

The human speno-occipital synchondrosis

II. A histological and microradiographic study of its growth

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The speno-occipital synchondrosis, dorsum sellae and clivus were studied *post mortem* in tissue samples from 53 males and 25 females, aged 2 days to 24 years 11 months. The investigation aimed at ascertaining the growth and remodelling changes in these structures during the growth period. Light microscopic and microradiographic techniques were used. In the early ages the organization of the synchondrosis was similar to that of an epiphyseal disc, except that the morphology of the synchondrosial cartilage was bipolar. With increasing age the hyaline cartilage in the upper part of the synchondrosis was replaced by fibro-cartilage, while the central zone in the lower part underwent asbestos transformation. The synchondrosis was completely ossified by 16—17 years of age in girls, and about two years later in boys. Appositional growth and endochondral ossification continued up to 3 years of age in cartilage covering the superior and clival aspects of the dorsum sellae. The cartilage on the superior aspect of dorsum sellae persisted until after puberty and occasionally longer. Minor areas of resorption were seen in the posterior wall of the sella turcica. This resorption, together with the growth of the cartilage covering the dorsum sellae, may cause a shift of the cephalometric reference point sella in an upward direction during the growth period. The intracranial surface of the occipital bone showed resorption. On the extracranial surface there was simultaneous bone apposition.

Key words: Sphenoid bone; bone development; maxillofacial development

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In a previous investigation (Ingervall & Thilander, 1972) it was shown macroscopically that closure of the human speno-occipital synchondrosis occurs at the age of 13—14 years in females and 2 years later in boys. Thus closure of the speno-occipital synchondrosis seems to occur 1—2 years after the maximal pubertal growth spurt and appears to coincide with the time of closure of the epiphyseal

line in the distal phalanx of the thumb (Björk, 1971). The time of closure varies with sex, as pointed out earlier by Powell & Brodie (1963). Concerning the actual time of closure of the synchondrosis, our findings are well compatible with those of Melsen (1969) in Indian skulls. The age given by Ford (1958) and by Scott (1958), however, was much higher (20—25 years and 17—20 years, respectively).

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Tomographic studies by *Irwin* (1960) and by *Powell & Brodie* (1963) suggest that incipient closure of the synchondrosis may be discerned at the beginning of puberty or even earlier. This discrepancy must be explained by differences in the methods used; tomography can hardly be as reliable and precise as histology in the investigation of closure of the synchondrosis.

Closure of the synchondrosis was judged only from the time when the cartilage became ossified. This does not necessarily mean that growth in the synchondrosis continued until that time. Information on this point requires investigation by histological methods. It was against this background that the present investigation was undertaken.

In most of the tissue samples from individuals below 17 years of age the dorsum sellae showed an area with cartilage at early ages, in continuity with the cartilage in the synchondrosis. With the method used in our previous investigation it was, however, not possible to decide whether the sellar cartilage was still growing or only a non-growing residue of the primordial chondro-cranium. The purpose of the investigation was therefore also to find out whether the sellar cartilage grows postnatally and whether bone remodelling occurs in the sella turcica and the clivus.

MATERIAL AND METHODS

The material consisted of tissue samples from 78 individuals (53 ♂ and 25 ♀), aged 2 days to 24 years 11 months. The age distribution is given in Table I.

The material included no samples from subjects who had died from diseases that might be thought to affect growth. Most

Table I. Age and sex distribution of subjects from whom tissue samples were obtained

Age Years, months	Histological*) samples		Micro-radio- graphic samples	
	♂	♀	♂	♀
0.0—4.11	8	8	4	2
5.0—9.11	6	1	6	0
10.0—14.11	4	4	2	0
15.0—19.11	7	3	4	1
20.0—24.11	7	5	5	1
Total	32	21	21	4

*) These samples have been reported on in an earlier paper (*Ingervall & Thilander, 1972*)

of the deaths had been due to some kind of accident.

As a rule the samples consisted of the major part of the clivus and of the dorsum sellae. Fifty-three samples were fixed in neutral formalin and decalcified in 50 per cent formic acid and 15 per cent sodium formiate and were serially sectioned in the sagittal plane. Seven consecutive sections, 12 μ , were stained with haemalun-eosin (Mayer), resorcin fuchsin (Weigert), picrofuchsin (van Gieson), azan (Heidenhain), htx-eosin (Bock), toluidine blue and with periodic acid (Schiff reaction).

Twenty-five samples were fixed in absolute alcohol and embedded in methyl-methacrylate, after which plane-parallel ground sections, 200—300 μ thick, were prepared. The sections were exposed to 1.54 Å roentgen radiation for 30 minutes at 30 kV and 22 mA, focus-film distance 30 cm. Kodak Maximum Resolution Plates were used.

