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# Analysis of time of closure of the spheno-occipital synchondrosis using computed tomography

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ABSTRACT

Current knowledge concerning closure of the spheno-occipital synchondrosis is inadequate for age estimation purposes in that of the few detailed studies conducted, these demonstrate considerable variation concerning the age at which the synchondrosis commences and completes fusion, thus creating uncertainty for forensic investigators who may use this developmental feature for age determinations. The aim of the present study was to determine the sequence and timing of closure of the spheno-occipital synchondrosis for a large sample of a modern Australian population to assess if this age marker is a useful tool for age estimation for individuals around the age of 18 years. The sample consisted of 666 individuals in the age range 15–25 years, who were admitted to the Victorian Institute of Forensic Medicine (VIFM) mortuary and who had undergone routine full body multi-slice CT imaging. Results show that fusion was well underway by the age of 15 years and was complete by 17 years. Fusion begins superiorly and progresses inferiorly. Persistence of a scar at the site of fusion was demonstrated through to age 25 years. After the age of 16 years there was no significant difference in progress of fusion between males and females. The study showed that this age marker is of limited value for age estimations around the age of 18 years in this population.



## 1. Introduction

There has been increasing interest in the study of skeletal age markers in recent years due to growing pressure on forensic practitioners to provide more accurate age estimations. This is particularly the case with the increasing numbers of undocumented individuals moving across international borders resulting in the need to determine the age status of many of these people; particularly around the adolescent/adult cut-off point of 18 years, an important legal demarcation in many jurisdictions [1,2]. Below the age of 14–15 years the developing dentition [3] and hand/wrist ossification [4] provide reasonably accurate age estimations, but once these development sites have completed growth, accurate age estimation becomes far more difficult. Determination of adult or adolescent status of an unknown age individual is difficult due to the paucity of skeletal and dental age markers available around this age; the only readily examinable markers being the 3rd molar tooth and the medial clavicular epiphysis, both of which display considerable variation in development [5,6].

A synchondrosis can be defined as a cartilaginous joint between two immovable bones that serves to allow growth until the cartilage is converted into bone before or during early adult life [7]. The spheno-occipital synchondrosis is the site of union between the occipital and sphenoid bones, situated in the clivus area at the base of the skull, anterior to the foramen magnum and inferior to the pituitary fossa. To date this synchondrosis has been studied mainly from the point of view of growth of the cranial base and its relationship to dento-alveolar development [8–14]. There have been few forensic studies concerning its use for age estimation, and those that do exist quote a range of different fusion times. Early radiological observations regarding the commencement of ossification of the synchondrosis vary from puberty to the third decade [15,16]. Irwin [17] examined 47 individuals and found that ossification began at the superior border of the synchondrosis at approximately 11–13 years, progressed inferiorly, and was generally completed by 18 years. Powell and Brodie [18] determined from their analysis of the radiographs of 398 individuals that closure was complete for males by the age of 15 years, and for females by 14 years. Melsen [19], in his study of 100 dried skulls, found that ossification was initiated anywhere between the ages of 12 and 18 years, but gave no time for completion of fusion. A further study of autopsy tissue samples by Thilander and Ingervall [20] revealed that the synchondrosis was completely ossified in females by the age of 16–17 years, and about 2 years later in males.

More recent work has concentrated on the use of computed tomography to visualise the synchondrosis, due to the superior

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visualisation of the skull base using this imaging modality, and the subsequent greater accuracy in determining closure. Okamoto et al. [21] examined the high resolution CT scans of 253 individuals aged from 1 to 77 years, and concluded that "no spheno-occipital synchondrosis persisted in any patient past the age of 13 years". This is in stark contrast to the various ages of closure seen in earlier studies. Madeline and Elster [11] also conducted a CT study of fusion of various synchondroses in the cranial base on 189 individuals and discovered a median age for stage 3 closure of the spheno-occipital synchondrosis of 13.5 years in boys, and 14 years in girls. Their results describe stage 4 closure at 17 years in girls and 18 years in boys. Mann et al. [12], in a detailed study of all cranial synchondroses, worked with a sample of 260 individuals ranging in age from birth to 22 years and stated that the spheno-occipital synchondrosis began fusion at around 8 years, and was essentially complete by 16 years (girls) and 18 years (boys). These more recent CT studies still show variation in the time of closure which merits further research, and also raises the issue of inter-population variation.

Another possible reason for this variation in fusion between studies is the different methods of analysis used by different researchers [22]. Dry skulls, histological sections, conventional radiography, and CT imaging may possibly be interpreted differently. A synchondrosis which looks completely closed in a dry skull may not be so when a high resolution CT scan of the same skull is viewed. The same applies to conventional radiography images, which for this particular age marker are very difficult to interpret due to the difficulties involved in aligning the X-ray beam with the synchondrosis, and the large number of overlying structures which can confuse interpretation of the image [23].

