Expansion Of The Midpalatal Suture In The Monkey

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Until recent years it was accepted that orthodontic expansion of the maxillary arch usually involved the movement of teeth and changes in the surrounding alveolar bone. Little or no reaction was thought to occur in the supporting bony structures. While observable changes in the bony structures following orthodontic tooth movement are usually confined to the alveolar bone, it has been suggested that certain types of orthodontic treatment may, in some cases, actually affect the surrounding bony structures. In some cases of malocclusion where a bilateral posterior dental crossbite associated with a narrow maxillary dental arch exists, a clinical procedure employing a rapid and strong expansion of the midpalatal suture is sometimes attempted. This expansion is usually achieved by the simultaneous application of strong orthodontic forces to the teeth, alveolar process, and the adjacent vertical region of the hard palate. It is surmised that rapid expansion of the maxilla, employing forces of large magnitude, causes an opening of the midpalatal suture and brings about gross and observable changes in the maxillofacial skeleton. It is contended that any mechanically-induced increase in the width of the palate, especially if coincident with a separation of the midpalatal suture, should also result in a widening of the nasal cavity.

There is some evidence to suggest that this hypothetical consideration may be true. It has been claimed that rapid expansion of the maxilla will split the midpalatal suture, thus widening the arch and increasing the width of the nasal cavity. A review of the literature shows that investigations on rapid expansion of the maxilla have been carried out on a clinical level as well as in animals. Korkhaus,[5] Derichsweiler,[2] and Haas[4] report that rapid expansion is possible, and that widening of the nasal cavity as well as a widening of the dental arches takes place. Krebs[6] and Thorne[7] report similar changes and also discuss the possibility of relapse. Debbane,[1] using cats, and Haas,[3] using pigs, described the direction of opening of the midpalatal suture and the changes taking place in the suture and the surrounding structures. If this procedure does result in a permanent widening of the arch by opening the midpalatal suture of the maxillary jaw, and is followed by new bone deposition, then it is, in effect, directly influencing the supporting bony structures. The important questions are whether the suture is actually opened and, if so, whether the resulting bony defect fills in with new bone, and whether depositions will remain stable? While information regarding the usefulness of the

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technique can be gained from clinical evidence, it is also important to determine the underlying tissue reactions. The tissue response to strong expansion must be examined in the regions of the midpalatal suture in the alveolar processes and within adjacent sutures and structures of the face.

Method

This report deals largely with tissue changes taking place in the region of the midpalatal suture. Since human material could not be studied, the rhesus monkey was considered the experimental animal of choice. One disadvantage in using monkeys is that these animals, dentally, have a normal buccal segment relationship and, therefore, the expansion of the maxillary arch tends to move the teeth into an abnormal buccal crossbite arrangement. Another disadvantage is that while the rhesus monkey provides a close approximation to human morphology, differences do exist. For example, the monkey has a distinct and separate premaxilla which articulates with the maxillary bones. There is no continuous midline suture running through the premaxilla. The midpalatal suture joins the two premaxillary-maxillary sutures immediately posterior to the premaxilla, the configuration of the suture outline forming a Y. However, despite these apparent differences it was felt that the monkey afforded the best animal material from which findings could be interpreted and applied to the human being.

From a total of twelve female Macacus rhesus monkeys, ranging in age from thirty to forty months, comparable to a seven to nine-year old human, it was finally possible to stabilize and maintain six monkeys. Prior to experimentation the following procedures were completed on each animal under nembutal anesthesia. Study models of the maxillary and mandibular arches were made to assess the degree of orthodontic expansion of the maxillary dental arch. Frontal cephalometric headplates were taken to measure the effect of orthodontic expansion on surrounding bony structures and the alveolar arch, as well as any possible angular changes in the inclination of the palatal shelves. Lateral cephalometrics were also completed. Identical records were repeated coincident with the sacrifice of each animal. Cephalometric radiographs were made using a standard Broadbent-Bolton cephalometer with ear rods modified to fit into the external auditory canals of the monkeys. The animals were supported in an open-mesh rope sling.

