J. Anat. (1970), **107**, 3, pp. 471–478
With 8 *figures*
Printed in Great Britain

Maxillary development and growth: the septo-premaxillary ligament

R. A. LATHAM

Institute of Child Health, The University of Liverpool, Alder Hey Children's Hospital, Liverpool, L12 2AP

(*Received* 17 *October* 1969)

INTRODUCTION

It is thought that the rapidly growing nasal capsule and septum of the embryo play an important part in the normal development and growth of the osseous facial skeleton by separating the early membranous bones from one another and allowing bone deposition to occur at the sutural margins; and that, as the nasal capsule disappears later in foetal life, the nasal septum continues to function in this capacity into the early years of childhood, thrusting the maxillae downwards and forwards (Scott, 1953). Recent observations have indicated, however, that the activity of the nasal septum in this respect may be much more limited (Latham, 1968; Moss, Bromberg, In Chul Song & Eisenman, 1968), but the possibility remains that it may still be of considerable importance in the prenatal period. Knowing when a growth process is active is important, but we must also know to what extent certain growth mechanisms actually contribute to the overall development and growth of a particular structure or region.

For the septal concept of facial growth to be useful clinically we need to know more about its precise *modus operandi* and to make some appraisal of the evidence that, in fact, such a mechanism operates. A histological examination of the apparatus underlying the septal growth hypothesis was therefore undertaken using human embryonic and foetal material. Particular attention was paid to the means whereby the cartilaginous septum might transmit its growth force to the maxillae, and to consideration of the available supporting evidence. This investigation led to the finding of an interesting developmental relationship between the early maxillae and the nasal septum, and to the recognition of an apparently 'key' structure—the septopremaxillary ligament.

MATERIALS AND METHODS

Twenty-four human embryos and foetuses ranging in age from 39 d to full-term were studied (Table 1). Ovulation ages were estimated where possible using Streeter's developmental horizons and growth curves (Streeter, 1920, 1951). Serial sections of the entire head, or of parts of the facial region, were cut in the coronal, sagittal or horizontal planes and routinely stained with haematoxylin and eosin and by the Masson trichrome method.

RESULTS

Septo-premaxillary ligament. The ribbon-like centres of maxillary ossification in an embryo of about 41 d (H. 419, Horizon XX) had no direct connexion with nasal capsule tissues. However, through their proximity and subsequent fusion with the premaxillary ossification centres, they were related to the anterior part of the nasal septum. The maxillary and premaxillary ossification centres were still separate at this stage but their cell territories were contiguous (Fig. 2). Medially in the presumptive site of the interpremaxillary suture the premaxillary area merged with a mid-line condensation of cells; this condensation was then joined by a column of cells descending from the anterior border of the nasal septum—the septo-premaxillary ligament. The ossification centres of the maxillae and premaxillae of the two sides were thus separated in the mid-line by sutural tissues yet were, at the same time, connected to the anterior border of the nasal septum (Figs. 1, 2).

Table 1.

Age	Specimen no.	Section plane	Crown–rump length (mm)
39 d	H. 376	Horizontal	18·0
41 d	H. 419	Horizontal	21·5
47 d	H. 340	Coronal	23·0
49 d	H. 273	Coronal	31·0
52 d	H. 563	Coronal	32·0
9 weeks	H. 22	Coronal	—
9 weeks	H. 274	Coronal	30·0
10 weeks	H. 762	Coronal	59·0
10 weeks	H. 555	Coronal	46·0
10 weeks	H. 769	Coronal	45·0
10½ weeks	H. 275	Coronal	(Foot length 7·5)
11 weeks	H. 1103	Sagittal	69·0
12 weeks	H. 1163	Horizontal	84·0
14 weeks	H. 345	Coronal	(Foot length 15·0)
16 weeks	H. 87	Sagittal	(Foot length 27·0)
17 weeks	H. 768	Sagittal	158·0
19 weeks	H. 1162	Coronal	171·0
24 weeks	H. 1161	Sagittal	220·0
30 weeks	H. 424	Sagittal	—
Full-term	H. 625	Coronal	—
Full-term	H. 1164	Coronal	—
Full-term	H. 1072	Sagittal	—
Full-term	H. 627	Sagittal	—
Full-term	H. 785	Sagittal	—

