

CT 1

:
 : 109 (: 29 -15)
 1mm CT ,
 18 5
 : 1-2
 . Intersphenoidal
 syn- chondrosis, intrapresphenoidal synchondrosis, intrapostsphenoidal synchondrosis
 grade 4
 sphenosquamal, sphenothmoidal, frontosphenoidal 3
 가 가
 6 Kerckring-supraoccipital synchondrosis
 occipitomastoidal suture petro-occipital
 synchondrosis 가
 :
 ,
 가
 (sphenoid bone) (occipital bone)
 (frontal bone), (ethmoid bone),
 (temporal bone) (central
 skull base) (membranous bone) (cartilage-
 nous bone) , 25 / CT
 (ossification center) 109
 (1-3). (suture) (synchon-
 drosis) . (high spatial frequency
 algorithm) (orbitomeatal line)
 (foramen magnum) (orbital roof)
 1mm 18
 (1).
 Kerckring-supraoccipital synchondrosis(KSS),
 exoccipital-supraoccipital synchondrosis(ESS), occipitomastoidal
 suture(OMS), basioccipital-exoccipital synchondrosis(BES),
 petro-occipital synchondrosis(POS), spheno-occipital
 synchondrosis(SOS) 6 (Fig. 1),
 anterior presphenoido-orbital synchondro-
 CT (thin-section)

sis(APOS), posterior presphenoido-orbital synchondrosis(PPOS), intersphenoidal synchondrosis (ISS), intrapresphenoidal synchondrosis(IPRES), intrapostsphenoidal synchondrosis(IPOS), rostrum-ossicles of Bertin synchondrosis(ROB), lateromedial postsphenoidal synchondrosis(LMPS), basisphenoidal-alisphenoidal synchondrosis(BAS), sphenosquamal suture (SSS), sphenothmoidal suture(SES), frontosphenoidal suture(FSS), inter-planum sphenoidale(IPS) 12 (Fig. 2A, B).

(pneumatization)가 가 (pneumatization)가 가 . CT low grade (grade 1, 2, 3) high grade(grade 4, 5)

CT Madeline Elster (1)가 Grade 1-5 5 (Fig. 3). Grade 1 , grade 2 가 (osseous bridge)가 , grade 3 / , grade 4 (sclerotic margin)가 , grade 5

Table 1. Subject Demographics

Age	Number of Subjects	
	Boys	Girls
< 3 mo	3	0
< 6 mo	4	2
< 12 mo	3	4
< 2 yrs	9	6
< 4 yrs	6	9
< 6 yrs	12	4
< 10 yrs	19	8
< 16 yrs	14	6
Total	70	39

CT

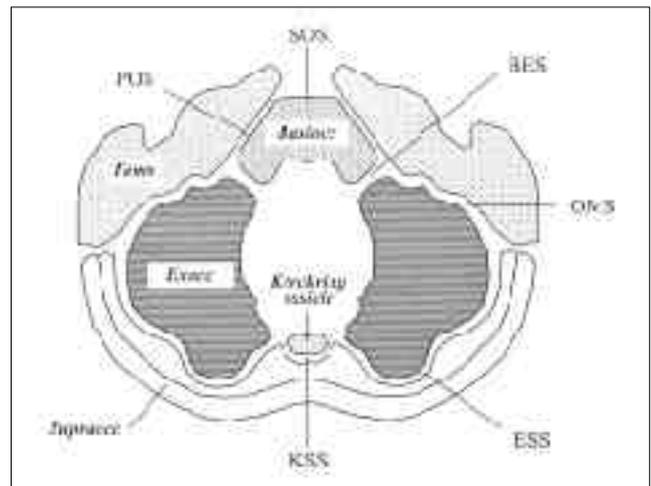


Fig. 1. Components of the occipital bone at birth with corresponding sutures and synchondroses. Basiocc = basioccipital bone, Exocc = exoccipital bone, Supraocc = supraoccipital bone, Temp = temporal bone, BES = basioccipital-exoccipital synchondrosis, ESS = exoccipital-supraoccipital synchondrosis, KSS = Kerckring-supraoccipital synchondrosis, OMS = occipitomastoidal suture, POS = petro-occipital synchondrosis, SOS = spheno-occipital synchondrosis.

