Egyptian Journal of Forensic Sciences

ORIGINAL ARTICLE Open Access

# Age estimation by spheno-occipital synchondrosis fusion in South Indian population using computed tomography

Rajesh Nayak[1], Nitika C. Panakkal[2*] and Visakh T[3]

## Abstract

**Background** Age estimation has paramount importance for the forensic practitioner. Depending on the timing of fusion, the spheno-occipital synchondrosis will be open during childhood and then later fuse during adulthood. Since there have been a lot of inconsistencies in terms of fusion degree, that can be attributed to variability in population or methodology. The aim of the present study was to determine the age of beginning of the spheno-occipital synchondrosis in the South Indian population using computed tomography.

**Results** The study reported a mean age of 8.38 ± 1.21 for males and 8.2 ± 1.16 for females in the stage 0 (completely open) category. Spheno-occipital synchondrosis began to fuse (stage 1) at the mean age of 11.64 ± 1.19 for males and 10.21 ± 1.19 for females.

**Conclusions** Spheno-occipital synchondrosis begins to close at the age of less than 15 years in males. Similarly, for females, the spheno-occipital synchondrosis begins to close at the age of less than 14 years. Also, a strong sexual dimorphism is seen as each stage of synchondrosis and starts earlier in females compared to males. In addition, the study also showed the degree of fusion increasing with age. This estimation will not only help in forensic and anthropological studies but also in assessing craniofacial growth in orthodontics.

**Keywords** Spheno-occipital synchondrosis, Age estimation, Computed tomography, South Indian population

## Background

Age estimation plays a crucial role in forensic and anthropological contexts. They help in estimating the age at death of bodies deteriorated, damaged or fragmentary (Ubelaker and Khosrowshahi 2019; Alkass et al. 2010). In living individuals, age estimation is required for logical affirmation of the judicial authority and certain administrative departments (Pate et al. 2018). Estimation of age is more accurate for the immature skeletal system (Cardoso et al. 2014). Various skeletal markers, such as the root of the third molar tooth, the diaphysis-epiphysis fusion of the clavicle, tibia, calcaneus, occipital condyles, the fusion of skull sutures, cervical vertebrae and ossification of wrist joint have been studied for the age estimation (Cardoso et al. 2014; Hisham et al. 2018). Among these, the examination of skull sutures and ossification of the wrist joint may not always provide accurate results to estimate the age at the time of death (Can et al. 2014a; Akhlaghi et al. 2010). However, the degree of fusion of spheno-occipital synchondrosis (SOS) is considered to be a good indicator of age (Pate et al. 2018; Can et al. 2014a; Akhlaghi et al. 2010). The SOS is considered an active growth site that lengthens the skull base during the postnatal period (Yang et al. 2019; Ford 1958). The fusion of

*Correspondence:
Nitika C. Panakkal
nitikacp@gmail.com; nitika.cp@manipal.edu
[1] Department of Radiodiagnosis, Kasturba Medical College, Manipal Academy of Higher Education, Mangalore, Karnataka, India
[2] Department of Medical Imaging Technology, Manipal College of Health Professions, Manipal Academy of Higher education, Karnataka, Manipal, India
[3] Department of Medical Imaging Technology, Manipal College of Health Professions, Manipal Academy of Higher Education, Manipal, Karnataka, India

the sphenoid and occipital bones proceeds from endocranial towards ectocranial, and the gap between the bones is completely closed in adulthood (Demirturk Kocasarac et al. 2016). Therefore, analysing the degree of fusion of the spheno-occipital synchondrosis will be useful for forensic age assessment due to its relatively late ossification (Sinanoglu et al. 2016; Krishan and Kanchan 2013). However, the literature reports a great amount of inconsistency in terms of fusion degree that can be ascribed to the variability in populations and various methodologies employed for examination (Sinanoglu et al. 2016; Shirley and Jantz 2011; Can et al. 2014b). The various methods include direct examination of skeletal material, dry skull, postmortem, bone histology, and imaging modalities. Although direct examination techniques are cost-effective, they are not always accurate. A synchondrosis may look completely closed in dry skull,however, it may not be so in the CT images of the skull (Bassed et al. 2010). Similarly, conventional radiography is also inexpensive and accessible, but there is a problem of superimposition and a lack of resolution that can interfere with the interpretation of the image. Therefore, imaging modalities like computed tomography that provide three-dimensional information have better resolution for visualising anatomical structures, thereby having a greater accuracy in analysing the various degrees of fusion of spheno-occipital synchondrosis (Sahni et al. 1998; Okamoto et al. 1996; Alhazmi et al. 2017). Therefore, this study aimed to assess the time of fusion of spheno-occipital synchondrosis for age estimations in the South Indian population using computed tomography.

