The Effect of Gingival Fiberotomy on Orthodontic Cuspid Retraction in Cats

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Distal tipping forces were applied to the maxillary cuspid teeth of five domestic cats. Surgical elimination of the gingival attachment of one tooth in each cat resulted in greater distal crown movement and a shift of the center of rotation toward the root apex.

The relationship between gingival connective tissue forces and relapse of orthodontic tooth movement has been well documented.[1-13] However, the relationship between these gingival forces and orthodontic tooth movement has not been studied.

If gingival forces are present after orthodontic tooth movement, it is reasonable to expect that they accumulate during the tooth movement. The possibility that these accumulated forces might affect the orthodontic movement is the subject of this investigation.

When the crown of a single-rooted tooth is subjected to a lateral force, the tooth tips or rotates. The crown moves in the direction of the applied force and the apex of the root moves in the opposite direction. The motionless neutral axis located somewhere between is referred to as the axis or center of rotation.

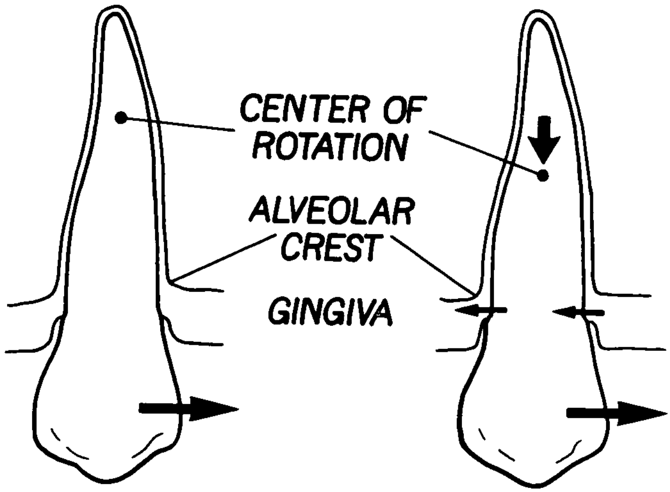

Fig. 1 Theoretical effect of gingival forces on the center of rotation
Left—Orthodontic force only
Right—Orthodontic and gingival forces combined, shifting center of rotation toward the crown.

Any gingival forces accumulating during orthodontic tooth movement would act at the level of the gingival attachment in a direction opposite to the direction of tooth displacement. Such forces acting on the tooth through the gingivae would add a countertipping moment that would cause a coronal shift of the center of rotation. Conversely, reduction or elimination of such gingival forces would cause a shift in the center of rotation toward the root apex (Fig. 1).

The purpose of this study is to determine whether elimination of the gingival force created during orthodontic tooth movement affects crown movement, root movement or the center of rotation.

Gingival Fibers and Relapse of Orthodontic Tooth Movement

In 1962, Burstone[14] stated that the theoretical center of resistance of a single-rooted tooth with a parabolic root shape is located at a point 0.4 times the distance from the alveolar crest to the apex. In addition, he stated that a tipping force applied to the crown would result in a center of rotation somewhere between the center of resistance and the apex.

According to Burstone, connective tissue forces operating through the gingivae can affect the exact location of the center of rotation by altering the force system acting on the tooth. He claimed that there was a wide individual variation in the degree to which the gingivae can affect the center of rotation.

In 1968, Utley[15] experimented with the maxillary cuspid teeth in cats. In all cases, he found the center of rotation within the middle fifth of the alveolus.

Materials and Methods

Five domestic cats, Felix catus, were chosen as the research animals in this study. Ages were 18 to 24 months, with maxillary cuspid root apices fully formed.

The cat is well suited for such a study for several reasons. It has two sets of teeth which are similar in development and eruption to those of the human.[16] The large cuspids are easily accessible and suitably shaped for adaptation and cementation of orthodontic bands. The large diastema distal to the cuspid provides ample space for cuspid retraction without removal of teeth. The entire maxillary dentition overlaps the mandibular dentition, so occlusal interference with the maxillary appliances or with tooth movement is no problem.

Under general anesthesia, orthodontic retracting appliances were placed on both maxillary cuspid teeth in each of five domestic cats. One of each pair was designated as the experimental tooth and subjected to gingival fiberotomy, while the cuspid on the other side served as the control.

