The Effect Of Local Heat On Tooth Movement

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A search of the literature reveals little concerning the effect of local heat on tooth movement. Anderson[1] has applied microwave diathermy to dogs undergoing tooth movement in the mandible. He has found no macroscopic, radiographic, or histologic evidence to indicate either a helpful or detrimental effect. Locally applied hyperthermia and its effect on long-bone growth have also been investigated. Richards and Stofer[2] have demonstrated an increase in femur length of rats and puppies following local heat application. Ring and Lee,[3] working with rabbit ulnas, have reported results which in their opinion did not support the hypothesis that local heat might initiate cartilage cell differentiation and replacement by bone. Previous work at this laboratory on bone growth in the mandible of rabbits has indicated positive effects of local heat.[4]

The present authors have been interested in the effects of local hyperthermia associated with the lateral movement of rabbit maxillary incisors. The purpose of this report is to present the results of attempts made in this laboratory to apply heat locally to the lateral surface of the right maxilla and note some of its effects. Changes observed in the alveolar bone, periodontal membrane and cementum, with analysis of these changes in terms of heat, are herein presented. If accelerated separation of teeth within physiological limits can be accomplished on experimental animals, a procedure might be developed in orthodontics to reduce overall treatment time and cost.

Materials and Methods

For this investigation a total of twenty female New Zealand white rabbits weighing from 1.5 to 3 kg were used. Six of these served for the initial exploratory procedures and fourteen were used to obtain experimental data and histological sections. This report cites results obtained in sixteen animals. Two were sacrificed as normal. Seven were designated experimentals; their littermates were the controls. In the experimental group, the right side of the maxilla was heated locally while the left side of the same animal served to some degree as an unheated control for the right side.

Of the available methods of heat application, two were selected for investigation, induction and short-wave diathermy. In order to heat by induction, a flat vitallium plate 5 x 22 x .5 mm was placed between the periosteum and alveolar bone overlying the right maxillary incisor root. Frontal and sagittal x-rays verified the exact locations of the plate in relation to the tooth (Fig. 1). An electric field was provided by an electronic high-frequency generator with a "Pi" network coupling to an induction coil. Eddy currents were set up in the vitallium plate by the electric field which heated the metal. A temperature control consisting of a second plate attached to a

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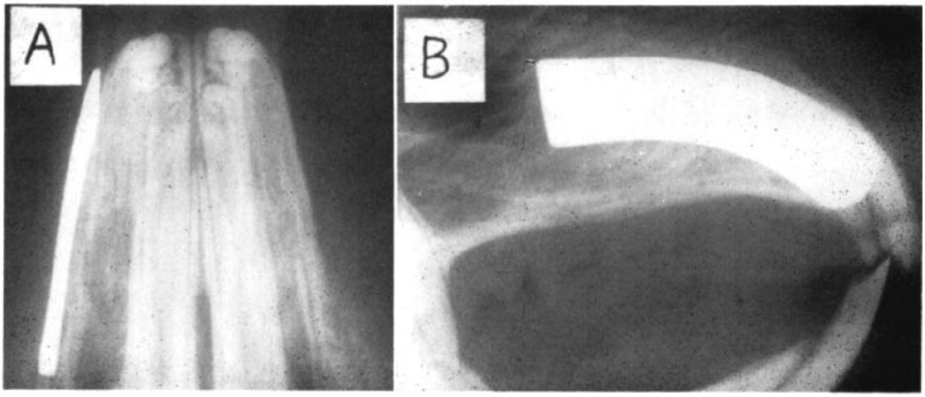

Figure 1
A. Anteroposterior roentgenograph at sacrifice relating location of vitallium plate to heated incisor and midline. Note separation of maxillary incisors in the midline.
B. Lateral roentgenograph immediately following placement of vitallium plate.

thermocouple was placed so that it touched the skin of the rabbit and lay in direct line between the implanted plate and the source of the electric field. An indicating potentiometer showed the temperature at the thermocouple, and an incorporated on-and-off switch maintained the heat at six degrees F. above body temperature.

When the animal had recovered from the operation, a period of from one to three days, induction thermal application was instituted following insertion of a helical coil spring using the Storey method.[5,6] The wire used was of .016 inch diameter high-temper steel of great resiliency (the so-called Australian "light wire"). The spring consisted of one loop of wire in a center coil and two free arms 13 mm in length. All the springs had uniform dimensions and maintained a force of 3 ounces. The arms of the springs were inserted into small holes drilled with a 701 cross-cut fissure bur from labial through to lingual 2 mm from the incisal tips of the maxillary incisors.

