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Morphological aspects of the mid-palatal suture in the human foetus: a light and scanning electron microscopy study

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SUMMARY Morphological features of the mid-palatal suture were studied in human foetuses from 4 to 9 months of intra-uterine life. The foetuses were divided into three age groups, GI (16–23 weeks), GII (24–31 weeks) and GIII (32–39 weeks). The mid-palatal suture in GI foetuses is rectilineal in form with a wide space between the palatal processes of the maxilla. The suture has a sinuous nature in GII and GIII foetuses due to growth of the bone processes crossing the mid-line. A wide zone of cellular proliferation observed in GI narrows in GII and GIII foetuses. The imbricating nature of the suture in GII and GIII is caused by bone growth adjacent to the mid-palatal suture. Sharpey's fibres, emerging from the bone processes, run to the median region of the mid-palatal suture and are observed from GI foetuses onwards. The collagen fibres of the mid-palatal suture are orientated transversely under the oral epithelium and exhibit a regular meshwork with a predominance of sagittal fibres in the median region of the suture. These fibres are orientated transversely and obliquely at the junction with the nasal septum.

Introduction

Microscopic features of the craniofacial sutures have been described at the light microscope level for several species of mammals (Mednick and Washburn, 1956; Pritchard *et al*., 1956; Moss, 1958; Young, 1959; Isotupa *et al*., 1965; Anderson *et al*., 1967; Herring, 1972; Droschl, 1975; Persson *et al*., 1978), and man (Weinman and Sicher, 1955; Scott, 1956; Sicher, 1957; Latham, 1968, 1970, 1971; Enlow, 1975; Melsen, 1975; Koskinen *et al*., 1976; Miotti *et al*., 1980). The suture pattern is defined as consisting of layers of collagen fibres (Weinman and Sicher, 1955; Pritchard *et al*., 1956; Droschl, 1975; Enlow, 1975) of straight aspect in childhood (Latham, 1968; Miotti *et al*., 1980), and taking on a sinuous pattern with bone islands in adolescence (Melsen, 1975).

Enlow (1975) reports that the osteogenic process in the suture is similar to periosteal growth and the response to replacement of adjacent bones. Sharpey's fibres penetrate the bone processes (Pritchard *et al.*, 1956; Devyatkin and Kostilenko, 1981), but lack a specific morphological relationship with the central fibres of the suture (Jones and Boyde, 1974).

Moss (1957), Young (1959), Droschl (1975), and Enlow (1975) hold that it is the firm attachment among the adjacent bones that allows bone growth; the sutures may act secondarily in craniofacial growth.

Scanning electron microscopic studies of the palatine region have been restricted to evaluation of the union of the primary palate and nasal septum (Mato *et al*., 1968), the closure of the secondary palate and primary palate (Meller *et al*., 1980; Schüpback *et al.,* 1983), and the surfaces of the developing secondary palatal shelves (Waterman and Meller, 1973; Cleaton-Jones, 1975; Takiguchi, 1979; Tassin *et al*., 1979) to understand the mechanisms and spatial relationships of the contributing regions (Gulamhusein and England, 1982).

In the present study, the pattern of the developing mid-palatal suture was analysed in the anterior portion of the hard palate in human foetuses by light and scanning electron microscopy to better comprehend the role of this suture in craniofacial growth during this stage of human life.

Subjects and methods

Forty-eight human foetuses, both male and female, obtained at necropsy, ranging from 16 to 36 weeks of intra-uterine life according to Streeter (1920) were used. They were divided according to age into groups GI (16–22 weeks), GII (23–29 weeks), and GIII (30–36 weeks). The anterior portion of the hard palate (AHP) formed by the palatal processes of the maxilla was removed and processed as follows.

Light microscopy

The AHP of six foetuses from each group were fixed for 7 days in a 10 per cent formalin solution, immersed in sodium phosphate buffer (0.1 M, pH 7.4) for 72 hours and demineralized in a 10 per cent nitric acid solution, replaced weekly for 1 month. The specimens were treated in 5 per cent sodium sulphate for 12 hours, dehydrated in an increasing alcohol series, immersed in benzol for 20 minutes, and embedded in paraffin.

Coronal and horizontal sections of 6 μm thickness were stained using the Azo-Carmine (Romeis, 1968) and Picro–Sirius (Junqueira *et al.*, 1978) methods to reveal collagen fibres. The latter preparations were examined under polarized light.

