Factors related to root resorption in edgewise practice

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Root resorption associated with orthodontic treatment has been recognized as a clinical problem since the 1920s,[1] but only in recent years has it been understood that some resorption occurs in almost every patient.[2] Kennedy et al.[3] demonstrated that in children treated for Class I crowding, the roots of all teeth were 1-2 mm shorter in patients who had fixed appliance treatment than in patients with serial extraction alone. Linge and Linge[4] showed that less resorption is observed in patients treated before age 11, perhaps due to a preventive effect of the thick layer of predentin on young undeveloped roots. They suggested that resorption could be avoided if tooth movement was completed before the roots were fully developed, but treatment at this age is impossible for many patients.

Remodeling of both the cementum and dentin of tooth roots occurs when orthodontic forces are applied. The cementum, however, is restored during periods of relative quiescence so that for most teeth in most patients, the changes in root length are so small as to be difficult to detect, and are clinically insignificant.[5] In a smaller number of patients, obvious shortening of the roots of some teeth occurs. Maxillary incisors have been reported to be the most susceptible to this severe resorption, with other teeth less affected.[6]

A number of treatment factors have been implicated. Several investigators have suggested that the length of active treatment is not related to the chance of severe resorption;[2,7] more recently, others have shown that the longer the active treatment time, the greater the chance of severe resorption.[8,9] The magnitude of force may or may not be a factor. Both Reitan[10] and Wainwright[11] suggested from histologic studies that uncontrolled tipping was particularly likely to cause resorption because of high stress levels in the periodontal ligament. Although Wainwright[11] did not find resorption when teeth were moved through the cortical plate in mon-

Abstract

In a series of 200 consecutively debanded patients receiving comprehensive orthodontic treatment with the edgewise appliance, six (3%) showed severe resorption (greater than one-quarter of the root length) of both maxillary central incisors. For other teeth, resorption of this extent occurred in less than 1% of the patients. Using a case-control design, the characteristics of 21 patients with severe resorption were compared to randomly selected controls from the case series. There were significantly more Class III patients among the severe resorption cases than would have been expected. Risk indicators for resorption that were related to treatment procedures included approximation of the maxillary incisor roots against the lingual cortical plate (odds ratio 20), maxillary surgery (odds ratio 8), and root torque (odds ratio 4.5).

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Key Words

Root resorption • Risk indicators

Figure 1
Photographs illustrating three of the categories of root resorption. (A) Slight blunting — Category 1; (B) Moderate blunting — Category 2; (C) Excessive blunting — Category 3.