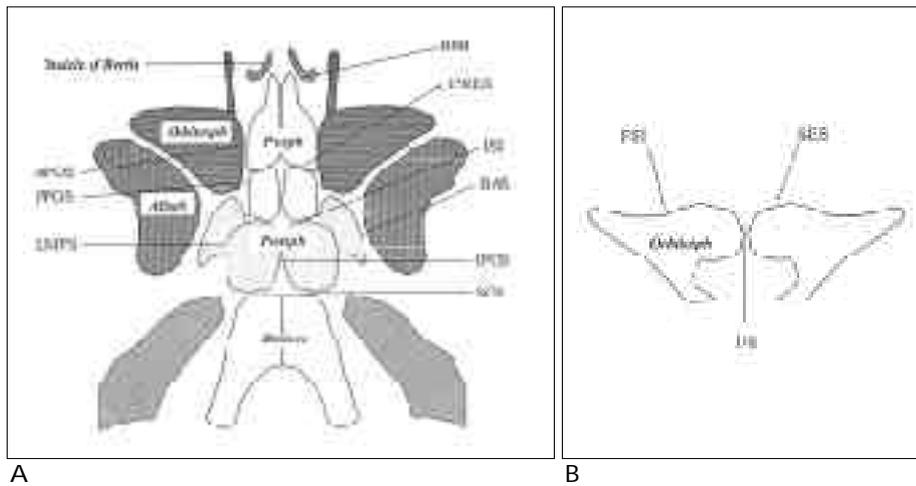


Fig. 2. Components of the sphenoid bone at birth with corresponding sutures and synchondroses at level of middle orbit (A) and upper orbit (B). The superomedial extension of the orbitosphenoid (B) extends across the superior aspect of the anterior accessory center of the presphenoid to form a prejugum ridge. Alisph= alisphenoid, Basiocc= basioccipital bone, Orbitosph= orbitosphenoid, Postsph= postsphenoid, Presph = presphenoid, APOS= anterior presphenoido-orbital synchondrosis, BAS= basisphenoidal-alisphenoidal synchondrosis, FSS= frontosphenoidal suture, IPOS= intrapostsphenoidal synchondrosis, IPRES= intrapresphenoidal synchondrosis, IPS= inter-planum sphenoidale, ISS= intersphenoidal synchondrosis, LMPS= lateromedial postsphenoidal synchondrosis, PPOS= posterior presphenoido-orbital synchondrosis, SSS= sphenosquamal suture, SES= sphenothmoidal suture.

postsphenoidal synchondrosis, IPRES= intrapresphenoidal synchondrosis, IPS= inter-planum sphenoidale, ISS= intersphenoidal synchondrosis, LMPS= lateromedial postsphenoidal synchondrosis, PPOS= posterior presphenoido-orbital synchondrosis, ROB= rostrum-ossicles of Bertin synchondrosis, SSS= sphenosquamal suture, SES= sphenothmoidal suture.

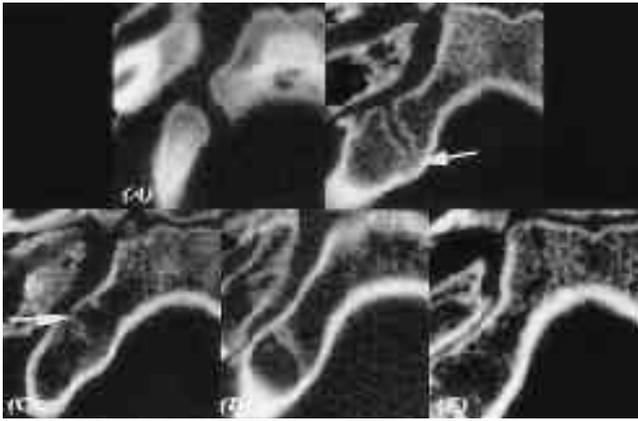


Fig. 3. Five-tier scheme for grading sutural or synchondrosal closure is illustrated along the basioccipital-exoccipital synchondrosis on CT scans.
 (A) Grade 1. Margins of the synchondrosis(suture) are clearly separated on all sections.
 (B) Grade 2. Clear separation of the synchondrosis is seen on most sections, but some areas are indistinct or suspicious for osseous bridge (arrow).
 (C) Grade 3. Area of fusion or bridging (arrow) across a portion of the synchondrosis is definitely seen.
 (D) Grade 4. Complete fusion of the synchondrosis with remnant sclerotic margins is seen.
 (E) Grade 5. Complete closure is seen with no apparent vestige remaining.

Table 2-Table 5
 6 (Fig.1)
 Kerckring-supraoccipital synchondrosis(KSS)
 Kerckring center
 (supraoccipital bone) . KSS
 3 3
 grade 2 grade 3 low grade 2 , grade 4
 1 . 3-6 low grade
 1 , high grade 3 1
 grade 4 1 grade 5
 (Fig. 1, 4, 5).
 Exoccipital-supraoccipital synchondrosis(ESS)
 (exoccipital portion) (su-
 praoccipital) 1-2
 CT 2-4
 high grade 4
 high grade (Fig. 1, 4, 5).
 Occipitomastoidal suture(OMS)
 ESS (mas-
 toid portion) (petrous portion)

Table 2. Prevalence of Low Grade and High Grade Fusion in Boys*

Sutures or synchondroses	Number of subjects															
	< 3mo(n= 3)		< 6mo(n= 4)		< 12mo(n= 3)		< 2yrs(n= 9)		< 4yrs(n= 6)		< 6yrs(n= 12)		< 10yrs(n= 19)		< 16yrs(n= 14)	
	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
Related to occipital bone																
Kerckring-supraoccipital	2	1	1	3	0	3	0	9	0	6	0	12	0	19	0	14
Exoccipital-supraoccipital	3	0	4	0	3	0	9	0	4	2	0	12	0	19	0	14
Occipitomastoidal	3	0	4	0	3	0	9	0	6	0	12	0	18	1	13	1
Basioccipital-exoccipital	3	0	4	0	3	0	9	0	6	0	12	0	8	11	0	14
Petro-occipital	3	0	4	0	3	0	9	0	6	0	12	0	19	0	14	0
Spheno-occipital	3	0	4	0	3	0	9	0	6	0	12	0	19	0	12	2
Related to sphenoid bone																
Anterior presphenoido-orbital	1	2	0	4	1	2	0	9	0	6	0	12	0	19	0	14
Posterior presphenoido-orbital	0	3	0	4	0	3	0	9	0	6	0	12	0	19	0	14
Intersphenoidal	0	3	0	4	0	3	0	9	0	6	0	12	0	19	0	14
Intrapresphenoidal	2	1	1	3	2	1	2	7	3	3	1	11	0	19	0	14
Intrapostsphenoidal	1	2	0	4	0	3	2	7	1	5	1	11	0	19	0	14
Rostrum-ossicle of Bertin	3	0	4	0	3	0	7	2	1	5	0	12	0	19	0	14
Lateromedial postsphenoidal	2	1	0	4	0	3	0	9	0	6	0	12	0	19	0	14
Basisphenoidal-alisphenoidal	3	0	2	2	1	2	1	8	1	5	0	12	0	19	0	14
Sphenosquamosal	3	0	4	0	3	0	9	0	6	0	12	0	19	0	14	0
Sphenoethmoidal	3	0	4	0	3	0	9	0	5	1	12	0	10	9	2	12
Frontosphenoidal	3	0	4	0	3	0	9	0	6	0	12	0	11	8	2	12
Inter-planum sphenoidale	3	0	2	2	1	2	0	9	0	6	0	12	0	19	0	14

