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Lateral Expansion of the Mandible in the Baboon

Following Osteotomy at the Symphysis

The mandibles of three baboons are expanded laterally by surgical osteotomy at the symphysis, followed by different regimes of stabilization and orthodontic movement.
KEY WORDS: ORTHOGNATHIC SURGERY

Orthopedic expansion of the human maxillae at the midpalatal suture was first reported by ANGELL IN 1860. Later in the nineteenth century and in the early decades of the twentieth century a number of other dental practitioners published similar reports (WHITE 1859-1860, FARRAR 1888, CASE 1893, GODDARD 1893, TALBOT 1893, MONSON 1898, BROWN 1903 1909, OTTOLENGUI 1904, BLACK G.V. 1909, BLACK N.M. 1909, DEAN 1909 1911, BADCOCK 1911, WILLIS 1911, WRIGHT 1911 1912, PULLEN 1912, BARNES 1912, HAWLEY 1912, KETCHAM 1912, DEWEY 1913 1914, LOHMAN 1916, LUNDSTROM 1925, HUET 1926, JAMESON 1928, MESNARD 1929,).

Within the last two or three decades, midpalatal expansion of the maxillae has gained renewed acceptance and has become a useful adjunct to orthodontic therapy and a recognized procedure in orthognathic surgery (KORKHAUS 1953 1960, DEBBANE 1958, BURSTONE AND SHAFER 1959, GROBLER 1959, HAAS 1959 1961 1965 1970 1980, KREBS 1959 1964, THORNE 1960, LINDER-ARONSON AND ASCHAN 1963, STARNBACH AND CLEALL 1964, ISAACSON AND MURPHY 1964, ISAACSON ET AL. 1964, ISAACSON AND INGRAM 1964, CLEALL ET AL. 1965, ZIMRING AND ISAACSON 1965, STARNBACH ET AL. 1966, JOFFE 1967, MOSS 1968, TIMMS 1968, DAVIS AND KRONMAN 1969, KOSUGI 1969, WERTZ

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1970, Byrum 1971, Gardner and Kronman 1971, Halpern 1971, White 1972, Biederman 1973, Hoffer and Walters 1975, Walters 1975 1976, Ekstrom et al. 1977).

The technique has been employed for expanding constricted maxillary arches, correcting posterior crossbites, flattening the palatal vault and for increasing nasal airflow capacity. The success of the procedure is attributable, at least in part, to the persistence of the intermaxillary palatal suture into adulthood, the lack of significant muscle attachments on the maxillae, and on the existence of fibrous junctions between the maxillae and the other bones with which they articulate.

Numerous procedures have likewise been described for the orthopedic manipulation of the mandible for the correction of malocclusion and facial anomalies, as well as for the treatment of cancer and of traumatic injuries. These procedures include many variations of horizontal advancement or retrusion, and vertical realignment (Bell et al. 1980, Bell and Jacobs 1981, Epker and Fish 1980).

Lateral expansion of the mandible at the symphysis has not been attempted. Early fusion at the mandibular symphysis, the attachment of masticatory, glossal and hyoidal musculature to the mandible, and the complicating presence and action of the temporomandibular joint articulations all present potential problems in relation to such a procedure. Nevertheless, a number of clinical situations, such as micrognathia, cannot be treated to a satisfactory orthodontic or orthopedic relationship without mandibular expansion.

The purpose of this investigation was to investigate the possibilities of such surgical expansion by surgically separating the mandibular symphysis in three adult female baboons in order to achieve, observe and evaluate the consequences of:

1. Lateral mandibular expansion at the symphysis and subsequent reunion through autogenous bone grafting.
2. Lateral mandibular expansion at the symphysis, reunion through autogenous bone grafting, and subsequent orthodontic tooth movement into the area of new bone growth at the symphysis.
3. Lateral mandibular expansion at the symphysis through steady application of mechanical pressure following surgical osteotomy at the midline.

— Subjects —

The experimental procedures were conducted on adult female baboons (Papio sp?) imported from Africa by the New York Primate Center. The adult female baboon was chosen because its jaw size and shape, tooth size and number and facial musculature are similar to the human. All three animals possessed a complete and normal dentition in proper occlusion.

