European Journal of Orthodontics 21 (1999) 491–496

Evaluation of apical root resorption following extraction therapy in subjects with Class I and Class II malocclusions

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SUMMARY The purpose of this study was to determine the amount of root resorption during orthodontic treatment, and to examine the relationship between tooth movement and apical root resorption.

Twenty-seven Class I and 27 Class II patients treated with edgewise mechanics following first premolar extractions were selected. The following measurements were made on the pre- and post-treatment cephalograms: upper central incisor to palatal plane distance, the inclination of upper central incisor to the FH and AP planes, the perpendicular distances from the incisor tip to the AP and PTV planes, and incisor apex to PTV. The amount of apical root resorption of the maxillary central incisors was determined for each patient by subtracting the post-treatment tooth length from the pre-treatment tooth length measured directly on cephalograms. Intra-group differences were evaluated by the Student's *t*-test and inter-group differences by the Mann–Whitney *U*-test. For correlations the Pearson correlation coefficient was used.

The results show that there was a mean of approximately 1 mm ($P < 0.01$) of apical root shortening in Class I patients, but in Class II division I subjects the mean root resorption was more than 2 mm ($P < 0.001$). The inter-group differences were statistically significant. No significant correlations were found between the amount of apical root resorption and tooth inclination, or the duration of active treatment.

Introduction

It has been reported that routine orthodontic treatment increases the risk of root resorption (Massler and Malone, 1954; DeShields, 1969; Sjölien and Zachrisson, 1973; Goldson and Henrikson, 1975; Rygh, 1977; Sharpe *et al.,* 1987; McFadden *et al.*, 1989). A number of risk factors have been noted, such as the magnitude of force (Reitan, 1974), intrusion (Reitan, 1974; Harry and Sims, 1982; Dermaut and DeMunck, 1986; McFadden *et al.*, 1989), duration of active treatment (DeShields, 1969; Harry and Sims, 1982; McFadden *et al.*, 1989; Melsen *et al.*, 1989), cortical plate approximation (Kaley and Phillips, 1991), the use of rectangular archwires and Class II elastics (Linge and Linge, 1983), and overjet correction (Linge and Linge, 1991). Other documented factors associated with root resorption are apical root form (Levander and Malmgren, 1988; Mirabella and Årtun, 1995a), history of trauma to maxillary incisors, and lip and tongue dysfunction (Linge and Linge, 1991), systemic diseases (George and Miller, 1986) and metabolic factors, hormonal regulation and genetic predisposition (Newman, 1975). However, although all of these risk factors are associated with root resorption, to date there is no consensus on the effect and cause relationship.

There have been suggestions that the amount and type of tooth movement are major determinants for root resorption (DeShields, 1969; Reitan, 1974) and that extensive tooth movements may be responsible for root resorption (VonderAhe, 1973; Harris and Butler, 1992; Mirabella and Årtun, 1995a).

In the majority of the studies, apical root resorption of the maxillary incisors has been

evaluated, since there is a general agreement that incisors are more subject to root resorption than other teeth (Sjölien and Zachrisson, 1973; Newman, 1975; Hollender *et al*., 1980; Kennedy *et al*., 1983; Copeland and Green, 1986; Dermaut and DeMunck, 1986; Proffit, 1986).

The purposes of this study were to determine the incidence and degree of root resorption during orthodontic treatment, to investigate the relationship between the amount of tooth movement and root resorption, and to evaluate the effect of treatment time on apical root resorption.

Subjects and methods

The radiographs of 54 subjects were selected from the files of the orthodontic department at Hacettepe University Faculty of Dentistry. The cases fulfilled the following criteria:

1. Clear pre- and post-treatment standardized lateral cephalometric films with visible upper incisor root apex and incisal tip.
2. The presence of all incisors with no evidence or history of trauma to the anterior teeth.
3. No alteration of the incisal edges during orthodontic treatment.
4. All subjects treated by extraction of four first premolars and fixed appliance therapy. An edgewise full-banded appliance with a 0.018×0.025-inch slot was used in each treated case.
5. Two groups each containing 27 patients (16 girls and 11 boys) were established: one with Class I anterior crowding and the other Class II division 1 patients with a large overjet in the full permanent dentition.