*Low grade fusion consists of grade 1,2, and 3, and high grade fusion consists of grade 4 and 5. Grade of fusion was determined by five-tier scheme for grading sutural or synchondrosal closure.

ESS 2-4 2.25 ± 0.93, 2.50 ± 0.54 low grade (Fig. 1, 2A, 6).

6-15 high grade 10-15 2.33 ± 0.52, 2.83 ± 0.41 12 (Fig. 2A, B)

(Fig. 1, 4, 5).

Basioccipital-exoccipital synchondrosis(BES) (basioccipital bone) 2-4 grade 3, 4 CT 1 2

10 high grade (Fig. 1, 3, 4, 5).

Petro-occipital synchondrosis(POS) Anterior and posterior presphenoido-orbital synchondroses(APOS, PPOS) APOS (orbitosphenoid) (anterior crus) (middle crus) (presphenoid) (Fig. 2A, 7), PPOS (posterior crus) (main center of the presphenoid) (Fig. 2A, 6)

10 high grade 6 grade 1 ± 0.54 (Fig. 1, 4).

Spheno-occipital synchondrosis(SOS) (postsphenoid) high grade 2 1 APOS grade 3 PPOS grade 4

POS 10 Intersphenoidal, Intrapresphenoidal, and intrapostsphenoidal synchondroses(ISS, IPRES, IPOS) (sphenoidal body) grade 4 grade 5 4

grade 1 , 10-15

Table 3. Prevalence of Low Grade and High Grade Fusion in Girls*

Sutures or synchondroses	Number of subjects															
	< 3mo(n= 0)		< 6mo(n= 2)		< 12mo(n= 4)		< 2yrs(n= 6)		< 4yrs(n= 9)		< 6yrs(n= 4)		< 10yrs(n= 8)		< 16yrs(n= 6)	
	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high
Related to occipital bone																
Kerkring-supraoccipital	-	-	1	1	0	4	1	5	0	9	0	4	0	8	0	6
Exoccipital-supraoccipital	-	-	2	0	4	0	6	0	7	2	1	3	2	6	0	6
Occipitomastoidal	-	-	2	0	4	0	6	0	9	0	4	0	8	0	6	0
Basioccipital-exoccipital	-	-	2	0	4	0	6	0	9	0	4	0	2	6	0	6
Petro-occipital	-	-	2	0	4	0	6	0	9	0	4	0	8	0	6	0
Spheno-occipital	-	-	2	0	4	0	6	0	9	0	4	0	8	0	6	2
Related to sphenoid bone																
Anterior presphenoido-orbital	-	-	0	2	0	4	0	6	0	9	0	4	0	8	0	6
Posterior presphenoido-orbital	-	-	0	2	0	4	0	6	0	9	0	4	0	8	0	6
Intersphenoidal	-	-	0	2	0	4	0	6	0	9	0	4	0	8	0	6
Intrapresphenoidal	-	-	2	0	1	3	1	5	0	9	0	4	0	8	0	6
Intrapostsphenoidal	-	-	0	2	1	3	1	5	1	8	0	4	0	8	1	5
Rostrum-ossicle of Bertin	-	-	2	0	3	1	3	3	0	9	0	4	0	8	0	6
Lateromedial postsphenoidal	-	-	1	1	0	4	0	6	0	9	0	4	0	8	0	6
Basisphenoidal-alisphenoidal	-	-	0	2	0	4	0	6	0	9	0	4	0	8	0	6
Sphenosquamosal	-	-	2	0	4	0	6	0	9	0	4	0	8	0	6	0
Sphenoethmoidal	-	-	2	0	4	0	6	0	9	0	4	0	5	3	0	6
Frontosphenoidal	-	-	2	0	4	0	6	0	9	0	4	0	6	2	1	5
Inter-planum sphenoidale	-	-	1	1	0	4	0	6	0	9	0	4	0	8	0	6

*Low grade fusion consists of grade 1,2, and 3, and high grade fusion consists of grade 4 and 5. Grade of fusion was determined by five-tier scheme for grading sutural or synchondrosal closure.