Scanning electron microscopy

Eight AHP from each group were fixed for 24 hours in a modified Karnovsky solution of 2 per cent paraformaldehyde and 2.5 per cent glutaraldehyde in 0.1 M phosphate buffer at 4ºC. They were washed in phosphate buffer for 30 minutes and treated with 5 per cent sodium hypochlorite at 4ºC for 7 days, according to the technique described by Lester *et al.* (1981). Two specimens from each group were immersed in liquid nitrogen, broken, and a few fragments selected.

The AHP and fragments were dehydrated in an increasing alcohol series, critical point dried with liquid CO_2 in a Balzers CPD-010 apparatus, gold coated in a Balzers SCD-040 ion sputterer and examined using a Cambridge Stereoscan-240 scanning electron microscope.

Results

In GI foetuses, the mid-palatal suture was rectilineal in form. A zone of intense cellular proliferation was observed in the ample space between the suture and the developing maxillary processes (Figure 1a,b). Collagen fibres, lying in a sagittal direction in the median region of the suture, were evident in horizontal sections (Figure 1c).

Under the oral epithelium, a thin layer of transversally orientated collagen fibres was seen (Figure 1d) underlying a network of predominantly sagittal fibres. Coronal sections of the centre of the mid-palatal suture showed a network with regular meshes (Figure 1e) and thick bundles of transverse fibres at the junction with the nasal septum (Figure 1f).

The subsequent phase (GII) showed the developing palatal processes of the maxilla exceeding the mid-line, imparting a sinuous aspect to the suture. Collagen fibres which penetrated the developing bone processes in the form of Sharpey's fibres were evident in this group (Figure 2a,b). The initial phase of imbrication observed in this group, imparted an arcuate pattern to the collagen fibres which followed the free margin of the bone processes with a consequent reduction in the zone of cellular proliferation (Figure 2c).

In horizontal sections, the sinuous nature of the mid-palatal suture, with a tendency to imbrication, was evident and, although the region between the bone processes and the mid-palatal suture was narrowed, intense cellular proliferation was still evident (Figure 2d,e).

In the GIII foetuses, the main features of the preceding phase were present. The bone processes interdigitated and the zone of cellular