During the heating periods, four consecutive hours daily from four to ten days (16-40 hours), the animals were confined in a rabbit holder with a plastic head positioner, which, being nonmetallic, was not affected by the induction field.

Diathermy was used to heat unilaterally the right maxillae of rabbits while helical coil springs moved the central incisors apart. Two rabbits were heated for twenty minutes daily at 160 milliamperes for eleven and sixteen days. Two rabbits were heated for ten minutes daily at 90 milliamperes for five and eight days. The machine used was a Mooradian combination short wave unit, Model C. Two heating pads were placed adjacent to the right maxilla of the animal, one anterior to the other and not in contact.

Following completion of the final period of heat application, the animal was sacrificed immediately with its littermate control. X-rays were again taken, the maxilla was removed intact and fixed in ten per cent formalin, decalcified in five per cent formic acid and embedded in paraffin. Serial five μ transverse sections through the anterior part of the maxilla were made and stained with hematoxylin and eosin.

A micrometer with sharpened points was used to obtain linear distance

TABLE I

Linear and angular deflection of rabbit maxillary incisors, following local application of heat by induction or diathermy. Controls and heated incisors were fitted with a spreading appliance.

	Animal Number	Linear Deflection after First Day		Linear Deflection at Sacrifice		Angular Deflection from Midline at Sacrifice				Days Right Maxilla Heated		Duration Daily Heating Period	
		Heated	Control	Heated	Control	Right Heated	Right Control	Left Heated	Left Control	Heated	Control	Heated	Control
INDUCTION	1	1.1 mm	0.6 mm	3.3 mm	2.9 mm	7°	5°	5°	5°	4	0	4 hrs.	0
	2	1.2	0.5	4.0	3.1	8	6	6	6	4	0	4	0
	3	1.0	0.6	4.4	3.7	12	9	7	8	10	0	4	0
	Mean	1.10	0.57	3.9	3.2	9.0	6.7	6.0	6.3				
DIATHERMY	4	0.7	0.3	3.6	3.0	11	7	8	8	11	0	20 mins.	0
	5	0.8	0.4	3.7	2.9	12	9	9	8	16	0	20	0
	6	0.5	0.2	2.7	2.4	9	6	7	5	5	0	10	0
	7	0.6	0.3	2.8	2.6	10	7	8	6	8	0	10	0
	Mean	0.65	0.30	3.2	2.7	10.5	7.3	8.0	6.8				
TOTAL MEAN		0.84	0.41	3.5	2.9	9.9	7.1	7.1	6.6				

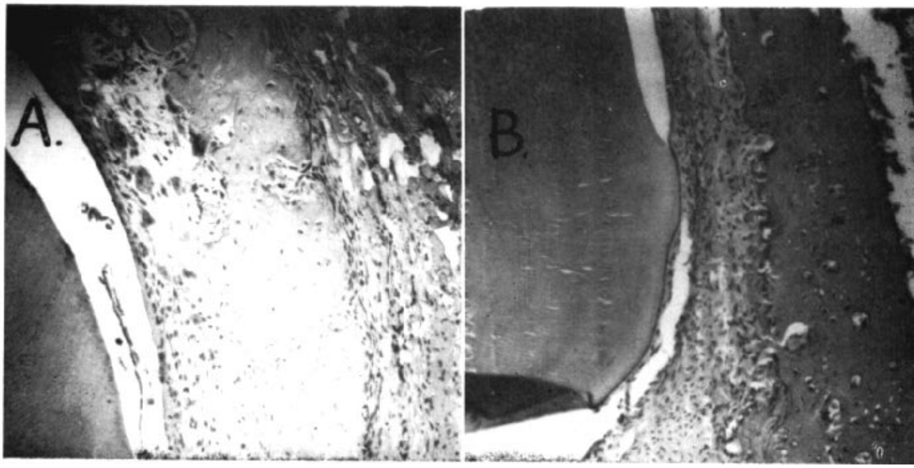

Figure 2 Pressure side.
A. Right pressure side in induction-heated animal for ten days. Osteoclastic activity has resulted in the perforation of the lateral alveolar plate of bone. Fibers of the periodontal membrane have been reoriented at right angles to the direction of force (x 32).
B. Right pressure side of control animal (helical coil spring separation for ten days, no heat). There is some increased cellular activity adjoining the bone. The integrity of the alveolar bone has not been impaired (x 8).

measurements between the mesial surfaces of the teeth at two times during the experiment: immediately after the initial period (first day) of heating and at sacrifice. The measurements were taken at the level of the drilled holes.