Table 4. Average Scores of Sutural or Synchrondrosal Closure in Boys According to Each Age Groups

Sutures or synchrondroses	CT scores (average \pm standard deviation)							
	< 3mo(n= 3)	< 6mo(n= 4)	< 12mo(n= 3)	< 2yrs(n= 9)	< 4yrs(n= 6)	< 6yrs(n= 12)	< 10yrs(n= 19)	< 16yrs(n= 14)
Related to occipital bone								
Kerckring-supraoccipital	3.00 \pm 1.00	4.00 \pm 0.82	4.67 \pm 0.58	5.00 \pm 0.00	4.83 \pm 0.41	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
exooccipital	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.67 \pm 0.53	3.00 \pm 1.41	4.27 \pm 0.45	4.63 \pm 0.51	4.93 \pm 0.28
-supraoccipital								
Occipitomastoidal	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.17 \pm 0.40	1.83 \pm 0.38	2.21 \pm 0.63	2.33 \pm 0.52
basioccipital-exoccipital	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.11 \pm 0.33	1.17 \pm 0.41	2.17 \pm 0.83	3.63 \pm 0.76	4.29 \pm 0.47
Petro-occipital	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.37 \pm 0.49	2.14 \pm 0.36
Spheno-occipital	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.16 \pm 0.37	2.25 \pm 0.93
Related to sphenoid bone								
Anterior								
presphenoido-orbital	3.67 \pm 0.58	4.25 \pm 0.58	3.67 \pm 0.58	4.56 \pm 0.52	4.83 \pm 0.40	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
Posterior								
presphenoido-orbital	4.00 \pm 0.00	4.75 \pm 0.50	4.67 \pm 0.58	4.67 \pm 0.50	4.67 \pm 0.51	4.92 \pm 0.28	5.00 \pm 0.00	5.00 \pm 0.00
Intersphenoidal	4.00 \pm 0.00	4.25 \pm 0.50	4.00 \pm 0.00	4.33 \pm 0.50	4.33 \pm 0.51	4.92 \pm 0.28	5.00 \pm 0.00	5.00 \pm 0.00
Intrapresphenoidal	3.00 \pm 1.00	4.25 \pm 1.50	3.33 \pm 0.58	4.11 \pm 0.78	3.5 \pm 0.54	4.83 \pm 0.57	5.00 \pm 0.00	5.00 \pm 0.00
Intrapostsphenoidal	4.00 \pm 1.73	5.00 \pm 0.00	5.00 \pm 0.00	4.56 \pm 0.88	4.67 \pm 0.81	5.00 \pm 0.00	4.95 \pm 0.45	5.00 \pm 0.00
Rostrum-ossicle of Bertin	1.33 \pm 0.58	1.50 \pm 0.58	2.33 \pm 0.58	2.78 \pm 1.05	4.67 \pm 0.81	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
Lateromedial								
postsphenoidal	3.33 \pm 0.58	4.40 \pm 0.89	4.67 \pm 0.58	4.78 \pm 0.44	5.00 \pm 0.00	4.75 \pm 0.45	4.95 \pm 0.45	5.00 \pm 0.00
Basisphenoidal								
-alisphenoidal	2.33 \pm 0.58	3.25 \pm 0.95	3.67 \pm 0.58	4.22 \pm 0.66	4.83 \pm 0.38	4.83 \pm 0.32	4.89 \pm 0.32	4.87 \pm 0.36
Sphenosquamosal	1.33 \pm 0.58	1.25 \pm 0.50	1.67 \pm 0.58	2.00 \pm 0.50	2.00 \pm 0.00	2.17 \pm 0.39	2.50 \pm 0.51	2.71 \pm 0.49
Sphenoethmoidal	1.33 \pm 0.58	1.5 \pm 0.58	2.00 \pm 0.00	2.00 \pm 0.00	2.50 \pm 0.83	2.88 \pm 0.38	3.53 \pm 0.61	4.57 \pm 0.75
Frontosphenoidal	1.33 \pm 0.58	1.75 \pm 0.50	2.00 \pm 0.00	2.33 \pm 0.50	2.50 \pm 0.54	2.50 \pm 0.52	3.53 \pm 0.69	4.36 \pm 0.74
Inter-planum sphenoidale	1.33 \pm 0.58	3.50 \pm 1.29	4.00 \pm 1.00	4.50 \pm 0.44	5.00 \pm 0.00	5.00 \pm 0.00	4.95 \pm 0.22	5.00 \pm 0.00

Table 5. Average Scores of Sutural or Synchrondrosal Closure in Girls According to Each Age Groups