Upon arrival, the animals weighed 14 kg., 19 kg., and 15 kg. respectively. They remained healthy, with stable weight, throughout the project. Although female baboons are generally less aggressive than males, it was nevertheless necessary to sedate the animals with ketamine hydrochloride (1 mg./kg., intramuscularly) every 30 minutes during all procedures involving animal contact.

— Methods —

Since each animal was treated individually, at different times and intervals, by diverse means and for differing purposes, the presurgical, surgical and postsurgical procedures are described separately for each animal.

Animal 1

The first baboon was used to demonstrate the possibility and stability of lateral mandibular expansion with autogenous bone grafting after osteotomy at the symphysis.

Presurgical Procedures Animal 1

In preparation for surgery and subsequent observation, this animal was given a thorough oral prophylaxis and photographs were made (Fig. 1).

Vitallium screws (2mm×5mm) were inserted at four surgically-prepared sites in the maxillae (malar processes and apical to the second premolars), and at four similarly-prepared sites in the mandible (antero-inferior to the canines and postero-inferior to the second molars). These metallic implants provided landmarks for recording changes in the dimensions and relationships of the facial bones. Lateral and postero-anterior cephalometric radiographs recorded the initial and subsequent positions of the implants (Fig. 2).

Two sets of plaster casts of the animal's dentition were made from alginate impressions taken in custom-made acrylic impression trays. One set was preserved for study, and the other used for fabricating appliances.

A titanium mesh or crib was adapted to the lower border of the mandible and fitted with titanium screws to secure it to the bone (Fig. 3). The mesh was intended to retain the autogenous graft material (Boyne 1969 1973, Boyne and Zarem 1976, Hahn and Corgill 1969, Salyer et al. 1973, Salyer et al. 1977, Terz et al. 1974, Terz et al. 1978) and stabilize the 10–12mm expansion of the mandible during healing. Postsurgical complications required later replacement of this mesh with an intraoral vitallium splint designed to stabilize the expanded mandible.

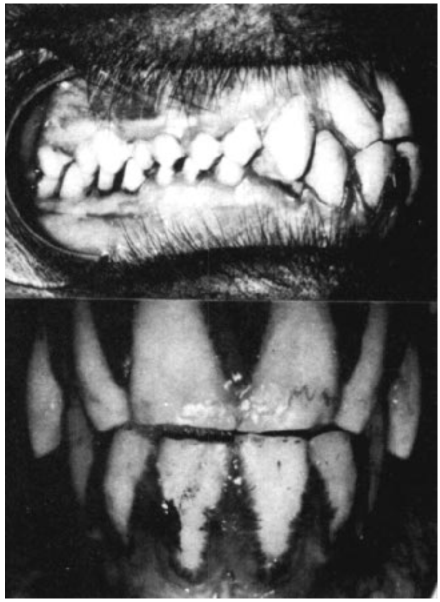

Fig. 1 Preoperative dental photographs of animal 1. The long maxillary canines were removed to allow the expansion of the mandible.

Surgical Procedures Animal 1

Under general anesthesia, cancellous bone fragments and marrow for use as autogenous bone graft material were obtained from the greater trochanter of the right femur and right iliac crest under sterile surgical conditions (Allard et al. 1978, Boyne 1969 1970 1973, Boyne and Zarem 1976, Mowlem 1944).

All lateral excursive interferences that were expected to follow mandibular expansion were eliminated by extracting the upper canines and removing the buccal cusps on all maxillary and mandibular posterior teeth. The mandibular symphysis was then approached extraorally from the inferior border of the mandible, the symphysis exposed, and a complete osteotomy performed anteroposteriorly at

