Morphologic Adaptations Secondary to the Production of Experimental Cleft Palate in Primates

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Many problems in the multidimensional treatment of cleft palate have their basis in the specific malformation and dysfunction presented by the individual patient. These factors are the resultant expression of both the abnormality in development and the malposition of the affected parts.

From early fetal life, the interrelationships of abnormality and malposition result in the characteristic, yet variable, appearance of the child with cleft palate.

These characteristics have been carefully described in several significant studies which have contributed to an understanding of the nature of the deformity and subsequently to improved treatment.

Among these investigations were the early studies of Graber (*4*). His research indicated that the growth of the maxilla in cleft lip and palate patients was deficient in all dimensions: lateral, anteroposterior, and vertical. He drew attention to the importance of proper timing and technique in surgical treatment.

Snodgrasse (*12*) analyzed various facial characteristics and concluded that, in addition to reduced midface development, the size and position of the mandible were less than expected.

Harvold (*7*) found facial asymmetry in the upper jaw, including the nasal septum and the position of the anterior nasal spine and alveolar process. He detected no significant asymmetry beyond the maxillary complex and attributed the important part of the cleft palate deformity to the change in position and shape of the maxillary segments.

Pruzansky (*10*) pointed to the beneficial narrowing which occurs along the cleft when normal muscle action is restored. He also emphasized the

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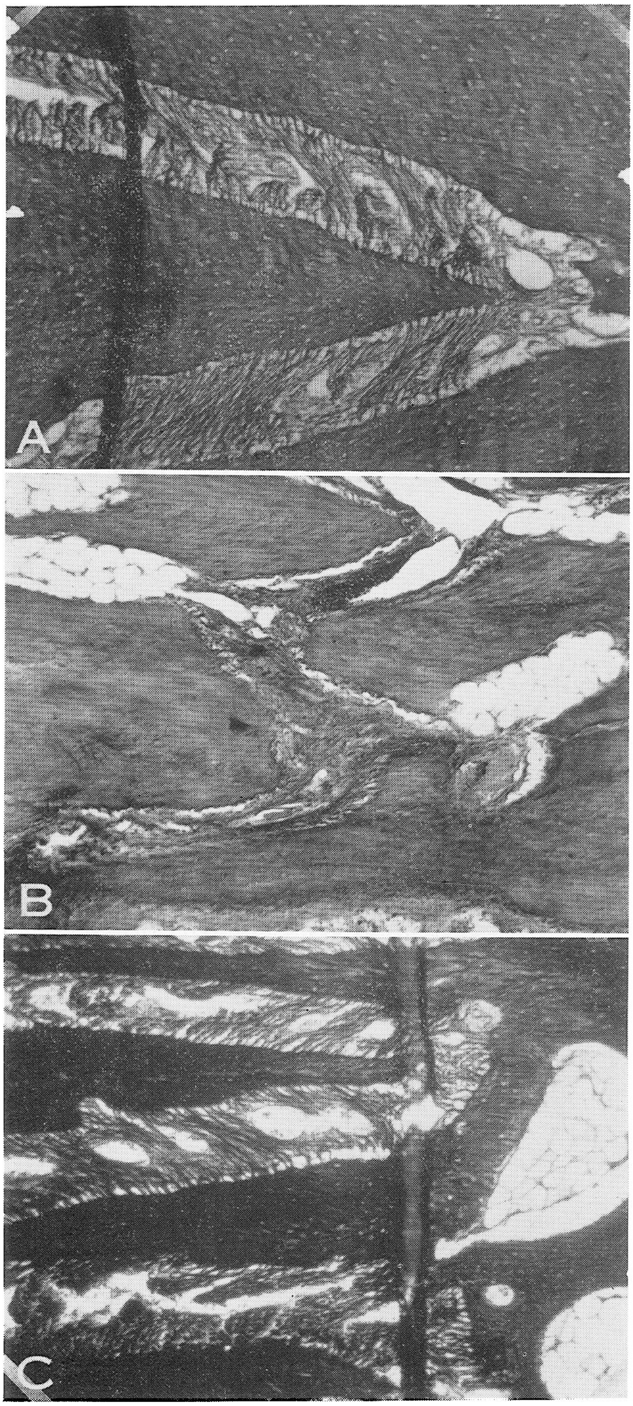

FIGURE 1a. Section of the midsagittal suture in the maxilla between the molar teeth in the guinea pig. The direction of the fibers indicates organization to resist compression. 1b. Section of the midsagittal suture in the maxilla in front of the molar region of the guinea pig. Sutural fibers appear unorganized. 1c. Section of the midsagittal suture of the maxilla behind the incisor teeth of the guinea pig. The direction of the fibers indicates organization of the suture to resist tension. Figures 1a, 1b, and 1c were made of the specified areas in the suture from the same animal.

variation in form and position of the maxillary segments and has classified crossbite relationships of the upper and lower teeth (*9*).