## Methods

The study was conducted retrospectively in a tertiary care hospital in South India after approval from the Institutional Ethical Committee [IEC 547]. A total of 123 male and 123 female participants, aged from 7 to 15 years, and having previously undergone a CT scan of the brain, PNS, temporal bone, cervical spine, orbits and facial bones were included in the study. The CT images that showed artefacts at the base of the skull were excluded from the study.

All the CT examinations were performed on a 128-slice Philips Incisive CT and a 16-slice Big Bore CT scanner. Scans were performed using 120 kVp with automatic tube current modulation. The axial images of the CT scan were acquired in 1 mm, and all the images were reconstructed into coronal and sagittal sections.

The images collected were retrieved from the PACS server, Mediff PACS (InstaRISPACS version 4.1.0). The midsagittal section was considered the choice for viewing. The window level and window width of the obtained images were changed to 800 and 1600, respectively.

The fusion of SOS was assessed using a modified 3-stage system referred from Bassed et al. (Bassed et al. 2010). The stages are as follows, as shown in Fig. 1. Stage 0 indicates a completely open SOS. In stage 1, the SOS is beginning to close, starting with the fusion of the superior border. In stage 2, the synchondrosis is fused for more than half the length.

The images were assessed by two subject experts. In cases of disagreement between the observers, a third observer was asked to rescore the image.

### Statistical analysis

Descriptive statistics were used to find out the mean age and standard deviation for each stage. The homogeneity of variances was checked using the Levene test. As the age (in years) was positively skewed, a log transformation was used to be able to fit a two-way ANOVA model for analysis. Therefore, to evaluate the significant difference between the groups and biological sex among each

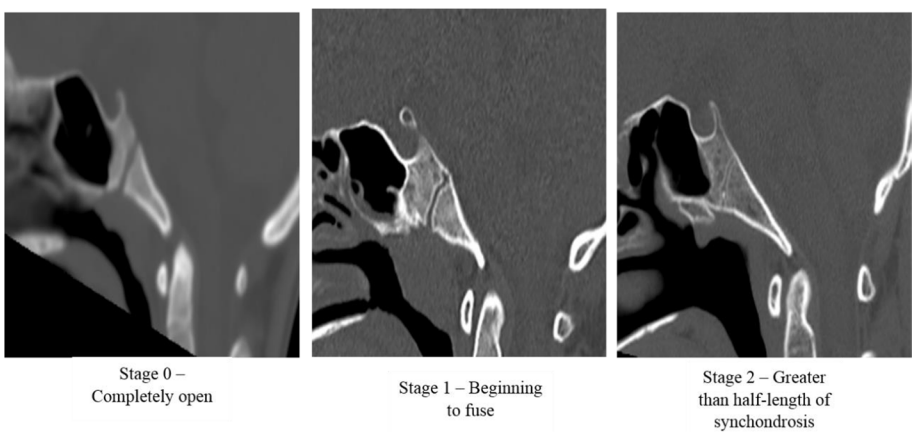


**Fig. 1** Stages of SOS fusion stages in the mid-sagittal plane

**Table 1** Age distribution of the sample population

| Age | Male (*N*) | Female (*N*) | Total |
|---|---|---|---|
| 7 | 14 | 14 | 28 |
| 8 | 18 | 24 | 42 |
| 9 | 8 | 9 | 17 |
| 10 | 6 | 18 | 24 |
| 11 | 16 | 23 | 39 |
| 12 | 14 | 17 | 31 |
| 13 | 15 | 9 | 24 |
| 14 | 17 | 7 | 24 |
| 15 | 15 | 2 | 17 |

group, a two-way ANOVA test was performed. For inter-observer agreement, Cohen's Kappa test was performed. A Kappa value less than 0.20 indicated the poorest agreement. Value between 0.21 and 0.40 indicated slight agreement. Value between 0.41 and 0.60 and 0.61 and 0.80 indicated moderate and good agreement, respectively, and value above 0.81 indicated almost perfect agreement (Rosner 2011).

## Results

The study analysed the degree of SOS for 246 subjects ranging from 7 to 15 years. The distribution of the age sample is shown in Table 1.

### Inter-observer agreement

The Kappa values showed almost perfect agreement ($k=0.854$) between observer 1 and observer 2.

