The Growth of the Bony Palate of the Pig Consequent to Transpositioning the Oral and Nasal Mucoperiosteum

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Introduction

In several mammals, possibly in all, the bony palate grows in a characteristic manner. The bone descends by a process of resorption of its superior surface and apposition on its inferior surface thus increasing the size of the nasal cavity. This process takes place in the cleft as well as the normal animal, and is shown diagrammatically in Figure 1.

In an experiment on the surgical closure of a cleft palate in a 7 week old dog by Atherton, White and Maisels (*1*) a small portion of oral mucoperiosteum was inadvertently transposed to the nasal surface of the palate. In this area the palatal bone apparently failed to descend at the same pace as the rest of the palate, so that at the end of the experiment which lasted 5 weeks the bony palate was markedly thicker beneath the transposed oral epithelium. This effect raised the question as to whether the replacement of nasal mucoperiosteum by oral mucoperiosteum had initiated a change in the normal pattern of bone growth. It seemed possible that it was the mucoperiosteum which had determined the pattern of bone growth rather than the bone itself. It was therefore decided to devise an experiment in a normal growing animal whereby a portion of the oral mucoperiosteum would be transposed to the nasal surface and nasal mucoperiosteum to the oral surface. The pig was selected because its size made such an operation possible.

The history of periosteal transplantation has been well reviewed by Ritsila, Alhopuro and Rintala (*8*) who themselves transplanted periosteal tissue experimentally in rabbits (*8*) and in the primary treatment of cleft alveolus and palate (*9*). Previous work has however been more concerned with the induction of bone rather than the details of bone apposition and resorption which is the concern of this paper.

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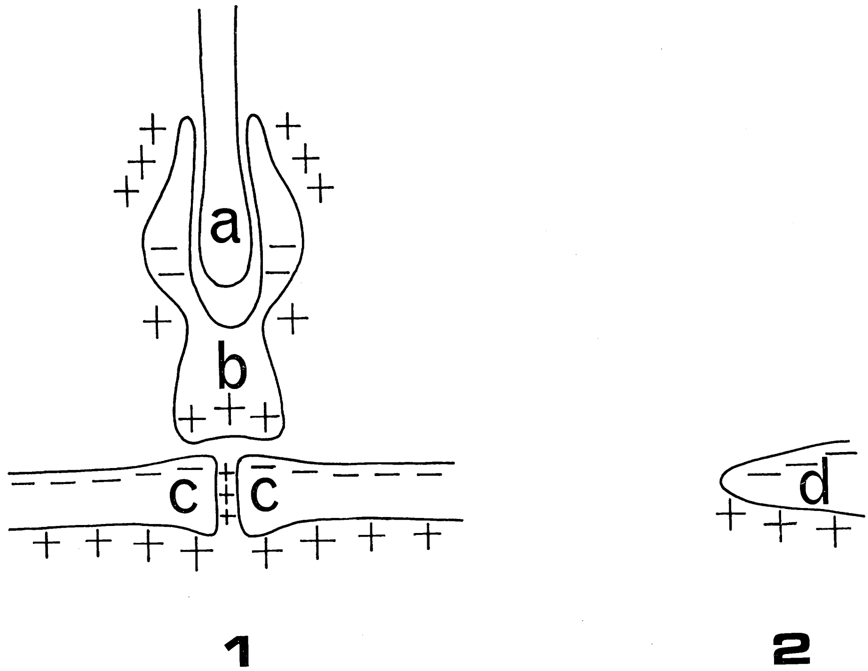

FIGURE 1. On the left, 1, is a diagrammatic representation of a coronal section of the mammalian palate. The vomer 'b' is shown with the nasal septum 'a', above, while below, are the two palatal processes of the maxilla 'c'. The surfaces undergoing resorption of bone are shown with 'minus' signs and those where bone is being laid down with 'plus' signs. On the right, 2, is a diagrammatic representation to show a palatal process of the maxilla 'd' in the case of a palatal cleft. There is a pattern of bone resorption and apposition similar to that found in the normal animal, although the process has failed to unite.

Material and Method

A young rapidly growing 50 lb pig was used and the following operation carried out.