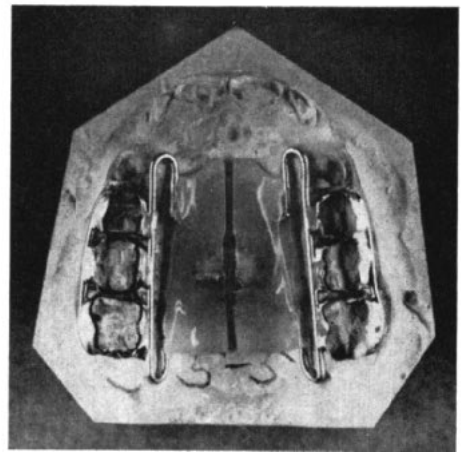


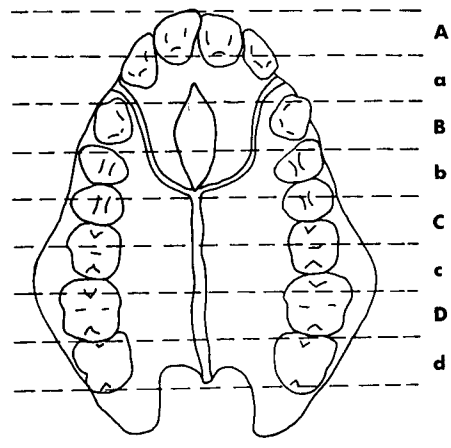
Fig. 1 An example of the split palate with expansion screw used in this study.

Four monkeys had expansion appliances placed in the maxilla, while the remaining two animals were used as controls. The expansion appliances were fabricated indirectly on duplicated stone casts (Fig. 1). Preformed bands were adapted to the first permanent molars and the first and second deciduous molars. These bands were soldered to a palatal wire to provide rigidity and to facilitate their attachment within the acrylic palate. An expansion screw was embedded in the midline of the acrylic

palate at the level of the second deciduous molar. Slice preparations were completed on the monkey's buccal teeth and the appliance was cemented into place. A short interval was permitted to elapse before activation to allow the animals to become accustomed to the appliances and to insure their stability in the mouth.

The first experimental animal was sacrificed two weeks after the initial appliance activation during which time 4 millimeters of expansion were achieved. In the remaining three experimental animals the appliances were activated 2 millimeters at four-week intervals for a period of twelve weeks, resulting in a total of 6 millimeters of expansion. After this three-month period, another experimental animal and one of the control monkeys were sacrificed. The third experimental animal was sacrificed after the appliance had been permitted to remain in place as a retainer for an additional three-month period. At this time the appliance was removed from the fourth experimental monkey and an additional three months was permitted to elapse. After this time, the fourth experiment animal and the final control animal were sacrificed. Thus, the fourth experimental monkey was subjected to three months of expansion, followed by three months with the appliance in place as a retainer, and finally, three months with no appliance subsequent to its removal.

The sacrificing procedure consisted of infusion and decapitation under nembutal anesthesia, following which the tissues were fixed and stored in ten percent neutral formalin. The maxillary complex was then removed and radiographed in an occlusal direction using a standardized procedure. These radiographs were obtained in order to grossly evaluate the palatal bony configuration. The maxilla was then cut transversely along its length into blocks 2.5



UNDECALCIFIED ... A, B, C, and D.

DECALCIFIED ... a, b, c, and d.

Fig. 2 Diagram showing the orientation of the tissue blocks cut from the palatal region of each monkey. Note the position of the midpalatal suture, the premaxillary sutures, and the incisive foramen.

millimeters wide as shown in Figure 2. This tissue was used for microscopic evaluation. Alternate blocks (A, B, C, and D) were embedded in Bioplastic and undecalcified sections cut at 100 micra in thickness. By taking standardized soft x-ray radiographs* of these sections it was possible to study the relative degree of mineralization of the midpalatal region and to compare one animal with another. The blocks (a, b, c, and d) were decalcified in fifteen percent formic acid, embedded in paraffin, sectioned at 10 micra in thickness, and stained with haematoxylin and eosin. These sections were used to assess the histologic reactions having occurred during the experimental period. While the use of alternate undecalcified and de-

* Soft x-ray radiographs were made on spectroscopic plates (Kodak 649-0, Eastman Kodak Company, Rochester, N.Y.) using a soft x-ray machine (Picker X-ray Corporation, White Plains, N.Y.) with a copper Machlett tube.

calcified blocks did not allow true serial histologic sections to be cut continuously along the complete length of the palate, the sizes of the individual maxillary specimens were similar for each animal and thus comparable anatomic regions were included in each series of blocks. Most decalcified blocks yielded 80-100 serial sections per block and the undecalcified blocks gave approximately twenty usable sections per block for soft x-ray analysis.

Results

A. Analysis of the monkeys used as controls

The records from the two control animals were used as a frame of reference with which to compare the gross morphology and histology of the four experimental animals. The posteroanterior cephalometric analysis of the control monkeys showed no measurable changes to have taken place in the palatal region during the experimental periods. Also, no changes were observed in the axial inclinations of the buccal teeth. The occlusal radiographs showed the premaxillary and midpalatal sutures to be well-defined and narrow (Fig. 3). Due to the normal palatal inclination of the crowns of the buccal teeth, their roots appeared to be lateral to the crowns.