RESULTS

At birth abundant cartilage was found in the sphenoid and occipital bones, and

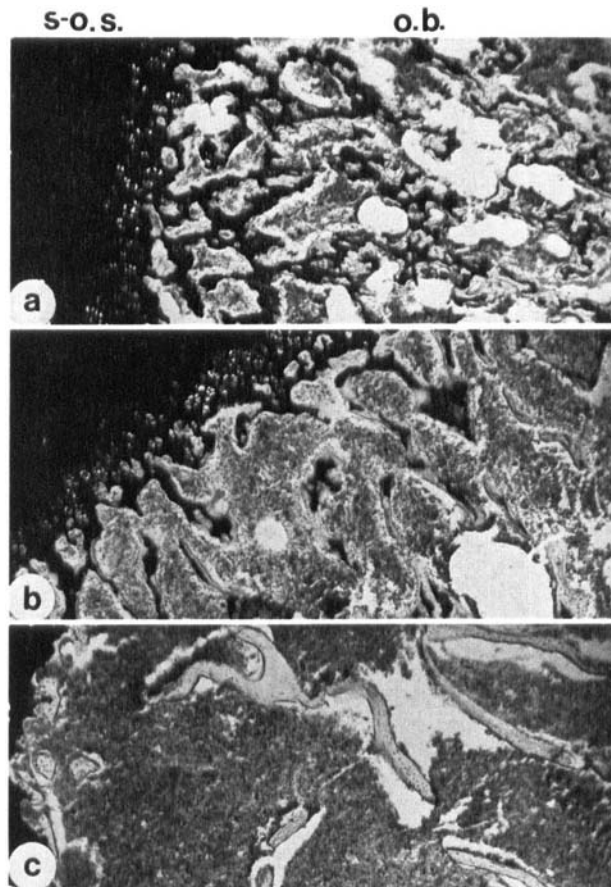


Fig. 1. The occipital bone (o.b.) showing
 a) abundant cartilage at birth
 b) remnants of cartilage at 1 year of age
 c) no cartilage after 2 years of age
 S-O.S.: the sphenoid-occipital synchondrosis

small cartilaginous remnants of the chondrocranium were observed up to 2 years of age. After this time, however, the sphenoid and occipital bones were ossified (Fig. 1).

In the early ages the structural organisation of the synchondrosial cartilage was quite similar to that of the epiphyseal disc, except that the morphology of the synchondrosial cartilage was bipolar (Fig. 2). The typical characteristics of a synchondrosis could thus be distinguished; *e. g.* a central zone of small cartilage cells with successive antero-posterior zones of proliferating and hypertrophic cartilage cells and endochondral ossification.

With age the structural organisation of the synchondrosis changed. At birth

the central zone was wide and very cellular (Fig. 3). The cells were elongated and arranged perpendicular to the longitudinal direction of the clivus. With increasing age the central zone became narrower and the cells decreased in number and became round.

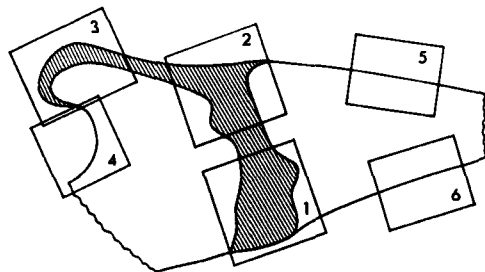


Fig. 2. Drawing of tissue sample showing areas represented by histological pictures.