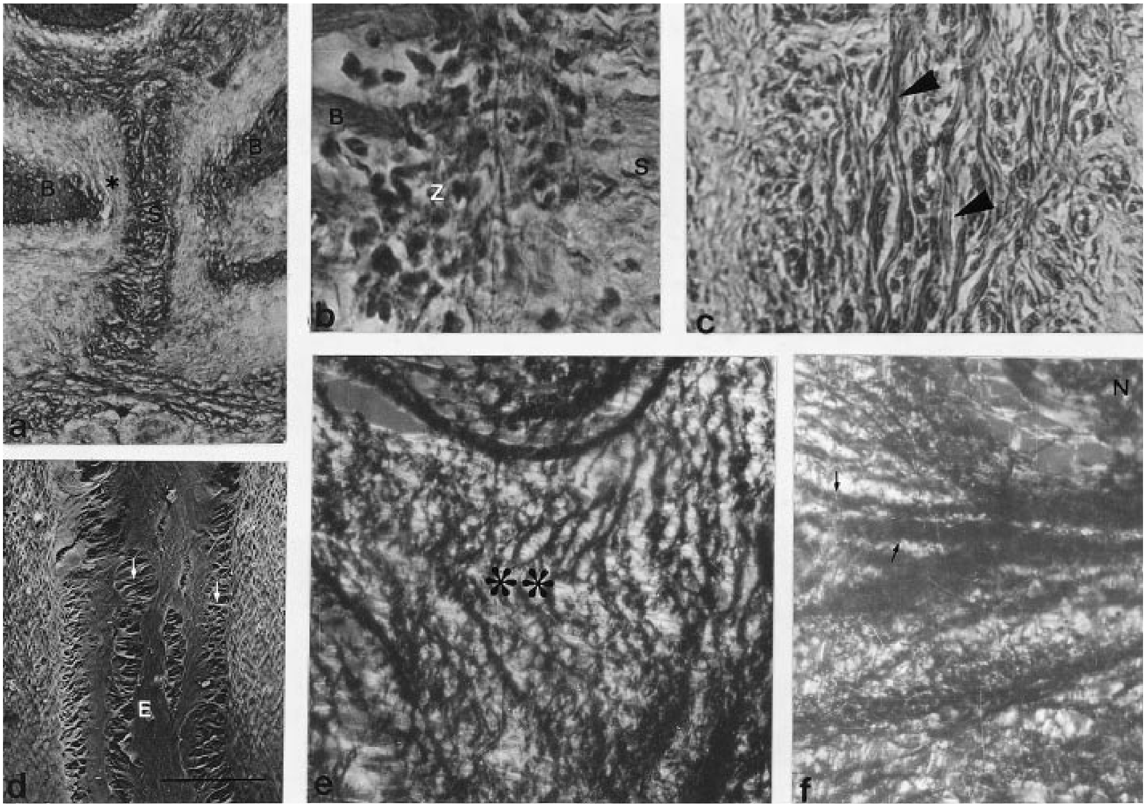

Figure 1 GI foetuses. (a–c) Light micrographs of the mid-palatal suture (S). A wide space (*) between the growing maxillary bone processes (B) and the suture, as well as a zone of intense cellular proliferation (Z) can be observed. The arrowheads indicate the anterior-posterior direction of the collagen fibres in the median region of the suture (Azo-carmine). (a,b) Coronal sections; (c) horizontal section. (a) ×96; (b) ×416; (c) ×248. (d) Electron micrograph showing transversely orientated collagen fibres (small arrows) under the oral epithelium (E) (scale bar = 200 μm). (e,f) Light micrographs of a network of collagen fibres in the centre of the mid-palatal suture (**) with thick transverse fibres (arrows) at the junction with the nasal septum (N) (Picro-sirius, polarized light; coronal sections; ×200).

proliferation decreased (Figure 3a,b). A regular network with elongated meshes was observed along the suture (Figure 3c). The suture had a stratified appearance in this group in which the different layers of collagen fibres were orientated in sagittal, transverse, or oblique directions (Figure 3d).

Discussion

According to Davis (1917) the human palatine processes attach to one another in the tenth week of intra-uterine life. Woo (1948) has observed that the processes fuse from the eighth to the eleventh week, while Fulton (1957) and Kitamura (1989) described the union of the processes in the seventh week of intra-uterine life. In the present investigation, the palatal processes of the maxilla of all specimens in GI were fused, although a wide space was present between them and the centre of the suture was observed. In the foetuses from GII and GIII, this space decreases as the bone processes develop, showing that the suture plays a secondary role in bone growth. These observations are in agreement with those of Moss (1957), Young (1959), Droschl (1975), and Enlow (1975).

According to Enlow (1975), the sutures are adapted to tension, as suggested by Herring (1972) who proposed that the imbricated nature