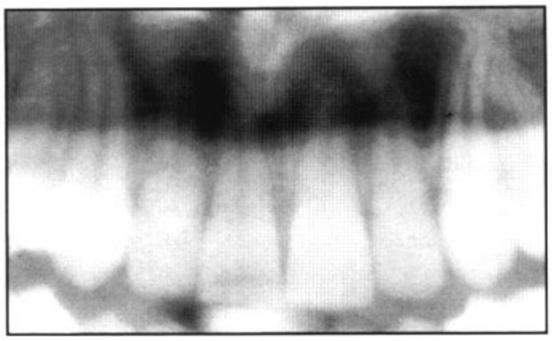

Figure 1A

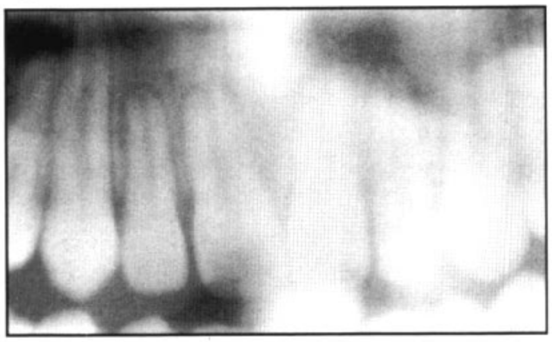

Figure 1B

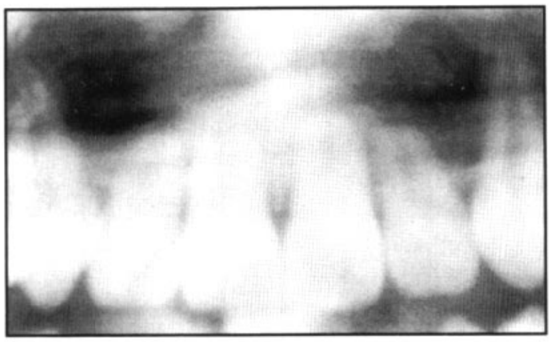

Figure 1C

keys, Ten Hoeve and Mulie,[12] Goldson[13] and Hickham[14] have reported that contact of maxillary incisors with the lingual cortical plate may predispose to resorption. Other clinical factors related to the type of malocclusion, type of tooth movement (especially "jiggling" movements), and presence of trauma or habits have been discussed as possible factors, without convincing evidence.[5]

This investigation had two purposes: (1) to survey, using a case series approach, consecutively treated cases in a reasonably typical edgewise practice to determine the prevalence of severe resorption; and (2) to estimate the risk of resorption associated with pretreatment and treatment characteristics using a case-control design.

Materials and methods

For the case series, panoramic radiographs prior to and immediately after treatment for the most recent 200 consecutively debanded orthodontic patients in the private practice of the senior author were reviewed to determine the amount of resorption, if any, that occurred during active orthodontic treatment. The examination focused on the roots of the maxillary central and lateral incisors, mandibular central incisors, and both maxillary and mandibular second premolars, because these have been reported to be the most commonly affected.[6] The teeth were scored using the following four categories suggested by Sharpe et al.[15]:

0 = No apical root resorption

1 = Slight blunting of the apex root (Figure 1A)

2 = Moderate blunting of the root apex up to one-fourth of the root length (Figure 1B)

3= Excessive blunting of the root apex beyond one-fourth of the root length (Figure 1C)

The same Retter pan oral and BF Wehmer cephalostat machines were used to obtain all the panorex films and cephalograms used in the case series and case control study and there were no changes in the practice protocol for obtaining films. However, there was no specific attempt to standardize patient position and several operators were responsible for taking films.

Demographic information (age at start of treatment, sex, race), pretreatment diagnostic information, and treatment information were obtained on all patients from a chart and record review (Table 1). Cephalometric radiographs, taken at the start of treatment and immediately after debanding, were also studied to determine the amount and direction of movement of the maxillary and mandibular incisors. The same rater evaluated all records and radiographs. Although a training period did occur, replicate measurements were not made; therefore, intra-examiner agreement statistics are unavailable.

The same rater then reviewed all the other finished fully-banded orthodontic cases with complete records and readable radiographs to find patients who had experienced severe (Category 3) root resorption on both of the maxillary central incisors during treatment. A total of 21 such cases were found, six subjects in the 200 consecutively debanded cases (3% prevalence) and 15 from the other 376 debanded cases reviewed (4% prevalence).

A case control study was designed in order to compare the pretreatment diagnostic measures and treatment factors (Table 1) of those with severe resorption on the maxillary central incisors (cases) and those without (controls). Each of the 21 cases was matched with three control patients, selected out of the 194 remaining patients in the case series. The three control patients per case were randomly selected from those of the same sex, race and duration of