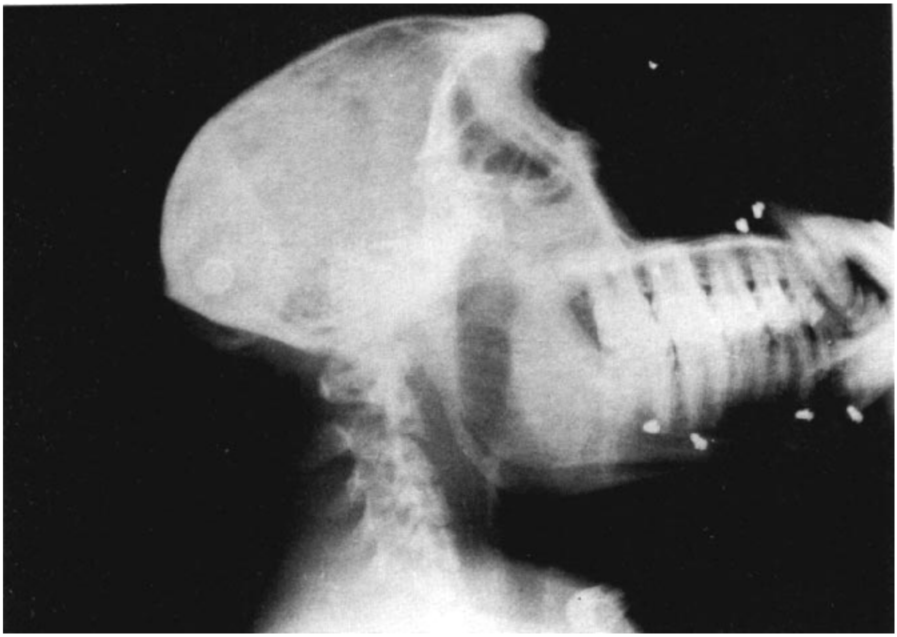

Fig. 2 Lateral radiograph of animal 1, showing implants.

the midline with a reciprocating saw. A lower central incisor was also removed after it was accidentally perforated during the osteotomy.

The osteotomy site was expanded 10mm and the titanium crib adapted to the inferior border of the mandible. The crib was filled with the cancellous bone fragments and marrow, and then secured to the inferior border of the mandible with titanium screws on each side of the osteotomy.

Both the intraoral and extraoral tissues were closed with sutures. The animal was intubated briefly with 100% oxygen, and extubated upon signs of awakening.

Postsurgical Procedures
Animal 1

Demerol for pain control and procaine penicillin for the control of infection were administered intramuscularly for three days postoperatively.

A slight infection which developed at the mandibular suture site was controlled by irrigation with dilute sodium hypochlorite (Dakin's solution). Nine days following discovery of this infection, it was deemed prudent to remove the titanium mesh and stabilize the expanded mandible with the previously fabricated intraoral vitallium splint.

Chlortetracycline (Aureomycin), which localizes in areas of bone formation and produces a characteristic fluorescence under ultraviolet light, was administered on two successive days ten weeks after surgery (Boyne 1961 1968, Boyne and Miller 1961, Milch et al. 1957 1958, Mizii 1961). A second labeling administration, using Achromycin, was given thirty days later, and a third four months after that. The two different preparations made it possi-

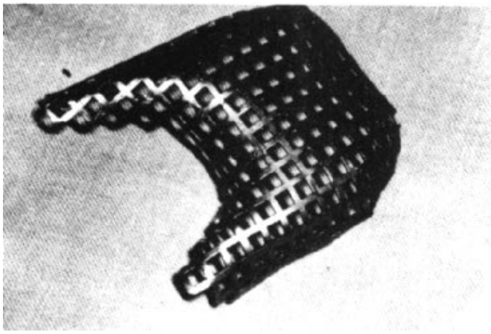

Fig. 3 **Titanium mesh after adaptation to the lower border of the mandible, adjusted for the expected expansion.**

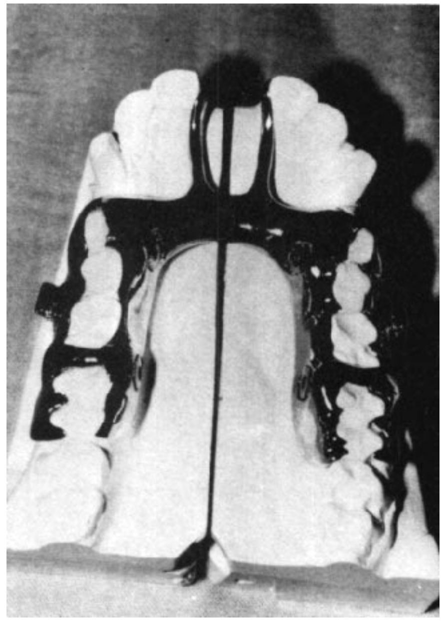

Fig. 4 **A chromium-cobalt stabilizing splint was used following the surgical expansion of the mandible in animal 2. The splint was held in place by four metal fasteners positioned interdentally, superior to the alveolar crest.**

ble to distinguish them under later examination.