The average ages at the start of treatment were 12.54 ± 1.88 years for the Class I treatment group and 13.61 ± 2.51 years for the Class II division 1 group.

The following measurements were made on the pre- and post-treatment cephalograms (Figure 1).

Vertical movement of the upper central incisor was determined by measuring the perpendicular distance from the incisal tip of the upper central incisor to the palatal plane (U1–pal, mm).

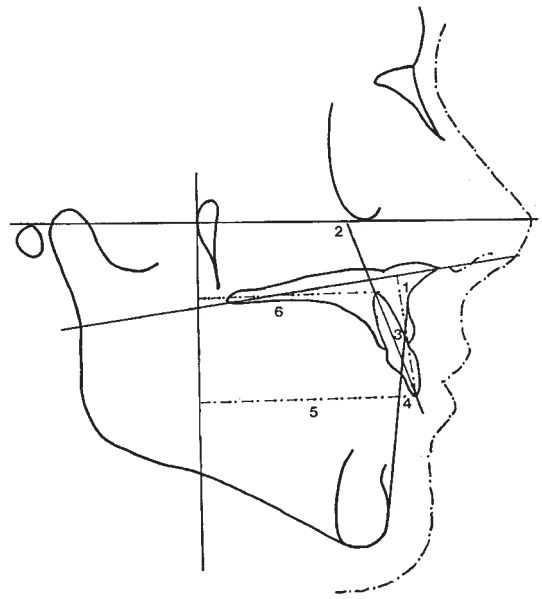

Figure 1 Angular and dimensional measurements to determine the incisor position. (1) U1–pal (mm); the perpendicular distance from the upper central incisor tip to palatal plane; (2) upper central incisor–FH angle; (3) upper central incisor–AP angle; (4) upper central incisor–AP distance; (5) U1incisal–PTV (mm); the perpendicular distance from the upper central incisor tip to PTV plane; (6) U1apical–PTV (mm); the perpendicular distance from the upper central incisor apex to PTV plane.

Inclination of the upper incisor was measured by the following angular and linear measurements:

1. U1–FH: the inclination of the upper central incisor to the Frankfort horizontal plane (degrees).
2. U1–AP: the inclination of the upper central incisor to the A–Pogonion plane (degrees).
3. U1–AP: the perpendicular distance from the upper central incisor tip to the A–Pog plane (millimetres).
4. U1incisal–PTV: the perpendicular distance from the incisal tip of the upper central incisor to the pterygoid vertical plane (millimetres).
5. U1apical–PTV: the perpendicular distance from the apical tip of the upper central incisor to the pterygoid vertical plane (millimetres).

Tooth length was measured directly on cephalograms as described by Copeland and Green (1986). The apex and incisal edges of the maxillary

Figure 2 Lateral skull cephalogram showing the callipers in place to determine the length of the incisors.

incisors were marked on acetate paper with a pinprick. The pinpricks were circled in pencil for easier location and the distance between the two marks was measured with a Helios calliper (Ganz-Gehärtet, Germany; Figure 2) to the nearest 0.02 mm. Root shortening was defined as any reduction in the length of a maxillary central incisor measured from the tip of the incisal edge to the apex of the root. The pre- and post-treatment tooth lengths were recorded for each patient. The amount of apical root resorption was determined for each patient by subtracting the post-treatment length from the pre-treatment length.

Statistical analysis

The Student's *t*-test was used to compare the means of the pre- and post-treatment measurements, and the Mann–Whitney *U*-test to determine inter-group differences. Correlations with the other parameters were calculated with Pearson's correlation coefficient.

The pre- and post-treatment tooth length measurements were made by one author, and pre- and post-treatment incisor movement by a second author in order to eliminate inter-examiner variability. Intra-examiner variability was tested by remeasuring 25 per cent of the radiographs chosen at random at least 1 week after the first recording. The means of the initial tracings and duplicate measurements were compared to determine the reliability of the procedure. No statistically significant difference was found between the means of the two measurements (Wilcoxon test, $P > 0.05$).