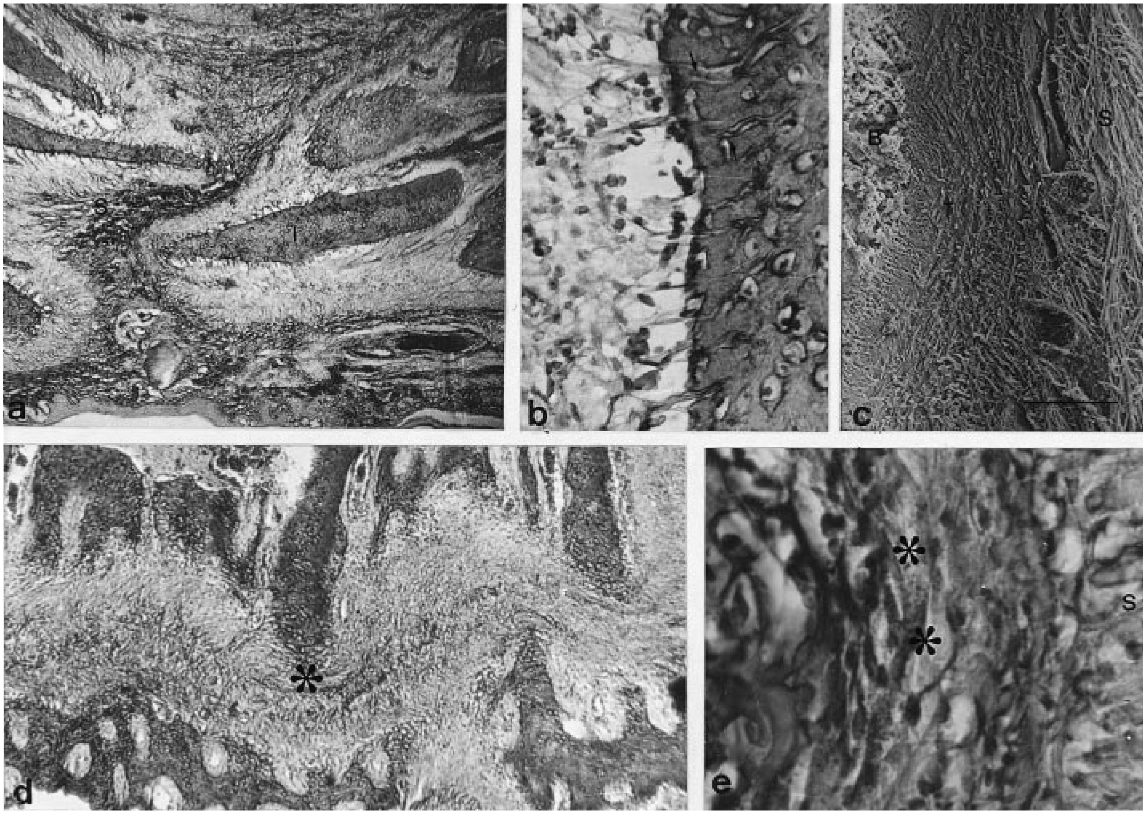

Figure 2 GII foetuses. (a,b) Light micrographs showing the sinuous nature of the mid-palatal suture (S) with Sharpey's fibres (arrows) (Azo-carmine, coronal sections). (a) ×62; (b) ×248. (c) Electron micrograph of the arcuate transitional space (T) between the suture and bone process (B) (scale bar = 200 μm). (d,e) Light micrographs showing the sinuous and imbricating nature of the mid-palatal suture (*) and the narrowed zone of cellular proliferation (**) (Azo-carmine, horizontal sections). (d) ×62; (e) ×416.

of the mid-palatal suture reflects the functional load. The features of the mid-palatal suture observed in human foetuses corroborate these affirmations and emphasize further the guiding role of the suture in bone growth as described by Enlow (1975) for other facial sutures.

The classic description that the mid-palatal suture has a rugous and imbricated nature (Bowman and Latham, 1967; Testut and Latarjet, 1978) and is sinuous with thick bundles of collagen fibres (Sicher and Tandler, 1981) is confirmed in the present work from the GII foetuses onwards.

Latham (1970, 1971) described the 'Y'-shaped nature of the mid-palatal suture in frontal sections at birth due to growth of the vomer toward the intermaxillary junction. Melsen (1975) has shown the broad and slightly sinuous aspect of the suture at birth, becoming interdigitated during puberty. These features were partially confirmed in the early GI foetuses where the 'Y'-shaped aspect was present, and in the GII and GIII foetuses where the sinuous form of the mid-palatal suture can be seen with clear imbrication of the bone processes.

Although three or four zones constitute the mid-palatal suture (Droschl, 1975), five zones of collagen fibres and undifferentiated cells have been described (Pritchard *et al.*, 1956), and three zones have been found in the central region (Weinman and Sicher, 1955). Enlow (1975) reported a zone of collagen fibres emerging from