This same pattern of connexions was more distinctly observed at a later stage of development in an embryo some 6 d older (H. 340, Hor. XXIII, 47 d). The column of cells forming the septo-premaxillary ligament and beginning at the anterior border of the nasal septum coursed postero-inferiorly and continued into the interpremaxillary suture and adjacent periosteum (Figs. 3, 4). The early formation of the interpremaxillary suture was well demonstrated in this specimen; it showed thick cambial layers of osteoblasts and osteogenic cells, and a broad middle zone consisting of cells orientated transversely and cells from the septo-premaxillary connexion coursing antero-posteriorly (Fig. 4). By this time maxillo-capsular connexions had developed, particularly where the maxillary frontonasal processes approached the superior border of the nasal capsule within a layer of fibrous tissue.

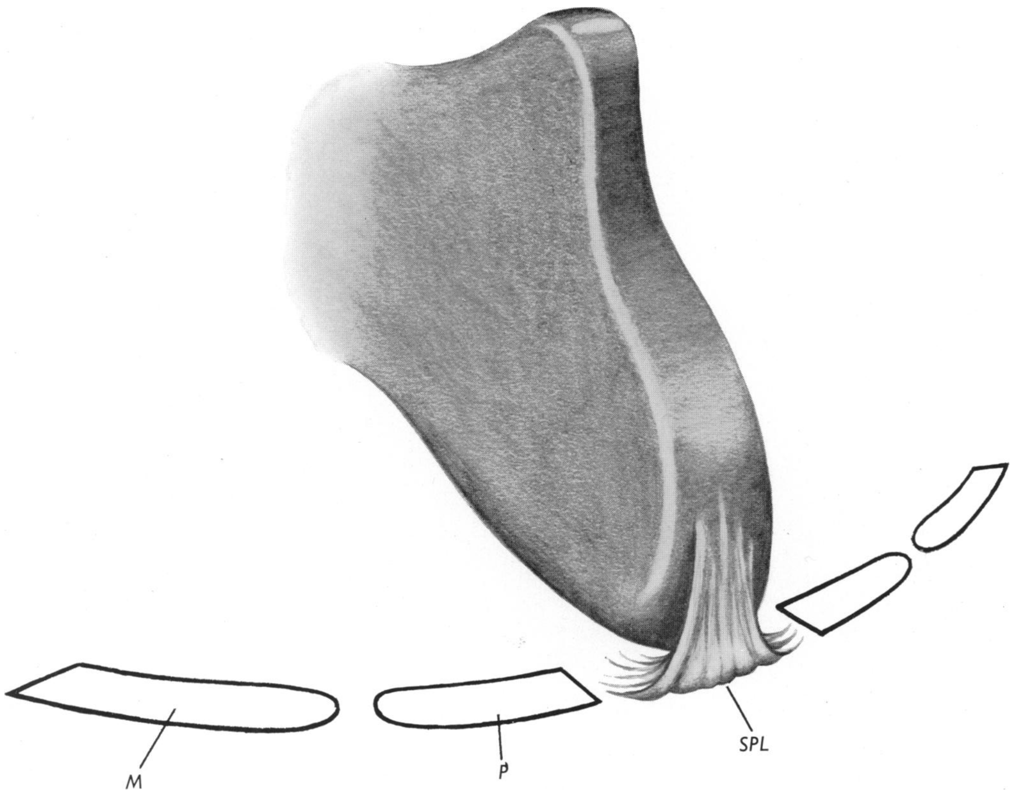
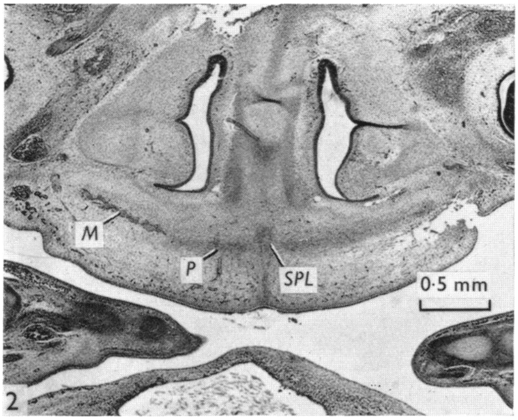
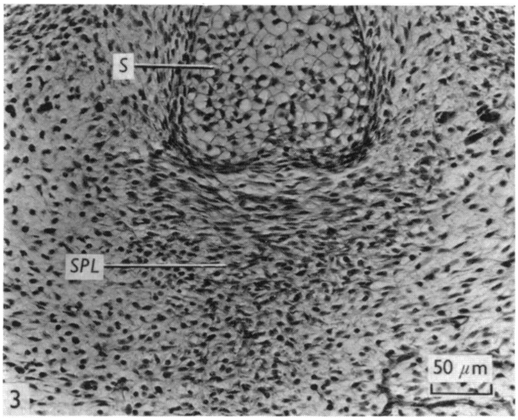