General anesthesia for all procedures was produced by a combination of intramuscular and intravenous injections of pentobarbital sodium.

Prefabricated band-eyelet combinations were cemented to the maxillary cuspids with the eyelets 3 to 3.5mm incisal to the marginal gingivae.

Latex rubber elastics (3/16 inch) providing approximately two ounces of force were used throughout the experiment. The distal ends of the elastics were ligated to the third premolar teeth, which were prepared with distogingival grooves and accentuation of the developmental groove between the mesial buccal and distal buccal cusps (Fig. 2).

Orthodontic forces were maintained continuously active on all ten teeth for six weeks. During this time the following procedures were accomplished under general anesthesia at weekly intervals: 1) alginate impressions of the maxillary arch for dental stone casts, 2) fiberotomy on the experimental cuspids, and 3) placement of fresh elastics.

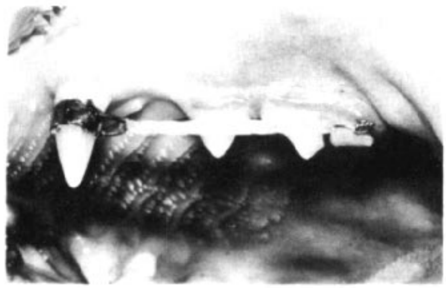

Fig. 2 Cuspid retraction appliance.

The animals were then sacrificed and lateral jaw sections prepared from the maxillary arch of each animal. These were radiographed and tooth movement and bone changes compared.

Histologic slides were also prepared from seven cuspids with their investing periodontium.

Tooth movement was measured by a photographic method, using tracings showing both incisal tip and root apex to determine the center of rotation. These data were analyzed statistically with a three-way cross-classification analysis of variance.

Weekly Procedures

The degree of gingival inflammation associated with both the experimental and control cuspids was subjectively rated as mild, moderate or severe. Elastics were changed, and both the initial and decayed force of each elastic were measured.

Alginate impressions were made of the maxillary arch and poured immediately in dense stone.

Gingival surgical procedures on the

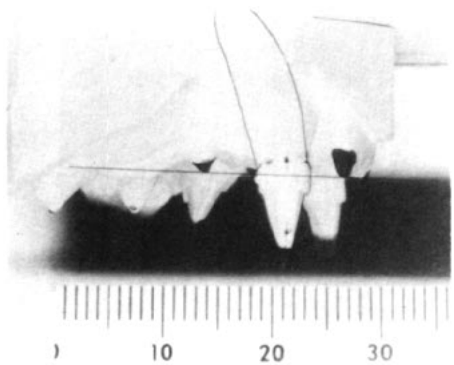

Fig. 3 Visualization of root apex.

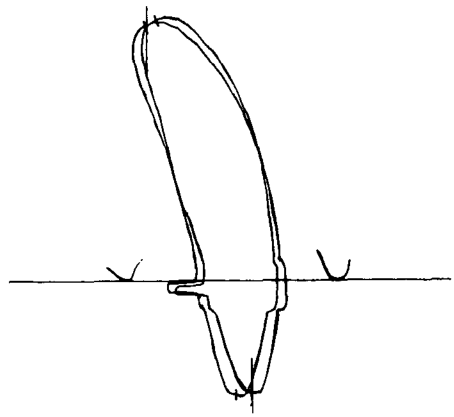

Fig. 4 Typical weekly change in tooth position.

experimental cuspids consisted primarily of circumferential supracrestal fiberotomy. A #12B Bard-Parker surgical blade was inserted into the gingival sulcus to a level at or slightly apical to the crestal bone, and an incision extended around the circumference of the tooth. All supracrestal fibers attached to root cementum were severed.

A small wedge of gingival tissue was excised from the distal aspect of the tooth to reduce resistance from gingival tissue "pile-up" at the advancing tooth surface.

Evaluation

The animals were sacrificed at the end of the 6-week period. Each maxilla was placed in 10% unbuffered formalin solution for radiography and later sectioning.

Radiographs were made with the cuspid long axis parallel to the film surface, and the x-ray tube positioned directly above and perpendicular.

Histologic slides were made from decalcified sections.

Right and left views of each of the seven serial stone models of each animal were photographed with a standardized technique with a millimeter rule in each photograph. The third incisor and first premolar were used as reference points for later superimposition of tracings.