Both the control animals showed similar sutural and bony morphology when examined histologically. The cellular activity was also comparable in both monkeys. Block a (Figure 2), showed the incisor roots with well-formed lamellar bone separating them. The anterior end of the incisive foramen and the premaxillary sutures were noted in the most posterior sections of Block a. Block b (Figure 2) included the posterior part of the incisive foramen, the premaxillary sutures (cut obliquely) and the midpalatal suture.

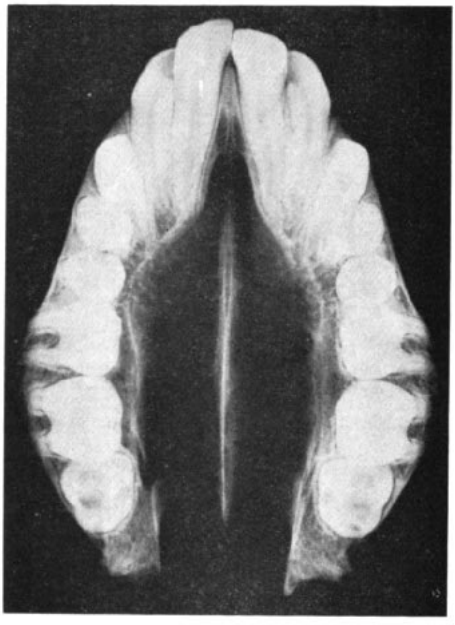


Fig. 3 Occlusal radiograph of palatal region showing normal sutural morphology.

The histologic examination showed a normally growing midpalatal suture in which sutural bony processes were found to interdigitate and were separated by a thin, well-organized band of fibrous connective tissue (Figure 4). The sutural bony processes, while being composed of mature lamellar bone, showed new bone formation on their free surfaces indicating that bony growth was taking place within the suture. The cellular reaction in the adjacent sutural connective tissue was mainly osteoblastic, but slight osteoclastic activity was also apparent. The premaxillary sutures also showed the histological appearance representative of normally growing sutures. The premaxillary-maxillary sutures were slightly narrower than the midpalatal suture and were slightly less complex in their morphological configuration. The morphological appearance of the midpalatal suture in the sections from Block c and Block d (Figure 2) differed only slight-

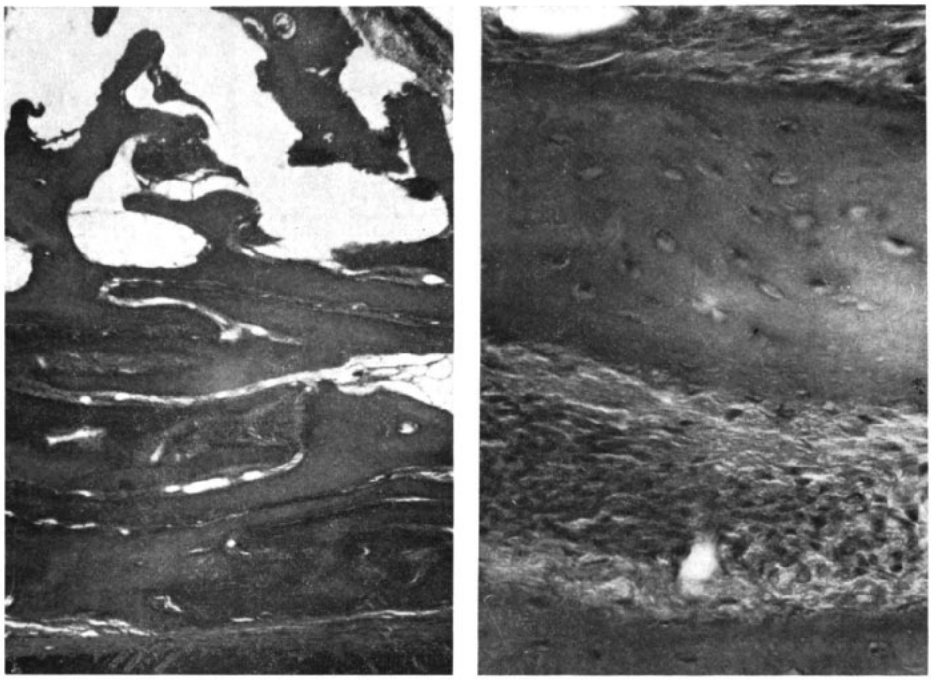


Fig. 4 Photomicrograph (x 40) of midpalatal region showing normally growing suture (left). High-power (x 400) photomicrograph showing bony process and sutural fibrous connective tissue (right).

ly from that discovered in Block b; the cellular reaction was similar and showed the histological appearance of a normally growing suture.