The study reported a mean age of $8.38 \pm 1.21$ for males and $8.2 \pm 1.16$ for females in the stage 0 (completely open) category. The spheno-occipital synchondrosis began to fuse (stage 1) at the mean ages of $11.64 \pm 1.19$ for males and $10.21 \pm 1.19$ for females. With regards to semi-closed (stage 2), the mean age was found to be $13.07 \pm 1.17$ and $11.8 \pm 1.14$ for males and females, respectively (Fig. 2). The descriptive properties of various stages of both sexes are shown in Table 2.

According to the two-way ANOVA test, the study result showed a significant difference among various stages of SOS fusion with age ($p<0.001$). Similarly, the results also showed a significant difference among sex in all 3 categories ($p<0.001$). Therefore, the study depicted

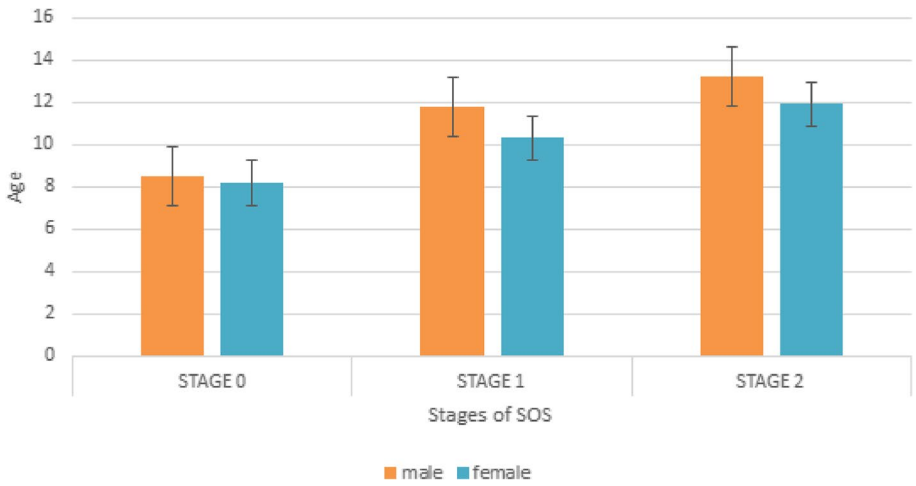


**Fig. 2** Mean degree of fusion for each age group for males and females. Standard deviation is represented by error bars

**Table 2** Descriptive statistics for SOS in the study population

| SOS stages | Gender | *n* | Mean | 95% CI | SD | Min–Max age |
|---|---|---|---|---|---|---|
| **Stage 0** | **M** | 41 | 8.38 | 7.95–8.65 | 1.21 | 7–14 |
| | **F** | 41 | 8.2 | 7.85–8.55 | 1.16 | 7–12 |
| **Stage 1** | **M** | 41 | 11.64 | 11.29–11.99 | 1.19 | 7–15 |
| | **F** | 41 | 10.21 | 9.86–10.56 | 1.19 | 7–14 |
| **Stage 2** | **M** | 41 | 13.07 | 12.72–13.42 | 1.17 | 9–15 |
| | **F** | 41 | 11.8 | 11.47–12.13 | 1.14 | 8–15 |

*CI* confidence interval, *SD* standard deviation, *n* number

that SOS closure occurs earlier in females (10.07) compared to males (11.03).

## Discussion

Age estimation has paramount importance for the forensic practitioner. Identifying the biological age of the individual depends on the skeletal indicator. The spheno-occipital synchondrosis is one such indicator that reflects the biological age. Information on the timing of spheno-occipital synchondrosis reported in literature shows that synchondrosis will be open during childhood and then later merge during adulthood (Ford 1958). A study conducted by Hariprasad et al. reported that there was no significant progression in SOS fusion after an age of 15 years in females and 16 years in males with a mean age of $20.3 \pm 3$ and $20 \pm 3.1$ in males and females, respectively among the South Indian population. However, this study only investigated the timing of complete closure of spheno-occipital synchondrosis (Nambiar et al. 2021). Hence, this study was conducted to assess the timing of beginning of the fusion of SOS. Based on the mean age of the study sample, we found that fusion starts at an age of $11.64 \pm 1.19$ years for males and $10.21 \pm 1.19$ years for females. These results were found to be similar to a study conducted by Salina Hisham et al., where the mean age at which SOS begins to fuse is 10.82 in females (Hisham et al. 2018). However, for males, the SOS begins to fuse at a mean age of 13.74 years. Even though SOS status was assessed using CT, the study was conducted in a Malaysian population. Several studies report morphometric parameter differences among inter- and intra-populations (Pate et al. 2018; Bassed et al. 2010; Sharma et al. 2020). The common factors affecting inter- and intra-populations are geographical, biological, age-related, biological sex-related, ecological, and environmental aspects such as diet, climate and weather (Durtschi et al. 2009; Buretic-Tomljanovic et al. 2007).