Results

Tables 1 and 2 show the pre- and post-treatment measurements for the Class I and Class II division 1 treatment groups. Tooth length decreased significantly in both groups ($P < 0.01$ and $P < 0.001$, respectively). Upper incisor to palatal plane distance increased significantly in the Class I treatment group ($P < 0.05$), but did not change significantly in the Class II division 1 group. In the Class I group, upper incisor inclination to FH plane did not change significantly, whereas upper incisor to AP plane angle and U1–AP plane distance significantly decreased ($P < 0.05$ and $P < 0.01$, respectively). U1incisal–PTV (mm) and U1apical–PTV (mm) did not change during orthodontic therapy. In the Class II division 1 group, the angular and linear measurements that show the inclination of the upper central incisor, U1–FH (degrees), U1–AP (degrees), U1–AP (mm), U1–PTV (mm) decreased ($P < 0.001$), whereas upper incisor apical to PTV distance did not change significantly during orthodontic therapy.

Table 3 shows the comparison of the mean differences in the Class I and Class II division 1 treatment groups. The mean root resorption was 0.98 ± 1.78 mm in the Class I group. Root shortening was more pronounced with a mean resorption of 2.08 ± 1.60 mm in the Class II division 1 group. Vertical movement of the upper central incisor did not change significantly between the groups. In the Class II division 1 group the upper incisors moved lingually with no change in the position of the apices compared with the Class I group. Correlation coefficients between root shortening and tooth inclination, and vertical movement of the incisor tooth were not significant.

The duration of active treatment was 22.3 ± 7.6 months in the Class I treatment group and 28.1 ± 9.0 in the Class II division 1 treatment group. Although the duration of active orthodontic treatment was longer in Class II division 1 group, it was not found to be correlated with the amount of root resorption.

Table 1 The measurements in the Class I malocclusion group before and after orthodontic treatment.

Class I	Before (B) and after (A)	$\bar{x}$	SD	*n*	*t*	*P* value
U1–pal (mm)	B	30.78	2.58	27	2.24	<0.05
	A	31.37	2.66	27		
U1–FH (°)	B	109.26	5.17	27	1.91	
	A	107.04	6.88	27		
U1–AP (°)	B	26.11	4.99	27	2.64	<0.05
	A	23.61	4.65	27		
U1–AP (mm)	B	6.24	1.96	27	3.53	<0.01
	A	5.07	1.63	27		
U1–PTV (mm) (incisal)	B	51.63	4.35	27	0.73	
	A	51.17	5.30	27		
U1–PTV (mm) (apical)	B	43.80	3.52	27	1.23	
	A	44.17	4.12	27		
Tooth length (mm)	B	25.75	1.97	27	2.84	<0.01
	A	24.77	2.85	27		

Table 2 The measurements in the Class II malocclusion group before and after orthodontic treatment.

Class II	Before (B) and after (A)	$\bar{x}$	SD	*n*	*t*	*P* value
U1–pal (mm)	B	31.59	2.54	27	1.60	
	A	32.39	2.88	27		
U1–FH (°)	B	111.32	9.16	27	6.37	<0.001
	A	104.04	7.70	27		
U1–AP (°)	B	33.43	7.98	27	10.17	<0.001
	A	23.02	6.12	27		
U1–AP (mm)	B	9.89	3.14	27	9.63	<0.001
	A	5.33	2.14	27		
U1–PTV (mm) (incisal)	B	54.37	5.88	27	6.18	<0.001
	A	50.80	5.73	27		
U1–PTV (mm) (apical)	B	45.04	3.41	27	0.25	
	A	45.17	4.43	27		
Tooth length (mm)	B	25.51	1.76	27	6.74	<0.00[1]
	A	23.43	1.94	27		

Discussion

The method used in this study to measure the amount of apical root resorption has been described by Copeland and Green (1986). Duplicate measurements revealed that the technique was very reliable. In the Class I treatment group, three subjects had a root elongation >1 mm. The average age of this group was 12.5 years at the start of treatment and some residual growth might have taken place. Although most of the upper incisor roots are fully developed after 11 years of age (Linge and Linge, 1983), incidents of growth followed by resorption are still possible in this age group (Linge and Linge, 1991).