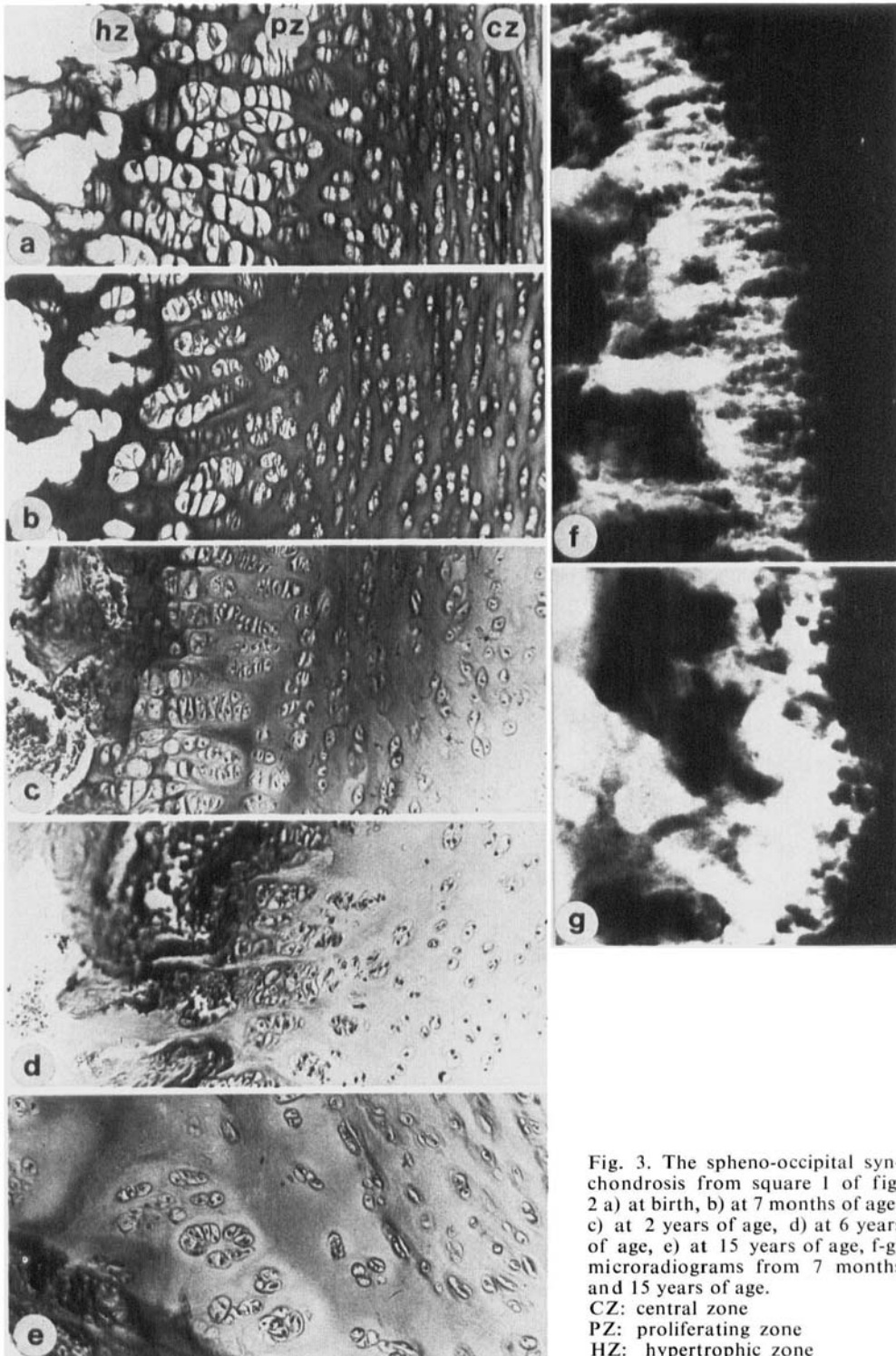


Fig. 3. The spheno-occipital synchondrosis from square 1 of fig. 2 a) at birth, b) at 7 months of age, c) at 2 years of age, d) at 6 years of age, e) at 15 years of age, f-g) microradiograms from 7 months and 15 years of age.