The soft x-ray radiographs proved to be a useful adjunct to the histological examination. As the decalcified and undecalcified blocks were cut alternately along the palate, comparison between the histological preparations and the soft x-ray radiographs could be made. The histological analysis gave only the morphology and cellular activity, whereas the analysis of the soft x-ray records made it possible to assess the relative degree of mineralization in various parts of the sutural region. The control animals showed the midpalatal suture as a well-demarcated radiolucent line bordered by well-mineralized sutural bony processes (Figure 5).

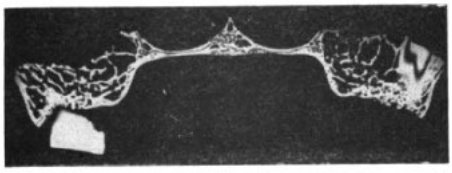


Fig. 5 Soft x-ray radiograph of an undecalcified section through the midpalatal suture.

B. Analysis of the monkeys subjected to: (1) two weeks of expansion, (2) three months of expansion

The first experimental animal (sacrificed after two weeks of expansion) showed that the expansion procedure did cause a disruption of the midpalatal suture, and that this occurred very soon after the application of pressure. From the cephalometric and occlusal film analysis this animal demonstrated a wide, flattened palate, concomitant with a midline bony defect (Figure 6). The buccal teeth were also noted to be

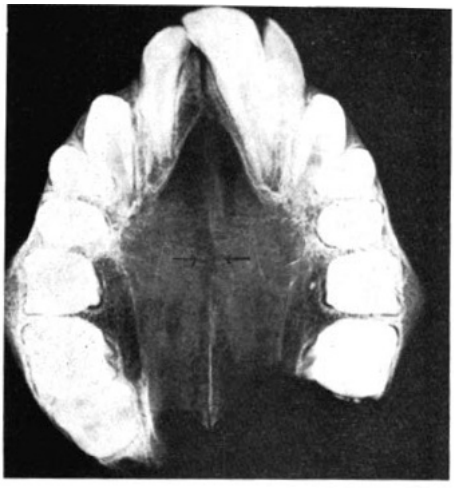


Fig. 6 Occlusal radiograph of palate. Note midline radiolucency. Also observe the absence of one central incisor in this animal.

tipped in a buccal direction. Examination of the histological sections showed the midpalatal suture to be dislocated leaving a bony defect filled with disorganized fibrous connective tissue and irregularly-positioned spicules of bone (Figure 7). The fibrous connective tissue was well-vascularized and showed a mild chronic inflammatory response. While evidence of tissue damage to the suture was obvious, the cellular reaction noted after two weeks of expansion was both reparatory as well as osteoclastic. The degree of cellular activity within

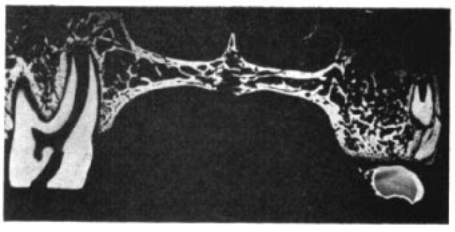


Fig .8 Soft x-ray radiograph showing marked midline radiolucency.

the premaxillary-maxillary sutures was abnormally high. The soft x-ray examination of the undecalcified sections showed a hypomineralized defect to be present in the region of the midpalatal suture (Figure 8).

Cephalometric examination of the changes taking place in the second experimental animal (sacrificed after three months of expansion) showed a widening of the maxillary arch. The buccal teeth appeared to be tipped buccally and the palatal contour was flattened. Probably due to the small changes involved or to the lack of definition of the lateral nasal walls, no increase in width of the nasal cavity was observed. The changes noted from the headplates were confirmed in the occlusal radiographs (Figure 9) in which the midpalatal area appeared to be open with roots of the buccal teeth palatal to the crowns. The premaxillary sutures were also found to be wide.

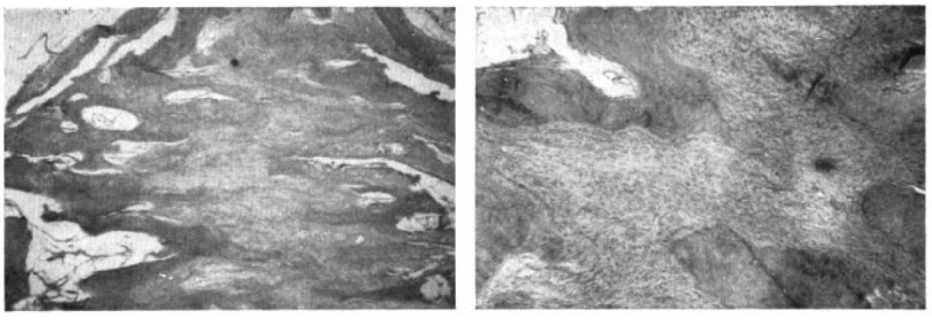


Fig. 7 Low-power (x 80) photomicrograph showing midline bony defect (left). Photomicrograph, medium-power (x 150). Note mass of cellular fibrous connective tissue between the separated bony sutural processes (right).

