The ossification process of the occipital bone and normal variants: evaluation by Computed Tomography (CT).

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Purpose

To present the development of the cartilaginous occipital bone by illustrating age-related changes of intraosseous and interosseous occipital synchondroses.

Methods and Materials

One hundred and eleven cranial CT examinations of patients aged from 6 days to 20 years (68 males, 43 females), performed during a 2-year period (2008-2010), were retrospectively reviewed for the development of the occipital bone. The majority of the patients (81) were referred to our radiology department with the indication of craniocerebral trauma. The remaining (30) patients were examined for various pathologies (seizures, headache, staging, loss of consciousness and ENT surgery planning).

Ossification centers of the cartilaginous occipital bone were identified and observations were made regarding timing of closure and CT morphology of synchondroses. The interparietal bone (membranous occipital bone) and the mendosal suture was not part of our study, which was limited to the chondrocranium.

Results

The occipital bone has dual embryologic origin from cartilaginous and membranous centers.

**Cartilaginous segments comprising the occipital bone are:**

- the basioccipital or basilar (anterior to the foramen magnum)
- the paired exoccipital or condylar (on either side of the foramen magnum)
- the supraoccipital or inferior squamus (posterior to the foramen magnum and below the mendosal suture)
- the Kerckring's ossicle (at the posterior margin of the foramen magnum adjacent to the supraoccipital bone)

**Membranous segment comprising the occipital bone is:**
- the interparietal or superior squamus (above the supraoccipital segment and the mendosal suture).  

(Fig.1) on page 5

The word "synchondrosis" ("###########" in the greek language) derives etymologically from the greek words "syn", which means "with" and "chondros", which means "cartilage". A synchondrosis can be defined as a cartilaginous joint between two immovable bones that allows growth until the cartilage is converted into bone tissue and the adjoining bones unite. [7]

The aforementioned occipital segments join at 6 synchondroses:

1. anterior intraoccipital (intraosseous, between basioccipital and exoccipital)
2. posterior intraoccipital or innominate (intraosseous, between exoccipital and supraoccipital)
3. spheno-occipital (interosseous, between the body of the sphenoid bone and basioccipital)
4. petro-occipital (interosseous, between basioccipital and petrous portion of temporal bones)
5. occipitomastoidal (interosseous, between exoccipital and the mastoid portion of temporal bones)
6. the synchondrosis between Kerckring's ossicle and supraoccipital bone. [1][6]

These five ossification centers and 6 synchondroses were identified in the skull base on axial CT images and were most prominent in newborns and infants, when the synchondroses appear as large "gaps" between the skull base bones. (Fig.2) on page 6

**The Kerckring's ossicle - supraoccipital bone synchondrosis.** [1]

It was the first synchondrosis to disappear during the development of the chondrocranium. Already at 2-3 months it cannot be identified as an independent bone structure in the posterior part of the foramen magnum and there is partial or complete fusion with the supraoccipital bone. Complete fusion was found in all children #1 year with the exception of one child. (Fig.3) on page 7

**The posterior intraoccipital synchondrosis.** [1][6]

The next in line to close was the posterior intraoccipital synchondrosis. In our specimen fusion began at 2 years of age and was completed by age #7. Complete closure was
identified in 57% of 3-year-old children, in 78% of 4-year-old, in 100% of 5-year-old, in 85% of 6-year-old and in all children #7-years. (Fig.4) on page 7

**The anterior intraoccipital synchondrosis.** [1]

The anterior intraoccipital synchondrosis closed later between 3-9 years. Beginning of fusion was noticed in children aged 3 years. In children <6 years various patterns of ossification were identified. It was found completely closed in 14% of children aged 6 years, in 50% of children aged 7 years, in 80% of children aged 8 years and in 100% of children aged 9 years. All children #9 years had already fused anterior intraoccipital synchondrosis. (Fig.5) on page 8

**The spheno-occipital synchondrosis.** [1][8][9]

The spheno-occipital synchondrosis plays major role in the growth of the skull base. It showed signs of fusion by the age of 9 with earliest complete closure observed at the age of 12 and latest at the age of 15. In our study all subjects #15 years had a completely ossified spheno-occipital synchondrosis. (Fig.6) on page 9

