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The development, structure and growth pattern of the human mid-palatal suture

R. A. LATHAM
Institute of Child Health, Alder Hey Children's Hospital, Liverpool L12 2AP

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INTRODUCTION

A knowledge of the normal development and function of the mid-palatal suture in man is particularly important in the study and treatment of cleft lip and palate. But, despite the interest shown in this and other aspects of the suture in the past, little, as yet, is known about it.

Some observations on its development and growth in experimental animals have been reported (Pritchard, Scott & Girgis, 1956; Linder-Aronson & Larsson, 1965). In man, consideration has been given mainly to the question of when this suture ceases to be a growth site (Scott, 1956).

This paper presents an account of the initial formation and subsequent development of the premaxillary and maxillary parts of the mid-palatal suture based on the histological examination of a series of human specimens. Particular attention has been given to the histological evidence for when bone deposition in the suture normally ceases.

MATERIAL AND METHODS

Twenty-eight specimens of the mid-palatal suture representing an age range from 6 weeks in embryonic life to 15 years in postnatal life were studied (Table 1). Foetal specimens were aged, where possible, according to crown-rump measurements and body weight with reference to Streeter's data (Streeter, 1920). Tissues were fixed in 10% formalin, decalcified in 7% formic acid and embedded in paraffin wax. Most sections were cut on a rotary microtome set at 10 μm, and stained by the Masson trichrome method and with either Van Gieson's stain or haematoxylin and eosin. The entire suture of the small foetal specimens was serially sectioned throughout its length. In the case of the larger, postnatal palates an attempt was made to obtain sections of both the interpremaxillary and intermaxillary parts.

RESULTS

Development

Premaxillary part. From an examination of embryos 41 and 47 d old respectively, it appeared that the interpremaxillary suture developed very soon after the appearance of the premaxillary ossification centres. Sections of the 41 d embryo (H419) showed

Table 1. *Ages of foetal specimens (estimated) and post-mortem material*

Prenatal		Postnatal	
Age	Specimen no.	Age	Specimen no.
Days		Months	
39	H 376	2	H 937
41	H 419	6	H 614
47	H 340	14	H 936
49	H 273	Years	
Weeks		2	H 942
8	H 563	3	H 938
9	H 274	4	H1106
10	H 762	5	H 475
10	H 555	6	H1042
10	H 769	8	H 628
10·5	H 275	11	H 615
12	H1163	15	H 448
14	H 345		
19	H1162		
26	H1071		
30	H 424		
Full term	H 625		
Full term	H1164	$N=28$.	

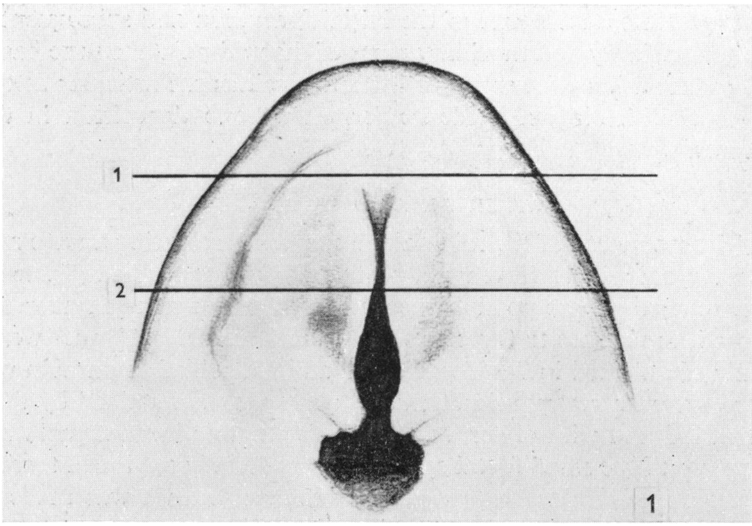
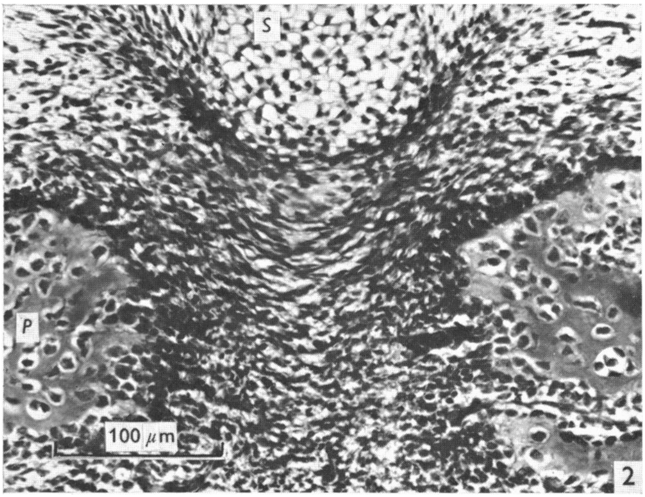