Root resorption was evident in both the Class I and Class II malocclusion groups in this investigation. This is in agreement with the results of Sjölien and Zachrisson (1973), Goldson and Henrikson (1975), and Sharpe *et al.* (1987), who reported apical root resorption following orthodontic treatment with premolar extractions. Mean root resorption measurements in this study were approximately 1 mm for the Class I treatment

Table 3 Comparison of the mean differences (post-treatment—pre-treatment) in the Class I and Class II malocclusion groups.

	Class I and Class II	$\bar{x}$	SD	*U*	*P* value
U1–pal (mm)	C I	0.59	1.37	334	
	C II	0.80	2.59		
U1–FH (°)	C I	–2.22	6.06	539	<0.01
	C II	–7.28	5.93		
U1–AP (°)	C I	–2.50	4.92	606	<0.001
	C II	–10.41	5.32		
U1–AP (mm)	C I	–1.17	1.72	86	<0.001
	C II	–4.56	2.46		
U1–PTV (mm) (incisal)	C I	–0.46	3.29	557	<0.001
	C II	–3.57	3.01		
U1–PTV (mm) (apical)	C I	0.37	1.57	378	
	C II	0.13	2.65		
Tooth length (mm)	C I	–0.98	1.78	507	<0.05
	C II	–2.08	1.60		

group and 2 mm for the Class II division 1 group. McFadden *et al*. (1989) measured average root resorption as 1.8 mm, Goldson and Henrikson (1975) a maximum of 2 mm, Sjölien and Zachrisson (1973) an average of 1.2–1.8 mm, Linge and Linge (1991) as 1.5 mm, and Mirabella and Årtun (1995b) an average of 0.94 mm. The upper central incisors in the Class II division 1 treatment group showed more apical root resorption compared with the Class I treatment group in this study. VonderAhe (1973), however, found approximately the same amount of root resorption in both Class I and Class II subjects.

The amount and type of tooth movement have been suggested to be related to root resorption (Reitan, 1974; DeShields, 1969). In this study, the upper central incisors were inclined lingually in the Class II division 1 group. Thus, overjet was corrected with controlled tipping of the upper incisors with no change in the apex position. Recently, overjet correction has been considered to be a risk factor for apical root resorption (Linge and Linge, 1991). However, the controlled tipping type of root movement was not found to be related to the amount of root shortening observed in this investigation. McFadden *et al*. (1989) also observed no relationship between changes in upper incisor angulation and root shortening.

Intrusion of teeth is reported to be associated with the risk of root resorption (Reitan, 1974; Harry and Sims, 1982; Dermaut and DeMunck, 1986). The amount of tooth movement in the vertical plane was small in our sample. The maxillary central incisors were slightly extruded in the Class I malocclusion group showing a mean of 0.59 mm and in the Class II group a mean of 0.8 mm. The extrusion of these teeth probably occurred as a result of continuing growth during treatment as in the samples of McFadden *et al*. (1989), and Kaley and Phillips (1991). In this study, root shortening was not found to be correlated with the amount of vertical movement of the upper incisors. This result confirms the findings of McFadden *et al*. (1989), and Kaley and Phillips (1991) who found little, if any, relationship between intrusion and root shortening.

It is controversial whether prolonged treatment time is a risk factor for apical root resorption (VonderAhe, 1973; Dermaut and DeMunck, 1986; McFadden *et al*., 1989). DeShields (1969) and McFadden *et al*. (1989) reported that overall treatment time was significantly related to the degree of root shortening. Graber and Vanarsdall (1994) stated that the periodontal fibres surrounding the apical portion of the roots will become gradually more compressed or stretched with time, and if pressure is then exerted against any existing resorbed root areas, this may accelerate root resorption. Duration of active treatment time was slightly longer in the Class II division 1

group of this study, but no significant correlation was found between the duration of orthodontic treatment and apical root resorption. This is in agreement with the findings of VonderAhe (1973) and Dermaut and DeMunck (1986).