The current study also shows a sexual dimorphism during the beginning of fusion, which is in accordance with various studies reported in literature (Pate et al. 2018; Hisham et al. 2018; Sinanoglu et al. 2016; Shirley and Jantz 2011; Can et al. 2014b; Okamoto et al. 1996). In the present study, the oldest male with an open SOS was 14 years old, whereas the oldest female with an open SOS was 12 years old. Table 3 demonstrates a summary of various studies reported in literature indicating the beginning of fusion for males and females in different populations.

As shown in the table, there is a variation in the time of fusion. These differences could be attributed to the differences in population. This highlights the requirement for a population specific data. The literature also

**Table 3** SOS fusion timing among genders found in literature in contrast with the current study showing the mode of assessment, sample size and place

| Author | Publication year | Modalities for assessment | Gender | Sample size | Location | Age in year | |
|---|---|---|---|---|---|---|---|
| | | | | | | Beginning of fusion | |
| | | | | | | Male | Female |
| Ismail Ozgur Can (Can et al. 2014b) | 2014 | CT | Male | 399 | Germany | 14 | 12.7 |
| | | | Female | 139 | | | |
| Salina Hisham (Hisham et al. 2018) | 2018 | CT | Male | 336 | Malaysia | 13.74 | 10.82 |
| | | | Female | 164 | | | |
| Alper Sinanoglu (Sinanoglu et al. 2016) | 2015 | CBCT | Male | 90 | Turkey | 13 | 12 |
| | | | Female | 148 | | | |
| Husniye Demirturk Kocasarac (Demirturk Kocasarac et al. 2016) | 2015 | CBCT | Male | 182 | Turkey | 11 | 12.3 |
| | | | Female | 167 | | | |
| Anka Sharma (Sharma et al. 2020) | 2020 | CBCT | Male | 145 | Nagpur (India) | 13 | 11 |
| | | | Female | 126 | | | |
| Oguzhan Ekizoglu (Ekizoglu et al. 2015) | 2015 | MRI | Male | 455 | Turkey | 13.78 | 13.08 |
| | | | Female | 623 | | | |
| Rajeshwar Sambhaji Pate (Pate et al. 2018) | 2018 | Cadavers | Male | 117 | Maharashtra (India) | 14 -15 | 11–12 |
| | | | Female | 81 | | | |
| Natalie R. Shirley (Shirley and Jantz 2011) | 2011 | Direct inspection | Male | 62 | America | 12.6 – 22.8 | 7.8 – 20.1 |
| | | | Female | 100 | | | |
| Present study | 2021 | CT | Male | 123 | Karnataka (India) | 11.64 | 10.21 |
| | | | Female | 123 | | | |

reports methodological differences that cause variation in the time of fusion. The most procedural variation depends on whether the research is conducted on live individuals or post-mortem. Several studies report a variation in results due to differences in assessment methods (Pate et al. 2018; Demirturk Kocasarac et al. 2016; Shirley and Jantz 2011; Okamoto et al. 1996). To analyse age, macroscopic and histological methods are used for post-mortem, whereas conventional radiography, CT, and MRI methods have been used for live individuals (Pate et al. 2018; Demirturk Kocasarac et al. 2016; Shirley and Jantz 2011; Okamoto et al. 1996; Ekizoglu et al. 2015). It is shown that a macroscopic assessment of SOS generally overestimates the age. On the other hand, various studies have reported the advantages of CT scans over conventional radiographs and macroscopic techniques. Due to its superior image quality in terms of resolution, obtaining three-dimensional images, and enabling earlier detection and accurate interpretation, CT can be used effectively to demonstrate various stages of spheno-occipital synchondrosis (Shirley and Jantz 2011; Bassed et al. 2010; Okamoto et al. 1996; Sharma et al. 2020). However, cost, radiation exposure, and accessibility are a few limitations of CT scans (Demirturk Kocasarac et al. 2016). The variability in SOS among different populations and studies can also be attributed to maturational events. A study conducted by Alhazmi A et al. reported a significant relation between the onset of puberty and SOS closure. The systemic and hormonal changes in a growing adolescent can be the reason affecting the closure (Alhazmi et al. 2017). However, the present study did not take into account the onset of puberty and its relationship to SOS closure. Also, as the current study collected the data retrospectively, it did not take into account the socio-economic status or ethnicity background,therefore, further studies can be done to understand the relationship of SOS closure with respect to these factors as well. Another limitation was that the study had a limited sample size. Therefore, studies involving a larger sample can be done to represent a diverse population. Also, there is a high chance that the fusion of SOS can vary among the South and North Indian populations due to morphometric differences caused by ecological and environmental factors such as climate and diet. Therefore, studies can be conducted in this region to provide a unique perception of the variability in population throughout the country.