One week after the third labeling, this animal was sacrificed with an overdose of ketamine hydrochloride followed immediately with an intra-carotid artery injection of formalin.

The intact mandible was debrided of all soft tissue in preparation for observation of the tetracycline fluorescence under ultraviolet light. After the gross staining was observed and recorded photographically, the mandible was sectioned laterally at the symphysis. Inferosuperior lateral cuts were also made through the head of the condyle. The two sections were ground on frosted glass to a thickness of approximately 80μ and then studied and photographed under a dissection microscope.

Animal 2

The second baboon was used to demonstrate the feasibility of orthodontic tooth movement into the area of the mandibular symphysis after lateral expansion, autogenous bone grafting, and bony reunion.

Presurgical Procedures Animal 2

In preparation for surgery and for subsequent observation, this animal was examined and treated much like the first, with the exception that the metallic implants were tantalum pins (0.5mm × 1.5mm) inserted by the method of Björk (1955 1963). Four pins were placed in the symphysis area and two opposite the mandibular first molars.

An intraoral chromium-cobalt splint was fabricated to stabilize the expanded mandible, along with the titanium cribwork attached to the inferior border of the mandible (Figs. 4 and 5). An appli-

Fig. 5 **The mandibular expansion, with a central insisor on each side of the newly-opened space, was stabilized with the cast splint shown in Fig. 4.**

ance was also prepared for the later orthodontic movement of the four mandibular incisors. This consisted of stainless steel archwires with posterior anchorage on the metal splint and anterior bonded brackets on the mandibular canines and four mandibular incisors (Fig. 6).

Surgical Procedures
Animal 2

The surgical collection of autogenous graft material, osteotomy at the symphysis, lateral expansion of the mandible, and autogenous grafting were comparable

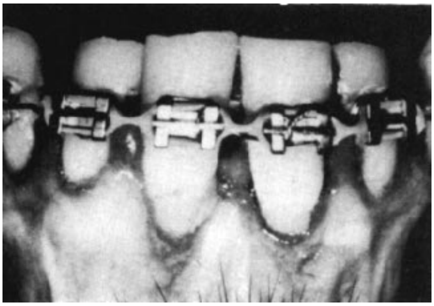

Fig. 6 Mandibular central incisors of animal 2 at the conclusion of orthodontic space closure.

to those procedures on the first animal. The only exception was that the intraoral splint was seated immediately after the osteotomy, and attached with four stainless fasteners positioned interdentally. The titanium meshwork was then placed and secured with titanium screws on each side. Procaine penicillin was administered during the surgery on this animal.

Postsurgical Procedures Animal 2

During surgery and for two days afterward, this animal was sustained on the pain control drug, nubain, and for eight days postoperatively on procaine penicillin, administered intramuscularly.

Nine days after surgery, while the sutures were being removed, intraoral exposure of the graft site and of the titanium mesh was observed, with dehiscence of graft tissue. Over the following eight weeks strenuous efforts were made to salvage the original graft with the administration of antibiotics, daily irrigation with saline and hydrogen peroxide, debridement of the area, and periodic irrigation with Dakin's solution.

After eight weeks, it was decided to repeat the entire surgical procedure. Autogenous graft material was collected from the left iliac crest. Particular precautions were taken at tissue closure to closely suture the mucosal flaps with additional fixation of the lower lip to the mandibular teeth to relieve tension.

After a routine postoperative course of eight weeks following the second surgery, orthodontic procedures were initiated. Due to the size of the animal's teeth, maxillary central incisor brackets were bonded to the mandibular six anterior teeth. Stainless steel arch wires and elastic power chains were utilized to produce medial dental movement of approximately 3mm/month. Lingual root torque was used to keep the roots in the area with the greatest amount of bony support during the repositioning phase.

Tetracycline labeling was again utilized for the observation of bone remodeling and growth. For this purpose oxytetracycline (20mg/kg of body weight) was given intramuscularly at the time of the second surgery and at 4 and 24 weeks postsurgically.

