A METHOD OF EVALUATION

OF

ROOT RESORPTION

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INTRODUCTION

The occurrence of root resorption in permanent teeth has interested many investigators, particularly in relation to orthodontic treatment. Ever since the problem of root resorption was officially presented to the dental profession by Ketcham[8] in 1927, the etiologic cause of this condition has been a source of considerable contention. The type of appliance,[8,22] degree of force used[17,19,20] and various endogenous factors[2,13] have all been suspected of being related to the resorptive process. It is generally accepted today that cementoclasts and dentinoclasts fulfill the identical role in root resorption that osteoclastic activity does in resorption of bone. The evidence indicates that root resorption does occur as a result of orthodontic appliance forces and that in extreme cases there may be an associated metabolic factor.[2,22]

Orthodontists have assumed that the presence of root resorption as a sequel to orthodontic therapy was frequently to be expected, but that careful appliance manipulation could minimize loss of root structure.[5,18] The usual evaluation has been based on the amount of apical root loss as determined by pre- and post-treatment periapical x-ray surveys. It is not possible by this method to ascertain the amount of lateral or surface resorption that occurs.[4,17] This investigation was designed to permit a study of lateral root resorption in the miniature swine by means of transverse serial histologic sections. A primary objective of this pilot study was to develop a technic for quantitating the amount of root loss in teeth subjected to orthodontic appliance forces.

REVIEW OF LITERATURE

Prior to 1927, there appeared many case reports and articles regarding root resorption, then referred to as "root absorption." The resorption of permanent teeth was first mentioned by Bates[1] in 1856. He stated the cause to be trauma to the periodontal membrane. Following this report, numerous others appeared in the literature, mainly describing severe and bizarre types of root resorption.

Ketcham[8] was the first investigator to graphically focus the attention of the dental profession on the problem of root resorption. He made several reports covering a number of years, the final report indicating that 21 percent of 500 patients treated by himself and other orthodontists showed roentgenographic evidence of root resorption. In some cases, Ketcham showed that resorption had occurred before orthodontic therapy was begun, but was considerably more marked after completion of treatment. Maxillary anterior teeth seemed to be the most vulnerable to resorption. At first Ketcham felt that root resorption was more prevalent in cases where the pin and tube and ribbon bracket were used, but later investigation showed this not to be the case.[9]

In the 1930's, Marshall[10,11,12] performed some experimental studies on monkeys and found histologic evidence of root resorption when orthodontic appliances were placed, even though resorption was not apparent radiographically. He found that animals maintained on a diet deficient in vitamin A were more likely to develop root resorption.[13] Marshall concluded that the type of appliance was not as important as diet and the amount of pressure applied; however, the relationship of dietary factors to root loss has not been substantiated.

Becks[2] observed that heavy orthodontic forces did not cause root resorptions in some patients, while lighter forces sometimes produced a large amount of resorption in others. From this, he concluded that a certain amount of the root resorptions observed following orthodontic treatment was not a direct result of the appliance, but due primarily to associated metabolic disturbances. In 1936, Becks[2] reported a study on 100 patients with extensive root resorption. Fifty of these patients had been treated orthodontically and 50 had not. Forty-six of the treated and 40 of the non-treated cases had a co-existent endocrine disturbance, usually diagnosed as hypothyroidism.

These findings should not be interpreted as a true cause and effect relationship since the incidence of hypothyroidism reported by Becks[2] is much too high, a result of the unreliability of the diagnostic methods used at that time. Also, as Becks[3] later stated: "The mere frequency with which endocrinopathies are found in patients with root resorption does not permit as yet any conclusion that these conditions have produced the resorption."

In 1936, Rudolph[19] reported that the incidence of root resorption in permanent teeth was as high as 75 percent after two years of orthodontic therapy. When treatment extended over longer periods of time, the frequency of root resorption reached 100 percent. Only five percent of a similar age control group (7 to 21 years) that had not been treated orthodontically showed root resorptions. He also stated that orthodontic treatment is less hazardous to the root structure when it is initiated at an early age. Although it is not stated in his paper, it is fairly certain that Rudolph, as did Ketcham, reported only obvious resorptions as evidenced by an x-ray picture of markedly foreshortened roots.