Results

At the end of the first day, the incisors of the heated animals were separated a distance nearly twice that of the unheated controls (Table 1). After several days of heating, at sacrifice, the separation of the incisors was greater in all animals than it was at the end of the first day. The animal exposed to diathermy for the longest time exhibited the greatest angular spread. All heated animals showed a greater linear separation at sacrifice than their controls; induction heating resulted in greater linear separation than that observed in half of the diathermy heated animals (Fig. 2). At sacrifice, the right incisor (heated side) had a greater deviation in degrees away from the midline than the left (Fig. 2). The heated incisor showed the greatest mobility; the incisors in the unheated control showed the least.

Examination of transverse sections which include both maxillae reveal a greater separation of the intermaxillary suture in the heated animals. This separation was greater in those heated longest.

Histologically, changes were evident in the alveolar bone and periodontal membrane consistently, and cementum and cartilage at random.

Bone: The normal alveolar bone encircles the incisor and is thinnest at the lateral edge. When compared with the left (unheated) side and with both sides of the control, the heated side of all experimental animals showed greater bone resorption (Fig. 3). The alveolar wall was entirely resorbed in one animal (Fig. 4). Osteoclastic and osteoblastic activity was more apparent in all of the heated animals compared with the controls (Fig. 5). Osteoclastic activity and bone remodelling were more striking on the pressure side (Figs. 2, 3, 4 and 6).

Periodontal membrane: In the heated animals, there appeared to be a disorganization of the normal architecture more on the pressure side of the right incisor than the left, as manifested by the reorientation of fibers at right angles to the pressure and evidence of change to fibrotic connective tissue. Increased cellularity was noted in all induction-heated animals and decreased cellularity in diathermy-heated animals on the pressure side.

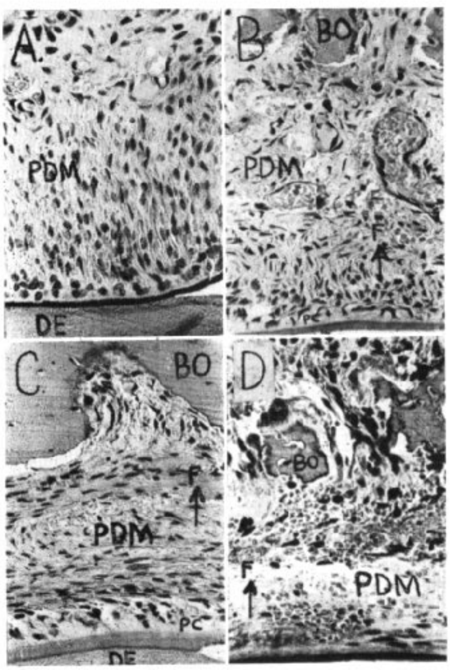

Figure 3 Pressure side at level of premaxilla (x 128).

A. Normal (no forces applied to incisors, no heat). Fibers of periodontal membrane perpendicular to cementum.
B. Control (helical coil-spring separation for ten days, no heat.) Fibers of periodontal membrane disorganized; precementum being deposited.

C. Induction-heated animal (helical coil-spring separation plus heat for ten days). Fibers of periodontal membrane aligned opposite that of normal, perpendicular to direction of force (F). Layered sections of periodontal membrane show fibrotic connective tissue changes. Increased thickness of precementum (PC) present. Bone resorption (BO) occurring.

D. Diathermy-heated animal (helical coil spring separation plus heat for eleven days). Complete disorganization of periodontal membrane fibers and decreased cellularity; islands of bone remain.

Cementum: Increased thickness of precementum is evident in the induction-heated animal compared with its control (Fig. 3, B and C). Discrete bays of cementum resorption occurred in two experimental animals in an area of tension on the heated side. In the diathermy-heated animals heated the longest, a large segment of cementum and dentin was eroded at what appeared to be the site of greatest pressure. A large necrotic area in the periodontal membrane lay adjacent to the

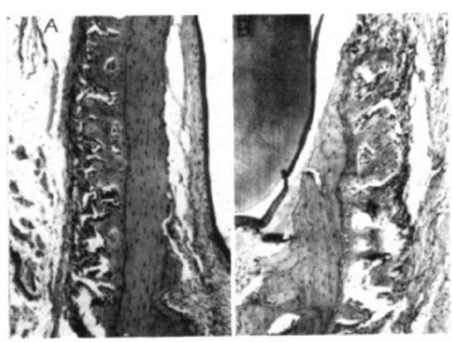

Figure 4 Diathermy-heated animal with separating spring in place for eight days.