The presence of new bone was established from occlusal and postero-anterior radiographs taken at surgery and again at two and four months postsurgically. The amount of expansion and of new bone formation was determined from the metallic implants and from the radiographic evidence of new bone formation.

Mobility of the lower anterior teeth before, during and following orthodontic tooth movement was measured with a periodontometer constructed from Muhlemann's design, provided by Dr. Ingvar Eriksson (Laster et al. 1975, Mühlemann 1951). The periodontometer was set for 100 grams, and force was directed at the middle of the tooth crowns. Measurement of interdental distances was made biweekly with a dial vernier caliper to evaluate the orthodontic progress of the mandibular incisors. Photographs were also taken periodically to document the postsurgical course. This animal was not sacrificed during the experimental period.

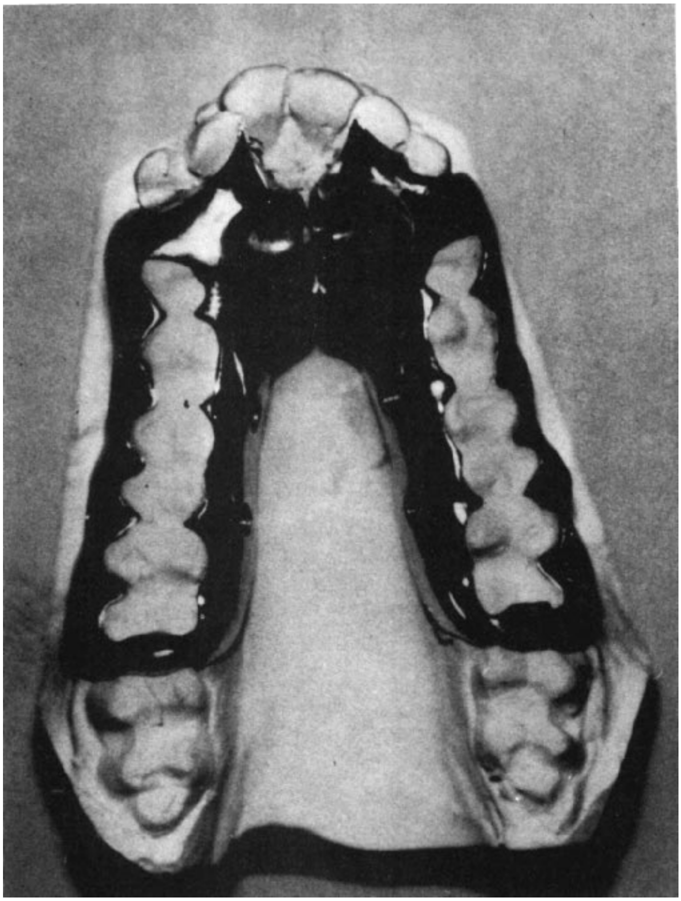

Fig. 7 **Jackscrew appliance for animal 3, showing the relationship of the metal to the teeth and gingivae.**

Animal 3

The third baboon was used to demonstrate the possibility and stability of lateral mandibular expansion accomplished by slowly applying mechanical force following the osteotomy at the symphysis, without bone grafting.

Presurgical Procedures Animal 3

This animal was treated the same as #2, with the exception that only four tantalum pins were surgically inserted - two on each side of the midline over the roots of the lower lateral incisors.

The only appliance consisted of a vitallium casting, closely adapted to both the buccal and lingual surfaces of the teeth and split vertically at the midline, with a jackscrew uniting the two halves (Fig. 7). The appliance was held firmly in place on each side by two metal screws joining the buccal and lingual extensions of the appliance through embrasures between the posterior teeth.

Surgical Procedures
Animal 3

The surgical procedures were also similar to those used on #2. The last 3 to 4mm of the osteotomy at the symphysis, however, was completed with a mallet and chisel to avoid perforating into the oral cavity and causing a mucoperiosteal dehiscence. No surgical separation, titanium meshwork or autogenous graft were employed on this animal.

The jackscrew appliance was inserted at the time of surgery and anchored in place. Using the holes in the appliance as guides, four holes were drilled in the embrasures between the posterior teeth below the height of contour. Metal bolts were inserted through these holes, tightened and trimmed flush with the lingual surface of the appliance.