Table 1
Measures obtained from review of patient records

Diagnostic	Operational definition
Angle classification	First molar relationship (I, II or III)
Overbite	Vertical overlap (mm)
Overjet	Horizontal overlap (mm)
Openbite	Lack of any incisor overlap (yes/no)
Crossbite	Unfavorable buccal-lingual relationship of opposing teeth (yes/no)
Crowding	Mesial-distal overlap of at least 2 teeth (yes/no)
Growth pattern	Vertical = FMA > 30 and SNMP > 35 Down and forward = 20 < FMA < 30 and 25 < SNMP < 35 Horizontal = FMA < 20 and SNMP < 25
Previous trauma	An accident to at least 1 tooth (yes/no)
Previous resorption	Blunting of any root prior to treatment (yes/no)
Treatment	
Lingual plate approx.	Contact of any tooth against cortical plate (yes/no)
Interarch elastics	Worn during treatment (yes/no)
Headgear	Any type of headgear during treatment (yes/no)
Extractions	Loss of any tooth for treatment reasons (yes/no)
Tipping movements	Movement of tooth crown with root apex as point of rotation (yes/no)
Translation	Bodily movement of tooth through bone (yes/no)
Round-tripping	Movement of tooth in one direction and then reversed (yes/no)
Root torque	Movement of root through bone but incisal edge remains in same position (yes/no)
Intrusion	Movement of tooth into bone (mm)
Extrusion	Movement of tooth out of bone (mm)
Angulation change	Change in long axis of tooth (degrees)
Rectangular archwire	Number of months of wear

treatment (+/- 1 year). Thus, a total of 63 patients were included in the control group. All of the 84 patients underwent full comprehensive orthodontic treatment with the .022 slot edgewise appliance, except one patient in the severe resorption group who had a complete upper edgewise appliance, but only a lip bumper in the lower arch.

Mantel Haenszel statistics[16] were used to compare the outcome measures of the two groups. The general association statistic was calculated to see if there was a difference between the two groups in the proportionality of outcomes with nominal responses, and the row mean score statistic was calculated to see if the two groups differed in the median values of outcome measures with continuous responses. Level of significance was set at .05.

Results

Case Series Report

Of the 200 consecutively debanded patients, 61% were female and 94% were Caucasian. The

Table 2
Percentage of patients in the case series showing the 4 categories of root resorption

	Category			
Maxillary teeth	0	1	2	3
Right central incisor	8	45	44	3
Left central incisor	8	44	43	4
Right lateral incisor	14	47	37	3
Left lateral incisor	14	48	36	3
Right second premolar	51	45	4	0.5
Left second premolar	51	45	4	0.5
Mandibular teeth				
Right central incisor	16	63	20	0.5
Left central incisor	16	64	20	0.5
Right second premolar	55	38	6	0.5
Left second premolar	55	39	6	0

Table 3
The occurrence of diagnostic measures reported as percentages in the case-control study

Measure	Cases	Controls	P value
Acceptable overjet	29	51	0.001
Class I	38	54	0.003
Normal growth direction	38	60	0.06
Previous trauma	10	2	0.09
Crowding	52	76	0.10
Openbite	29	14	0.14
Crossbite	57	43	0.26
Acceptable overbite	57	59	0.32
Previous resorption	24	21	0.81

Table 4
Median values for treatment measures recorded for the case-control study

Maxillary arch	Case	Control	P value
Rectangular wire Length of wear	12 mos	3	0.05
Angulation change	10°	5	0.03
Intrusion	1 mm	0	0.97
Extrusion	1 mm	0	0.34
Retraction	1 mm	2	0.71
Mandibular arch			
Rectangular wire Length of wear	17 mos	8	0.003
Angulation change	5°	5	0.35
Intrusion	0 mm	0	0.29
Extrusion	1 mm	0	0.19
Retraction	0 mm	0	0.11

average age at the start of treatment was 16.6 years and patients ranged in age from 11 to 48. Seventy percent of the patients were between 10 and 15 years old at the start of treatment. The average length of treatment was 34 months (range 18 to 64 months).

The percentage of patients in the case series for each category of resorption for each tooth scored is given in Table 2. Approximately 40% of these patients showed at least moderate resorption on at least one of the maxillary central or lateral incisors, while only 20% had similar levels of resorption on the mandibular central incisors. Six (3%) of the patients had severe resorption on both of the maxillary central incisors at the end of treatment. The premolars in both arches were moderately resorbed in only 6% of the patients. The mean resorption score for the maxillary teeth was 1.17 while the mean score for the mandibular teeth was only 0.87.

Case-Control Study

Of the 21 cases identified as having severe resorption on both maxillary central incisors, 12 (57%) were female and all were Caucasian. The average age at the start of treatment was 18.9 years old with a range from 11 to 40. Fifty-two percent were between 10 and 15 at the start of treatment. The matched controls were slightly younger on average (mean age = 16.2 years), but the difference in age was not statistically significant.