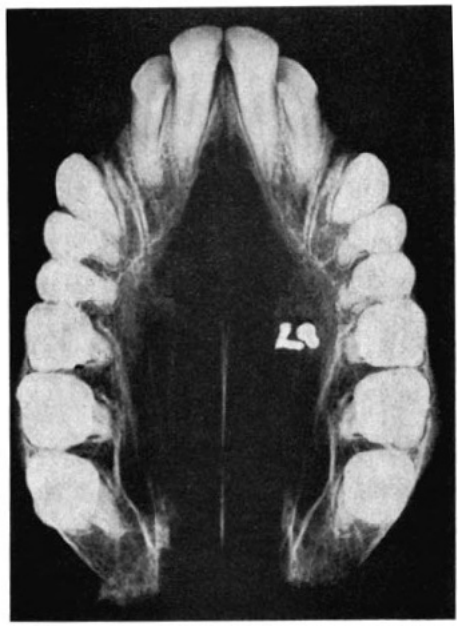


Fig. 9 Occlusal radiograph showing extensive midline radiolucent area.

The serial sections obtained from the decalcified blocks were examined for tissue response to the expansion procedure. The study of the most anterior block (Block a) revealed that, although no midline suture was present, there was a reaction to the rapid expansion of the maxilla in the interincisal bone. The growth of bone on the nasal and oral surfaces was found to be greater than normal. Examination of sections taken from the more posterior blocks showed the midpalatal suture region to be completely disorganized (Figure 10). A large bony defect filled by fibrous connective tissue containing numerous fibroblasts was present. The soft x-ray radiographs of the undecalcified sections from this animal also showed evidence of this large bony defect (Figure 11); there was a large radiolucent area in the midline with mineralized spicules

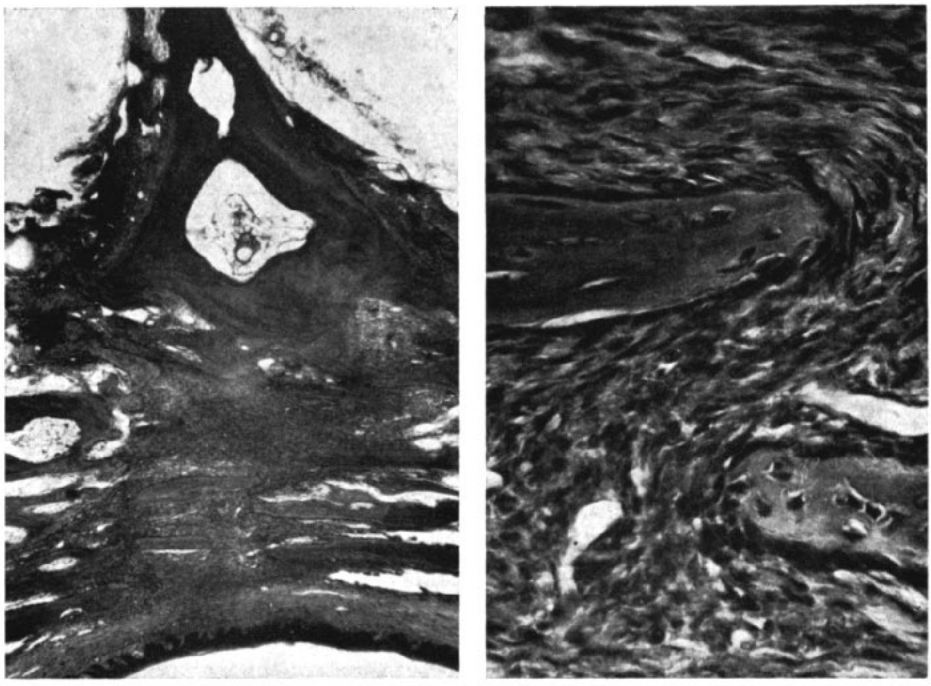


Fig. 10 Photomicrograph (x 40) showing disrupted sutural region (left). High-power (x 400) showing marked osteoblastic cellular reaction in region of bony sutural processes (right).