The explanation for the high incidence of resorptions reported by Rudolph is probably related to the conditions of treatment. The patients were treated by undergraduates without clinical orthodontic experience; treatment concepts and use of appliances differed; and finally, evaluation of root resorption was not made by one individual but by several members of the orthodontic staff.

Hemley[5] reported a study in 1941 of 195 orthodontically treated patients, including 121 that were started and completed by the same student. Forty-two (21.5 percent) of the 195 cases treated showed some degree of root resorption.

It is interesting to note that this is almost exactly the percentage reported by Ketcham (21 percent), although comparisons are difficult to draw because Hemley did not state the types or methods of application of appliances used. Of a total of 4,959 teeth exposed to orthodontic therapy, 172 (3.5 percent) showed some degree of root resorption. Only eight teeth (0.2 percent) in this group had as much as approximately one-third of the root involved and none had a loss of more than one-third of the root. Hemley concluded that: "The incidence of root resorption can be reduced to the extent that it need not be regarded as a hazard to orthodontic treatment."

The problem of root resorption was attacked histologically by Henry and Weinmann,[6] who, in 1951, reported a quantitative study of the resorption pattern of cementum of permanent teeth. They found that 90.5 percent of the 261 teeth examined histologically showed areas of resorption, most of which had undergone repair. Contrary to the views of earlier investigators, they found no evidence that inflammation, per se, caused resorption. There was little or no cementum resorption in the gingival third of the root, although periodontal and gingival inflammation was common in this region. The most common site of resorption areas (76.8 percent of the total) was at the apex of the root where no inflammatory changes could be seen. Henry and Weinmann concluded that it is normal for a tooth to incur some degree of resorption during its life and that trauma appeared to be the most important local factor in the production of resorption.

Massler and Malone[14] studied the resorption potential of permanent teeth by analyzing the frequency and severity of root resorptions in 708 sets of full-mouth roentgenograms of complete dentitions. None of the patients had undergone orthodontic therapy. In the second part of the study, full-mouth roentgenograms of 81 patients who had been treated orthodontically were examined.[15] In the first group, 100 percent of the patients and 86.4 percent of the teeth examined showed some evidence of resorption under 3 x magnification. No reason for the resorption was obvious in 81.2 percent of the involved teeth (idiopathic resorption). The authors stated that the number and severity of the resorptions were markedly increased in the orthodontically treated group. Massler and Malone concluded that a definite resorptive potential is inherent in the permanent teeth of all persons. A concurrent report by Massler and Perreault[16] indicated that the resorption potential of the permanent teeth is higher in young adult females that in males.

One of the most comprehensive studies of root resorption due to orthodontic therapy was reported by Phillips[18] in 1955. The results of this investigation are contrary to many generally accepted conclusions drawn by authors in the past. Before and after treatment, intra-oral x-rays and lateral cephalometric head films were used to compile pertinent data for statistical evaluation. No significant correlation of apical root resorption with reference to sex, age of patient and length of treatment was found. In addition, the amount of apical root loss was not related in any way to the amount of tooth movement. A surface area study was also done on maxillary incisors to illustrate the effect that apical root loss has on the amount of root surface area left for periodontal ligament attachment. It was determined that a 2 mm. loss of apical root structure leaves 10 percent less area for periodontal attachment. However, the planimetric method used introduced an error of approximately 10 percent into the measurements involved.

In summary, many of the views presented in the literature appear to have little real evidence to support them. In the light of our present knowledge there is apparently no connection between the resorptive process and length of treatment, amount of tooth movement through bone or age and sex of the patient. The majority of investigators now regard loss of apical root length or root surface area as not being clinically significant unless the loss is extreme. More accurate methods of evaluating root resorption are necessary to permit reliable determination of total root structure loss occurring under orthodontic tooth movement.