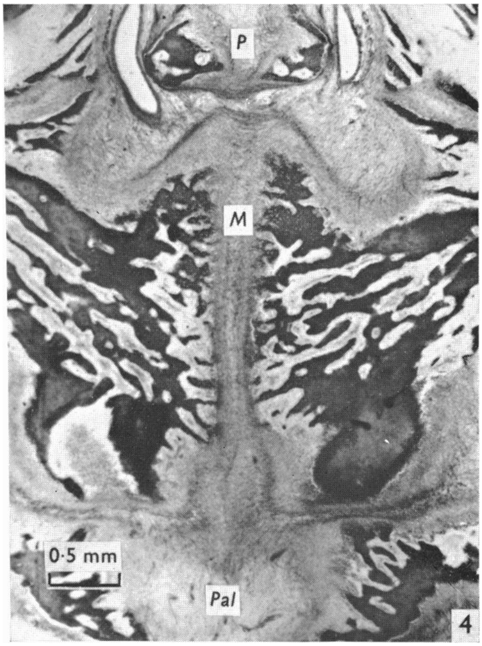
Fig. 1. Drawing of palate of 47 d human embryo, after removal of lower jaw, showing relative development of primary palate (premaxillary region) and secondary palate (maxillary region). Guide lines 1 and 2 show location of sections illustrated in Figs. 2 and 3 respectively.

small, and presumably recently formed, premaxillary ossification centres, and a condensation of mesenchyme at the site of the presumptive interpremaxillary suture.

A well-established interpremaxillary suture was found in the 47 d embryo (H 340); cells in the sutural soft tissues were orientated transversely between the bone margins, and in the middle zone they were longitudinally orientated and came mainly from the inserting septopremaxillary ligament (Figs. 1, 2). It therefore appeared that the interpremaxillary part of the mid-palatal suture formed at about 45 d.

Maxillary part. The secondary palate, in which the maxillary and palatine parts of the mid-palatal suture form, was still rudimentary at 47 d (Figs. 1, 3). After fusion of





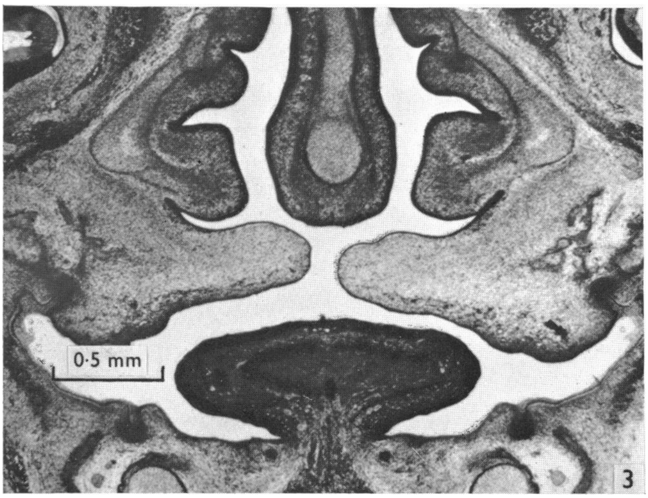
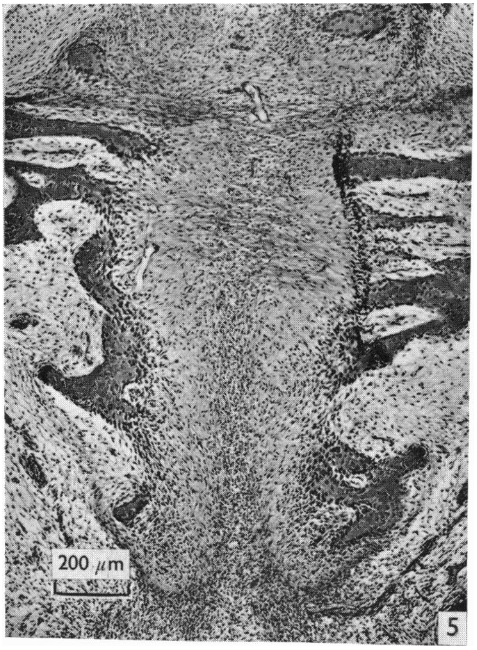