## Conclusions

The study concluded that in the South Indian population, when the SOS begins to close, the age is less than 15 years in males. Similarly, for females, if SOS begins to close, the age is less than 14 years. Also, a strong sexual dimorphism is seen as each stage of synchondrosis starts earlier in females compared to males. This estimation will not only help in forensic and anthropological studies but also in assessing craniofacial growth in orthodontics.

### Abbreviations

| | |
|---|---|
| SOS | Spheno-occipital synchondrosis |
| CT | Computed tomography |
| PNS | Paranasal sinuses |
| kVp | Kilovoltage potential |
| PACS | Picture Archival communication system |
| ANOVA | Analysis of variance |
| MRI | Magnetic resonance imaging |

### Acknowledgements

The authors would like to acknowledge, Kasturba Hospital and Manipal College of Health Professions for their support to undertake this study. We also extend our heartfelt gratitude to the faculties and Head of the Department of Radio-diagnosis and Imaging for their cooperation in the phantom study. We also acknowledge the support of the Department of Statistics for the guidance during data analysis and interpretation.

### Authors' contributions

NCP conceptualised the study. VT has given inputs in the study design. RN collected the data. NCP and VT analysed the data. RN wrote the final draft of the manuscript. NCP and VT revised and added inputs to the manuscripts.

### Funding

There is no external funding for this research project as this project was conducted within the institute itself which provided us will all facilities required to conduct the project.

### Availability of datamaterials

Since the data sets in the study are derived fromdicom images, the images cannot be shared publicly to maintain participantconfidentiality, However the data derived from those images are well summarizedin the article and can be made available from the corresponding author onreasonable request.

## Declarations

### Ethics approval and consent to participate

The study was approved by the institute ethical committee and followed all ethical guidelines during the research.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

Received: 26 January 2023 Accepted: 28 May 2023
Published online: 06 June 2023

### References

Akhlaghi M, Taghaddosinejad F, Sheikhazadi A, Valizadeh B, Shojaei SM (2010) Age-at-death estimation based on the macroscopic examination of spheno-occipital sutures. J Forensic Leg Med 17(6):304–308. https://doi.org/10.1016/j.jflm.2010.04.009

Alhazmi A, Vargas E, Palomo JM, Hans M, Latimer B, Simpson S (2017) Timing and rate of spheno-occipital synchondrosis closure and its relationship