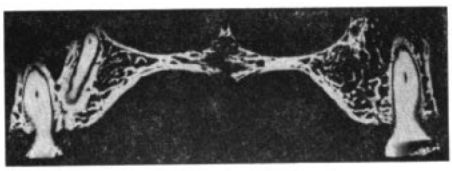


Fig. 11 Soft x-ray radiographs showing gross lack of mineralization in midline of palate.

projecting into the defect. Histologically, the area was vascular and showed a slight inflammatory response (much less than observed in the first experimental animal). No interdigitating bony sutural processes were present and only small spicules of cellular bone existed within the sutural region. The bone at the margins of the defect was irregular and very cellular indicating that rapid bone formation had been taking place. The connective tissue fibers in the bony defect tended to run across the region and, in general, osteoblastic activity was found to predominate suggesting that, after three months of expansion, there had been an attempt to fill in the defect. The intact bone surrounding the area was found to be lamellar bone and the arrangement of reversal lines suggested that bone resorption had taken place to a greater extent at some stage than was apparent at the time of sacrifice. Presumably following this gross resorption, bone had been rapidly and progressively laid down into the midline defect. The premaxillary-maxillary sutures were found to react to the rapid expansion of the maxilla. While these sutures were narrow and showed little cellular activity in the control animals, they showed considerable osteoblastic and osteoclastic response in the second experimental animal.

C. Analysis of the monkey subjected to three months of expansion followed by three months of retention

An assessment of the cephalometric radiographs taken of the third experimental animal (sacrificed after three months of expansion followed by three months retention), showed a widened and flattened vault of the palate. This corresponded to what was observed in the other two expanded animals. Lateral tipping of the buccal teeth was apparent but to a lesser degree than was observed in the second experimental animal. The occlusal film showed the teeth to have an almost normal inclination. From this record the midpalatal suture showed little evidence of prior damage (Figure 12).

Fig. 12 Occlusal radiograph showing improvement of midline region.

Photomicrographs of Block b taken from the animal that had been expanded and retained are shown in Figure 13. The midpalatal suture appeared similar in morphology to the control animals. However, the adjacent bone and bony trabeculae were very cellular. This bone was irregular in nature and did not follow the usual lamellar pattern as was seen some distance from the sutural area. While osteoblastic activity predominated in the midpalatal suture, this block showed some osteoclastic activity that appeared greater than in the second experimental animal and sug-

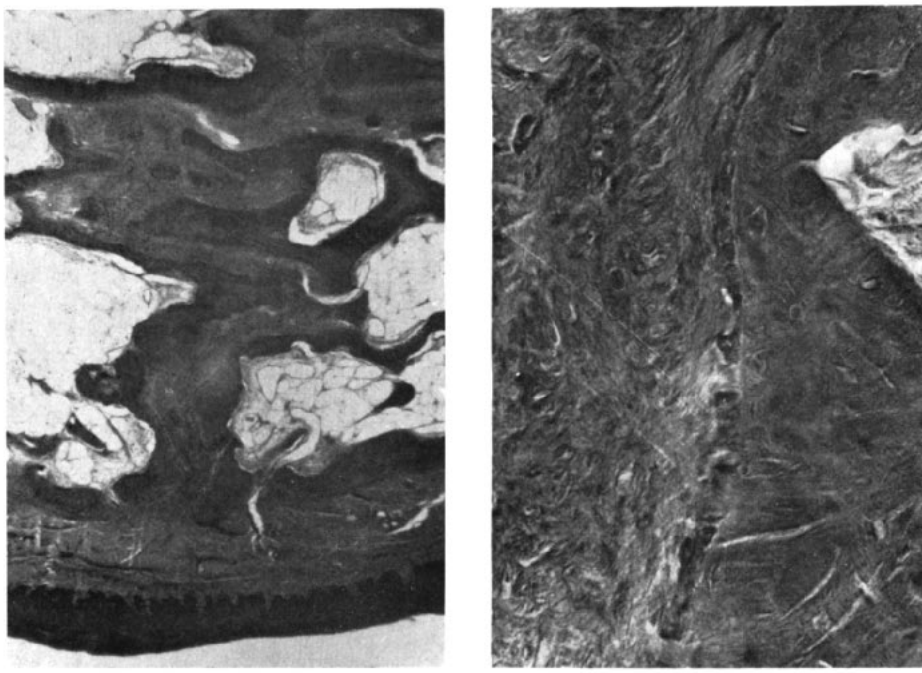


Fig. 13 Photomicrograph (x 40) showing repairing sutural region (left). Photomicrograph (x 400) showing marked osteoblastic activity at margin of bony sutural process (right).

gested that considerable remodelling of the newly repaired suture was taking place. In this "expansion and then retention" animal some reaction was still found to be taking place in the premaxillary sutures, but was far less than observed in the second experimental animal. Following the three-month retention period the third experimental animal showed the sutural region to be more highly mineralized than was observed in the previous animal (Figure 14). The sutural morphology, as assessed from the soft x-ray radiographs, was still disorganized and the area poorly mineralized when compared with the control animals. This finding was not at variance with the histological findings, however, for although the suture as seen from the decalcified specimens was similar in appearance to that seen in the controls, the bone in the area was loosely arranged cellular bone, and was presumably not well mineralized.