Subtelny (*13*) demonstrated variable but excessive width in unoperated clefts. He found that the increased width was confined to areas closely associated with the cleft.

Coupe and Subtelny (*3*) investigated the relative contribution of palatal tissue deficiency and displacement of the maxillary segments. According to them, both factors were involved to some degree, with differences between cleft types and individual variation.

Bohn (*2*) showed that clefts influence the number and morphogenesis of the teeth. He also found evidence that the innervation of the orofacial region was abnormal in a pair of conjoined twins only one of whom had a cleft palate (*1*).

Johnston (*8*), in summarizing the facial characteristics of patients with cleft lip and palate, noted that they exhibited an over-all smaller size, a variable retrusion of the midface, and a downward and backward displacement of the anterior part of the mandible. This was accompanied by an increased mandibular gonial angle.

Ross and Coupe (*11*) reported similar findings in their study of affected and non-affected cleft palate twins.

Most descriptions of craniofacial morphology associated with cleft palate are derived from comparisons between cleft and noncleft individuals, between cleft and noncleft twins, and between operated and unoperated cleft palate patients.

A difficulty inherent in these comparisons is that of separating the effects of the intrinsic abnormality from the effects of the local environment within which development proceeds.

Does the failure of fusion of the palatal shelves also reduce the potential for development of the involved maxillary segments? To what extent are the described characteristics of the cleft palate deformity due to the hypopotential of the affected part? To what degree are they ascribable to the influence of an altered environment (that is, the displacement of the maxillary segment)? Some of these questions cannot be answered through observations of human patients. It would be useful, therefore, if an experimental model were available.

In 1950, Harvold (*5*) reported the effects of expansion and compression appliances upon sutures adjacent to the maxilla in surgically produced cleft palates. He found that total remodeling of the maxilla took place while only minimal changes occurred in the zygomatic bone. The morphology of the sutures surrounding the maxilla in the experimental animal did not indicate any special functional organization of the sutures as found, for example, in pilot studies on the midline sagittal suture of the guinea pig (Figure 1a, b, and c). The original primate model has been modified and subsequently developed for use in a series of experiments.

Material and Methods

A colony of 50 young rhesus monkeys with primary or early mixed dentition was established in 1967 and is currently under experimental study. The extent of the deformity resulting from induced maxillary displacement under the influence of normal facial musculature is being tested.

Metal bone markers have been implanted in selected locations in the facial skeleton. Plaster dental casts were made and photographs and cephalometric x-ray films were taken of normal, healthy animals.

Under pentobarbital anesthesia, the animals were intubated, and labial and palatal incisions were made. For access, the central and lateral incisors were removed on the selected side and bony clefts were surgically produced. These extended from the piriform aperture through the alveolar process to the incisive foramen and continued posteriorly to the end of the hard palate (Figure 2). The soft palate remained intact; the attachments of the nasal septum and vomer were undisturbed in the midline.

In order to prevent reunion of the bony margins, compression appliances were wired into position, using teeth on both sides. Action of the appliance produced resorption of the bony edges of the defect and induced medialward