In order to visualize the cuspid root as well as the crown, the tissue specimen radiographs were enlarged to the same magnification as the photographs. Tracings of the individual cuspids, made from the enlarged radiographs, were then superimposed on their respective clinical crowns in the serial photographs (Fig. 3). This made it possible to visualize the positions of the root apices as well as the crowns on the photographs.

Distal movement of the incisal tip and mesial movement of the root apex could thus be measured relative to the tracing of the stable reference line (Fig. 4). All measurements were made with a Boley gauge calibrated in 0.1 mm increments.

The center of rotation (CR), expressed as the fraction of total tooth length from the apex, was computed from the distal movement of the incisal tip (I) and mesial movement of the root apex (A) using the following formula:

$$CR = A/(A + I)$$

Results

Each of the five animals appeared healthy, maintained a good appetite, showed no apparent sign of appliance interference with eating, and remained friendly despite the repeated injections of pentobarbital sodium.

Examination of the serial record models in all cases revealed distal movement of the crowns of the maxillary cuspids accompanied by mesial movement of the root apex, with the center of rotation located within the root.

Comparisons of the experimental tooth movement versus control tooth movement in each animal are seen in Table 1.

On average, gingival surgery resulted in 108% more distal crown movement, 11% more mesial root movement, and a center of rotation 2.9mm closer to the root apex.

Statistical analysis with a three-way cross-classification analysis of variance showed the response among the individual animals to be significantly different with regard to crown movement, root movement and center of rotation, all with $P < .001$.

The week-to-week values of both crown movement and root movement were found to change significantly in linear fashion ($P < .001$), but there were no significant changes in the center of rotation.

The response to gingival surgery was not found to be the same for all animals with regard to either crown movement ($P < .005$), root movement ($P < .025$) or the center of rotation ($P < .001$). A good example of this is the great difference in gingival and apical response seen in animal number four compared with the marked similarity in animals three and five.

After the first two weeks, the rate of mesial root movement decreased. The animals were found to respond differently from week to week with regard to root movement ($P < .025$), but not in crown movement or center of rotation.

Gingival surgery resulted in significantly more crown movement and centers of rotation positioned more apically ($P < .001$), but differences in mesial movement of the apex were not statistically significant.

The difference in crown movement of the experimental teeth versus

TABLE 1

Difference in Experimental Tooth Movement Compared to Control Tooth Movement in Each Animal

Animal	*Additional Distal Crown Movement*	*Additional Mesial Root Movement*	*Center of Rotation Nearer to Root Apex*
1	56%	29%	2.3mm
2	328%	—33%	6.3mm
3	44%	38%	1.7mm
4	200%	8%	3.7mm
5	—11%	—9%	—0.2mm
Mean	108%	11%	2.9mm

crown movement of the control teeth was found to progressively increase each week ($P < .005$). However, there was no such change in either root movement or center of rotation.

Histologic Examination of the Control Cuspid

Histologically, the specimen revealed collagen fibers attached directly into cementum below the epithelial attachment.

On the mesial aspect, a few of the smaller fibers extended coronally parallel to the inner marginal epithelium, but most extended horizontally and appeared taut. Below these superficial fibers, very coarse collagen fibers extended horizontally over the crestal bone. These fibers also appeared taut and presumably belonged to the transseptal group of fibers.

On the distal aspect, a larger number of the more superficial fibers ran vertically, parallel to the inner marginal epithelium. The vertical orientation of these fibers gave the marginal gingivae a compressed appearance. The transseptal fibers, however, appeared taut, much like the transseptal fibers on the mesial aspect of the tooth.

Areas of periodontal ligament compression and bone resorption were observed adjacent to the distal root surface near the alveolar crest, and adjacent to the mesial root surface near the apex. Conversely, areas of periodontal ligament tension and bone apposition were found adjacent to the distal root surface near the apex and adjacent to the mesial root surface near the alveolar crest.

Bone apposition adjacent to the distal root surface near the apex was osteophytic in nature. Shallow root resorption was observed on the mesial surface near the root apex.

Immediately Following Surgery

Mesially and distally, the surgical incision extended from the gingival sulcus past the alveolar crest and into the periodontal ligament space. On the mesial aspect, a line of scar tissue was seen adjacent to the fresh incision.

In contrast to the taut appearance of the transseptal fibers seen in the control tooth specimen, the transseptal fibers did not appear to be under tension.