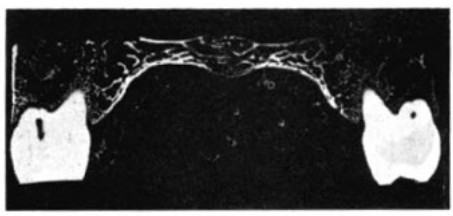


Fig. 14 Soft x-ray radiograph demonstrating improved mineralization in sutural region after retention.

D. Analysis of the monkey that was subjected to expansion, retention, and then a post-retention period

The cephalometric record of the fourth experimental animal revealed that the flattening and widening of the palate that had taken place during the experimental period had persisted. No changes in the axial inclination of the buccal teeth were noted; this was con-

firmed from the occlusal films (Figure 15) which also showed the sutural regions to be normal. This final animal in the series, the animal sacrificed three months after the removal of the retentive appliance which followed three months of expansion and three months of retention, showed the midpalatal suture to be well organized and essentially histologically normal (Figure 16). The interdigitating bony processes, however, appeared to be cellular and to have been more rapidly formed than similar areas in the control animals. The region was much more consolidated than was seen in the previous experimental animals. It would appear that the defect had continued to be repaired and organized following the removal of the retention appliance and that there was no evidence of a breakdown of the repaired suture. The premaxillary-max-

Fig. 15 Occlusal radiograph showing restoration of normal palatal morphology.

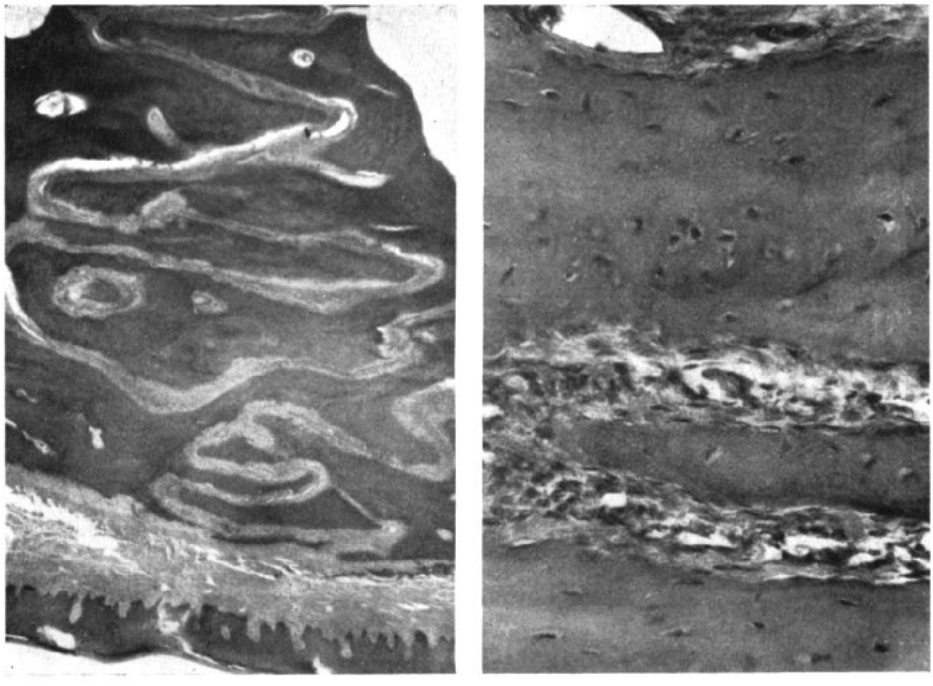


Fig. 16 Photomicrograph (x 40) showing essentially normal sutural morphology (left). High-power (x 400) photomicrograph reveals that the histology of the sutural region resembles that of the control animal (right).

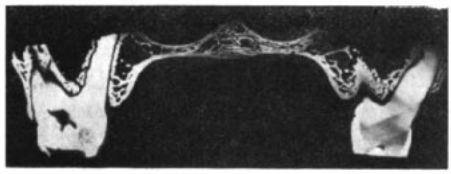


Fig. 17 Soft x-ray radiograph showing a midline region resembling that observed in the control animal.

illary sutures in this postretention animal also showed the sutures to be indistinguishable from those in the control animals.