Postsurgical Procedures
Animal 3

The animal was maintained on procaine penicillin given intramuscularly every other day for ten days postoperatively.

After the initial separation of 1.5mm at surgery, the jackscrew was activated 0.5mm every other day for approximately two weeks. The external sutures were removed ten days postoperatively. Twenty days postoperatively the initial jackscrew had reached its maximum extension of 5mm. That jackscrew was then removed, and a longer one fitted and processed into the appliance with cold-cure acrylic.

Ten days after placement of the second jackscrew, further activation became difficult, suggesting that bony union had occurred between the two halves of the mandible. This was confirmed with radiographs. In order to continue the expansion, a small flap was made on the inferior border of the mandible to expose the bone. A surgical chisel was forced into the bony midline until the two halves of the mandible were luxated. The flap was closed with sutures and antibiotics administered for ten days.

At the time of the luxation, the appliance was expanded an additional 1.5mm. This was followed by a further 0.75mm expansion every other day until the maximum expansion of 12mm was achieved. The total period for expansion was five weeks.

The appliance was left in place an additional eight weeks, and then removed. The stability of the mandible was observed for six more weeks before the animal was sacrificed. Eleven days before this animal was sacrificed, tetracycline was injected intramuscularly on two consecutive days.

Photographs of the animal were taken periodically to document the postsurgical course. Final radiographs and impressions were also taken so that the changes in arch width and tooth position could be observed.

The mandible was carefully dissected from the skull so the articular discs could be inspected for any gross abnormalities. The discs were removed and preserved in formalin. The mandible itself was fully debrided so that the areas of tetracycline fluorescence could be observed under ultraviolet light.

— Findings —

Osseous Changes

Lateral expansion of the mandible following osteotomy at the symphysis was achieved in all three experimental animals. The expansion was maintained throughout the period of splint support and remained stable without apparent relapse when this support was removed (Fig. 8). The magnitude of final expansion ranged from 6mm in the third animal to 10mm in the second and 11mm in

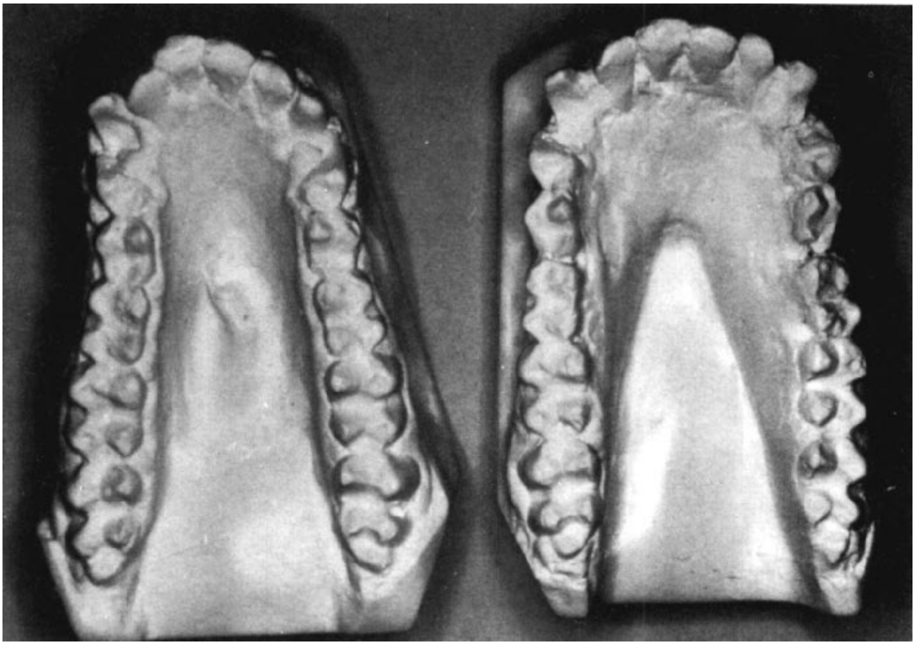

Fig. 8 **Pretreatment (left) and posttreatment mandibular casts of animal 3**

the first. In each instance the expansion was greatest at the symphysis, less in the molar area and least at the head of the condyle.