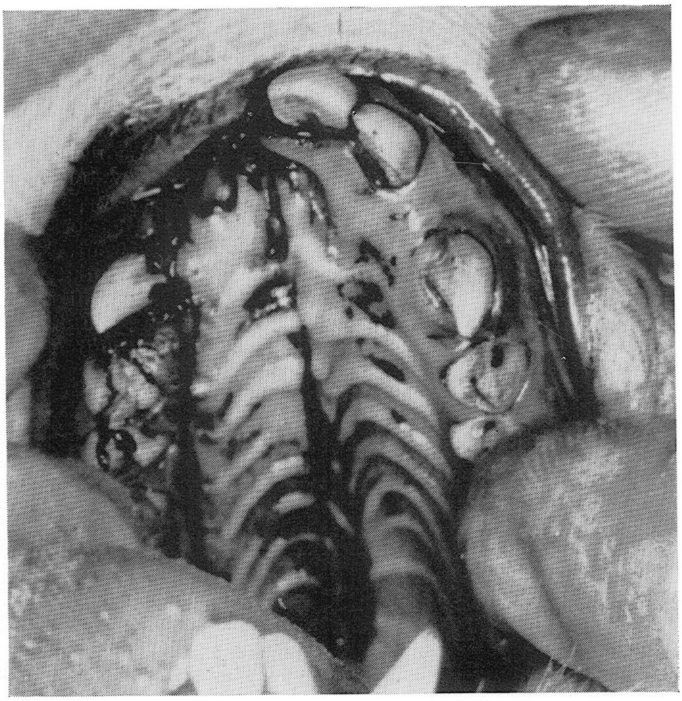

FIGURE 2. The palate of the rhesus monkey prior to fixation of the compression appliance. The central and lateral incisors have been removed on the operated side. The palatal soft tissue overlies a bony cleft 3 mm in width extending from the piriform aperture to the end of the hard palate. The lip and soft palate are intact.

displacement of the maxillary segment. A few days following the operation, the animals were returned to the colony with no apparent ill effects. They remained healthy and continued to grow.

At periodic intervals, the operated animals, as well as the control monkeys, were anesthetized; dental casts were made; photographs and cephalometric x-ray films were taken. Changes in facial morphology became apparent within a month of the surgical procedure.

The experiment has been in progress for a year and a half and will continue. Detailed analysis of the degree of response and detection of more subtle deformation must await further progress of the experiment. However, certain changes are so far outside the range of normal variation that they can be characterized as pathologic without statistical analysis. Only those alterations which are patently significant are reported here.

Findings and Discussion

Inspection of the faces of operated monkeys shows obvious asymmetry in contrast to the remarkable symmetry of certain parts of the normal facial skeleton in rhesus monkeys. The position of the ala on the affected side is altered and there is an apparent septal deviation (Figure 3). This septal deviation is difficult to confirm cephalometrically, probably because the

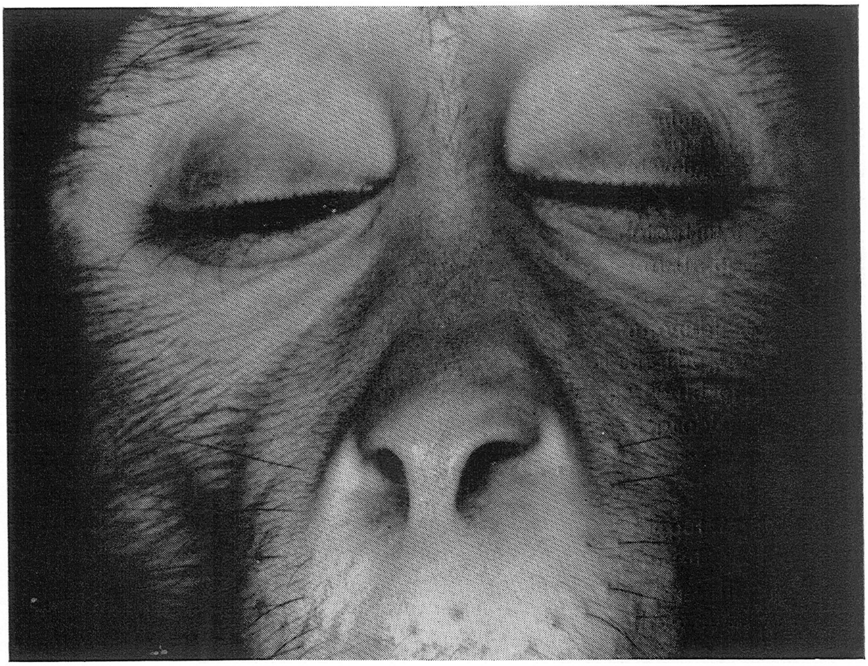

FIGURE 3. The facial asymmetry is obvious in this animal 6 months after the operation. The ala is lower on the operated side and the nasal septum and columella are deviant.