There was more gingival vascularity on the distal aspect.

Root resorption was also observed on the distal aspect. The area of resorption was shallow and extended to the depth of the incision. Crestal bone height, periodontal ligament areas of tension and compression, and apical root resorption were similar to those in the control tooth specimen.

One Week Post-Surgery

Free gingival and transseptal fibers were completely reattached on the mesial aspect, and partially on the distal.

However, physiologic reorientation of these fibers was interrupted by scar tissue formation. The mesial gingival fibers lacked definite orientation. On the distal aspect, proportionately more fibers were vertically oriented, giving an impression of greater tissue compression.

A high degree of vascularity was found in both the mesial and distal marginal gingivae.

Crestal bone height, especially on the mesial, appeared lower than in either of the other two specimens.

Root resorption was observed adjacent to the distal alveolar crest.

Periodontal ligament areas of compression and tension, and apical root resorption were also similar to those seen in the control specimen.

Discussion

The findings of this study showed that, on the average, surgical elimination of gingival attachment doubled the rate of distal crown movement without significantly increasing the rate of mesial movement of the root apex. This resulted in the centers of rotation being located an average of 2.9 millimeters closer to the root apex.

The fact that the center of rotation was found to be located within the root is in agreement with the findings of numerous other investigators.[14,15,17-23] However, the center of rotation of the control cuspids was found to be nearer the level of the alveolar crest than has been previously reported. The center of rotation of the control tooth in each animal was within the coronal half of the root, and 3 of the 5 were near the alveolar crest itself.

The wide variation in response among individual animals was similar to that reported by Utley,[15] who also retracted maxillary cuspids in cats. This wide range of individual variation was expected, since the animals were not litter-mates and not of the same sex. However, since each animal had both an experimental cuspid and a control cuspid, each served as its own control.

The histologic appearance of gingival connective tissue anatomy reported in this study is in complete agreement with the description of the gingival fibers reported earlier by Miake *et al.*[24] The compressed appearance of the distal marginal gingivae of the control tooth is in agreement with the description of gingival compression reported by Atherton.[25] However, it appeared that only the more superficial collagen fibers were affected, while the deeper transseptal fibers appeared normal.

Microscopic examination also revealed that surgical procedures may have resulted in some reduction of crestal bone height. If this is true, surgically-induced bone resorption could account for at least some of the observed differences in tooth movement.

In the clinical practice of orthodontics, gingival surgical procedures are currently being used to enhance post-treatment stability of tooth position. On a purely theoretical basis, the use of gingival surgical procedures to facilitate active tooth movement might be proposed. One might expect that surgical elimination of gingival attachment would be especially advantageous in conjunction with difficult anchorage problems and to facilitate tooth movement through very fibrous gingivae.

The appropriateness of such gingival surgical procedures during active orthodontic treatment is still open to question. Gingival fibers were found to be reattached one week after surgery, and frequent surgical procedures would certainly present additional patient management problems.

Even on a limited basis, the effects on the epithelial attachment and crestal bone require further study. The consequences of scar formation within the gingival and periodontal tissues, the risk of root resorption secondary to surgical trauma, and the effect of plaque accumulation all raise serious questions.

Obviously, there are many unanswered questions concerning the nature of gingival forces, what we are capable of doing about them, and what the consequences would be if something were done.

It is hoped that the desire to answer these questions will stimulate further research into the effects of the gingivae on orthodontic tooth movement.

Conclusions

1. Significantly more distal crown movement was found with surgical elimination of gingival attachment.
2. Mesial movement of the root apex was not affected by surgical elimination of gingival attachment.
3. The center of rotation was significantly closer to the root apex with surgical elimination of gingival attachment.
4. Although it appears that surgical elimination of gingival attachment facilitates orthodontic tooth movement, it is not recommended that this be done on human subjects due to gingival and periodontal scarring, root resorption and inadequate knowledge of the consequences of such procedures on the overall health of the cementum and periodontium.
5. Consideration of the variable inhibiting effects of gingival tissue on tooth movement could be helpful in treatment planning.