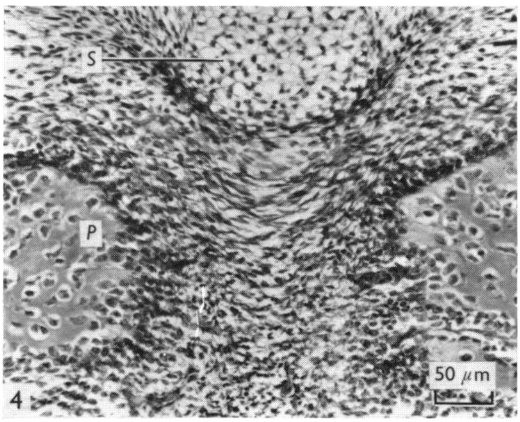
Fig. 1. Diagrammatic representation of the septo-premaxillary apparatus seen in Fig. 2 at 41 d. The maxillary (*M*) and premaxillary (*P*) ossification centres, very soon after their first appearance, are connected to the nasal septum by a septo-premaxillary ligament (*SPL*).

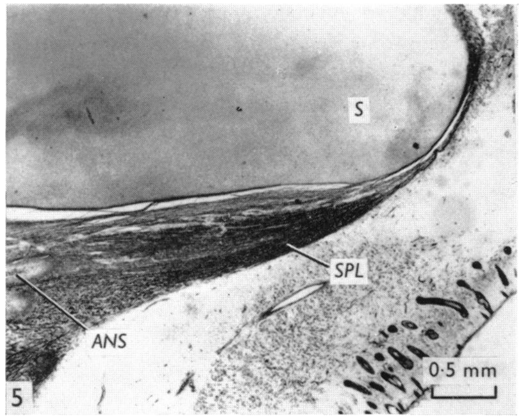
The septo-premaxillary attachment was best seen in sagittal sections; its ligamentous nature was suggested not only by its form but also by its staining intensity with Masson's trichrome method, which was comparable to that of collagen-containing structures (Fig. 5). In horizontal sections lateral connexions from the septal border passed postero-laterally to an insertion on the facial and nasal aspects of the premaxillary bone (Fig. 6).

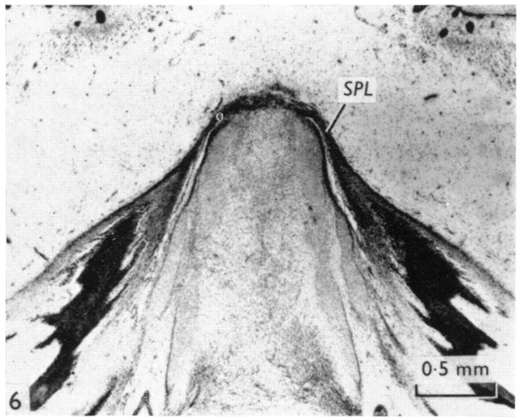
The composite impression gained of what might now be termed the 'septo-premaxillary ligament' was of a principal bundle of fibres arising from the antero-inferior border of the nasal septum and coursing postero-inferiorly to an insertion on the anterior nasal spine and in the tissues of the interpremaxillary suture. Less dense lateral bundles radiated postero-laterally towards a broad insertion on the facial and nasal surface of the premaxillary bones. Hence in coronal sections from a 14-week foetus at the level of the anterior nasal spine the anterior septo-

