employed by the researchers, we are of the opinion that each methodology has its own merits and is of value in variety of cases encountered during medicolegal investigations and forensic anthropology case work. Standards derived based on different methodologies are likely to differ and thus, the applicability of standards derived from a particular method should be restricted to similar case work in medicolegal investigations and forensic anthropology. For instance, standards derived from radiologic investigations should not be applied during macroscopic examination of the skull base. Likewise, during examination of unknown skeletal remains, findings of ectocranial closure holds importance, whereas during autopsy of unknown young individuals, endocranial examination may be of value in estimating the age of the individual.

Scoring employed in studies and observation bias

There is a lack of uniformity on the scoring of the status of closure of spheno-occipital synchondrosis. While some researchers score the status as "open/unfused," "closing/fusing," and "closed/fused,"[10,22] others have tried to categorize the status only as "open/unfused" and "closed/fused." El-Sheikh and Ramadan[20] for instance in a study based on CT examination for visualization of the base of skull noted the state of closure of the spheno-occipital synchondrosis as closed or open. They categorized "partially closed" sutures as "open." Similarly, Kahana *et al*.[19] categorized sutures into "open" and "closed" categories. Shani *et al*.[17] have categorized the degree of fusion as complete (+2), partial (+1), and unfused (0).

Irrespective of the methodology applied for evaluation of synchondrosis, the examination of closure of spheno-occipital synchondrosis needs a great deal of practice and experience, especially when a direct inspection or naked eye examination of suture is done. There are chances of error due to variability in the observations made by the examiners. Thus, the studies need to describe the accuracy and reliability that was achieved by the observers with regard to the degree of fusion of the suture. The biases and repeatability of the methods used needs to be explained for the practical applicability of the work. Das and Ghafar[23] in a recent communication on the study of Akhlaghi *et al*.[22] have commented that naked eye examination of spheno-occipital synchondrosis may not be the accurate method for interpreting the degree of fusion of sutures. Akhlaghi *et al*.[22] had also mentioned that the macroscopic study of sutures was carried out by unique examiners. Das and Ghafar[23] have raised the issue of "unique examiners" and possibility of observer variability and bias in studies involving observation.

Sample size, age and sex distribution, and population variations

Sample size is one of the important criteria in forensic anthropology studies. Sample size should be adequate enough to represent the population in question to bring out acceptable outputs applicable in forensic case work. A lot of variation in sample sizes is evident in studies on closure of spheno-occipital synchondrosis. Kahana *et al*. for instance present their results on a female sample comprising of only 21 subjects.[19] Although most of the studies on closure of spheno-occipital synchondrosis are conducted on samples during the first three decades of life, there has been a gross variation in the age ranges and sex distribution of the samples included in these studies. This has a bearing on the outcome derived in these studies. It thus, needs to be stressed if the sample is balanced in terms of age and sex distribution for the years.

A need for population-specific data in forensic anthropology is emphasized time and again.[6,24,25] It is a well-established

fact that standards may vary in different populations and ethnic groups and thus the standards drawn for a particular population/ethnic group should not be employed on a different group. Shirley and Jantz[10] mention their inability to evaluate ethnic differences statistically in their study on American population due to issues relating to the sample size.

Statistical analysis

Different statistical approaches have been adapted by various researchers for estimation of age from the closure of spheno-occipital synchondrosis. While a few studies have commented on the fusion status of the synchondrosis directly, others have utilized a scoring system for the state of fusion.

Akhlaghi *et al*.[21,22] calculated mean ages for status of closure of synchondrosis. Akhlaghi *et al*.[22] studied the correlation between the degree of closure and chronologic age using Spearman's correlation ratio and utilized regression analysis taking age as a dependent variable and degree of fusion as an independent variable. To study the correlation and derive regression models the open sutures were coded as "0," semi-closed as "1" and closed as "2." Similar regression analysis is presented by Sahni *et al*.[17] We are of the opinion that such quantification of qualitative data is of limited utility in forensic case work. For the regression models derived by Akhlaghi *et al*.[22] for male skulls ($Y = 12.07 + 4.50X$), if the spheno-occipital synchondrosis is found to be closed in a male skull, the age of the skull will be estimated as 21.07 years. Our observations in this regard are an extension of views put forth by Kanchan *et al*.[26] on the use of "coded" variables for sex in deriving regression models for estimation of stature in unknown remains. They proposed that coding of variables does not have any added benefit and that such quantification of qualitative data should be avoided by the researchers. The mean age calculated by Akhlaghi *et al*.[22] for suture closure in males (21.17 years) and females (19.44 years) is observed to be much higher than that reported in any of the earlier studies on closure of spheno-occipital synchondrosis. We are of the opinion that the estimated mean ages for the status of suture closure is dependent on the age range of the study sample and not directly related to the age and state of suture closure. Thus, the mean ages provided by Akhlaghi *et al*.[22] for the open and closed sutures are not useful since that simply depend on the sample age ranges. For the very same reason the applicability of regression equations derived by the authors[22] for the ages of open and closed sutures appear limited.

Shirley and Jantz[10] indicate that the scoring method, sample size, and age range are important limitations of studies on age estimation from the spheno-occipital synchondrosis. They used the "transitional analysis" technique to determine the average ages at which an individual transitions from unfused to fusing and from fusing to fused status. Konigsberg *et al*.[27] in this regard emphasized on finding statistical methods that will have the correct "coverage." They showed that if an appropriate age distribution is used, then "transitional analysis" will provide accurate "coverages" than percentile methods, rate methods, and means.

Conclusion

Age estimation by closure of spheno-occipital synchondrosis has a limited utility in forensic case work owing to the wide variability in its age of closure as presented in various previous studies and thus, it can be concluded that the closure has only a very general relationship with age. The onset, progress, and obliteration of suture closure is observed to be so erratic, that it just provides a general pattern at various age levels. Thus, it acts as a guide rather than a determining feature in age estimation and such a trend is of limited use in modern forensic anthropology. It only acts as a supportive evidence for age estimation in the presence of other, more determinate and accurate, clues. Suture closure may possibly be affected by nutritional and health status of the deceased, allometric growth, general growth and development of the bones, and to some extent by race. It may also be affected by exercise and physical activity of an individual. These factors may have possible and reasonable influences that could explain the variability observed in the age of closure of the synchondrosis.

However, it is necessary that more studies are conducted on modern populations worldwide on the closure of spheno-occipital synchondrosis using standard methodologies and techniques so that more effective standards are drawn. There is a need to make careful investigations with due emphasis on the technical considerations proposed in the paper during investigation of spheno-occipital synchondrosis to draw valid conclusions.

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