References

1. Boese, L. R.: Increased stability of orthodontically rotated teeth following gingivectomy in Macaca nemestrina. Am. J. Orthodont., 56:273-290, Sept. 1969.
2. ———. A surgical procedure to eliminate rotational relapse. Am. J. Orthodont., 57:35-46, Jan. 1970.
3. ———. The prevention of relapse in extraction cases. Am. J. Orthodont., 60:128-141, Aug. 1971.
4. Erikson, B. E., Kaplan, Harry, and Aisenberg, M. S.: Orthodontics and transseptal fibers: a histological interpretation of repair phenomena following the removal of first premolars with retraction of the anterior segment. Am. J. Orthodont. and Oral Surg. (Orthodont. Sect.), 31:1-20, Jan. 1945.
5. Strahan, J. D., Mills, J. R. E.: A preliminary report on the severing of gingival fibers following rotation of teeth. Dent. Pract. and Dent. Rec., 20:101-102, Nov. 1970.
6. ———, Myers, H. I., Waterman, J. N., and Flanagan, V. D.: Preliminary macroscopic observations concerning the potentiality of supra-alveolar collagenous fibers in orthodontics. Am. J. Orthodont., 44:485-497, July 1958.
7. Wiser, G. M.: Resection of the supra-alveolar fibers and the retention of orthodontically rotated teeth. Abstr. Am. J. Orthodont., 52:855-856, Nov. 1966.
8. Aisenberg, M. S.: The tissues and changes involved in orthodontic tooth movements. Am. J. Orthodont., 34:854-859, Oct. 1948.
9. Breitner, Carl.: Bone changes resulting from experimental orthodontic treatment. Am. J. Orthodont. and Oral Surg., 26:521-547, June 1940.
10. Burket, L. W.: The effects of orthodontic treatment on the soft periodontal tissues. Am. J. Orthodont., 49:660-671, Sept. 1963.
11. Edwards, J. G.: A study of the periodontium during orthodontic rotation of teeth. Am. J. Orthodont., 54:441-461, June 1968.
12. Reitan, Kaare: Tissue behavior during orthodontic tooth movement. Am. J. Orthodont., 46:881-900, Dec. 1960.
13. Thompson, H. E.: Speculations on the potentialities of connective tissue fibers. Am. J. Orthodont., 41:778-789, Oct. 1955.
14. Burstone, C. J.: The biomechanics of tooth movement. p. 197-213. (In Kraus, B. S., and Riedel, R. A., ed.) Vistas in Orthodontics. Philadelphia, Lea & Febiger, 1962, 397 p.
15. Utley, R. K.: The activity of alveolar bone incident to orthodontic tooth movement as studied by oxytetracycline-in-

duced florescence. Am. J. Orthodont., 54: 167-201, Mar. 1968.

16. Shapiro, H. H.: Growth in the dental arches of the cat: a daily study from birth through one year of development. Dent. Res. J., 17:349-357, Mar. 1938.
17. Angle, E. H.: The Angle system of regulation and retention of the teeth. Philadelphia, S. S. White, 1897. 111 p. (p. 30).
18. Haack, D. C., and Hafts, E. E.: An analysis of stress in a model of the periodontal ligament. Internat. J. Engineer. Science, 10:1093-1106, 1972.
19. Johnson, A. L., Appleton, J. L. and Rittershofar, L. S.: Tissue changes involved in tooth movement. Internat. J. Orthodont., Oral Surg. and Radiog., 12: 889-898, Oct. 1926.
20. Moyers, R. E., and Bauer, J. L.: The periodontal response to various tooth movements. Am. J. Orthodont., 36:572-580, Aug. 1950.
21. Sandstedt, C.: Some contributions to the theory of regulation of the teeth. Nordic Dent. J., 5: 236-252, 1904.
22. Schwarz, A. M.: Tissue changes incidental to orthodontic tooth movement. Internat. J. Orthodont., Oral Surg. and Radiog., 18:331-352, Apr. 1932.
23. Storey, E.: Bone changes associated with tooth movement: a radiographic study. Aus. J. Dent., 57:57-64, 1953.
24. Miake, K., Shohei, H., and Nomura, H.: Changes in development of the elastic fibers in gingiva of cat with the growth of tooth. Bu. Tokyo Dent. Col., 6:93-111, Nov. 1965.
25. Atherton, J. D.: The gingival response to orthodontic tooth movement. Am. J. Orthodont., 58:179-186, Aug. 1970.

Maxillary Dentition

Many previous mixed dentition studies have evaluated the effects of extraoral traction in the treatment of