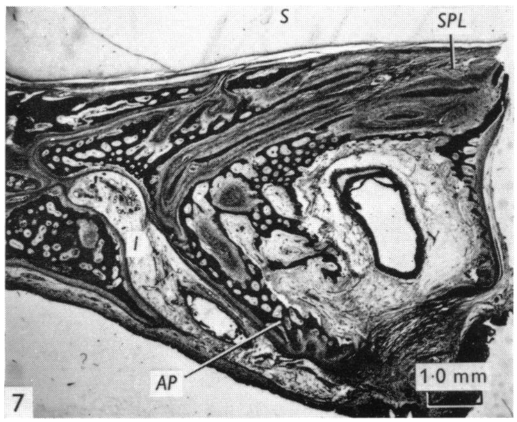

M
P
SPL
0·5 mm
2


S
SPL
50 μm
3


S
P
50 μm
4


S
SPL
ANS
0·5 mm
5


SPL
0·5 mm
6


S
SPL
I
AP
1·0 mm
7

premaxillary ligament was seen as a U-shaped investment at the base of the nasal septum. Because the ligament itself lay anterior to the premaxillary bone, its presence and therefore the real nature of the septo-premaxillary attachment was not apparent in standard coronal sections through the premaxillary region. In some of the younger embryos, for example specimen H. 563–52 d, such sections showed a space between the inferior septal border and the premaxillae which was occupied by loose mesenchyme. Later, as the premaxillary bones extended posteriorly to form the infravomerine processes, these lay between the paraseptal cartilages and inferior to the nasal septum to produce an intimate interconnexion between periosteal and perichondrial tissues (Fig. 8). Later, however, the vomer extended anteriorly through this region until its forward progress was limited, presumably by the anterior septo-premaxillary ligament.

The nasal septum. Coronal sections normally showed a bulbous enlargement of the inferior part of the nasal septum which, when viewed in terms of a growth mechanism, gave the impression of a rod-like thickening reinforcing the septum antero-posteriorly. This thicker portion of the septal cartilage was in direct continuity with the broader, basisphenoid region posteriorly, while anteriorly it formed the inferior septal border, terminating in the region of the septo-premaxillary ligament (Fig. 8). The greater, upper part of the nasal septum, including the ethmoid region, consisted of a relatively thinner sheet of cartilage.

Premaxillary bone. The structure of the premaxillary bone showed two interesting features. First, paramedian sagittal sections from the vicinity of the interpremaxillary suture showed the marginal sutural bone as parallel trabeculae having an orientation similar to that of fibre bundles of the anterior septo-premaxillary ligament, i.e. from the septal border running downwards and backwards (Fig. 7). Secondly, throughout foetal life the interpremaxillary suture showed coarse transverse bundles of fibres passing between the bone margins; and at full term the corresponding part of the suture had developed an interlocking, serrate structure.

Fig. 2. Human embryo 41 d, H. 419; horizontal section showing mid-line condensation of cells of presumptive interpremaxillary suture and septo-premaxillary ligament (*SPL*), and relationship to premaxillary (*P*) and maxillary (*M*) ossification centres. Masson's trichrome.

Fig. 3. Human embryo 47 d, H. 340; coronal section just anterior to premaxillae showing condensation of fibroblasts (septo-premaxillary ligament—*SPL*) at antero-inferior border of nasal septum (*S*). Masson trichrome. ×250.

Fig. 4. A more posterior section to that in Fig. 3, same specimen, showing well-established interpremaxillary suture. Cells of septo-premaxillary ligament (cut transversely) disperse in lower part of middle sutural zone. *P*, premaxillary bone; *S*, nasal septum. ×250.

Fig. 5. Mid-line sagittal section through anterior nasal spine (*ANS*) and nasal septum (*S*) showing the septo-premaxillary ligament (*SPL*). Seventeen-week foetus, H. 768; Masson's trichrome.

Fig. 6. Horizontal section at antero-inferior border of nasal septum showing septo-premaxillary ligament (*SPL*) coursing postero-laterally towards premaxillary periosteum; twelve-week foetus, H. 1163. Masson's trichrome.