PROCEDURE

The histologic sections used in this project were obtained from a tooth movement study conducted in the Department of Anatomy of the University of Oregon Dental School. This previous investigation utilized three adult male miniature pigs of the Pitman-Moore strain. The second, third and fourth premolars and first permanent molar were banded in one mandibular posterior quadrant. A sectional edgewise orthodontic appliance was fabricated and adjusted to effect rotation of the third premolar tooth, using a force typical of that applied in clinical orthodontic procedures. The opposite mandibular quadrant served as a control. The appliance was activated at three-week intervals throughout the study and discontinued after 63 days when it was observed that clinical tooth movement had occurred.

Teeth and a surrounding block of bone were removed, fixed in Lavdowsky's solution, decalcified and embedded in celloidin. Transverse 12 micron sections of the rotation block and its opposite quadrant control were cut on a sliding microtome. Every twentieth section was mounted and stained with hematoxylin and eosin.

In addition to histologic examination of representative experimental and control sections, the amount of root structure loss was determined by comparing the root volume of the rotated tooth with the within animal control. Mesial and distal root cross-sections were selected at approximately 800 micron intervals from both experimental and control teeth. The exact distance varied because of the necessity of obtaining an artifact-free section. Both the experimental and control series began at the level of the root bifurcation and extended as far apically as possible for an equal distance. There were 21 sections in each series; however, the shorter distal root extended through only 15 sections of both rotated and control teeth. These sections represented approximately 17 mm. of mesial root and 13 mm. of distal root from the experimental and control teeth.

The area of each cross-section was obtained by tracing a ray-o-scope projection on frosted acetate paper, cutting it out, and weighing the cut-out section on a Mettler analytic balance, the weight per square centimeter having been previously determined. Projection enlargement was determined with the aid of a stage micrometer. An unbiased sample of 16 representative sections was analyzed by the double determination method to obtain an estimate of reliability. $\left(SEMeas. = \sqrt{\frac{\Sigma d^2}{2N}}\right)$

Volume determinations were made by considering each root as a series of non-circular conical frustums, their bases formed by the transverse sections of known area. The amount of root structure between each cross-section and the next was thus computed using the formula $V = 1/3h(B + \sqrt{BB'} + B')$, where B and B' represent the areas of the upper and lower bases, respectively, and h the perpendicular distance between them.

The total volume between the first and last sections of each root was then easily obtained by adding the between-section volume increments.

RESULTS

Histologic examination of the control sections revealed a rather thick layer of cellular cementum surrounding the dentin of the tooth. A large number of local resorption areas were evident and were not confined to any particular surface of the root. Osteoclastic and osteoblastic activity on the mesial and distal alveolar walls, respectively, indicated a pattern of mesial tooth drift. Epithelial rests were found close to the root surface in the hematoxylin and eosin-stained control sections.

The experimental sections were characterized by the presence of severe root resorption in all areas of the root (apical, middle and cervical thirds). This root resorption was found principally opposite areas of pressure and had frequently penetrated into the dentin of the tooth. Heavy osteoclastic activity was generally found opposite areas of resorption. Where the cementum was still intact, an outer layer of cementoid tissue was frequently apparent. The periodontal ligament space was widened and in some sections there was evidence of hemorrhage into the space. Epithelial rests which were readily visible in the control slides appeared to be less frequently observed in the experimental sections.

Results of the root-volume studies of the control and rotated teeth are summarized in Table 1. It is immediately evident that the mesial and distal roots of the rotated tooth exhibited striking agreement in the proportions of root structure that were lost due to resorption. This is true not only for the total root lengths under consideration (approximately 17 mm. for the mesial root and 13 mm. for the distal root) but also when the cervical, middle and apical regions of the roots were compared.

The total loss of root structure in both roots of the rotated tooth as compared with the control was 45 percent. Approximately 40 percent of this loss occurred in the cervical third, 36 percent in the middle third, and 24 percent in the apical third of the roots. When root loss is expressed as a percentage of the control by region, there is 37 percent less root structure in the cervical third, 50 percent less in the middle third, and 59 percent less in the apical third of the roots of the rotated tooth as compared with the equivalent thirds of the control tooth roots.