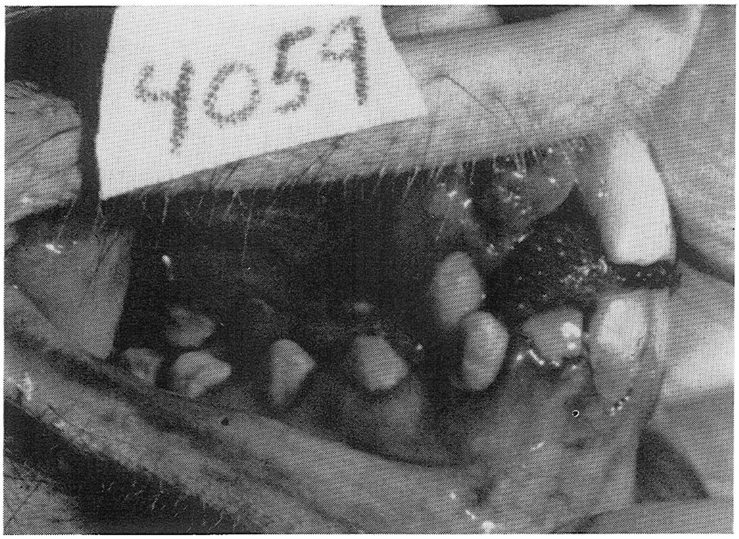

FIGURE 4. The dental crossbite relationship in an operated animal. The normal eruptive pathway of the teeth is disturbed by displacement of the maxillary segments.

anteroposterior length of the septum obscures partial curvature. Substantiation of this observation will not be complete until gross sections are obtained from a larger number of operated animals.

The medialward displacement of the maxillary segment is evident. Rotation occurs with increased collapse anteriorly and dental crossbites of varying degrees (Figure 4). The compression appliance itself produces a dental crossbite through movement of the teeth to which it is attached. However, the crossbite also occurs in teeth not tied to the appliance. The difference in measurement between the 2nd molar teeth of the operated monkeys is significantly less when compared with a control group of animals.

The crossbite relationship appears to be closely related to the degree of displacement of the segment. These observations substantiate the pattern suggested by Harvold's hypothesis (*6*) that, as the maxillary arch narrows and rotates, the tongue is unable to maintain its influence on the shape of the upper dental arch. The tongue comes to lie below the dentition then on the affected side and reduces the eruption of the teeth. This, in turn, restricts development of the alveolar process.

The tongue maintains its contact with the lower dental arch, and narrowing is not evident in the mandible.

Additional secondary involvement of the dentition is apparent in the canine area. As the maxillary segment collapses, it carries the developing canine tooth along with it. Dependent on the extent of the displacement, the canine may fail to erupt on the affected side because it is unable to pursue its normal eruptive pathway. If the canine does manage to erupt, it will usually proceed lingual to its normal position and continue inside the lower arch.

In the anterior section of the dentition, disturbances in tooth positions following maxillary displacement are markedly aberrant (Figure 5). The remaining central incisor tilts far across the midline and deflects lingually. There is a marked retrusion in the alveolar process and anterior teeth when compared with the lower arch (Figure 6). This retrusion is similar to that frequently found in cleft palate patients. It should be observed that the appliance did not contact the incisors, nor exert force on them. Furthermore, the lips of these animals were not involved in the surgical procedure. The changes occurred under the influence of normal musculature.

A few observations should be mentioned regarding structures outside the cleft area. Thus far, no changes can be detected in the position of the neighboring zygomatic bone.

With regard to the mandible, some changes are demonstrable. There is significant increase in the gonial angle of the operated animals when compared with controls. This is also in agreement with descriptions of human cleft palate patients.

Longitudinal observations of the primate colony are still under way. The experimental model employed should provide information which will contribute to understanding the nature of the defect. It may be further useful in testing selected aspects of surgical or orthodontic treatment. For instance, early restoration of bony continuity of the cleft maxilla may