Sutures or Synchrondroses	CT scores (average \pm standard deviation)							
	< 3mo(n= 0)	< 6mo(n= 2)	< 12mo(n= 4)	< 2yrs(n= 6)	< 4yrs(n= 9)	< 6yrs(n= 4)	< 10yrs(n= 8)	< 16yrs(n= 6)
Related to occipital bone								
Kerckring-supraoccipital	-	3.00 \pm 1.41	4.50 \pm 0.58	4.50 \pm 0.83	4.90 \pm 0.33	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
exooccipital-supraoccipital	-	1.50 \pm 0.71	1.25 \pm 0.50	1.83 \pm 0.75	3.11 \pm 0.60	3.75 \pm 0.50	4.12 \pm 0.83	4.83 \pm 0.41
Occipitomastoidal	-	1.00 \pm 0.00	1.00 \pm 0.00	1.17 \pm 0.41	2.00 \pm 0.00	2.00 \pm 0.00	2.25 \pm 0.46	2.83 \pm 0.41
basioccipital-exoccipital	-	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.44 \pm 0.53	2.75 \pm 0.50	3.75 \pm 0.46	4.17 \pm 0.41
Petro-occipital	-	1.00 \pm 0.00	1.75 \pm 0.46	2.50 \pm 0.54				
Spheno-occipital	-	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.00 \pm 0.00	1.25 \pm 0.50	1.25 \pm 0.52	2.50 \pm 0.54
Related to sphenoid bone								
Anterior presphenoido	-	4.50 \pm 0.70	4.50 \pm 0.54	4.33 \pm 0.54	4.86 \pm 0.37	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
-orbital								
Posterior presphenoido	-	4.50 \pm 0.70	4.75 \pm 0.50	4.67 \pm 0.52	4.78 \pm 0.44	5.00 \pm 0.00	4.87 \pm 0.35	5.00 \pm 0.00
-orbital								
Intersphenoidal	-	4.00 \pm 0.00	4.00 \pm 0.00	4.33 \pm 0.52	4.78 \pm 0.44	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
Intrapresphenoidal	-	4.00 \pm 0.00	4.00 \pm 1.41	4.33 \pm 0.81	4.89 \pm 0.33	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
Intrapostsphenoidal	-	5.00 \pm 0.00	4.25 \pm 0.95	4.50 \pm 0.83	4.67 \pm 0.71	5.00 \pm 0.00	5.00 \pm 0.00	4.60 \pm 0.89
Rostrum-ossicle of Bertin	-	2.50 \pm 0.70	2.50 \pm 1.00	3.17 \pm 1.15	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00
Lateromedial								
postsphenoidal	-	3.50 \pm 0.70	4.5 \pm 0.58	4.83 \pm 0.41	4.89 \pm 0.33	4.75 \pm 0.50	4.75 \pm 0.46	4.83 \pm 0.41
Basisphenoidal								
-alisphenoidal	-	4.00 \pm 0.00	4.00 \pm 0.00	4.67 \pm 0.52	4.71 \pm 0.48	5.00 \pm 0.00	4.75 \pm 0.46	5.00 \pm 0.00
Sphenosquamosal	-	1.50 \pm 0.70	1.50 \pm 0.57	1.83 \pm 0.41	2.11 \pm 0.35	2.50 \pm 0.58	2.87 \pm 0.35	2.83 \pm 0.41
Sphenoethmoidal	-	2.00 \pm 0.00	2.00 \pm 0.00	2.00 \pm 0.00	2.89 \pm 0.33	3.00 \pm 0.00	3.38 \pm 0.52	4.67 \pm 0.52
Frontosphenoidal	-	2.00 \pm 0.00	2.00 \pm 0.00	2.00 \pm 0.00	2.56 \pm 0.52	2.22 \pm 0.50	3.12 \pm 0.64	3.83 \pm 0.41
Inter-planum sphenoidale	-	3.00 \pm 1.41	3.75 \pm 1.50	4.50 \pm 0.54	4.89 \pm 0.33	5.00 \pm 0.00	5.00 \pm 0.00	5.00 \pm 0.00

CT

APOS PPOS 가 : 3.50 ± 0.54 . IPOS 2 grade 2

6 grade 4 11 grade 3

ISS 가 5 4 low grade grade 5 (Fig.

가 grade 4 high grade 3 2A, 8).

6 4.25 ± 0.50 4.00 ± 0.00 (Fig. 2A, 8). IPRES 가 Rostrum-ossicles of Bertin synchondrosis(ROB)

low grade 10 2 rostrum-ossicles of Bertin

(Fig. 2A, 8). 1 , 2 4 1-2 . Grade 1 6

6 1 grade 2 high grade 4 3 (grade 3)

grade 3 2-4 4 3

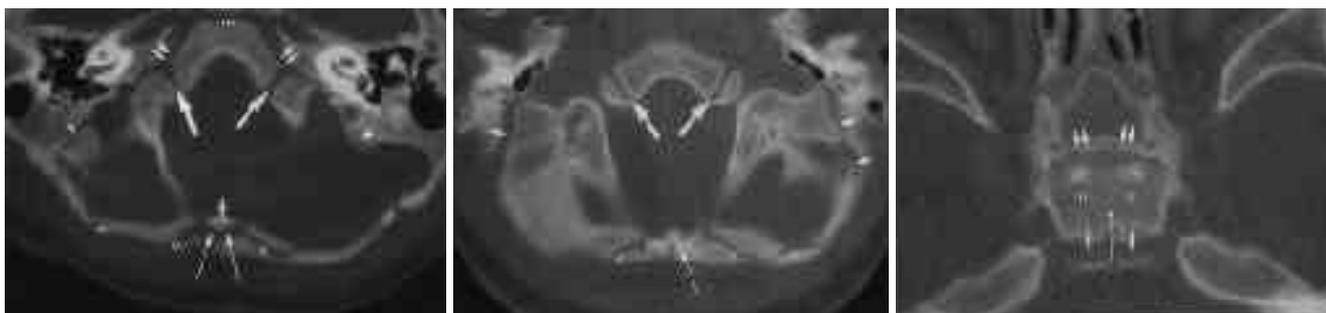


Fig. 4. Axial CT scan of the occipital bone in a 5-month-old female infant. All sutures and synchondroses are widely open, including Kerckring-supraoccipital synchondrosis (long arrows), exoccipital-supraoccipital synchondrosis (double arrows), occipitomastoid suture (arrowheads), basioccipital-exoccipital synchondrosis (large arrows), petro-occipital synchondrosis (double arrows), and sphenoccipital synchondrosis (triple arrows). Note the Kerckring ossicle (single arrow) located in the middle of the posterior aspect of the foramen magnum.

Fig. 5. Axial CT scan of the occipital bone in a 9-month-old female infant. Kerckring-supraoccipital synchondrosis has already fused (long arrow). The exoccipital-supraoccipital synchondrosis (small double arrows) and occipitomastoid suture (single arrows) are still open. Basioccipital-exoccipital synchondrosis (large arrows) is also widely open.

Fig. 6. Axial CT scan of the sphenoid bone in same infant as in Fig. 5. The posterior presphenoido-orbital synchondrosis (small single arrows) shows early high grade fusion with some sclerotic remnants. The intersphenoidal synchondrosis (small double arrows) and intrapostsphenoidal synchondrosis (long arrow) have completely fused without remnant. However, the intrapresphenoidal synchondrosis (large double arrows) remains partially open (grade 3), which fuses last among three synchondroses within the sphenoidal body. Note the widely open sphenoccipital synchondrosis (large single arrows) posterior to the postsphenoid.