Pretreatment Diagnostic Measures. The distributions of the pretreatment diagnostic measures were similar for the case and control groups except for Angle classification and overjet (Table 3). There were significantly more Class III patients among the cases (24%) than would have been expected given the proportions of Angle classifications among the controls (Class III = 2%). Six (28%) of the 21 severe resorption cases started treatment with a negative overjet while nine (43%) had an increased overjet. In the control group, none of the 63 had a negative overjet while 31 (49%) had increased overjet. There was also a marginally significant difference between the two groups in the proportion of patients who had a downward and forward facial growth pattern. Sixty percent of the controls exhibited this pattern while only 38% of the cases did. Only 14% of the controls exhibited a horizontal growth pattern while 38% of the cases did.

Treatment Measures. Treatment variables appeared to have more of an effect on the occurrence of severe resorption than pretreatment measures. The cases, on average, wore rectangular archwires for a significantly longer time

Figure 2A

Figure 2B

Figure 2
Photographs illustrating the effect of lingual plate approximation on the roots of maxillary central incisors. (A) Intrusion without lingual plate approximation — Category 0 resorption. (B) Lingual plate approximation following torquing of the maxillary incisor roots — Category 3 resorption.

than did the controls (Table 4) and more frequently had torquing of the maxillary anterior teeth (Table 5). The odds ratio associated with root torquing was 4.5, indicating that maxillary incisors are 4.5 times more likely to have severe resorption if they undergo root torque. Also, the median angulation change of the maxillary incisors, regardless of the method, was significantly higher in the cases (Table 4).

The most significant measure associated with root resorption in the maxillary arch was the approximation of the maxillary incisors against the lingual or cortical plate, i.e. torquing the maxillary incisor roots against the lingual cortical plate of bone. Examination of the pre- and posttreatment cephalometric radiographs showed that in 20 of 21 cases the incisors were retracted against the lingual plate of bone (Figure 2A, B). Of the controls, almost half had lingual plate approximation (Table 5) and at least mild incisor root resorption. The odds ratio was 20, implying that a patient is 20 times more likely to undergo severe resorption of the maxillary incisors when the root apices are forced against the cortical plate. The amount of retraction, intrusion, and extrusion, and the frequency of occurrence of tipping, translation, and expansion, and the use of elastics and headgear were similar in the two groups.

A higher percentage of cases underwent both maxillary and mandibular surgery (Table 5). The odds ratio for maxillary surgery was 8, indicating that patients who underwent maxillary surgery were 8 times more likely to show severe

Table 5
The occurrence of treatment characteristics reported as percentages in the case-control study

Maxillary arch	Cases	Controls	P value
Lingual plate approximation	95	51	0.001
Torque	76	44	0.01
Extraction	62	32	0.01
Tipping	43	43	1.00
Translation	48	43	0.70
Round tripping	24	27	0.89
Elastics	95	82	0.15
Expansion	48	43	0.70
Mandibular arch			
Lingual plate approximation	90	73	0.10
Torque	67	62	0.70
Extraction	33	25	0.48
Tipping	43	65	0.07
Translation	38	22	0.15
Round tripping	24	14	0.31
Elastics	76	79	0.76
Expansion	10	27	0.10
Type of treatment			
Maxillary surgery	29	5	0.002
Mandibular surgery	24	8	0.05
Headgear	14	32	0.12

maxillary central incisor resorption. Five cases (24%) showed moderate to severe resorption throughout the entire dentition. Four of these five cases had undergone two-jaw surgery.

Discussion

Case Series

It has been reported previously that some resorption occurs in almost every orthodontic patient[2,3] and that maxillary incisors are particularly prone to resorption.[6] The findings in this study confirm both observations. Over 90% of the maxillary central incisor roots had resorption apparent on careful examination of panoramic radiographs, and the figure was nearly as high for maxillary laterals. However, over 50% of maxillary and mandibular premolar roots showed no apparent resorption.