Fig. 2. Early interpremaxillary suture in a coronal section corresponding to level 1 in Fig, 1, 47 d human embryo (H340). Transversely orientated cells are present in the upper sutural area, longitudinally coursing cells predominate in the lower middle zone. *S*, nasal septum; *P*, premaxillary bone. Masson.

Fig. 3. Embryonic palatal processes at horizontal approaching stage in a more posterior section corresponding to level 2 in Fig. 1, 47 d (H340). Hard palate formation is still rudimentary compared with skeletal development in primary palate seen in Fig. 2. Masson.

Fig. 4. Newly formed intermaxillary suture (*M*) in a horizontal section through palate of 12 week foetus (H1163). The boundaries of the other two parts of mid-palatal suture; interpremaxillary (*P*) and interpalatine (*Pal*), are also shown. Masson.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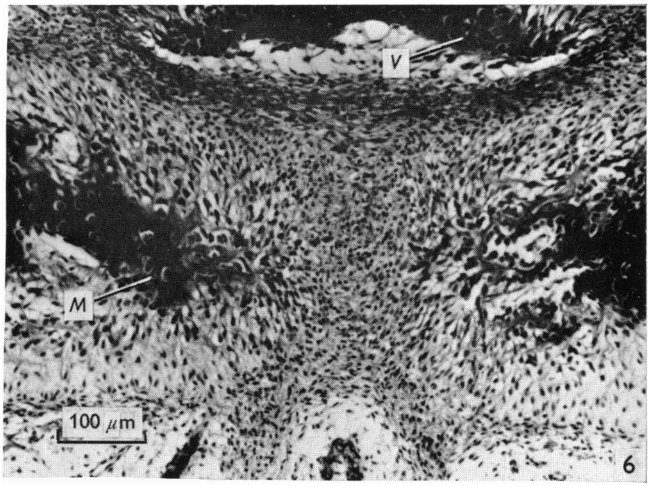
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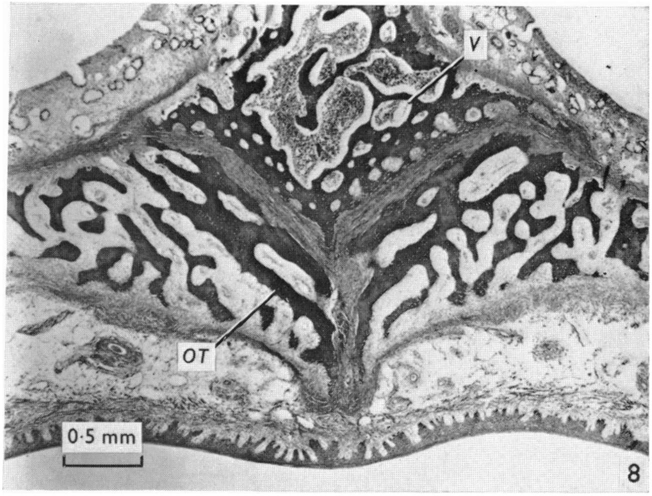
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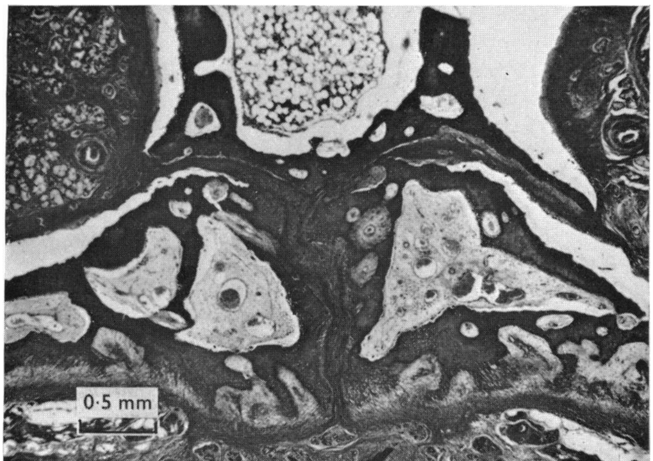
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the embryonic palatal processes (between 47 and 54 d) a further 5 weeks elapsed before the horizontal processes of the maxillary bones extended to the midline where sutural union could occur. The first indication of sutural formation was at $10\frac{1}{2}$ weeks when the superior uniting layer of fibre bundles developed across the midline in close proximity to the vomer's periosteum. Epithelial fusion remnants, on the oral aspect, appeared to have a retarding effect upon sutural development. A definitive intermaxillary suture was established at 12 weeks (Fig. 4).