CZ: central zone
 PZ: proliferating zone
 HZ: hypertrophic zone

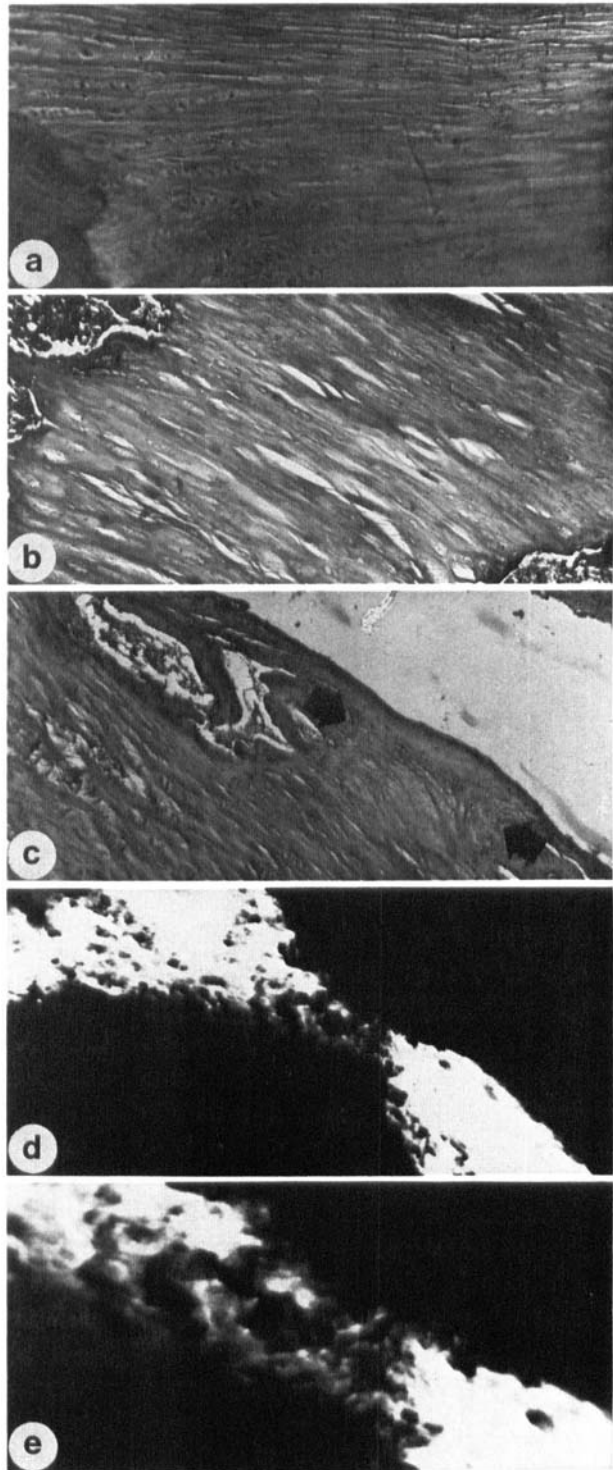


Fig. 4. The cranial part of the spheno-occipital synchondrosis from square 2 of fig. 2

- a) longitudinally arranged fibre bundles (3 years)
- b) densely packed bundles (6 years)
- c) the ossification starting from the anterior and posterior margins, indicated by arrows (girl 10 years)
- d) incipient ossification (micro-radiogram from 13-year-old girl)
- e) higher magnification of d.

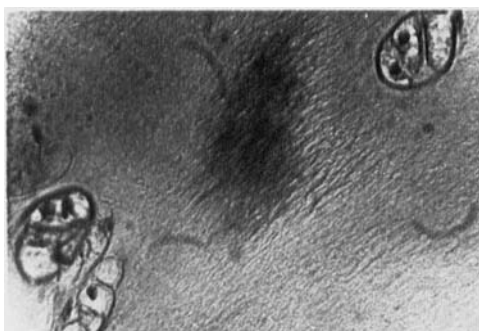


Fig. 5. Asbestos formation from region 1 of fig. 2 (14-year-old girl)

The zones of proliferating and hypertrophic cells were of the same width on both sides of the synchondrosis. It was, as a rule, difficult to recognise the transition between the two zones. At birth the proliferating zone was thin and the columns in the hypertrophic zone were short. The transition between the central and the proliferating zones showed PAS activity, which was most marked in the hypertrophic zone. With increasing age the two zones increased in width up to 3—4 years of age, after which they again became narrower and less densely packed. During closure of the synchondrosis a certain disorientation was observed in these zones. Only a few cells in proliferation stage were observed and the hypertrophic cells were no longer arranged in characteristic columns.

In the cranial part of the synchondrosis (Fig. 4) a change in the structural organisation nearest the perichondrium was observed early in life (3—4 years of age). Bundles of collagen fibres were seen in the longitudinal direction of the clivus. These bundles increased in number relatively rapidly, and at 6—7 years they occupied the upper fourth of the synchondrosis. Between them there were elongated chondrocytes, which became

hypertrophic towards the edges of the bones (Fig. 4c). The fibre bundles were closely packed in the upper part, the cells were few, and no mitoses could be seen. Further down in the synchondrosis the cells were grouped together (chondrons) and the earlier homogenous intercellular mass now showed a fine fibred structure (asbestos transformation) (Fig. 5). Only a few mitotic cells were observed.

Concurrently with the replacement of the hyaline cartilage by fibrocartilage the superior part of the synchondrosis became narrower through ossification from the sides (Fig. 4). The cranial part was completely bridged by bone at 12—13 years of age in girls and about 2 years later in boys. The first signs of this bridging were observed in the lateral parts (Fig. 6). The endochondral ossification thus occurred not only from the anterior and posterior edges of the synchondrosis but also from the lateral sides. The synchondrosis therefore had a relatively uniform structure only in its central part, while, its peripheral parts showed a very eroded appearance. The synchondrosis was not completely ossified before 16—17 years of age in girls, and about 2 years later in boys. Small residues of cartilage islands in this region could, however, be observed in several tissue samples up to 20 years of age.