Operation. The operation is best understood if Figure 2 is followed. Stage 1: An oral mucoperiosteal flap was folded back on both sides of the palate shaped as in the Figure 2.1. As in man, the flap was easily raised from the palate leaving a clean bone surface. Stage 2 (Figure 2.2): The full thickness of bone was removed from the area of the palate marked 'A' and discarded. The exposed nasal epithelium was folded as an anteriorly based flap onto bone surface 'a'. The circle of bone marked with a 'star' was removed, inverted, and placed in situ. The flap of mucous membrane marked 'B' was folded onto 'b'. Stage 3 (Figure 2.3): The palate now has nasal epithelium marked 'A' and the circle of bone is back in place. Stage 4 (Figure 2.4): The oral mucous membrane is folded back leaving a small area of the oral aspect of the palate covered with nasal epithelium. The result of the operative procedure was that three experimental areas were produced as follows: 1) An area with oral mucoperiosteum on both sides (with no bone between). 2) An area with nasal mucoperiosteum on both sides and 3) An area where the mucoperiosteal rela-

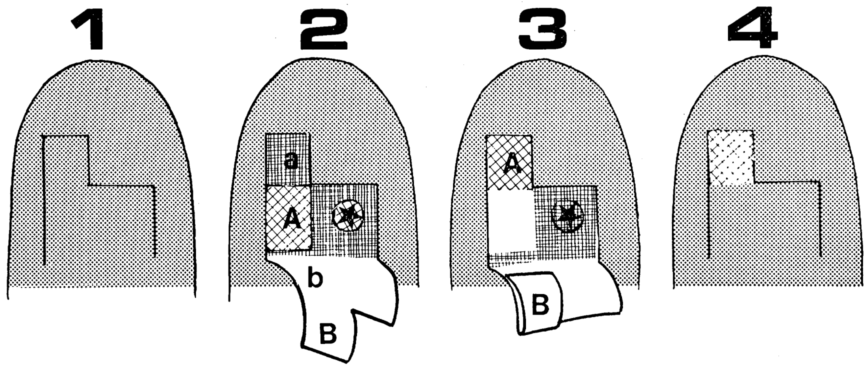

FIGURE 2. A diagrammatic representation of the palate showing the stages during the operation. (1.) Outline of the flap raised from the oral mucoperiosteum. (2.) The oral mucoperiosteum flap has been turned back, and a rectangular segment of bone has been removed, exposing the underlying nasal mucoperiosteum, which is marked 'a'. In addition a circle of bone 'b' has been cut, freed from the underlying nasal mucoperiosteum, and inverted. (3.) The nasal mucoperiosteum 'a' has been freed on 3 sides leaving an anteriorly based flap which has been folded forwards, so that the surfaces of the nasal mucoperiosteum is now within the oral cavity. The front part of the oral mucoperiosteum is folded on itself, so that when the flap is replaced, the area from which the rectangle of bone was removed will now have oral mucoperiosteum on both the oral and nasal surfaces. (4.) The appearance following closure of the flaps.

tionships were normal but a small area of the palatal bone between the oral and nasal mucoperiosteum had been inverted.

The experiment was terminated after 7 weeks. The block of tissue incorporating the experimental areas of the palate was cut out and fixed in buffered formol saline and is seen in Figure 3a and b. The block was further subdivided for sectioning. The individual blocks were embedded in wax using a modified Brain's technique (4). Sections were cut at 10μ, and stained with Ehrlich's haemotoxylin and eosin, Masson's and Van Gieson.

Results

Three experimental areas were produced and the results are summarized in Table 1, which indicates the effect on bone growth of the surgical experiment.

In experiment area 1 the oral mucoperiosteum was folded on itself into the nasal cavity. Thus there was oral stratified squamous epithelium in the normal position for this epithelium on the oral or inferior surface and also on the nasal or superior surface. Examination of the prepared histological slides showed no morphological change in the appearance of the epithelium transferred to the nasal surface. Similarly the greater palatine artery was folded over along with the mucoperiosteum and remained patent. Some regeneration of bone had taken place between the superior and inferior layers of the oral mucoperiosteum. In this area the direction of bone growth appeared to be reversed with apposition taking place on the su-