Fig. 7. Paramedian sagittal section through septo-premaxillary region. Upper trabeculae of premaxillary bone are orientated obliquely and aligned parallel to inserting fibres of septo-premaxillary ligament (*SPL*). *S*, nasal septum; *AP*, alveolar process; *I*, incisive canal. Thirty-week foetus, H. 424. Masson's trichrome.

DISCUSSION

The septo-premaxillary ligament appears to be the means for the transmission of septal growth force to the maxillae (Figs. 1, 8). The nasal septum in growing downwards and forwards would apply a 'pull' upon the premaxillary bone, rather than a push.

It is important to appreciate that the maxillae of the embryonic and foetal periods may readily respond to forward traction. The maxillary sutures are aligned in approximately the antero-posterior direction thus allowing the maxillae to move in this direction relative to the adjacent sutural margins of the zygomatic and palatine bones; for this movement to occur sutural growth is neither necessary nor does it occur to the extent formerly supposed (Latham, 1968). The important sites of bone deposition associated with this downward and forward displacement are the free orbital and posterior surfaces of the maxillae.

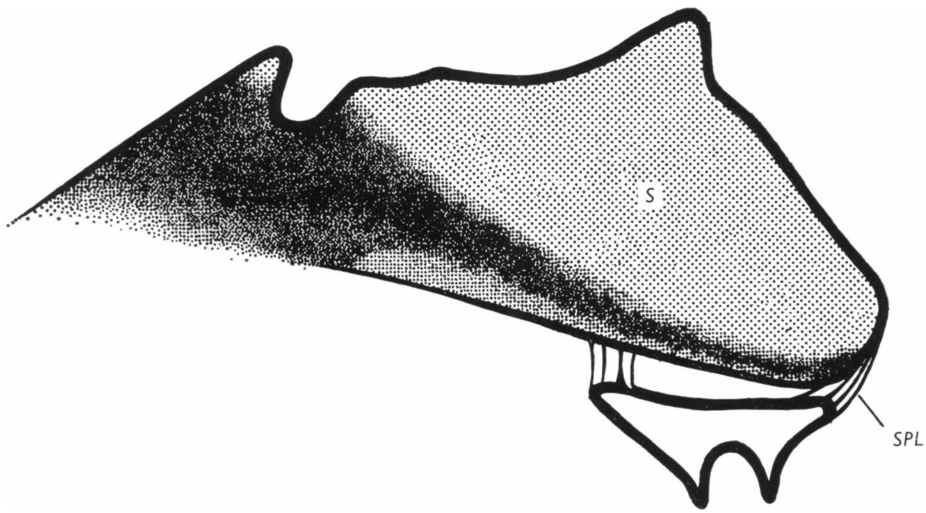


Fig. 8. Diagram illustrating the mode of attachment of upper jaw to nasal septum (*S*) by means of the septo-premaxillary ligament (*SPL*). Within the nasal septum a reinforcing stem of thicker cartilage is shown in heavy stipple. Forward septal growth would result in forward 'pull' upon bones of upper jaw.

This mode of interaction between the septal cartilage and the maxillae is in conformity with what we know about bone biology. Harrison (1958) has described this particular type of growth mechanism in the case of pelvic growth. Using the rat, he showed that the growth cartilage at the iliac crest was harnessed to the sacrum by the sacro-iliac ligament; iliac growth resulted in the sacrum being pulled up the smooth medial surface of the ilium. In this way the general proportions of the pelvis remained the same throughout the growing period.

Only evidence of an experimental nature can be used to prove the septal hypothesis. For the present purpose it is helpful to note that known human embryos with unilateral cleft of the primary palate show a deformity which conforms to expectation assuming its validity (Veau & Politzer, 1936; Latham, 1969). The nasal septum has a downward and forward direction of growth. In the event of a unilateral cleft the normal resistance to septal growth would be lacking on the cleft side. Because of the unilateral pull of the septo-premaxillary ligament from the normal side, the nasal septum would be expected to become bent, and the attached premaxillary region displaced towards the non-cleft side. The six-week embryos of Hochstetter and Hoepke-Maurer (21·3 mm and 22 mm crown–rump length), coronal sections of which have been illustrated by Veau & Politzer, show such a deformity.