Structure

Premaxillary part. In early foetal life the interpremaxillary suture was typically wide with pronounced transverse bundles of fibres connecting the two bones. Anteriorly it was rather dominated by the septopremaxillary ligament whose fibre bundles inserted mainly on to the anterior nasal spine, but some fibre bundles continued into the sutural tissues; in an older foetal specimen (H424) the orientation of the bony trabeculae at the sutural border suggested that they had been drawn out in conformity to the direction of these inserting fibres (Latham, 1970). In transverse sections these bony trabeculae appeared as interlocking bony processes which transformed the interpremaxillary suture into one of the serrate type (Fig. 7). However, the inferior part of the suture within the alveolar process remained straight.

During development the vomer extended forwards between the inferior border of the nasal septum and the premaxillary bone (Fig. 7); its forward progress was presumably stopped by the septopremaxillary ligament.

Maxillary part. The intermaxillary suture extended from the incisive canal to the transverse palato-maxillary suture posteriorly. It was much narrower than the interpremaxillary suture, less than half as wide at 14 weeks, and its sutural cells and fibres ran along the suture, parallel to the bone margins. The marked structural difference between the maxillary and premaxillary parts of the mid-palatal suture is shown in Figs. 5 and 6.

The vomer at first lay across the upper part of the intermaxillary suture, with its periosteum blending with the upper transverse fibre bundles of the suture (Fig. 6). Then, beginning at about 20 weeks, the vomer progressively grew into the inter-

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Fig. 5. Coronal section through interpremaxillary suture, 14 week foetus (H345) showing greater width and transversely coursing fibre bundles contrasting with structure of intermaxillary part of same specimen in Fig. 6. Masson.

Fig. 6. Coronal section through intermaxillary suture, same specimen (H345) at almost twice the magnification of Fig. 5. Suture is narrower and intervening cells are orientated longitudinally. Masson.

Fig. 7. Coronal section through interpremaxillary suture at full term (H625) showing interlocking serrate structure in upper part and straight lower part between tooth germs of permanent central incisors (*PI*). The vomer (*V*) shows immediately inferior to nasal septum (*NS*). Masson.

Fig. 8. Intermaxillary suture of same specimen (H625) 'Y'-shaped due to invagination by vomer (*V*). Oblique maxillary trabeculae (*OT*) appear to result from slower rate of bone deposition in maxillo-vomeral than in intermaxillary part of suture. Masson.

Fig. 9. Intermaxillary suture, 6 months postnatal (H614). The most striking feature is inferior remodelling growth mechanism: resorption—superiorly on nasal surface where periosteum has lifted, inferior endosteal surface where osteoclasts are numerous; deposition—inferiorly on periosteal palatal and superior endosteal surfaces Note medullary excavation of bones. Masson.

maxillary joint, reaching a maximum involvement at full term when the sutur presented a 'Y'-shaped cross-section (Fig. 8). At this time the maxillary palata processes articulated more with the vomer than with each other.