**The petro-occipital and occipitomastoidal synchondroses.** [1][10][11]

The petro-occipital synchondrosis has a rather complex anatomy. The superior part, which is the main synchondrosis, remains open until adolescence and is known to fuse between 20 and 50 years of age. In our study only one adult (female 19-years-old) showed completely closed petro-occipital synchondrosis and four adults showed partially closed synchondrosis. According to bibliographical data this partial closure can remain a permanent condition for this type of synchondrosis for many years. (Fig.7) on page 10

The petro-occipital synchondrosis extends to the occipitomastoidal suture. As with the petro-occipital synchondrosis, the occipitomastoidal suture remains partially open even in adults, with or without sclerotic margins. (Fig.8) on page 11

**CT morphology of synchondroses.** [8][12]

Common appearance of synchondroses ranged from clearly separated margins to complete closure without remnants. Bizarre morphology was also identified and included variants such as foramina, clefts, accessory ossification centers, cruciform patterns and vestiges. In particular these variants were identified:
a) **Spheno-occipital pseudoforamen:** as the lateral parts of the spheno-occipital synchondrosis ossify, the middle still cartilaginous part may appear as a round lucency. *(Fig.9)* on page 12

b) **Canalis basilaris medianus:** it is thought to demarcate the cephalic end of the notochord and can be identified as a tubular, midline canal in the basioccipital bone. *(Fig.9)* on page 12

c) **Anterior basioccipital clefts:** located at the anterior border of the basioccipital bone and in the midline. *(Fig.9)* on page 12

d) **Cruciform anterior intraoccipital synchondrosis:** during its ossification process the synchondrosis may take a cruciform appearance. *(Fig.10)* on page 13

e) **Anterior intraoccipital pseudoforamina:** they are small canal-like defects that remain at the site of the anterior intraoccipital synchondrosis when maturation has progressed. *(Fig.10)* on page 13

f) **Sclerotic vestiges:** after the completion of the fusion at the various synchondroses sclerotic remnants may be found. *(Fig.11)* on page 14

g) **Ossification centers:** usually in the middle of the synchondrosis as single or multiple hyperdense foci. *(Fig.11)* on page 14

**Images for this section:**
**Fig. 1:** Two consecutive CT images of a 6-day-old newborn male. All the parts of the occipital bone of the skull base are easily identified due to the presence of prominent synchondroses: anterior basioccipital (B), lateral exoccipitals (E), posterior supraoccipital (S) and Kerckring's ossicle (yellow arrowhead). The occipital synchondroses are depicted as large "gaps": anterior intraoccipital (red arrows), posterior intraoccipital (white arrows), spheno-occipital (black arrows), petro-occipital (black arrowheads), occipitomastoidal (red arrowheads) and the synchondrosis between the Kerckring's ossicle-supraoccipital (yellow arrow).

**Fig. 2:** Images of three female infants aged 2-months (a), 6-months (b) and 8-months (c). The occipital cartilaginous parts are depicted: basioccipital (B), exoccipitals (E), supraoccipital(S) and Kerckring's ossicle (k). The synchondroses between them are wide at this age and easily identified as such, when the radiologist is familiar with the anatomy of the skull base for this age group: anterior intraoccipital (red arrows), posterior
intraoccipital (white arrows) and spheno-occipital (black arrows), the petro-occipital (black arrowheads), the occipitomastoidal (red arrowheads) and the synchondrosis between the Kerckring’s ossicle-supraoccipital (yellow arrow).