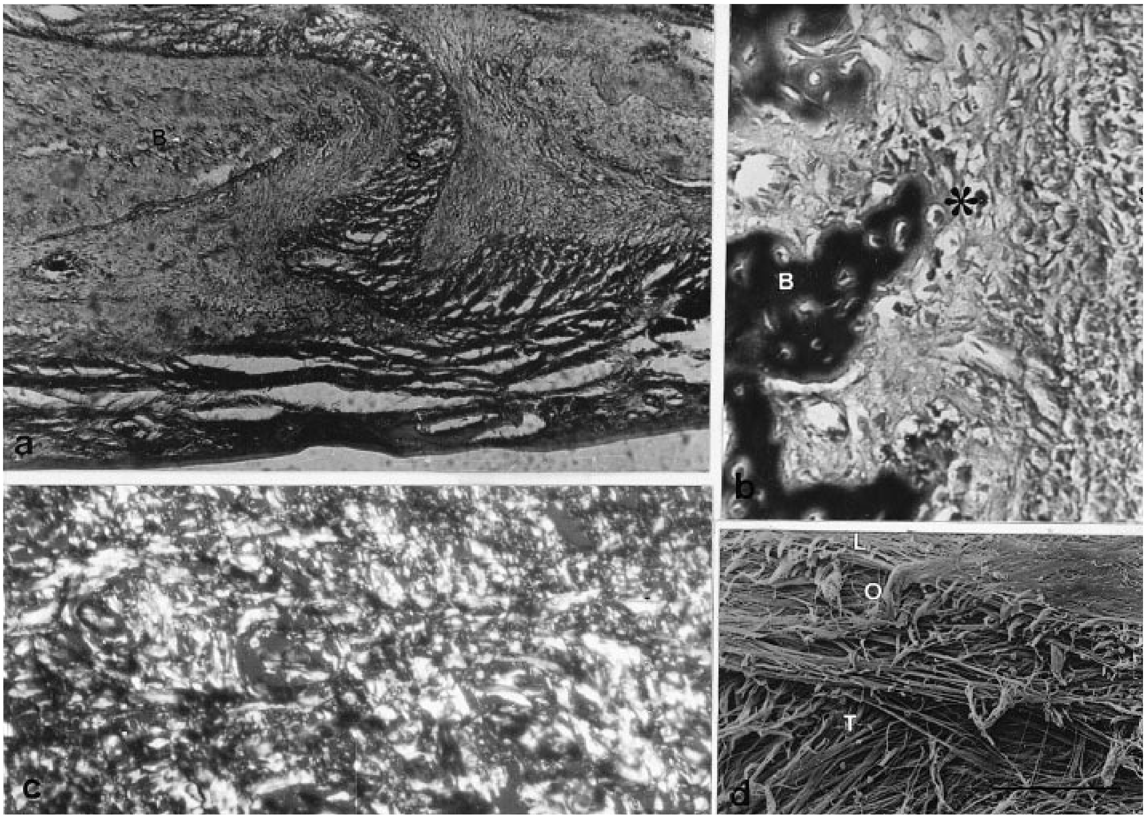

Figure 3 GIII foetuses. (a,b) Light micrographs of the sinuous mid-palatal suture (S) with a narrow zone of cellular proliferation (*) and the calcified maxillary bone processes (B) (Azo-carmine, coronal sections). (a) ×62; (b) ×248. (c) Light micrograph revealing the regular network of collagen fibres in the mid-palatal suture (Picro-sirius, polarized light; coronal section, ×248). (d) Electron micrograph of a stratified mid-palatal suture with sagittal (S), oblique (O), and transverse (T) layers of collagen fibres (scale bar = 100 μm).

the bone processes, a fibrous linkage zone, and a central fibrous zone. In the GIII foetuses, the number of fibrous zones was not clear, but the mid-palatal suture showed well defined layers. This pattern was observed from the GI foetuses onwards where the relatively loose meshworks of collagen fibres had a stratified arrangement according to their direction. Bowman and Latham (1967) found no transverse collagen fibres in the central part of the palatal mucosa. These were seen only subjacent to the oral epithelium.

In the three groups, Sharpey's fibres, arising from the palatal processes of the maxilla, extend towards the central zone of the mid-palatal suture (Pritchard *et al*., 1956; Jones and Boyde, 1974). These fibres which contribute to fluid transport from the conjunctive tissue to the bone tissue (Devyatkin and Kostilenko, 1981) are of varying diameter and emerge from the developing bone channels to the cellular zone of proliferation.

The description of the sutures as similar to the epiphyseal cartilage of long bones (Persson and Roy, 1979) and the endochondral ossification of craniofacial areas in certain mammals (Moss, 1958) was not confirmed for the mid-palatal suture since cartilaginous cells were not found, at least in the earliest group studied (GI). Droschl (1975) described the intermediate layer between the palatine bone processes and the central part of the suture as an active growth zone, similar to the zone of cellular proliferation seen in the GI–GIII foetuses. Thus, the microscopic features of the human mid-palatal suture in these early stages suggest that the palatine bone processes develop from the fibrous tissue of the suture.

In conclusion the mid-palatal suture of GI foetuses is of rectilineal nature, with a wide zone of intense cellular proliferation between the bone processes and the suture. In the GII and GIII foetuses, the suture has a sinuous form due to the interdigitating bone processes with consequent narrowing of the zone of cellular proliferation. The collagen fibres are involved in the development of the palatine bone processes where emerging Sharpey's fibres are evident. The collagen fibres of the suture have a stratified disposition from GI onwards with a thin, transversally orientated layer under the oral epithelium, a regular meshwork with predominantly sagittal fibres in the central region, and a transverse to oblique meshwork at the junction with the nasal septum.

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