More root resorption occurred in the Class II division 1 group in this study, but the amount was not found to be related to the degree of tooth movement or treatment time. This may be due to the relatively small amount of tooth movement measured in these patients. Harris and Butler (1992) stated that in malocclusions that require greatest orthodontic correction, the expected amount of root resorption is greater. Accordingly, care should be taken when treating severe malocclusions that require extensive tooth movement to minimize the risk of apical root resorption.

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References

Copeland S, Green L J 1986 Root resorption in maxillary central incisors following active orthodontic treatment. American Journal of Orthodontics 89: 51–55

DeShields R W 1969 A study of root resorption in treated Class II division 1 malocclusions. Angle Orthodontist 39: 231–245

Dermaut L R, DeMunck A 1986 Apical root resorption of upper incisors caused by intrusive tooth movement: a radiographic study. American Journal of Orthodontics and Dentofacial Orthopedics 90: 321–326

George D I Jr, Miller R L 1986 Idiopathic resorption of teeth. A report of three cases. American Journal of Orthodontics 89: 13–20

Goldson L, Henrikson C O 1975 Root resorption during Begg treatment: a longitudinal roentgenologic study. American Journal of Orthodontics 68: 55–66

Graber T M, Vanarsdall R L 1994 Orthodontics, current principles and techniques. C V Mosby, St Louis

Harris E F, Butler M L 1992 Patterns of incisor root resorption before and after orthodontic correction in cases with anterior open bites. American Journal of Orthodontics and Dentofacial Orthopedics 101: 112–119

Harry M R, Sims M R 1982 Root resorption in bicuspid intrusion: a scanning electron microscope study. Angle Orthodontist 52: 235–258

Hollender L, Rönnerman A, Thilander B 1980 Root resorption, marginal bone support and clinical crown length in orthodontically treated patients. European Journal of Orthodontics 2: 197–205

Kaley J, Phillips C 1991 Factors related to root resorption in edgewise practice. Angle Orthodontist 61: 125–132

Kennedy D B, Joondeph D R, Osterberg S K, Little R M 1983 The effect of extraction and orthodontic treatment on dentoalveolar support. American Journal of Orthodontics 84: 183–190

Levander E, Malmgren O 1988 Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. European Journal of Orthodontics 10: 30–38

Linge B O, Linge L 1983 Apical root resorption in upper anterior teeth. European Journal of Orthodontics 5: 173–183

Linge L, Linge B O 1991 Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics 99: 35–43

Massler H, Malone A J 1954 Root resorption in human permanent teeth. A roentgenographic study. American Journal of Orthodontics 40: 619–633

McFadden W M, Engstrom C, Engstrom H, Anholm J M 1989 A study of the relationship between incisor intrusion and root shortening. American Journal of Orthodontics and Dentofacial Orthopedics 96: 390–396

Melsen B, Agerbæk N, Markestam G 1989 Intrusion of incisors in adult patients with marginal bone loss. American Journal of Orthodontics and Dentofacial Orthopedics 96: 232–241

Mirabella A D, Årtun J 1995a Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients. American Journal of Orthodontics and Dentofacial Orthopedics 108: 48–55

Mirabella A D, Årtun J 1995b Prevalence and severity of apical root resorption of maxillary anterior teeth in adult orthodontic patients. European Journal of Orthodontics 17: 93–99

Newman W G 1975 Possible etiologic factors in external root resorption. American Journal of Orthodontics 67: 522–539

Proffit W R 1986 Contemporary orthodontics. C V Mosby, St Louis

Reitan K 1974 Initial tissue behavior during apical root resorption. Angle Orthodontist 44: 68–82

Rygh P 1977 Orthodontic root resorption studied by electron microscopy. Angle Orthodontist 47: 1–16

Sharpe W, Reed B, Subtelny J D, Polson A 1987 Orthodontic relapse, apical root resorption and crestal alveolar bone levels. American Journal of Orthodontics and Dentofacial Orthopedics 91: 252–258

Sjölien T, Zachrisson B U 1973 Periodontal bone support and tooth length in orthodontically treated and untreated persons. American Journal of Orthodontics 64: 28–37

VonderAhe G 1973 Postretention status of maxillary incisors with root-end resorption. Angle Orthodontist 43: 247–255