Direct postmortem and/or radiographic examination of the expanded area in the first two animals revealed that the new grafts had filled the defects created by the osteotomy and lateral expansion of the mandible, and that in both instances the grafts had contoured with the original adjoining bone.

Similar examination of the symphysis in the third animal, in which lateral expansion was achieved by mechanical means rather than surgical separation and grafting, also revealed normal bone formation (Fig. 9).

The new bone tissue was virtually indistinguishable from the old bone under gross and radiographic examination with respect to color, surface texture, alveolar height, periosteal covering, tissue attachment and tooth-to-bone attachment.

Gross examination of the debrided mandibles from the first and third animals under ultraviolet light revealed the areas of mandibular bone deposition following lateral expansion at the symphysis (Fig. 10).

Animal 1, which had received a symphyseal graft, showed fluorescence at four sites on the mandible:

1. Inferolabial and lingual surfaces of the symphysis.
2. Lingual surface of the ramus extending superiorly to the tip of the coronoid process.
3. Mental foramen area extending to the alveolar crest.
4. Anterior border of the head of the condyle extending to the lateral but not the medial edge.

Fig. 9 **Radiograph of symphysis of animal 3 after postoperative healing, 20 weeks after surgery, showing normal trabeculation at the surgical site.**

Animal 3, which had an osteotomy at the symphysis followed by gradual mechanical expansion, showed a similar distribution of the tetracycline fluorescence:

1. A wide band on the buccal and lingual surfaces at the symphysis from the inferior border to the alveolar crest.
2. Lingual surface of the coronoid process.
3. Neck of the condyle.
4. Head of the condyle along the anterosuperior surface from the lateral border to within 1mm of the medial border.

Lateral sections of bone taken from the symphysis (Fig. 11) and from the head of the condyle of the first animal were examined with the dissecting microscope under ultraviolet light. Both sites showed

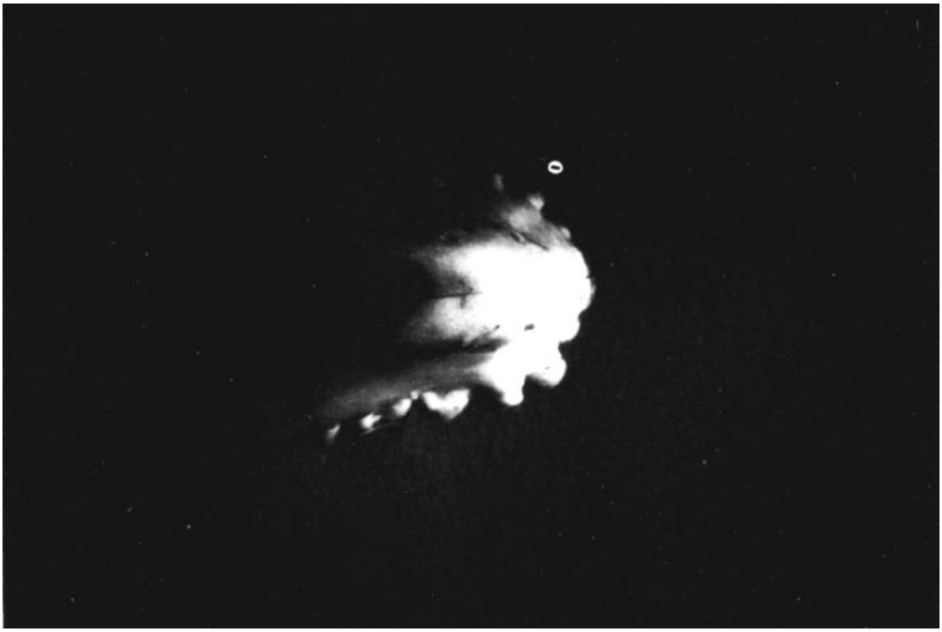

Fig. 10 Ultraviolet fluorescence, showing areas of active postsurgical bone formation on the anteroinferior surface in animal 3.

characteristic tetracycline fluorescence in two or three distinct lines around haversian systems.

Serial 2mm anteroposterior sections at the mandibular symphysis in the third animal were ground to a thickness of approximately 80μ on frosted glass and examined under the dissecting microscope. This revealed both cortical and cancellous areas of new bone, similar in appearance to the adjacent old bone. Under ultraviolet light, the new bone revealed a normal-appearing matrix, with tetracycline fluorescence around the haversian systems.