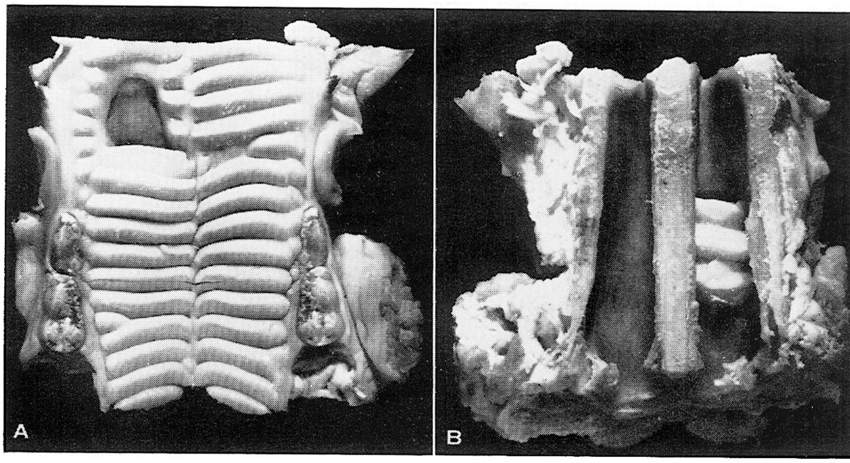

FIGURE 3. (a) The appearance of the oral surface of the palate showing the oral mucoperiosteum at the end of the experiment. The area covered by transposed nasal mucoperiosteum can be seen in the upper left hand area where there are no rugae. (b) The rugae of the transposed oral epithelium can be clearly seen on the nasal floor (nasal surface of the palate) in this photograph of the floor of the nose at the end of the experiment.

perior surface of the palate and resorption taking place over a great part of the inferior surface. The situation is shown diagrammatically in Figure 4a. Figure 4b shows the nasal (or superior) surface of the palate bone and its covering of periosteum; the picture is one of bone apposition with numerous osteoblasts and newly formed trabeculae parallel to the surface. Figure 4c shows the oral (or inferior) surface and its periosteum with Howship's lacunae and multinucleated giant cells on the surface indicative of resorption.

In experimental area 2 the nasal mucoperiosteum was folded onto the

TABLE 1. Summary of the effect on palatal bone growth as a result of the experiment.

procedure	*result*
1. Transferral of oral mucoperiosteum to nasal cavity.	Some bone was laid down between the two layers of oral mucoperiosteum and this bone showed evidence of apposition on the nasal surface and resorption on the oral surface.
2. Transferral of nasal mucoperiosteum to oral cavity.	Ciliated columnar epithelium changed to a pseudostratified squamous type. Bone beneath this showed evidence of resorption.
3. Inversion of bony palate between oral and nasal mucoperiosteum.	Little change in character of bone growth.

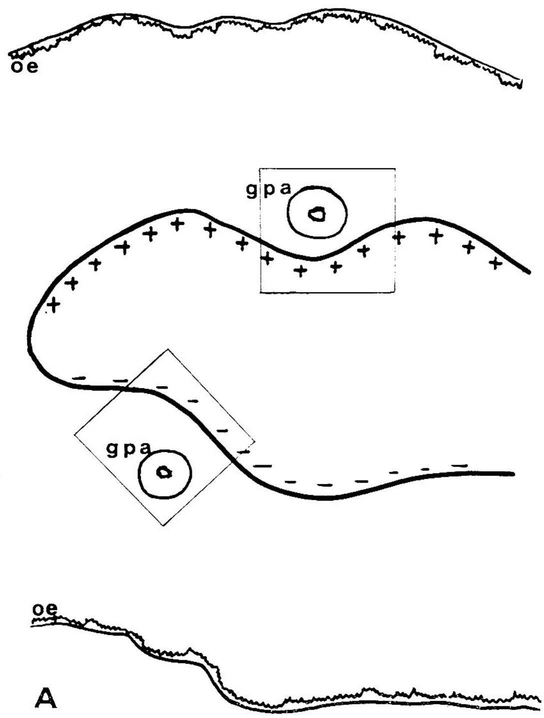

FIGURE 4a. A diagrammatic view of the area where oral mucoperiosteum was transposed to the nasal surface giving a double layer of oral epithelium (OE) and two greater palatine arteries (g.p.a.). The pattern of resorption of apposition is indicated by minus and plus signs and the areas for larger magnification in figures 4b and c are outlined.

FIGURE 4b. Close up of the greater palatine artery on the nasal surface and the adjacent bone surface. This surface shows typical newly formed bone trabeculae indicative of bone apposition. (Haemotoxylin and Eosin × 150).