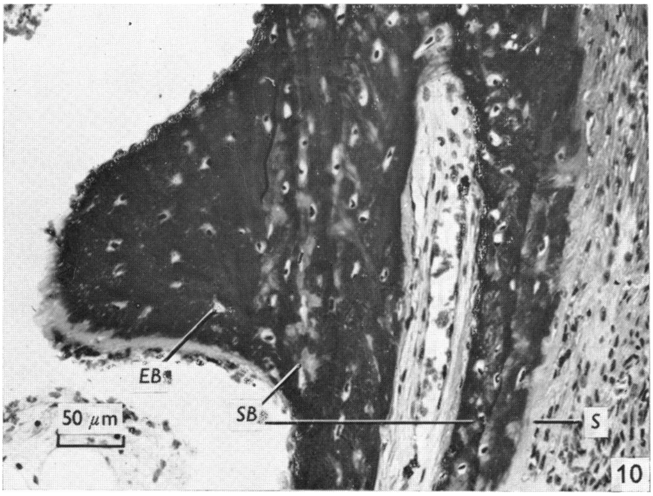

Fig. 10. Intermaxillary sutural margin 14 months postnatal (H936), coronal section, at higher magnification to show localized deposition of endosteal bone (*EB*) on sutural bone (*SB*). Osteogenesis at sutural surface (*S*) is either very slow or has ceased. Masson.

Fig. 11. Intermaxillary suture at 3 years (H938). Suture is more extensive vertically, narrower and more fibrous. Sutural growth has ceased but pattern of superior bone resorption and inferior deposition is still present. Van Gieson.

Whether this vomeral encroachment was due to pressure from the nasal septum or to an inductive influence by the intermaxillary suture was not clear. The vomer also reached its greatest relative size at birth; thereafter it became progressively thinner due to bilateral resorption.

In the immediate postnatal period the fine cancellous bone of the palate was replaced by bone having a cortex and medullary spaces, and the medial ends of the palatal processes gradually thickened (Figs. 9, 11). During the first 2 years the inferior

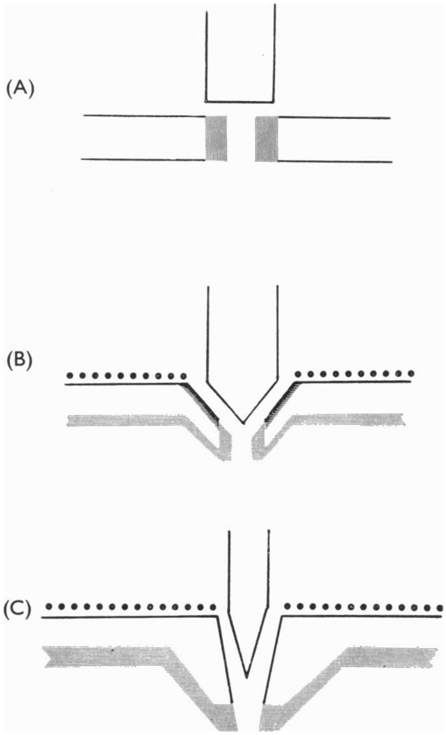

Fig. 12. Diagram illustrating the changing growth pattern and structure of intermaxillary suture. Shaded areas represent bone deposition, dots represent resorption. (A) Simple marginal extension (sutural growth) characteristic of early foetal life until about 16 weeks. See Figs. 5 and 6. (B) The 'Y'-shaped suture of late foetal life resulting from vomeral invagination, sutural growth is directed infero-medially and mechanism of nasal resorption and oral deposition becomes increasingly active. See Figs. 8 and 9. (C) After 1–2 years in postnatal life when sutural growth has ceased, growth activity now confined to palatal surface in association with nasal resorption. Vomer becomes thinner and less invaginated into suture.

cortical layer remained cancellous in nature, due to the rapid deposition of bone on its oral surface; the intermaxillary suture increased markedly in height and became narrower; and the sutural bone margins tended to become parallel and to be formed by continuous cortical bone.

At 3 years, and in all older specimens, compact cortical bone and clear medullary spaces, confined to the thickened medial area, were characteristic. The intervening sutural tissue was mainly fibrous and the fibre bundles coursed parallel to the bone margins (Fig. 11).