Dental Changes

The mobility of the mandibular incisors in the second animal was measured with the periodontometer under loads of 100 and 500gm before orthodontic treatment and at 1 and 5 weeks following active treatment (Table 1). As one might expect, the findings indicate an increase in tooth mobility during active treatment, but with a consistent reduction in mobility during retention.

It is clear that the separation of the central incisors which occurred during expansion was essentially closed during the retention phase, probably as a result of the action of the transseptal fibers.

— Summary and Conclusions —

Although the size of this experimental series was small, and postsurgical complications occurred in each of the animals, the central objectives of the study were achieved. It was found to be feasible to intervene surgically at the mandibular

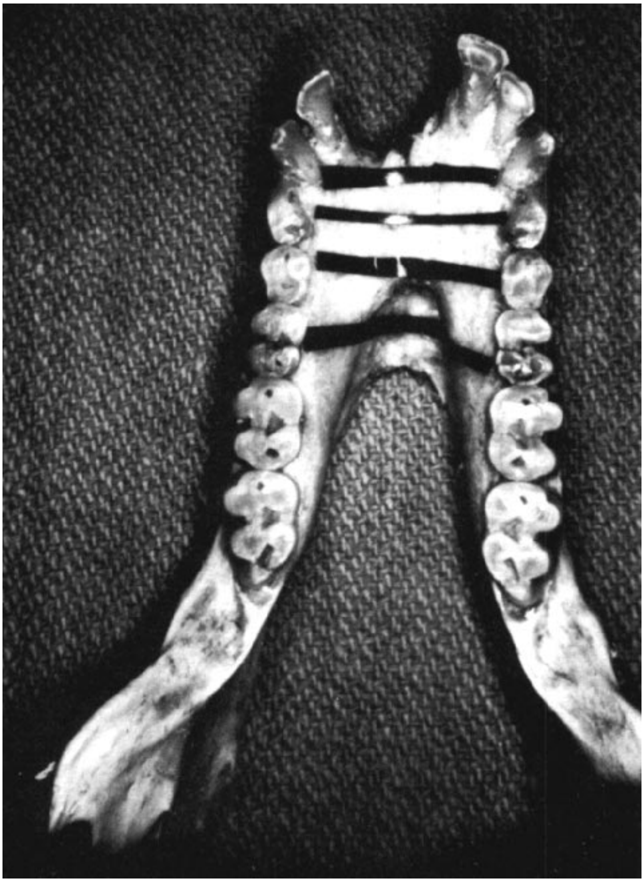

Fig. 11 **Mandible of animal 1, showing sections of bone removed for microscopic examination.**

symphysis, to perform a midline osteotomy and laterally expand the mandible, either at the time of surgery, followed by autogenous grafting, or by slow mechanical tension. In either case,there was no evidence of subsequent short-term relapse.

New bone formation and remodeling accompanied and followed mandibular expansion, restoring and maintaining the bony architecture and the mandibular contours after the splint support was removed. Minimal changes occurred at the head of the condyle, and there was no evidence of temporomandibular joint dysfunction. Both orthodontic and spontaneous movement of the lower incisors into the newly-formed or reorganized bone occurred readily, with subsequent normalization of tooth mobility.

The positive findings and surgical experience gained from this study suggest that lateral expansion of the mandible at the symphysis following osteotomy may have some application to humans suffering with severe mandibular micrognathia or other facial anomalies or traumatic injuries. A/O

Table 1

Tooth Mobility (mm) in Animal 2

		Pretreatment		Retention one week		Retention five weeks	
		100gm	500gm	100gm	500gm	100gm	500gm
Right lateral incisor	T_1	.10	.17	.17	.27	.12	.26
	T_2	.12	.18	.14	.27	.13	.25
Right central incisor	T_1	.09	.18	.29	.56	.22	.47
	T_2	.10	.23	.30	.57	.24	.49
Left central incisor	T_1	.17	.27	.49	.61	.25	.50
	T_2	.17	.26	.53	.63	.24	.52
Left lateral incisor	T_1	.19	.29	.42	.54	.23	.31
	T_2	.19	.26	.38	.58	.22	.32

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