FIGURE 4c. Close up of the greater palatine artery on the oral surface and the adjacent bone surface. This surface shows Howship's lacunae and multinucleated giant cells indicative of resorption. (Haemotoxylin and Eosin × 150).

oral surface of the palatal bone. The histological appearance is seen in Figure 5a. The nasal epithelium underwent a morphological change to a pseudostratified squamous epithelium following its transfer to the oral environment. The glandular character of the subepithelial tissues remained unchanged by the transferral. The bone on the oral surface of the palate underwent an abrupt change in morphology where the normal oral mucoperiosteum was adjacent to the transposed nasal mucoperiosteum (Figures 5b & c). Beneath the oral mucoperiosteum the bone was appositional in character whilst beneath the nasal mucoperiosteum it was resorptive.

In the third experimental area where the bone had been inverted, the pattern of bone growth had changed so little in character that it was difficult to differentiate from the surrounding bone. It would seem that what had happened was that the area of bone which was inverted was resorbed by the normal process of palatal descent leaving little residual effect on the bone.

Discussion

The palate of the pig has a pattern of growth similar to that seen in other mammals including man. The photomicrograph of a normal palate (See Figure 6) shows the inferior or oral surface of the palate with an osteogenic periosteum which has laid down trabeculae parallel to the sur-