to puberty. PLoS One 12(8):1–16. https://doi.org/10.1371/journal.pone.0183305
Alkass K, Buchholz BA, Ohtani S, Yamamoto T, Druid H, Spalding KL (2010) Age estimation in forensic sciences: application of combined aspartic acid racemization and radiocarbon analysis. Mol Cell Proteomics 9(5):1022–1030. https://doi.org/10.1074/mcp.M900525-MCP200. Epub 2009 Dec 4. PMID: 19965905; PMCID: PMC2871409
Bassed RB, Briggs C, Drummer OH (2010) Analysis of time of closure of the spheno-occipital synchondrosis using computed tomography. Forensic Sci Int 200(1–3):161–164. https://doi.org/10.1016/j.forsciint.2010.04.009
Buretic-Tomljanovic A, Giacometti J, Ostojic S, Kapovic M (2007) Sex-specific differences of craniofacial traits in Croatia: the impact of environment in a small geographic area. Ann Hum Biol 34(3):296–314. https://doi.org/10.1080/03014460701211017
Can IO, Ekizoglu O, Hocaoglu E, Inci E, Sayin I, Kaya KH (2014a) Forensic age estimation by spheno-occipital synchondrosis fusion degree: computed tomography analysis. JCraniofacSurg 25(4):1212–1216. https://doi.org/10.1097/scs.0000000000000847
Can IO, Ekizoglu O, Hocaoglu E (2014b) Forensic age estimation by spheno-occipital synchondrosis fusion degree: computed tomography analysis. Journal of Craniofacial Surgery 24(4):1212–1216. https://doi.org/10.1097/scs.0000000000000847
Cardoso HFV, Abrantes J, Humphrey LT (2014) Age estimation of immature human skeletal remains from the diaphyseal length of the long bones in the postnatal period. Int J Legal Med 128(5):809–824. https://doi.org/10.1007/s00414-013-0925-5
Demirturk Kocasarac H, Sinanoglu A, Noujeim M, Helvacioglu Yigit D, Baydemir C (2016) Radiologic assessment of third molar tooth and spheno-occipital synchondrosis for age estimation: a multiple regression analysis study. Int J Legal Med 130(3):799–808. https://doi.org/10.1007/s00414-015-1298-8
Durtschi RB, Chung D, Gentry LR, Chung MK, Vorperian HK (2009) Developmental craniofacial anthropometry:assessment of race effects. Clinc Anat. 22(7):800–808. https://doi.org/10.1002/ca.20852
Ekizoglu O, Hocaoglu E, Can IO, Inci E, Aksoy S (2015) Spheno-occipital synchondrosis fusion degree as a method to estimate age : a preliminary, magnetic resonance imaging study. Aust J Forensic Sci 48(2):159–170. https://doi.org/10.1080/00450618.2015.1042047
Ford HER (1958) Growth of the human cranial base. Am J Orthod 44:498–506. https://doi.org/10.1016/0002-9416(58)90082-4
Hisham S, Flavel A, Abdullah N, Noor MHM, Franklin D (2018) Quantification of spheno-occipital synchondrosis fusion in a contemporary Malaysian population. Forensic Sci Int 284(2018):78–84. https://doi.org/10.1016/j.forsciint.2017.12.046
Krishan K, Kanchan T (2013) Evaluation of spheno-occipital synchondrosis: a review of literature and considerations from forensic anthropologic point of view. J Forensic Dent Sci 5(2):72
Nambiar HT, Mehanaz A, Panakkal NC, Suresh S, Visakh T (2021) A Prospective study to determine the timing of complete fusion of spheno-occipital synchondrosis using computed tomography. Indian J Forensic Med Toxicol 15(4):1284–1289. https://doi.org/10.37506/ijfmt.v15i4.16886
Okamoto K, Ito J, Tokiguchi S, Furusawa T (1996) High-resolution CT findings in the development of the sphenooccipital synchondrosis. Am J Neuroradiol 17(1):117–120. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/pmc8337967/
Pate RS, Tingne CV, Dixit PG (2018) Age determination by spheno-occipital synchondrosis fusion in Central Indian population. J Forensic Leg Med 54:39–43. https://doi.org/10.1016/j.jflm.2017.12.013
Rosner B (2011) Fundamentals of Biostatistics, 7th edn. Brooks/Cole, Cengage Learning, Boston
Sahni D, Jit I, Neelam SS (1998) Time of fusion of the basisphenoid with the basilar part of the occipital bone in northwest Indian subjects. Forensic Sci Int 98(1–2):41–45. https://doi.org/10.1016/s0379-0738(98)00135-2
Sharma A, Kumbhare SP, Kalaskar AR, Motghare P, Gondivkar S, Upmanyu A (2020) Age estimation in an Indian subpopulation by cone-beam computed tomographic analysis of spheno-occipital synchondrosis fusion. Forensic Sci Int Rep 2(February):100085. https://doi.org/10.1016/j.fsir.2020.100085
Shirley NR, Jantz RL (2011) Spheno-occipital synchondrosis fusion in modern Americans. J Forensic Sci 56(3):580–585. https://doi.org/10.1111/j.1556-4029.2011.01705.x
Sinanoglu A, Kocasarac HD, Noujeim M (2016) Age estimation by an analysis of spheno-occipital synchondrosis using cone-beam computed tomography. Leg Med 18:13–19. https://doi.org/10.1016/j.legalmed.2015.11.004
Ubelaker DH, Khosrowshahi H (2019) Estimation of age in forensic anthropology: historical perspective and recent methodological advances. Forensic Sci Res 4(1):1–9. https://doi.org/10.1080/20961790.2018.1549711. PMID: 30915413; PMCID: PMC6427487
Yang JH, Cha BK, Choi DS, Park JH, Jang I (2019) Time and pattern of the fusion of the spheno-occipital synchondrosis in patients with skeletal Class I and Class III malocclusion. Angle Orthod 89(3):470–479. https://doi.org/10.2319/052218-386.1

## Publisher's Note