Fig. 7. Axial CT scan shows grade 4 fusion of the anterior presphenoido-orbital synchondrosis (arrows) in a 3-year-old boy.

Fig. 8. Axial CT scan of the sphenoid body in a 1-month-old male infant. The intersphenoidal synchondrosis (single arrows) fuses earlier than the other synchondroses in the sphenoidal body. The intrapostsphenoidal synchondrosis (long arrow) and intrapresphenoidal synchondrosis (double arrows) show low grade fusion (grade 2).

Fig. 9. Axial CT scan in a 1 year-old boy. The rostrum-ossicle of Bertin synchondrosis (long arrow) shows low grade fusion (grade 2). Note the paired ossicles of Bertin (small arrows). The sphenosquamosal suture (arrows) shows its complex and interwoven appearance with the sclerotic remnants along the suture.

2 grade 5 . 2
 ossicle of Bertin 가 (Fig. 9).

Lateromedial postsphenoidal and basisphenoidal-alisphenoidal synchondroses(LMPS BAS)
 LMPS (medial center) (lat-eral center)
 1 6 grade 3 low grade high grade
 3-6 4.40 ± 0.89,
 4.50 ± 0.58 (Fig. 2, 10A, 10B). BAS LMPS
 (pterygoid process) (alisphe-noid)
 LMPS grade 4 high grade
 2 (Fig. 2, 10A, 10B).

Sphenosquamosal suture(SSS)
 (greater wing) (squamous temporal bone)
 grade 3 . 10-15
 2.71 ± 0.49 2.83 ± 0.41 (Fig. 2, 9, 10A, 10B).

Sphenoethmoidal suture(SES)
 (ethmoid bone)
 . 6 1
 low grade 6-10
 high grade 10 high grade
 grade 2 grade 2가 , 2-8 grade 3, 9 grade 4 (Fig. 2B, 11).

Frontosphenoidal suture(FSS)
 FSS SES
 SES
 6 low grade , 6-10
 high grade 10 high grade
 . SES 4
 grade 2가 , 4-10 grade 3, 10 grade 4
 5가 (Fig. 2B, 12).

Inter-planum sphenoidale(IPS)
 (jugum sphenoidale) . 3 2
 10 1 grade 1 1
 grade 4 high grade
 1-2 4.50 ± 0.44,
 4.50 ± 0.54 (Fig. 2B, 11).

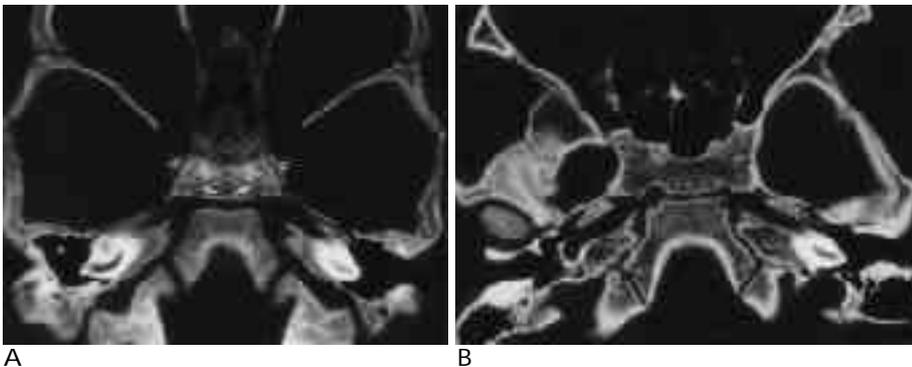


Fig. 10. The lateromedial postsphenoidal synchondrosis and basisphenoidal-alisphenoidal synchondrosis. A. Axial CT scan in a 2-month-old male infant shows fusion of the lateromedial postsphenoidal synchondrosis (arrows) earlier than that of the basisphenoidal-alisphenoidal synchondrosis (small double arrows). B. Axial CT scan in a 3-year-old girl shows complete fusion of both synchondroses.

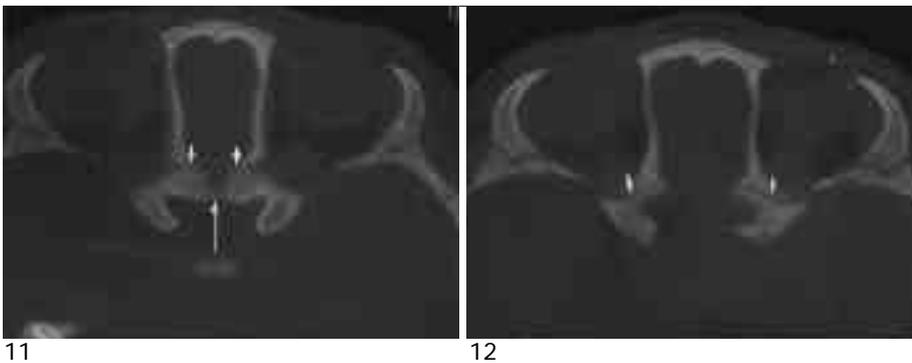


Fig. 11. Axial CT scan shows grade 2 fusion of the sphenoethmoidal suture (short arrows) and interplanum sphenoidale (long arrow) in a 5-month-old female infant.
 Fig. 12. Axial CT scan shows grade 2 fusion of the frontosphenoidal suture (arrows) in a 5-month-old female infant.