The Victorian Institute of Forensic Medicine (VIFM), located in Melbourne, Australia, investigates all deaths reported to the Victorian State Coroner. As part of the routine forensic investigation procedure a full body CT scan is performed on all of these cases. These scans consist of 2 mm slices of the entire body, and 1 mm slices of the head and neck. Currently the VIFM has performed CT imaging on approximately 15,000 individual forensic cases. This database includes individuals from all age groups, with approximately 1000 individuals falling into the target age group for this study (15–25 years).

The aim of the current study was to examine the development of the spheno-occipital synchondrosis in individuals, aged from 15 to 25 years, who had been admitted to the VIFM, and who had all undergone full body high resolution multi-slice CT scanning. Visualisation of the spheno-occipital synchondrosis is straightforward using this modality as mid sagittal slices of the area of interest are readily accessible and are easy to interpret. The closure of this synchondrosis proceeds in an orderly fashion, beginning at the superior border and progressing inferiorly until complete. This pattern of fusion is amenable to being divided into stages which can be scored and correlated with age.

## 2. Materials and methods

High resolution multi-slice CT scans were examined in individuals of known birth date aged from 15 to 25 years. The study population consisted of a random sample of modern multicultural Australian society. No attempt has been made at this stage to categorise individuals according to ancestry or socio-economic status, although this is the subject of future research. Individuals of unknown age or those who had suffered significant head trauma which potentially affected the area of interest were excluded from the sample.

The imaging system utilised at the VIFM is a Toshiba Aquilion 16® multi slice scanner, which captures 1-mm thick slices of the head and neck which are then reconstructed and viewed using the TeraRecon, Inc, Aquarius-Net® software package. Mid sagittal sections of the skull base were considered the view of choice.

The ossification status of the spheno-occipital synchondrosis was assessed using a five stage system modified from that developed by Powell and Brodie [18]. The stages are as follows (see also Fig. 1): in stage 1 the synchondrosis is completely open and unfused. In stage 2 the superior border has fused whilst the remainder of the fusion site is patent. In stage 3 half the length of the synchondrosis is closed. In stage 4 closure is essentially complete, but the site is still visible by way of a fusion scar, and in stage 5 the site has been completely obliterated with the appearance of normal bone throughout. Stage 4 is a new growth stage added specifically due to the

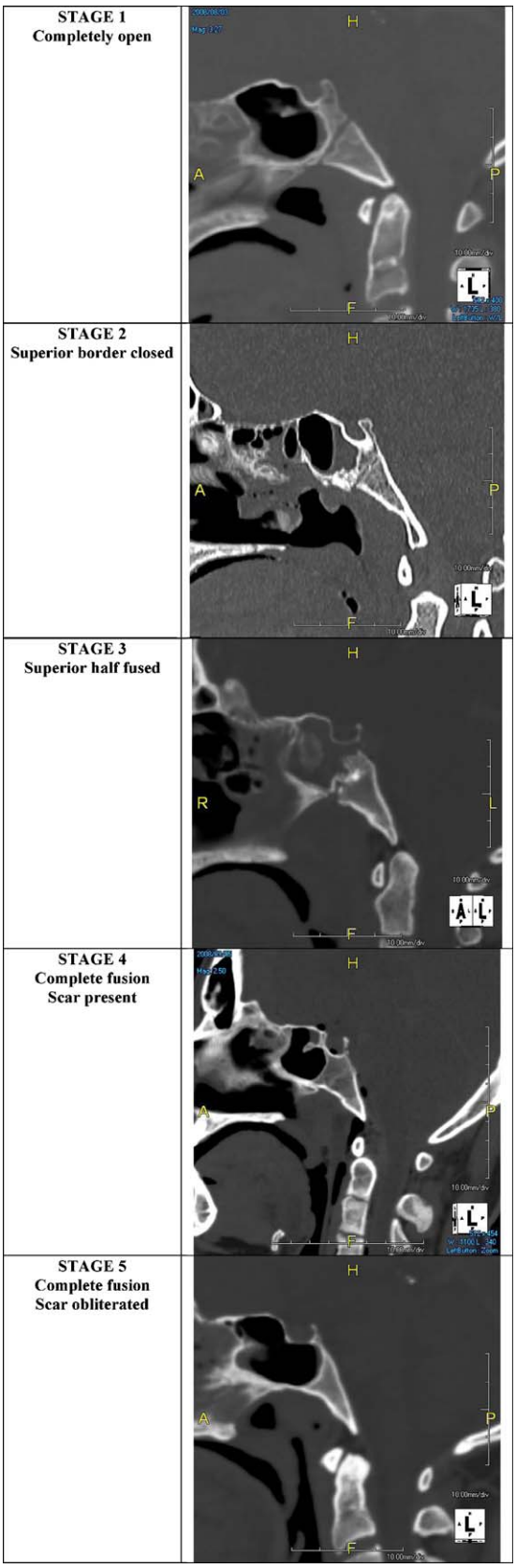


**Fig. 1.** Developmental staging.