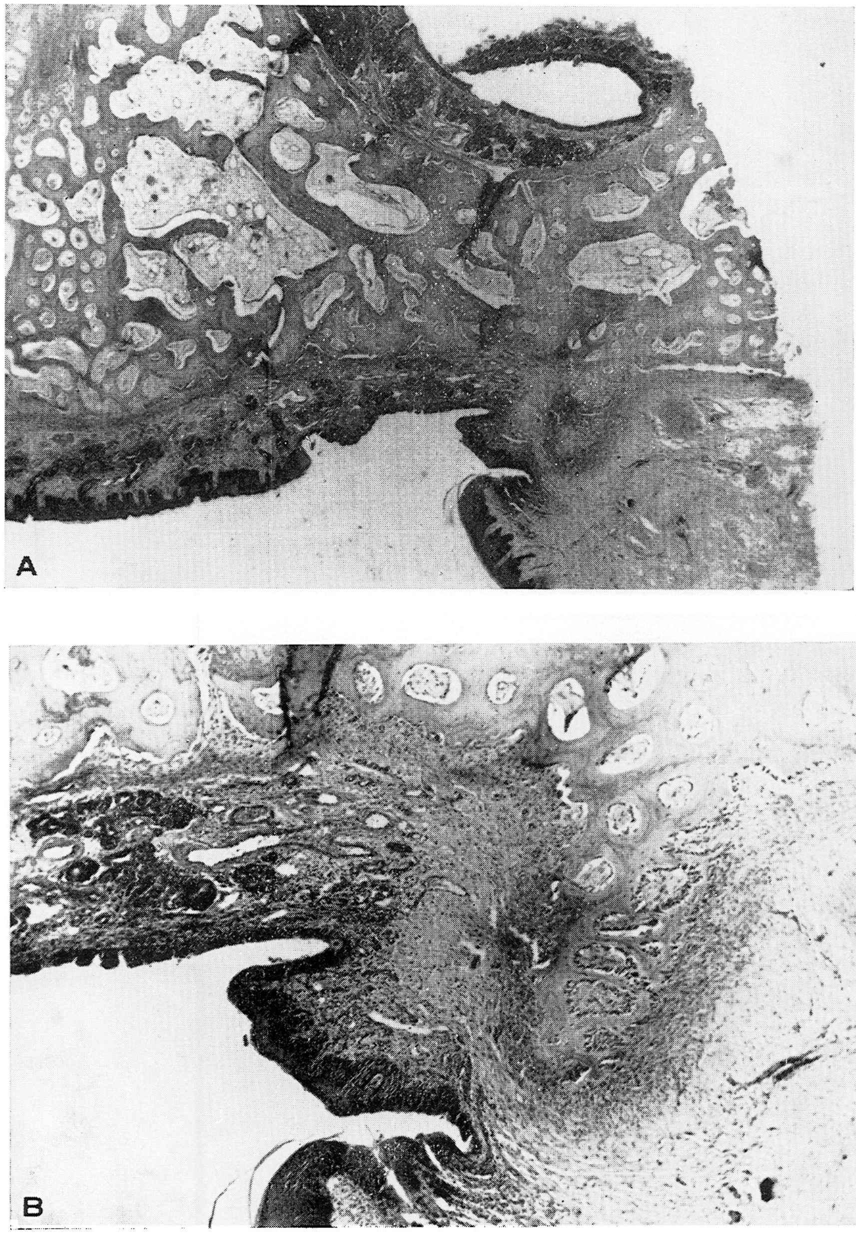

FIGURE 5. Photomicrographs of the experimental area 2. a) There is nasal ciliated columnar epithelium on the superior surface as well as in the area in the centre of the inferior surface (× 40). This inferior part is shown at larger magnification in b. b) Here there is an abrupt change in the character of the bone modeling from apposition beneath the oral epithelium to resorption beneath the nasal epithelium. (Haemotoxylin and Eosin × 150).

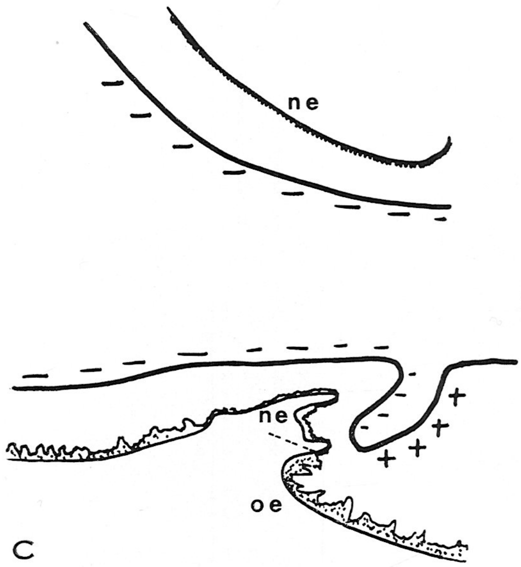

FIGURE 5c. A diagrammatic representation of the pattern of apposition and resorption; compare this with Figure 5a.

face of the periosteum. Gradually as growth carries these trabeculae towards the nasal surface their morphology becomes modified into a more solid structure until finally the bone is resorbed beneath the nasal periosteum on the upper surface. This picture of apposition inferiorly and resorption superiorly is fairly consistent throughout the length of the palate in the growing animal.

It is not clearly understood what determines the direction that bone modelling takes in a particular area. On the one hand there are several theories relating to the overall growth of membrane bone such as those of Scott (*10*) and Moss (*6*), but these do not account for details of surface modification. On the other hand a mass of information exists on the physiology and biochemistry of bone which describes and accounts well for the actual changes taking place on the bone surface but not for the factors determining the direction of these changes in the growing bone.

Something is now understood following the work of Bassett (*2*) and his colleagues of the mechanism whereby the bone pattern might become changed in response to mechanial stress and Baumrind (*3*) has suggested that a similar mechanism might be responsible for tooth movement.

It does seem, however, from these experiments, that the overlying mucoperiosteum must also be a factor. In both experiment 1 and experiment 2 there is a difference between the growth pattern of the experimental area and the normal. In experiment 1 (Figure 4), the growth pattern is completely reversed with apposition on the nasal (superior) surface of the bone where there is normally resorption and resorption on the oral (inferior) surface where there is normally apposition. In experiment 2 (Figure 5c), there