The cartilage on the superior and clival aspects of the dorsum sellae (the sellar cartilage) (Fig. 7) was at birth very cellular, with formation of new cells from the perichondrium. Towards the bone surface there were seen zones of proliferating and hypertrophic cells as an extrusion of the corresponding zones in the synchondrosis. An appositional growth thus occurred from the perichondrium accompanied by an endochondral ossification. After 3 years of age no certain signs of continued en-

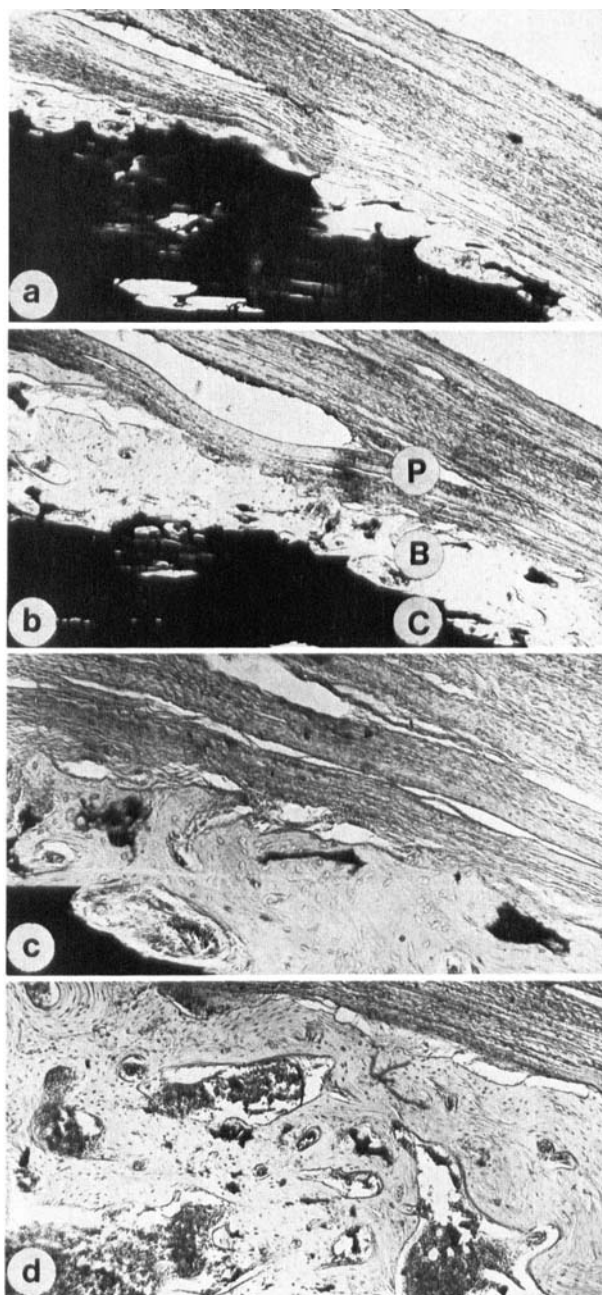


Fig. 6. The sphenoid-occipital synchondrosis (15-year-old boy), showing various degrees of bone-bridging in four levels of clivus
 a) central part, d) lateral part,
 b-c) intermediate regions
 P: perichondrium
 B: bone
 C: cartilage, stained with toluidine blue

dochondral ossification could be observed. Microradiograms, however, showed that ossification occurred from the underlying bone surface. The sellar cartilage therefore became thinner with increasing age at the same time as appositional growth de-

creased. At early ages the sellar cartilage was in continuity with the cartilage of the synchondrosis, but later on they separated. This started at 5–6 years of age by radiation of the collagen fibre bundles from the cranial part of the synchondrosis