Growth

Associated with the changing structure of the intermaxillary suture during development corresponding changes in its growth pattern were observed. Three stages could be identified (Fig. 12): (i) sutural growth; (ii) sutural and remodelling growth; (iii) remodelling growth only.

(i) *Sutural growth.* As the horizontal processes of the maxillary bones approached the midline, bone deposition occurred mainly on their medial edges. Later this pattern was continued as sutural growth, in association with growth in width of the facial skeleton (Fig. 12A). The sutural cambial layers were typically cell dense and produced a highly cellular, woven bone (Fig. 6). Additional evidence of this sutural growth was seen in the premaxillary region: the lateral movement of the bony palatal processes with respect to the nasal septum brought bone to bear against the paraseptal cartilages and here some remodelling of the bone by resorption was observed.

(ii) *Sutural and remodelling growth.* At about 16 weeks osteoclasts appeared on the free nasal aspect of the maxillary palatal bone and, in association with the obvious picture of osteogenesis on the oral aspect, remodelling inferiorly of the palatal bone as a whole commenced. It was soon after this time that the vomeral intrusion began. Meanwhile sutural bone deposition continued.

The medial border of the maxillary process now presented two sutural surfaces in different planes, and, from the evidence of their bone structure, having different growth rates—growth being slower in the maxillo-vomeral part than in the intermaxillary part. The bone therefore tended to form in trabeculae parallel to the slower growing surface. These trabeculae in turn were being remodelled infero-medially by resorption on their nasal surface and bone deposition on the intermaxillary surface, The sutural surface of the vomer was also depository in character (Fig. 8).

After birth the mechanism of palatal remodelling inferiorly predominated, and was particularly in evidence at 6 months (Fig. 9). The cross-sectional form of the suture now changed to a 'T' shape, the maxillo-vomeral part becoming more aligned with the nasal floor and becoming, like it, a resorptive surface. Appearances suggested that separational growth at the suture was slowing down and that the rate of remodelling inferiorly had increased.

(iii) *Remodelling growth only.* The onset of this stage was marked by the slowing and cessation of sutural growth, the thinning of the vomer and increasing height of the suture (Figs. 11, 12C).

Sutural growth evidently ceased between the ages of 1 and 2 years. This was indicated by a change in growth pattern of the bone forming the sutural margin. When bone had been actively deposited on the sutural margin, a corresponding resorption occurred on the adjacent medullary surface (Fig. 9). When sutural growth ceased, the medullary resorptive surface changed to a depository one, giving rise to lamellae of the endosteal bone on the sutural plate. At first endosteal bone formation was localized to small trabeculae or ridges protruding into the medullary space, as was seen at 14 months (Fig. 10), but in the next older specimen of 26 months (H942) endosteal bone extended more evenly along the sutural area. The number of sutural osteoblasts was also reduced.

In all older specimens, viz. at 3, 4, 5, 6, 8, 11 and 15 years, no indication of sutural growth was found. The resorptive-depository pattern of inferior palatal remodelling was recognised in each case, but little inference was possible about its rate of activity.

DISCUSSION

The timing of the development of the mid-palatal suture is of interest for two reasons. First, the interpremaxillary suture establishes a skeletal bridge across the embryonic primitive palate from the earliest possible time. Growth tensions appear to be present in the face between the fifth and the seventh week as it rapidly develops. The forward growing nasal septum is thought to act as a primary force not only in the formation of the early facial profile, but also in the development of the bones of the upper jaw and their soft tissues by means of its connexions with them (Scott, 1953; Latham, 1970). If this is so, early formation of the interpremaxillary suture would be necessary to support the primary palatal region and to ensure equal loading of each side of the face to the growing septum. It is noteworthy that the interpremaxillary suture is the first of all the cranial sutures to develop. Disruption of the primary palate, as when a developmental cleft occurs, is quickly followed by widening of the cleft and facial asymmetry (Latham, 1969).