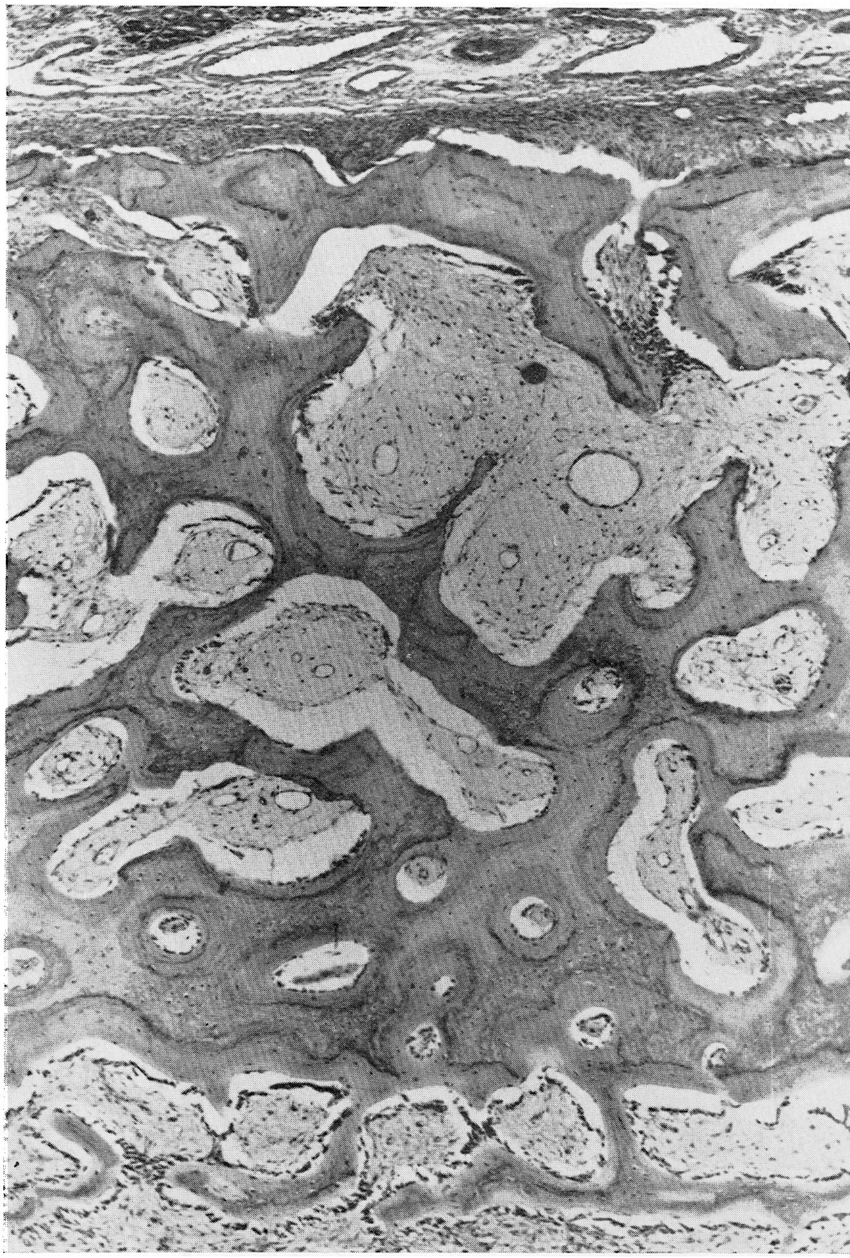

FIGURE 6. Photomicrograph of the normal growing palate of a growing pig showing the nasal surface of the bone (above) undergoing resorption and oral surface (below) undergoing apposition. (Haemotoxylin and Eosin × 70).

is an abrupt change in the morphology of the bone from a surface appositional in character beneath the oral mucoperiosteum to one of resorption beneath the nasal mucoperiosteum. Some resorption is occasionally found in this area but in this instance the change is abrupt and appears closely linked to the position of the nasal epithelium. There is one inconsistency in these experiments which is difficult to account for and that is the resorption which extends along the oral surface in experiment 1. This is an area which is normally appositional in character and it would seem logical that this should persist; however the histological picture is one of resorption. Other considerations may play a part. The interference with the normal blood supply may be one. Brookes (*5*) has shown in the long bone that the blood supply passes from the medulla to the cortex and Owen (*7*) has pointed out that this is in fact from a resorptive surface to an osteogenic surface. A possible explanation therefore in this case is that the pattern of bone growth was reversed because its blood supply came from the reverse direction. The precise directions of blood flow in relation to the growing bony palate have yet to be explored and it is our intention to investigate this. The influence of surgery itself cannot be discounted and may account for some of the changes observed. Clearly more experimental work is needed in this field.

Summary

The normal bony palate (palatal process of the maxilla) of growing primates descends by a process of resorption of the superior surface and apposition on the inferior surface. In ungulates there is a similar pattern of palatal growth. A surgical operation was carried out on a growing young pig to examine the role in palatal growth of the mucoperiosteum of the oral and nasal surfaces. From the results it appears that the mucoperiosteum plays some part in influencing the growth pattern of the palatal process of the maxilla.

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