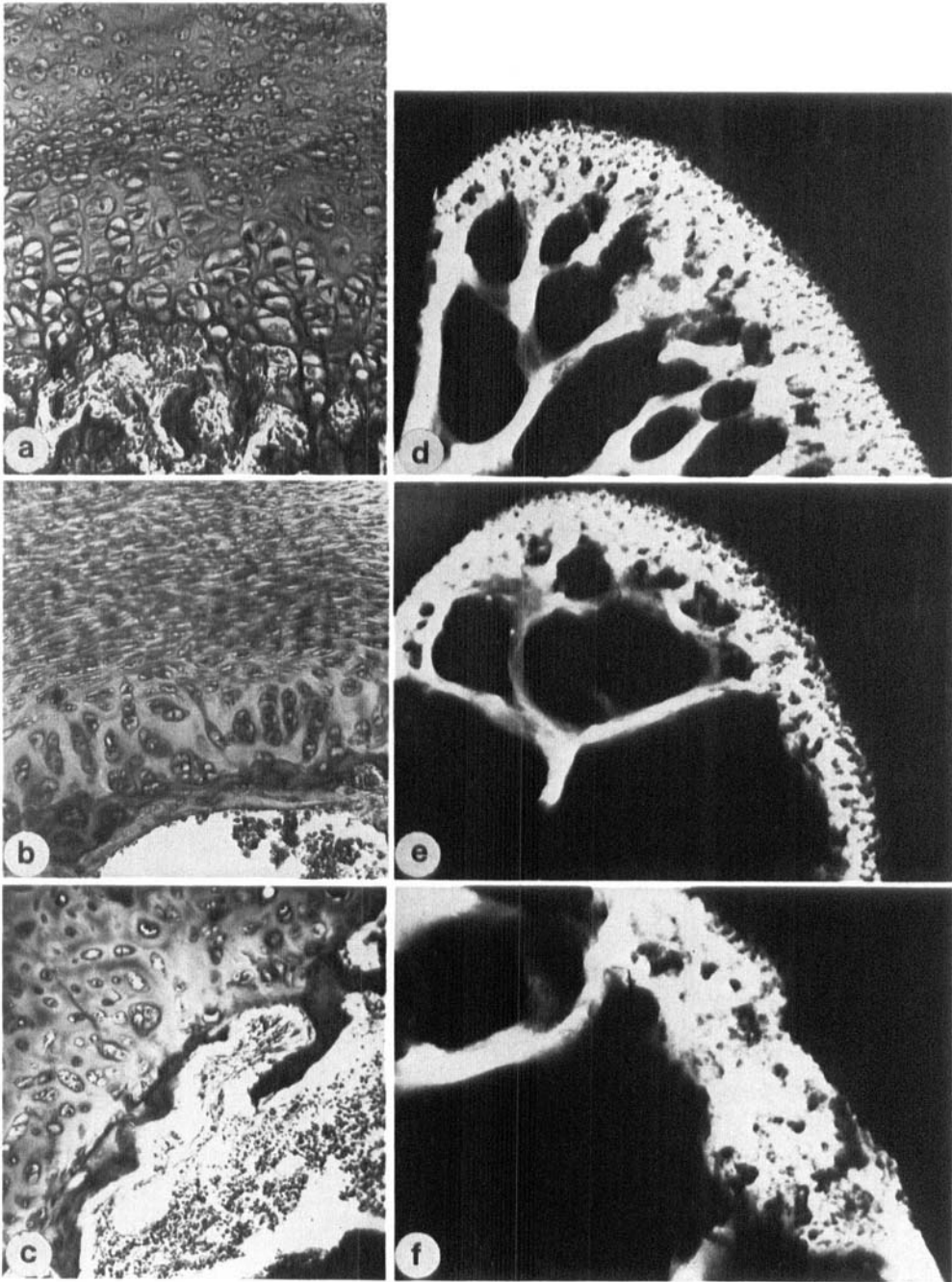


Fig. 7. The sellar cartilage from square 3 of fig. 2 a) at birth, b) at 2 years of age, c) at 8 years of age, d-f) microradiograms at birth, 3 years and 14 years of age.

into the sellar cartilage at the same time as fibres from the perichondrium penetrated down into the cartilage. This was accompanied by ossification of the clival part of the sellar cartilage. The cells decreased in number with age and became hypertrophic, and the cartilage showed a typical degenerative picture. Minor areas of the sellar cartilage were seen in almost all samples below 17 years of age and occasionally in those from older subjects.

The anterior wall and the floor of the sella turcica were missing in most samples. In those cases where they did occur they were smooth. The posterior wall showed certain signs of resorption in young individuals (Fig. 8). However, only a few osteoclasts were seen except in one case (6-year-old boy), in whom osteoclasts were observed in a large area of the superoposterior wall of the sella. Microradiograms of young individuals also suggested that some resorption had occurred in the posterior wall of the sella, especially in the upper part.

The upper surface of the occipital bone in all samples from subjects below 20 years of age showed resorption (Fig. 9), which was particularly distinct before the time of closure of the synchondrosis. It was afterwards seen in more limited areas and was less intense. On the lower surface of the occipital bone there was simultaneous bone apposition.