A. Left incisor pressure side. Alveolar bone remains along entire lateral border of incisor and from this old bone newly-formed trabeculae extend parallel to the direction of force. In the lacunae there is active cellularity of fibroblasts and some narrowing of the periodontal membrane (x 32).

B. Right incisor pressure side. Alveolar bone that was not resorbed shows thickening along the newly formed trabeculae where the heat was applied. The soft tissues outside the bone show greater increase of fibrous tissue (x 32).

eroded dentin.

Cartilage: Cartilage in the nasal region of one heated animal showed greater thickening and proliferation on the heated side. This appeared to be due to marked hyperplasia of chondroblasts and chondrocytes.

Discussion

Intermaxillary Suture: In the control, the interlocking fingers of bone appear elongated and narrow, and maintain their gross appearance with the exception of being separated slightly (Fig. 7). In the induction-heated animal, the fingers are blunted and thickened, and this trend is continued in the diathermy-heated animals. Increased remodelling of bone is evident in both the heated animals.

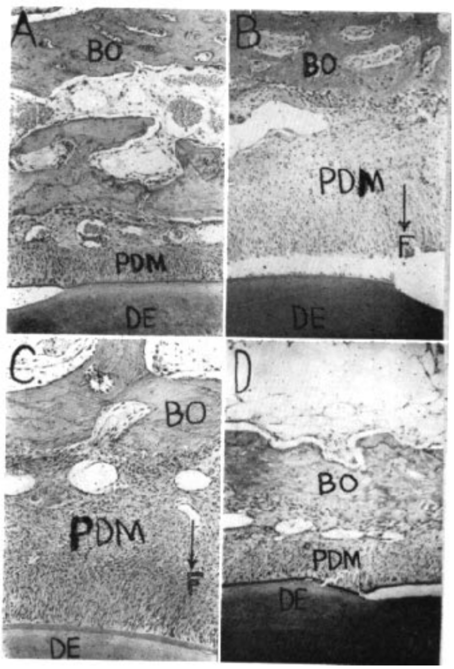

Figure 5 Tension side, (x 32).
A. Normal (no forces applied to incisors, no heat). Periodontal membrane of normal thickness with normal degree of cellularity adjacent to bone.
B. Control (helical coil-spring separation for ten days, no heat). Thickness of periodontal membrane increased; osteoblastic activity increased.
C. Induction-heated animal (helical coil-spring separation plus heat for ten days). Slightly increased thickness of periodontal membrane; increased osteoblastic activity.
D. Diathermy-heated animal (helical coil-spring separation plus heat for eleven days). Slightly increased thickness of periodontal membrane with osteoblastic activity slightly above normal; decreased cellularity.

The greater separation observed during the initial period of heating was probably due to the compression of the periodontal membrane under the influence of the longer application of heat using the induction method. The physical changes that occur when the tissue is compressed are enhanced by the longer application of heat.

The greater angular and linear separation observed in those animals exposed to heat for several days over that of the controls indicates that changes other than physical compression are involved. Observations indicate that these greater separations are due to changes in the bone and perhaps the midline suture structure. The greater spread observed among the diathermy-heated animals may have been a result of some bilateral heating which was not the case in the induction method, or the extreme effects of diathermy, including some necrosis which allowed the right incisor to be moved more easily through the area. The above extreme effects on the periodontal membrane and bone may have been due to the fact that in the early diathermy runs, tissue heating may have been above optimum.

In conclusion, the gross changes observed in the separation of the rabbit maxillary incisors could be related directly to the histological changes, i.e., greater osteoclastic activity on the compression side, greater osteoblastic activity on the tension side and midline sutural separation. It is impossible to state whether the histological changes are

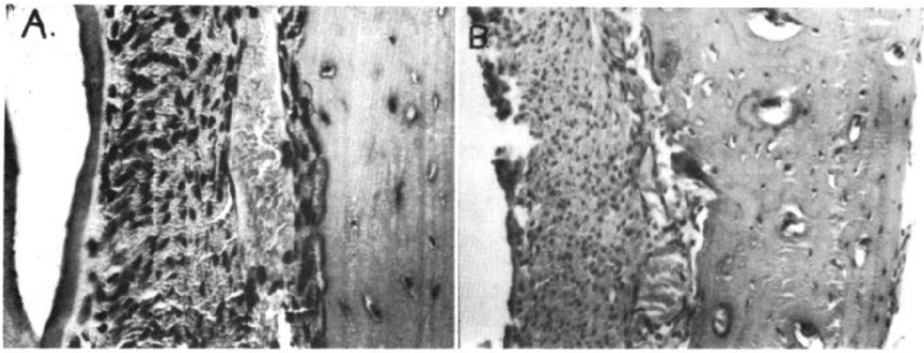

Figure 6 Right pressure side.