11

12

CT

25

18

2).

(well-vascularized, dense fibrous connective tissue)

(specific functional zone)

(4, 5).

(incorporation)

CT

가

CT

(1).

5-6 (notochord)

(desmocranium)

(chondrification)가

(chondrocranium)

(endochondral ossification)가

7 (brainstem)

2

(6).

가

1995

가

CT

18

1mm

CT

Madeline Elster

6

4

(exoccipital portion),

(1, 7)(Fig. 1, 13).

6

mendosal suture

CT

가

6

KSS

OMS POS 가

Kerckring-supraoccipital synchondrosis(KSS)

Kerckring ossicle

(1).

Kerckring center

KSS 3 3

가

grade 1

Madeline Elster

13

2-3

high grade

Exoccipital-supraoccipital synchondrosis(ESS)

Posterior intraoccipital synchondrosis

1-2

high grade

Madeline Elster

4

BES

OMS

Occipitomastoidal suture(OMS)

ESS

ESS

Madeline Elster

7-10

grade 4

10-15

grade가

3

grade 4

2

5

Madeline Elster

grade

Basioccipital-exoccipital synchondrosis(BES)

Anterior intraoccipital synchondrosis

ESS

OMS

2-4

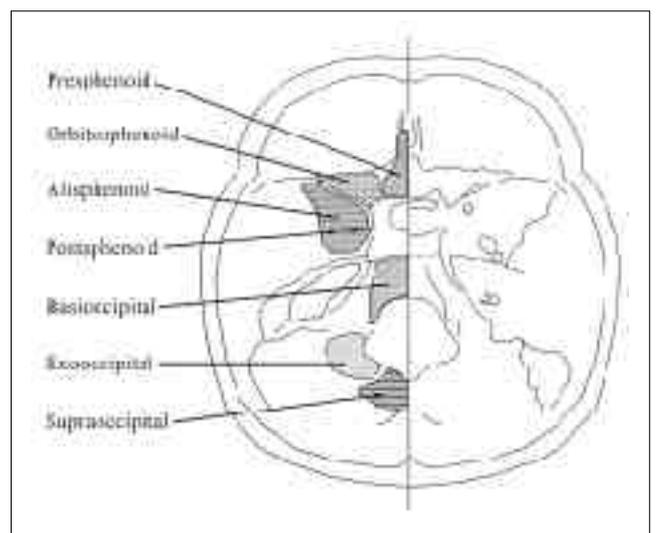


Fig. 13. Schematic representation of the skull base of a newborn. This drawing depicts the relationship of the sphenoidal and occipital centers to their neighboring structures.

10 high grade
 가
 Madeline Elster Anterior and posterior presphenoido-orbital synchondroses(APOS, P-POS)
 APOS 2
 Petro-occipital synchondrosis(POS) grade 3 high grade PPOS
 Madeline Elster POS가 16 grade 4 high grade Madeline Elster
 high grade 18 grade 4 APOS PPOS가 4 12 8 low grade
 16 Madeline 3
 high grade Madeline
 Elster 10-16 가 10 1 APOS가 grade 3
 2.14 ± 0.36, 2.5 ± 0.54 가

Spheno-occipital synchondrosis(SOS) Intersphenoidal, Intrapresphenoidal, and intrapostsphenoidal synchondroses(SS, IPRES, IPOS)
 POS 10 grade 4 grade 5 3 Madeline
 Okamoto (8) SOS CT Elster 3 high grade
 13 SOS가 8-13 IPRES가 가 ISS
 SOS 가 가 IPOS grade가 4
 Okamoto 6 11 grade 3
 13-15 7 5 grade IPRES 가
 3 , Madeline Elster low grade
 95% grade 4 ISS IPRES IPOS Madeline Elster
 18 16 grade 4 SOS 4
 (9) 가 IPRES ISS
 12-17 5 grade 5
 Okamoto 가 6 10 가
 1 가 grade 1 가
 Madeline Elster 5 가
 grade 2 (sphenoid sinus) ROstrum-ossicles of Bertin synchondrosis(ROB)
 (8). (ossicle) 가 Rostrum-ossicles of Bertin
 (sphenoidal choncha) ROB가
 가 ROB 가
 12 (1, 10), (1). Madeline Elster 1-2
 19 3
 13 CT (grade 4) 2 grade
 (lesser wing) 5

(Fig. 2A, 2B, 13). Lateromedial postsphenoidal and basisphenoidal-alisphenoidal synchondroses (LMPS BAS)
 Madeline grade 4
 (tu- Elster 6 5.3 LMPS가 6
 berculum sellae), (olivary eminence) , BAS LMPS
 2-4 high grade

high grade	3	Madeline	Elster	가	high	(overestimation)
grade	2	Madeline	Elster			
				1975	X	(11).
Sphenosquamosal suture(SSS)				(vertical cleft)		3
				SOS	FSS	ISS
						2
						(11).
				가	ISS	2
						CT
						가 grade 4
15				FSS	7-8	grade 4
high grade		Madeline	Elster	12	14	1
6		가				가
						grade 4
Sphenoethmoidal suture(SES)						(ossification center)
		Madeline	Elster	1/3		
		가	가	1 mm		CT
				SES		CT
						(skeletal dysplasia)
		Madeline	Elster	2	15.1	sia)
		가	grade 4			
		1	grade 2		10	
		20	2			high grade
		가				
Frontosphenoidal suture(FSS)						
SES		FSS	SES			
Madeline	Elster	5		12		
	grade 4				S-	
ES	가	1		10		
	20	3				high grade
	Madeline	Elster				
Inter-planum sphenoidale(IPS)						
Madeline	Elster		3.3	2.8	95	
percentile		grade 4				
		1				grade 4
high grade						
	Madeline	Elster				
			1 mm	CT		
가		LMPs, BAS, FSS, SES, IPS				
						(partial vol-
ume effect)	가		3-5 mm			