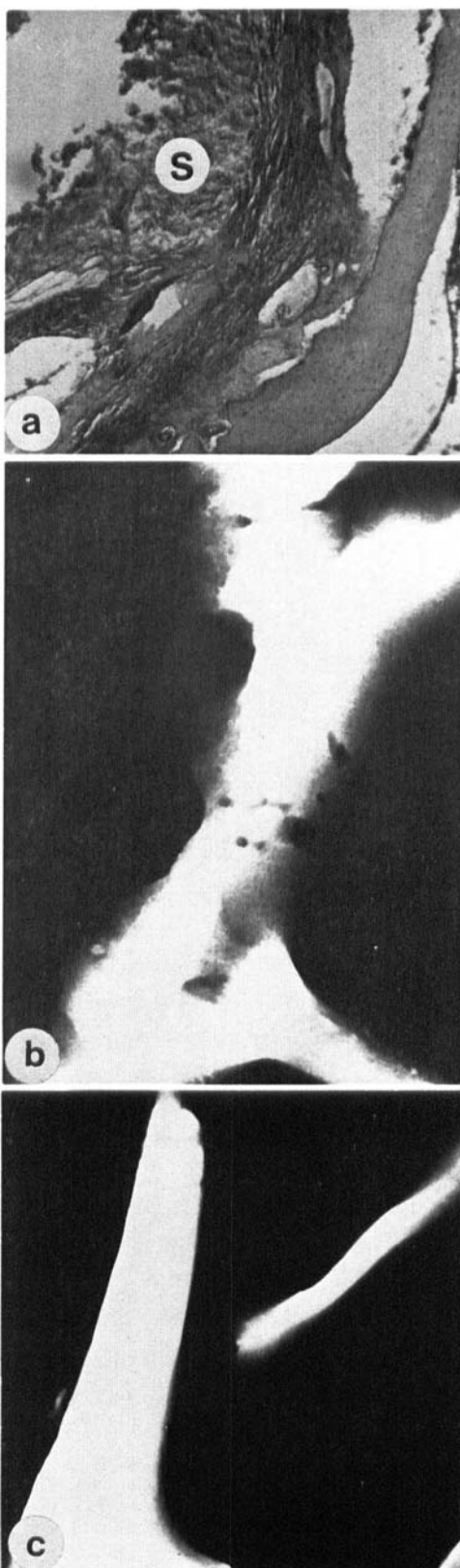


Fig. 8. The posterior wall of the sella turcica (S) from square 4 of fig. 2

- a) more advanced resorption in one case (6-year-old boy)
- b) slight resorption (4 years)
- c) no resorption (8 years)

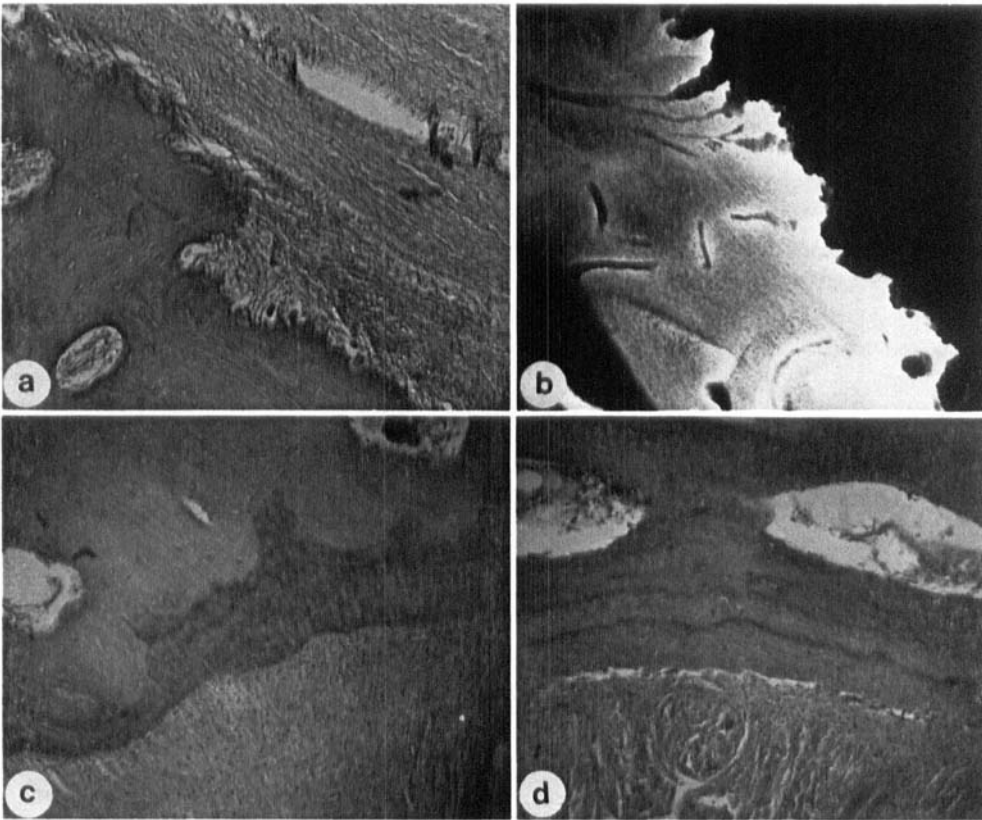


Fig. 9. a-b) The upper surface of the occipital bone (square 5 of fig. 2), showing resorption c-d) The lower surface (square 6 of fig. 2), showing apposition