The fourth experimental animal showed the degree of mineralization of the midpalatal suture region to be similar to that in the control animals (Figure 17). This finding substantiates the observations made on the decalcified sections in that the sutural area, after a postretention period, was found to closely approximate the normally growing suture as seen in the control monkeys.

Discussion and Conclusions

The results of this study leave no doubt that the midpalatal suture was opened when strong expansion forces were applied to the maxillary arch. The resultant bony defect was rapidly filled by new bone and the region eventually returned to its normal form. Following the removal of the retention appliance there was a continuation of the healing process and, at the end of a subsequent postretention period, the suture showed no evidence of breakdown and resembled a normal sutural area. All evidence showed that the widened, flattened palate and the repaired suture were stable.

Splitting of the midpalatal suture occurred rapidly after the application of expansion forces. The histologic evidence on the first experimental animal sacrificed in this study (after two weeks of expansion) showed the suture to have been disrupted some time previous to sacrifice as reparatory processes were noted to be well underway at the time of sacrifice. Animals with expansion appliances, sacrificed at shorter time intervals than the minimum two-week period used in this study, would be required to determine the precise time at which the palatal processes are separated.

While this paper has been confined largely to the reactions in the midpalatal suture region, some mention must be made of the reactions around the teeth. The buccal teeth were found to tip laterally following expansion. While one might immediately consider that the changes in inclination of the teeth would be due to reactions in the alveolar process, this contention is not necessarily correct. Once the midpalatal region had been disrupted and providing adjustments were made in adjacent sutures, it would be quite possible for the palatal processes, teeth, and alveolar processes to rotate outward. If this occurred, the palatal vault would become flattened and the buccal teeth would appear to have been tipped laterally with very little reaction in the alveolar bone. This type of change has been suggested by Krebs[6] and Derichsweiler.[2]

From an initial examination of the histological reactions in the periodontal ligament and alveolar bone, the impression is obtained that the reactions around the teeth are less than are usually seen after gross tipping movement. The cephalometric radiographs and occlusal x-ray films showed marked buccal inclination of these teeth in the animal sacrificed after only two weeks of expansion. It is unlikely that a tipping movement of ten to fifteen degrees could have occurred within two weeks by tooth movement alone.

The axial inclinations of the buccal teeth, after being tipped, seemed to revert to more normal axial inclinations following the removal of the retention

appliance. Whether this change is due primarily to the teeth tipping or to palatal rotation is unknown; however, following the removal of the retention appliance, the repaired midpalatal sutural region was found to be stable.

While it is generally unwise to apply the results of experiments on laboratory animals to reactions in the human, it is considered that the results of the present study may, to a degree, be applied to certain clinical procedures in the human being. Most clinical evidence available on strong rapid expansion of the maxilla suggests that the midpalatal suture is split. The amount of expansion achieved in the monkeys was comparable in amount to that usually required in the human and, as the experimentally invoked bony defect was observed to heal rapidly and completely, it would appear reasonable to assume that the sutural region would be repaired similarly in the human.

The present study was conducted using animals in the mixed dentition period during a time of active maxillary growth. The midpalatal suture was noted to react rapidly to the expansion procedure at this time and it is suggested that in the human child the best reparatory reaction would be at a time when the suture is actively growing. However, while the midpalatal structures may be best able to repair at an active growth stage, the possibility exists that this very lability of the suture may allow a breakdown and return toward the pretreatment situation unless retention is prolonged. This question can only be resolved under clinical conditions in the human.

The nasal cavity must have been widened slightly as a result of the expansion procedure, as evidenced by the results of the histological, soft x-ray radiographs, and occlusal x-ray analyses. The reason for failure to demonstrate this reaction in the frontal cephalometric radiographs was probably due to the difficulty in obtaining detailed well-standardized records and due to the small magnitude of the changes taking place in the monkey.

The palates of the monkeys were expanded from a "normal" condition to a state in which the buccal segments were close to being in a bilateral buccal crossbite relationship. In the human, expansion is undertaken to influence a narrow palate and maxillary arch to become a wider and presumably more "normal" structure. It would appear, therefore, that the possibility of "relapse" from the unphysiologic experimental arrangement in the monkey would seem to be greater than in a result obtained from treatment of the human. As no evidence could be found of a breakdown of the midpalatal structures in the present study, it would suggest that, after repair following expansion, this region at least is quite stable. The degree of final stability of the treated case in the human, however, can only be determined from long-term clinical studies.

Summary

An investigation has been conducted to consider the effects of strong expansion forces on the midpalatal suture in the rhesus monkey. The results show that an increase in width of the maxillary arch and palatal vault is achieved, and that this increase is largely due to a disruption of the midpalatal suture. The resultant bony defect is rapidly and completely healed with the restoration of the normally growing suture.

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