A. Diathermy-heated animal (helical coil spring separation plus heat for five days). There is greatly increased cellular activity adjoining the bone (x 128).

B. Control animal (helical coil spring separations for five days, no heat). There is only slightly increased cellular activity adjoining the bone (x 32).

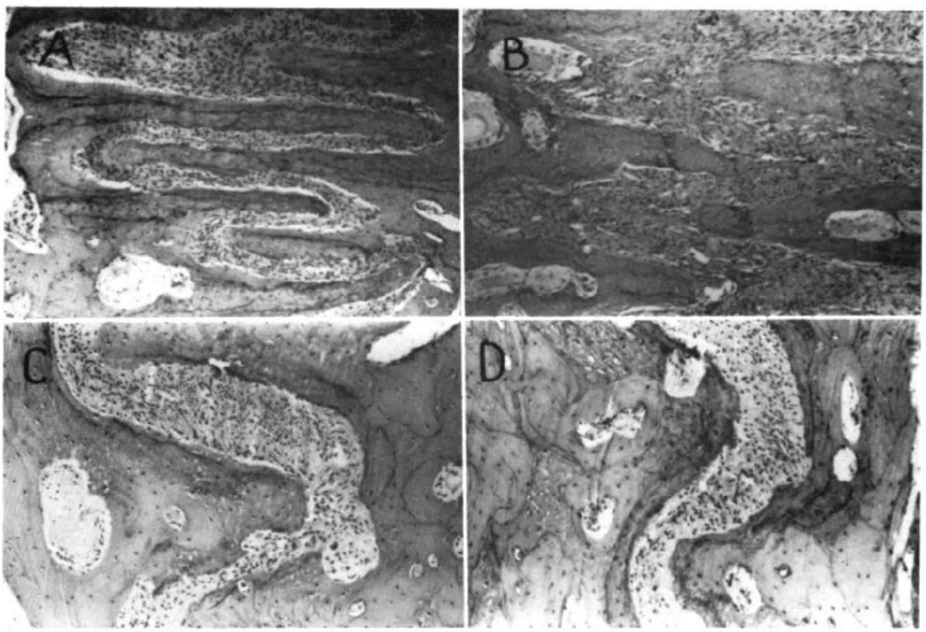

Figure 7 Midline suture of maxilla.

A. Normal (no separation, no heat). Lengthy interlocking of narrow bony fingers is shown with connective tissue between them (x 32).

B. Control (coil-spring separation for ten days, no heat). Fingers of bone are scarcely interlocking (x 32).

C. Induction-heated animal (coil spring separation plus heat for ten days). Fingers of bone are blunted and thickened with lengthy interlocking (x 32).
D. Diathermy-heated animal (coil spring separation plus heat for eight days). Fingers of bone further blunted and thickened, compared with A, B and C (x 32).

due to increased vascularity, increased cellular enzymatic activity or a combination of these or unknown factors.

Summary

The effects of local hyperthermia associated with forced lateral movement of rabbit maxillary incisors are reported here. Seven animals were heated locally on the right side of the maxilla. Littermate controls were maintained. Vitallium plates were placed between periosteum and the bone overlying the tooth root in three rabbits which were heated by induction. Four animals without vitallium plates were heated unilaterally with diathermy. Separation was caused by helical coil springs of uniform three-ounce force inserted into small holes drilled approximately two millimeters from the incisal edge. The length of heating varied from 16-40 hours over a four to ten day period for induction heating, and 10-20 minutes per day over a five to sixteen day period for diathermy.

Gross changes included a greater separation of the teeth in the heated animal at the end of the first day of heating when compared with the control, and at sacrifice, a greater angular separation of the heated tooth from the midline.

Histologically, the heated side of all experimental animals showed greater bone resorption than the unheated side or both sides of the control. Osteoclastic and bone remodelling activity was most striking on the pressure side of the heated animals. Periodontal membrane fibers were more reoriented at right angles to the force applied on the heated side than on the unheated side or either side of the control. Cementum resorption and cartilage proliferation occurred unilaterally.

Locally applied heat has resulted in an increased rate of tooth movement as observed in separation of the maxillary incisors of the rabbit.

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