DISCUSSION

The histological picture of the sphenoccipital synchondrosis in young human individuals agrees with that demonstrated in the rat (Dorenbos, 1971; Rönning, 1971). While the synchondrosis in the rat remains open throughout life it has the same characteristic morphology in its different parts. In man, however, a change occurs in the morphological structure at an early age.

Growth of the human synchondrosis is considerable during the first 3—4 years of life, which is very probably explained by the increase in volume of the brain. The growth of the neurocranium is believed to be related to the rapid morpho-

logical development of the central nervous system. This is reflected in the circumference of the skull, which at 2 years of age is almost 90% of that of adult age and then increases only 0.5 cm per year up to puberty (Yakovlev, 1962). The parallelism in growth between the volume of the brain and of the synchondrosis would thus support the view that growth of the synchondrosis is passive and due to stimulation by the expanding brain (Koski, 1960, 1968; Rönning *et al.*, 1967) in accordance with the theory of Moss (Moss & Salentijn, 1969).

Of interest is the change of morphology in the upper part of the synchondrosis, which occurred already in early age. The

occurrence of collagen fibres, arranged in the longitudinal direction of the clivus, must be a sign of traction, while the persistent cartilage in the lower part of the synchondrosis is probably due to compression, possibly by the growing cerebellum against the occipital bone (Fig. 10). This pressure probably causes the resorption of the clival part of the occipital bone, which was observed up to puberty, by which time the brain has almost reached its maximum weight (Yakovlev, 1962). The apposition on the lower surface of the occipital bone may be regarded as a compensatory effect. This resorption and apposition have not been described earlier in homo, but have been described in the Rhesus monkey (Baume, 1958, Lager, 1958). The observed remodelling of the occipital bone may result in a decrease of the angle of the medial cranial base during the growth period. That such a decrease occurs has been shown roentgencephalometrically (Zuckerman, 1955, Stramrud, 1959, Koski, 1960).

The fibro-cartilage developing early in life undergoes ossification more readily than hyaline cartilage, which may explain the fact that the bone-inducing effect starts in the upper part of the synchondrosis, which thus closes first. The asbestos transformation of the hyaline cartilage was observed some years before closure of the synchondrosis. This is a manifestation of degeneration and thus implies that the growth of the synchondrosis ceases a year or so before it is bridged.

The presence of cartilage on the dorsum sellae has earlier been observed in Rhesus monkeys (Lager, 1958) and in man (Riach, 1966, Latham, 1972). In the present study it was shown that growth occurred in this region up to 3 years of age, after which no certain signs of further growth could be seen. Yet the cartilage persisted up

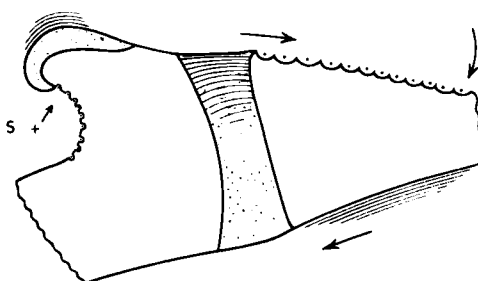


Fig. 10. Drawing illustrating the pressure-traction hypothesis of the synchondrosis

to high ages, which may be a manifestation of compression by the meningeal membranes. Growth of the sellar cartilage probably contributes to an increase in the pituitary fossa, which is most marked during the first years of life (Silverman, 1957). Through this growth the cephalometric reference point »sella» shifts backwards and upwards, as shown by Latham (1972), and not as claimed by Melsen (1969) backwards and downwards.

According to Peter (1936) the hypophysitis increases 2 mm in height and 6 mm in length from birth to puberty and the pituitary fossa increases in size up to high ages (Israel, 1970). This, according to Latham (1972), is due to resorption of the posterior wall of the sella. In our material the resorptive processes observed in this part were not of such magnitude as to be able to contribute to an increase in size of the pituitary fossa. An increase in the pituitary fossa may be due to resorption of the entire sella and not only of its posterior wall. Since our material included the anterior wall and floor in only a few cases, nothing can be said about what happens in these parts. Marked resorptive processes suggest pathological changes owing to increased intracranial pressure. No such changes were seen in our material, in which most of the deaths were due to some kind of accident.

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