Secondly, while the embryonic secondary palate was formed in the eighth week (fusion commencing at about 47 d), it was not wholly supported by bone until the twelfth week. It follows that for fully 5 weeks prior to this time union of the maxillary bones across the midline was effected solely in the primary palate by the interpremaxillary suture. The scope that this provides for malformation in the event of primary palatal failure but successful secondary palate formation is considerable. This explains why facial deformity accompanying a unilateral cleft of the primary palate only (cleft lip) is frequently as severe as when the cleft affects both the primary and secondary palatal regions (cleft lip and palate).

The structural differences between the premaxillary and maxillary parts of the mid-palatal suture in foetal life may be simply a reflexion of their different times of development or they may have been due to the effect of a tension across the suture anteriorly and a slight pressure posteriorly. It is possible that the forward pull of the growing cartilaginous nasal septum upon the premaxillary region caused a tension across the anterior part of the suture where interlocking spurs of bone later formed, and that there was an associated tendency for the maxillae to be pressed together posteriorly to make a simple end to end joint.

The method for detecting cessation of sutural growth appeared to be reasonably reliable. It was not so much a subjective matter as the observation of an end point, when endosteal resorption of bone gave way to endosteal deposition. The finding, on histological evidence, of cessation between one to two years agrees with that of Scott (1956) who thought it doubtful whether any growth occurred after the first year. The question of when growth normally ceases at the mid-palatal suture is an important one in relation to the timing of surgery for the closure of cleft palate. Until recently in some centres, operations were delayed until six years of age to avoid interference with growth centres of the palate, but to the detriment of speech development. The present findings support the view that early closure of the hard palate (between 1 and

2 years of age) will not interfere materially with growth in palatal width normally occurring in the mid-palatal suture.

The mid-palatal region is occasionally marked on its oral aspect by a bony ridge or smooth eminence (torus palatinus). While this is of interest mainly when a full upper denture is to be fitted, an explanation is suggested by the changes normally occurring in the mid-palatal suture. With the invagination of the vomer it appeared that the original sites of sutural growth were displaced inferiorly (Fig. 12B).

The sutural osteogenic cells would have already been in the process of blending with those of the adjacent palatal periosteum inferiorly, which was developing as a zone of rapid surface deposition. Then as resistance to lateral palatal growth increased the sutural osteogenic cells might have been extruded on to the oral surface. Thus it appears possible that the formation of a median bony ridge could result from removal of cells with growth potential from their intra-sutural position on to the inferior sutural borders where the existing growth process might be augmented.

It might be expected that the lowering of the hard palate by resorption of the nasal floor would result in the formation of a median nasal ridge on the superior aspect of the horizontal processes of the maxillae where these articulate with the vomer. It was found, however, that the resorptive area of the nasal floor extended medially as far as the intermaxillary suture (Fig. 9), so that no part of the nasal bony surface was excluded from the resorptive process. The possible exception was in the interpremaxillary region where the septopremaxillary ligament maintained a tight connexion between the cartilaginous nasal septum and the underlying bone; here the nasal crest was a characteristic feature (Fig. 7). The formation of a nasal crest, in general, should not be regarded as a criterion of activity of the remodelling mechanism for palatal descent.

The fact that the mid-palatal suture can be widened and the palate expanded by orthodontic appliances after the age of 10 years is probably more a reflexion of its special character in being only in part a tension resisting joint and in having deep, relatively flat, opposing surfaces which would appear to be adapted to resist intermittent medial pressures. It appears that at no time after the cessation of sutural growth does synostosis take place in the mid-palatal suture. Possibly the range of masticatory movements characteristic of man, causing constant slight movement of the bones, is one of the factors involved.

SUMMARY

The development, structure and growth pattern of the human mid-palatal suture were studied using 28 specimens ranging in age from 6 weeks in embryonic life to 15 years. The interpremaxillary part was formed at about 45 days and the intermaxillary part at about 12 weeks. The different developmental structures of the intermaxillary suture were associated with three different patterns of growth: (1) an initial, purely sutural type of growth until 16 weeks in foetal life; (2) sutural growth combined with inferior remodelling of the entire palate, from 16 weeks until about 1–2 years of age when sutural growth ceased; (3) continued inferior palatal remodelling (including the sutural area) without sutural growth. The change on the endosteal side of the sutural bony plate from a resorptive to a depository surface provided a criterion for the cessation of sutural growth.

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