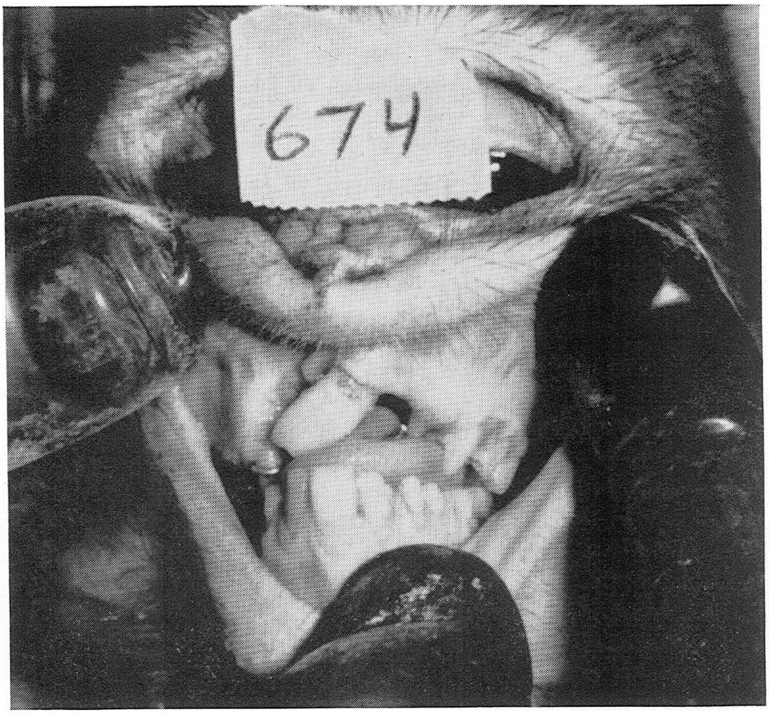

FIGURE 5. Deviation in the position of the anterior teeth in an operated animal. These changes occurred under the influence of normal lip musculature.

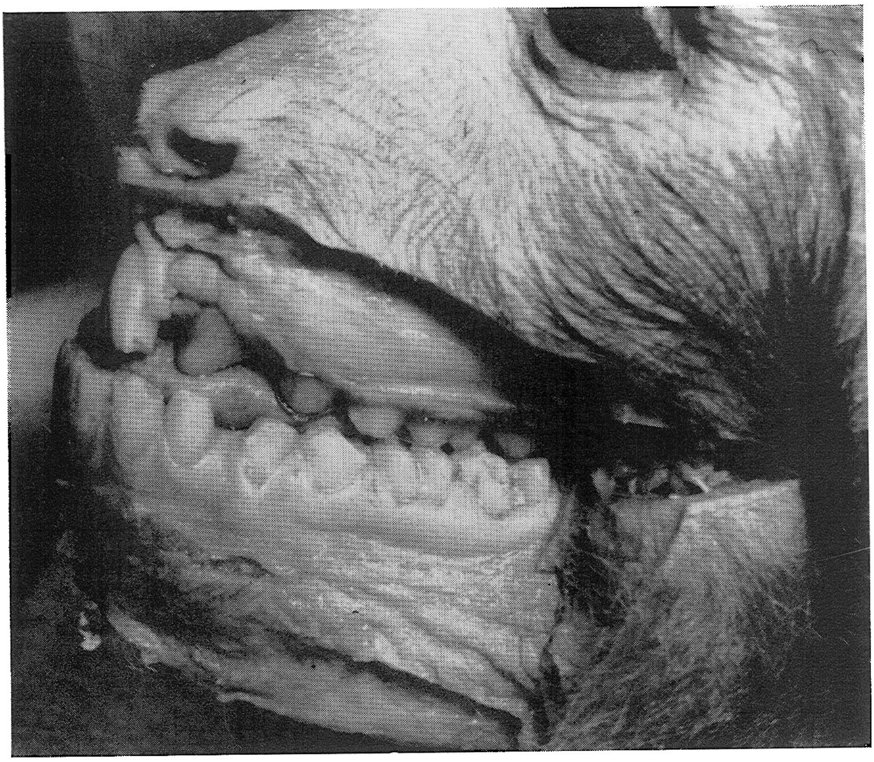

FIGURE 6. Altered relationships of the incisor teeth in an operated animal. Lip and cheek musculature have been removed in the sacrificed animal. The eruption of the upper teeth is reduced and the maxillary alveolar process is underdeveloped.

appear desirable. If so, consideration must be given to the potential for development of a maxillary segment which may or may not be in its optimum position.

It is possible that several clinical uncertainties might be amenable to experimental testing. The use of primate models may shorten the time required to assess certain procedures in human patients. This could only serve to enhance more effective treatment of long-term growth problems.

Summary

The morphogenesis of a congenital malformation such as cleft palate is difficult to understand because of the problem of separating the inherent defect from the secondary changes which occur in response to it. A primate model was developed in order to test the extent of the facial abnormality resulting from medialward position of the maxilla in an otherwise normal animal. Collapse of the maxillary segment was induced following surgical production of a bony cleft of the palate in a series of experimental rhesus monkeys. The resultant asymmetries, the dental crossbites, and alterations

in the mandibular gonial angle were significant when compared to a group of control animals. Many of the changes occurring in the operated animals were similar to those frequently seen in the human cleft palate population, indicating secondary adaptations rather than a congenital basis.

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