**Fig. 3:** CT images of the Kerckring’s ossicle (arrows) and its fusion with the supraoccipital bone in children aged #1-year-old (images k1–k9). The ossicle is rapidly assimilated to the supraoccipital bone during the first months. With the exception of 1 child (image k8) all children #1 year had no identifiable Kerckring’s ossicle. Specific ages of children in images k1–k9 are: 11-days-old female(k1), 2-months-old male(k2), 2 months-female(k3), 3-months-old female(k4), 4-months-old male(k5), 9-months female(k6), 1-year-old female(k7), 1-year-old male(k8), 1-year-old female(k9).
**Fig. 4:** CT images of the posterior intraoccipital synchondrosis in 9 children aged between 2-6 years: 2-years-old(p1), 2-years-old(p2), 3-years-old(p3), 3-years-old(p4), 4-years-old(p5), 4-years-old(p6), 5-years-old(p7), 6-years-old(p8) and 6-years-old(p9). Open synchondroses (fully or partially) are depicted with white arrows in images p1, p2, p3, p6, p8. Site of partial-early signs of fusion is pointed out in image p3 (yellow arrow). Completely fused synchondrosis in images p4, p5, p7, p9.
**Fig. 5:** The anterior intraoccipital synchondrosis in children aged 3-9 years. The earliest signs of ossification were noticed in children aged 3 years (image a1, white arrow). Open synchondrosis in images a2, a3 and a5. A vestige of the closed synchondrosis as a hyperdense line was apparent in some children after fusion (yellow arrow in images a4, a6,a8,). Ages of children in images are:3-years(a1), 5-years(a2), 6-years(a3), 7-years(a4), 7-years(a5), 8-years(a6), 9-years(a7).
Fig. 6: The spheno-occipital synchondrosis in children and adults (ages 9-18 years): Early signs of ossification were identified in a child aged 9 (image s1, yellow arrow). The earliest complete closure was found at the age of 12 (image s5). Still open synchondroses as an easily detected horizontal gap in the clivus (images s1,s2,s3,s4). Almost complete fusion, with barely visible synchondrosis in a 14-year-old female (image s6, yellow arrow). Completely closed spheno-occipital synchondrosis in images s5, s7 and s8. Specific ages in images are: 9 years(s1), 11 years(s2), 11 years(s3), 12 years(s4), 12 years(s5), 14 years(s6), 15 years(s7) and 18 years(s8).
Fig. 7: The petro-occipital synchondrosis does not completely fuse until adulthood and even then part of the petro-occipital unit (the inferior) remains open as a homonymous fissure (image a6-yellow arrows). Closed superior petro-basioccipital synchondrosis was observed in a 19-year-old girl (a6-white arrows). Open synchondroses in images a1-a5 in various degrees of bridging. Ages: a1) Male 3-years-old, a2) male 6-years-old, a3) female 9-years-old, a4) male 11-years-old, a5) female 14-years-old and a6) female 19-years-old.
**Fig. 8:** CT morphology of the occipitomastoidal synchondrosis-suture from 1-19 years of age. It becomes narrower with age but still remains visible in all children, usually with sclerotic margins (a3,a5 - arrows). Images: a1) male 1-year-old, a2) Male 4-year-old, a3) male 11-year-old, a4) female 14-year-old and a5) female 19-y-old.
Fig. 9: a) Spheno-occipital pseudoforamen in an 11-year-old, b) Canalis basilaris medianus in a 12-year-old, c1-c2) Anterior basioccipital clefts in two 8-year-old children.
**Fig. 10:** d1-d3) CT appearance of cruciform anterior intraoccipital synchondrosis in 3 children aged 1, 2 and 3-years-old, e1-e2) Anterior intraoccipital pseudoforamina as depicted in a 8-year-old and a 4-year-old child.

**Fig. 11:** f1-f2) CT appearance of sclerotic vestiges in fused synchondroses in two children 10 and 14 years-old, g1-g3) Ossification centers as hyperdense foci in children 9, 10 and 10 years-old. Usually these ossification centers are single(g1,g2), but they may be multiple as well(g3).
Conclusion

The major occipital synchondroses that form the occipital bone fuse with chronological order: first the synchondrosis between Kerckring's ossicle and supraoccipital bone, then the posterior intraoccipital and the anterior intraoccipital and finally the spheno-occipital. The petro-occipital and the occipitomastoidal remain partially open even in adulthood.

Knowledge of the anatomic location and time of closure of synchondroses can be helpful to various medical specialties:

- to the pediatric dentist in planning orthodontic treatment since growth of the spheno-occipital synchondrosis influences the development of the upper face and the upper teeth

- to the forensic pathologist or anthropologist to estimate age of a cadaver and,

- to the radiologist to accurately evaluate pathologies such as skeletal dysplasias, craniosynostoses, encephaloceles, but usually and most importantly to differentiate without doubt a fracture line from a synchondrosis in craniocerebral trauma cases. [5][13][14][15][16][17]

Demonstration of the morphologic changes in computed tomography of the central skull base can provide imaging "maps" of this complex ossification process of the pediatric chondrocranium.

References


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