Mild to moderate shortening of the roots as a consequence of orthodontic treatment, with loss of up to one-quarter of the root length, has no clinical significance.[17] Severe resorption, defined as loss of more than one-quarter of the root length,[15] is distressing to the orthodontist and potentially significant, but even in these patients, it is difficult to demonstrate major adverse effects. Fortunately, resorption related to treatment almost never continues once the active phase of treatment has ended. Von der Ahe[7] did not find any evidence of increased mobility in affected teeth, and Remington[17] found in his study of posttreatment cases that even the most severely affected teeth were "functioning in a reasonable manner many years after orthodontic intervention." Kalkwaf et al.[18] reported that for support of the tooth, 3 mm of apical root loss is equivalent to 1 mm of crestal bone loss, which implies that the apical portion of the root has a minor role in overall periodontal support. Nevertheless, avoiding severe resorption should be a goal of orthodontic treatment.

Case-Control Study

Case-control studies, such as this one, have the major limitation of relying on retrospective data. Therefore, the potential for information bias inherent in using records not obtained using standardized protocols should be kept in mind when interpreting these findings. The prevalence of severe maxillary resorption reported is for those cases that met the eligibility criteria for review. Information on demographic or treatment differences between those patients who met the eligibility criteria and those who did not is not available and the impact of the eligibility criteria on the generalizability of these findings is unknown. However, the case-control design is particularly suited for evaluation of potential etiologic characteristics when the outcome, such as severe root resorption, is relatively rare (3% in the case series). Although the prevalence rates in the case series and case-control study were similar (3 vs 4%), a cohort effect may be a potential confounder in this study. Fifteen of the cases were not matched to controls with similar treatment start dates since controls were only selected from the most recently debanded 200 patients (the case series). Changes in treatment approaches and techniques may impact the occurrence of severe maxillary incisor resorption.

Linge and Linge[4] found that patients who started treatment before age 11 had less root resorption than those treated later, perhaps because tooth movement was completed before root growth ended. Other investigators have suggested that resorption increases with increasing length of active treatment so that severe resorption is more likely in patients with long treatment times.[8,9] However, the cases and controls in this study were matched on duration of treatment and therefore this characteristic could not be evaluated as a risk indicator.

Two other factors[6] cited as important indicators of the possibility of severe resorption — previous trauma to the teeth and previous resorption — were not related to severe resorption. A history of trauma was present more frequently in the severe resorption cases, but the percentage difference between cases and controls was not statistically significant. Evidence of previous resorption was present as frequently in the control patients as in the cases.

Patients with acceptable overjet and Class I occlusion at the beginning of treatment were significantly less likely to have severe resorption. This probably reflects the smaller amount of tooth movement, particularly of the maxillary incisors, required in treatment of Class I problems. One might expect that the maxillary incisors would be most likely to be affected when they protrude, i.e., in Class II patients. However, Class III patients were overrepresented in the group with severe resorption. Perhaps this is related to the increased chance that proclined maxillary incisors, tipping forward in compensation for the Class III jaw relationship, will have their roots forced against the lingual cortical plate during treatment.

Contact of maxillary incisor roots with the lingual cortical plate has been emphasized previously as a contributor to resorption by Hickham[14] and by Goldson.[13] In this study, 20 of the 21 patients with severe resorption had lingual plate approximation. In the control group, 31 of 63 patients had lingual plate approximation, and almost all of these showed some incisor root resorption. Lingual plate approximation may be related directly to the other statistically significant treatment measures that we observed: maxillary incisor torque, changes in angulation, length of wear of rectangular archwires, and maxillary extractions. All of these treatment modalities increase the chance that the incisor roots will be brought back into contact with the lingual plate.

Since the amounts of intrusion and extrusion were not significant factors in root resorption, it may be beneficial to design tooth movements to avoid lingual plate approximation. For protruded and extruded teeth, particularly the maxillary incisors, this would first involve intrusion of the teeth to bring the root apices into a wider area of cancellous bone followed by retraction and torque.

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