The standard error of the measure in determining transverse section areas was 0.0778 square millimeters, or approximately 0.65 percent for the average root cross-section. Assuming that the SEMeas. was calculated from an unbiased sample, the percentage error is of comparable magnitude for root volume expressed in cubic millimeters.

TABLE 1

	Mesial Root (17 mm)				Distal Root (13 mm)			
	Cervical	Middle	Apical	Total	Cervical	Middle	Apical	Total
Control (mm^3)	126.90	78.84	44.15	249.89	109.40	80.01	41.77	231.18
Rotation (mm^3)	79.83	39.43	18.03	137.29	68.75	39.35	17.03	125.13
Root loss (As % of Control)	37%	50%	59%	45%	37%	51%	59%	46%
Root loss (As % of Total)	42%	35%	23%		38%	38%	24%	

DISCUSSION

One of the main purposes of this investigation was to develop an accurate method for determining the amount of root loss that occurs as a result of orthodontic tooth movement. The results of this pilot study indicate that under certain conditions root resorption may lead to the loss of a greater amount of root structure than has generally been acknowledged.

This project was limited to an investigation of root resorption due to rotation movement and utilized serial sections cut in the horizontal plane. In addition to being easily adaptable to computation of root volumes, serial transverse root sections have several other advantages. A representative picture of the pattern of root resorption is provided; histologic sections of teeth are probably more accurate when cut in the horizontal plane; and comparisons of the cervical, middle and apical segments of experimental and control teeth are facilitated.

The large proportion of root loss demonstrated in this study is probably due not only to the apparent severity of root resorption found in the miniature swine, but also to the type of tooth movement employed. Resorption along the entire length of root below the alveolar crest is not unexpected in rotation movement, where the fulcrum approximately coincides with the long axis of the tooth and many points along the surface are exposed to pressure.

In addition to the marked resorption found in the rotated tooth, cementum resorption was histologically apparent in the control. It may be that the heavy bruxism to which the pig is subject was responsible for this condition, or perhaps tooth movement in one quadrant affected the occlusal forces in the opposite quadrant a sufficient amount to cause root resorption. Another possible explanation is that the cellular cementum in the pig is less resistant to resorption than the alveolar bone and therefore is the first structure to be affected. In any case, traumatic incidents and subsequent root resorption probably are so frequent that some degree of resorption of the control roots should be regarded as within normal range.[6,15]

For purposes of comparison, it was necessary to assume that the roots of the rotated premolar in one quadrant were the same size before movement as the roots of the control premolar in the opposite quadrant. However, the amount of root loss appeared great enough to outweigh any slight tooth size discrepancy that may have been initially present. An additional source of controversy may lie in the choice of the root bifurcation, rather than the alveolar crest, as a reference point for measuring root length. Since the assumption that rotated and control teeth were originally equal in size was considered valid, it appeared logical to use an aspect of tooth morphology as a reference point. In addition, the amount of surface resorption that occurred in the cervical region of the rotated tooth indicated that the level of the alveolar crest was likely to be relatively unstable.

The method error of the tracing, cutting and weighing of the acetate sections to determine root cross-sectional areas was less than one percent, far surpassing the reported five to ten percent error introduced by use of the compensating planimeter. Other potential sources of error, such as variation in section thickness and the distance between mounted sections were not under our control.

It is not possible to reach many conclusions as to the clinical significance of this study on the basis of the results from one experimental animal. The miniature swine appears to be a good animal in which to study root resorption and has the additional advantage of having root morphology similar to that of human teeth. Future studies of a larger sample of animals should include tipping and bodily tooth movements and the elimination of occlusal forces as the potential cause of root resorption.

SUMMARY AND CONCLUSIONS

1. A method of evaluating root resorption utilizing transverse serial histologic root sections has been presented. A marked amount of root structure was demonstrated to have been lost following experimental tooth movement in the miniature swine.

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