1. Madeline LA, Elster AD. Suture closure in the human chondrocranium: CT assessment. *Radiology* 1995;196:747-756
2. Madeline LA, Elster AD. Postnatal development of the central skull base: normal variants. *Radiology* 1995;196:757-763
3. CT 1999; 41:1209-1214
4. David DJ, Poswillo D, Simpson D. *The craniosynostoses: causes, natural history, and management*. New York, NY:Springer-Verlag, 1982: 18-19
5. Furuya Y, Edwards MS, Alpers CF, Tress BM, Ousterhout DK, Norman D. Computerized tomography of cranial sutures, part I: comparison of suture anatomy in children and adults. *J Neurosurg* 1984;61:53-58
6. Belden CJ, Mancuso AA, Kotzur IM. The developing anterior skull base: CT appearance from birth to 2 year of age. *AJNR* 1997;18:811-818
7. Shapiro R, Robinson F. Embryogenesis of the human occipital bone. *AJR* 1976;126:1063-1068
8. Okamoto K, Ito J, Tokiguchi S, Furusawa T. High resolution CT findings in the development of the sphenoccipital synchondrosis. *AJNR* 1995;17:117-120
9. Melsen B. Time and mode of closure of the sphenoccipital synchondrosis determined on human autopsy material. *Acta Anat* 1972;83:112-118
10. Shopfner CE, Wolfe TW, O Kell RT. The intersphenoid synchondrosis. *AJR* 1968;104:184-193
11. Hoyte DAN. A critical analysis of the growth in length and the cranial base. *Birth Defects* 1975;11:255-282

Normal Development of Sutures and Synchondroses in the Central Skull Base : CT Study¹

Hong Gee Roh, M.D., Hyung-Jin Kim, M.D., Jee Hee Kang, M.D., Kyung-Hee Lee, M.D.,
Myung Kwan Lim, M.D., Young Kuk Cho, M.D., Cheol Su Ok, M.D., Chang Hae Suh, M.D.

¹Department of Radiology, Inha University College of Medicine

Purpose : To evaluate the developmental patterns of the sutures and synchondroses in the central skull base.

Materials and Methods : We evaluated the CT scans of 109 children (age range, 29 days to 15 years) with no skull base abnormality who had undergone axial CT of the skull base with 1-mm collimation. Using a five-tier scheme, we analyzed the developmental patterns of the 18 sutures and synchondroses related to the sphenoid and occipital bones.

Results : Fusion of the sutures and synchondroses related to the sphenoid bone progressed rapidly during the first two years. Thereafter, changes in the sphenoid bone were dominated by pneumatization of the sphenoid sinus. Fusion of the synchondroses within the sphenoid body, including intersphenoidal, intrapresphenoidal, and intrapostsphenoidal synchondrosis occurred early and in most cases was graded 4. Fusion of the sphenosquamosal, sphenothmoidal, and frontosphenoidal sutures was delayed, and residual sclerosis was a common finding. Except for Kerckring-supraoccipital synchondrosis, fusion of the six sutures and synchondroses related to the occipital bone occurred more gradually than that of those related to the sphenoid bone. Among these, fusion of the occipitomastoidal suture and petro-occipital synchondrosis was the last to occur.

Conclusion : A knowledge of the developmental patterns of sutures and synchondroses can help differentiate normal conditions from those such as fracture, osseous dysplasia, or congenital malformation, which are abnormal. Our results provide certain basic informations about skull base maturity in children.

Index words : Skull, anatomy
Skull, CT
Skull, growth and development

Address reprint requests to : Hyung-Jin Kim, M.D., Department of Radiology, Inha University Hospital
7-206, 3rd Street, Shinheung-dong, Choong-gu, Incheon, 400-103, Korea.
Tel. 82-32-890-3402 Fax. 82-32-890-3097

2000 43		99. 11. 1()- 6 () 99. 11. 8()-13 () 99. 12. 20()-22 ()	
	1 2 (slide) ()	00. 1. 13() 10:00-13:00 00. 1. 20() 10:00-13:00 00. 1. 21() 08:00-22:00	
	1 2	00. 1. 18() 16:00- 00. 2. 3() 12:30-	ARS,
	2000	00. 1. 31()	
		00. 4. 22()	
	1999 2000	00. 1. 31()	
		00. 1. 31()	
ECR 2000	European Congress of Radiology	00. 3. 5()-10()	Vienna, Austria
SGR	The 29th Society of Gastrointestinal Radiologists	00. 3. 12()-17()	Kawai, Hawaii
		00. 3. 18()	
ISMRM	The 8th International Society for Magnetic Resonance	00. 4. 1()- 7()	Denver, Colorado
ASNR	The 38th Annual Meeting	00. 4. 2()- 8()	Atlanta, GA
	2000	00. 4. 21()-22()	
	가	00. 1. 31() 00. 3. 15() 00. 2. 29()	
	2000	00. 4. 22() 13:30-17:30	
		00. 3. 15()	
	2000	00. 5. 6()-10()	Florence, Italy
ARRS	100th American Roentgen Ray Society	00. 5. 7()-12()	Washington DC
	2000	00. 5. 19()-20()	
	2000	00. 5. 13()	
		00. 4. 29()	