The results of this study tend to support the septal concept. First, the maxillary and premaxillary ossifications, immediately following their appearance, are connected to their fellows across the midline and to the nasal septum by the septo-premaxillary ligament. This suggests an initial dependence of these membrane bones upon the nasal septum whereby proper skeletal relationships may be maintained at a time when the chondrocranium represents the dominant skeletal system. Secondly, and not generally appreciated, the nasal septum incorporates a stem-like thickened zone which is so aligned as to reinforce the septum antero-posteriorly and to assist in the application of its growth force via the septo-premaxillary ligament. The growth forces involved are probably relatively small in the embryo and foetus. Thirdly, the structure of the premaxillary bone appears to reflect the existence and influence of a tension at the site of insertion of the septo-premaxillary ligament. It may also be inferred that the formation of the anterior nasal spine is due to this insertion.

The role of the nasal septum in the general context of facial growth may be seen as a starter mechanism, initiating the downward and forward pattern of maxillary displacement until the maxillae have grown to their definitive boundaries, after which they acquire the capacity to carry on this pattern of movement downwards and forwards by their own intrinsic displacing growth on the free orbital and posterior surfaces (Latham, 1968).

CONCLUSIONS

1. The first distinct connexion relating the embryonic bones of the upper jaw to the nasal capsule was found to develop between the nasal septum and the anterior premaxillary region—the septo-premaxillary ligament.

2. The influence of septal growth upon the maxillae would be in the nature of a forward pull by means of the septo-premaxillary ligament.

3. Supporting evidence from the study of normal material of a septal role in maxillary development and growth may be seen in the following: (*a*), the early and simultaneous development of structures comprising the septo-premaxillary apparatus; (*b*), the structural reinforcement of the nasal septum; (*c*), the orientation of premaxillary bone towards the site of insertion of the septo-premaxillary ligament; and (*d*) the development of serrations in the cross-sectional form of the inter-premaxillary suture.

SUMMARY

An investigation of the apparatus underlying the septal mechanism of facial growth was carried out as a preliminary to the study of congenital facial malformations. The development of functional connexions between the cartilaginous nasal

capsule and the developing bones of the upper jaw was examined histologically in 24 human embryos and foetuses. The earliest distinct connexion consisted of an anterior septo-premaxillary ligament coursing from the anterior border of the nasal septum postero-inferiorly towards the anterior nasal spine and the interpremaxillary suture. By this means the growing nasal septum could exert a forward 'pull' upon the maxillae. Morphological observations supported the view that the nasal septum contributes to maxillary development and growth in this way, but it was seen as a mainly embryonic and foetal mechanism.

The writer gratefully acknowledges the help and interest of Dr W. R. Burston in this work and thanks Mr C. C. Knowles, Dr R. M. Rawcliffe and Dr R. E. Rewell for their co-operation in obtaining post-mortem material. Thanks are also due to Mrs Patricia Harris for histological work, Miss Hazel Carline for the drawings of Figs. 1 and 8 and Messrs S. Bailie and K. Walters for photomicrography.

REFERENCES

HARRISON, T. J. (1958). The growth of the pelvis in the rat—a mensural and morphological study. *J. Anat.* **92**, 236–260.

LATHAM, R. A. (1968). A new concept of the early maxillary growth mechanism. *Trans. Eur. orthod. Soc.*, 53–63.

LATHAM, R. A. (1969). The pathogenesis of the skeletal deformity associated with unilateral cleft lip and palate. *Cleft Palate J.* **6**, 404–414.

MOSS, M. L., BROMBERG, B. E., IN CHUL SONG & EISENMAN, G. (1968). The passive role of nasal septal cartilage in mid-facial growth. *Plast. reconstr. Surg.* **41**, 536–542.

SCOTT, J. H. (1953). The cartilage of the nasal septum. *Brit. dent. J.* **95**, 37–43.

STREETER, G. L. (1920). Weight, sitting height, head size, foot length and menstrual age of the human embryo. *Contr. Embryol., Carneg. Inst. Wash.* **11**, 143–170.

STREETER, G. L. (1951). Developmental horizons in human embryos. *Contr. Embryol.* **34**, 165–196.

VEAU, V. & POLITZER, G. (1936). Embryologie du bec-de-lievre, le palais primaire. *Ann. Anat. Path.*, **13**, 275–326.