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Apical root resorption after orthodontic treatment—a retrospective study

Satu Apajalahti and Jaakko Sakari Peltola
Department of Dental Radiology, Institute of Dentistry, University of Helsinki, Finland

SUMMARY The purpose of the study was to compare the incidence and severity of apical root resorption in patients treated with different orthodontic appliances and to evaluate the effect of treatment duration on the degree of apical root resorption. A further aim was to analyse the degree of apical root resorption in different tooth groups in patients presenting with root resorption.

The sample consisted of 625 patients (269 males, 356 females) aged 8–16 years at the beginning of treatment. Active removable plates and fixed appliances were used most frequently. Following exclusion of poor quality radiographs, the final sample included 601 patients (348 females, 253 males). Root resorption in all tooth groups, except third molars, was evaluated from pre- and post-treatment panoramic radiographs. The correlation of root resorption with treatment modality and duration was studied using multinomial logistic regression analysis.

Of the tooth groups, maxillary incisors showed apical root resorption most frequently, followed by the mandibular incisors. Root resorption was significantly correlated with fixed appliance treatment ($P < 0.001$). In addition, the duration of fixed appliances treatment was found to contribute significantly ($P < 0.01$) to the degree of root resorption. The mean duration of treatment in patients without root resorption was 1.5 years, whereas in those with severe resorption was 2.3 years. The most severe resorption was seen in the maxillary incisors and premolars.

It is concluded that with a long duration of fixed appliance treatment, the risk of severe resorption increases. In patients where treatment is prolonged, a 6-month radiographic follow-up is recommended.

Introduction

Root shortening as a result of apical root resorption is an undesirable consequence of orthodontic treatment. Radiographic examination of orthodontically treated patients shows some loss of root length in 48 per cent (Remington *et al.*, 1989). The maxillary incisors have been regarded as the most susceptible to root resorption, in particular those with blunt or pipette-shaped roots (Newman, 1975; Levander and Malmgren, 1988; Remington *et al.*, 1989). A 3-month radiographic control has been recommended for maxillary incisors with an enhanced risk of root resorption (Levander *et al.*, 1998).

Patient characteristics such as type of malocclusion, gender, age, root morphology, dental anomalies, and previous trauma have been suggested as possible risk factors. There is some controversy as to whether the age of the patient is related to orthodontically induced resorption (Beck and Harris, 1994; Owman-Moll and Kurol, 1998; Mavragani *et al.*, 2000). Most studies have found no significant relationship with gender, although some have shown a greater prevalence of root resorption in females (Newman, 1975; Kjær, 1995). The amount and type of tooth movement are other determinants of root resorption (Beck and Harris, 1994; Janson *et al.*, 2000). As for the type of tooth movement, intrusive force has been suggested as the most detrimental to the root in some studies (Beck and Harris, 1994). Opinions differ as to whether a correlation exists between the duration of active treatment and the incidence and degree of root resorption (Linge and Linge, 1991; Beck and Harris, 1994; Levander *et al.*, 1998; Mavragani *et al.*, 2000; Brin *et al.*, 2003).

The aim of this study was to analyse the incidence and degree of root resorption in relation to active treatment time in patients treated with different orthodontic appliances. A further aim was to analyse the degree of apical root resorption in different tooth groups, i.e. incisors, canines, premolars, and molars, in patients presenting with root resorption.

Subjects and methods

Patients

Six hundred and twenty-five children (269 males, 356 females) who had received orthodontic treatment at the Department of Pedodontics and Orthodontics, Institute of Dentistry, University of Helsinki, between 1973 and 1986 were included in the study. The same group had previously participated in a radiographic study of condylar changes in orthodontically treated children and young adults (Peltola, 1995). The mean age at the end of the treatment was 14.5 years [standard deviation (SD) 1.7; Table 1]. The patients were between 8 and 15.9 years of age at the beginning of treatment (mean 11.0 years). Active removable plates and fixed appliances were used most frequently. Most patients (82 per cent) had more than one type of appliance during

active treatment. The mean duration of the orthodontic treatment was 3.0 years (SD 1.5). The type and mean duration of active treatment are shown in Table 2. Fifty-seven per cent of patients had an angle Class I malocclusion, 37 per cent a Class II division 1 malocclusion, 2.4 per cent a Class II division 2 malocclusion, and 4 per cent a Class III malocclusion.

Methods

The radiographs were taken with an Orthopantomograph OP 2, OP 3, or Cranex DC, all of which have the same magnification. The degree of root resorption was evaluated by one author (JP) from pre- and post-treatment panoramic radiographs taken on average 0.5 years after the end of active treatment. All panoramic radiographs in which the roots were distorted and not clearly visible were rejected. Based on these criteria, 24 technically poor radiographs were rejected from the original sample. The final sample thus included 601 patients (348 females, 253 males). The post-treatment root lengths of all tooth groups, except third molars, were compared with the root lengths on the pre-treatment radiographs. In three patients in the younger age group, only the incisors and first molars were included.

Table 1 Age distribution of orthodontically treated patients at the end of treatment.

Age (years)	Male	Female	Total
8–10	3	1	4
11	4	6	10
12	21	42	63
13	42	61	103
14	71	79	150
15	75	69	144
16	29	41	70
17	16	35	51
18–19	8	22	30
Total	269	356	625
Mean age	14.4	14.5	14.5

Table 2 The type and the mean duration of treatment in years [±standard deviation (SD)] in the orthodontic patients (n = 625).

Appliance	n*	%	Mean duration of treatment (SD)
Fixed appliances	359	57	1.9 (±1.0)
Active removable plates	382	61	1.7 (±1.3)
Activator	69	11	2.0 (±1.1)
Functional corrector	11	2	1.8 (±1.4)
Headgear	338	54	1.9 (±1.1)
Chincap	38	6	3.2 (±2.5)
Extractions	309	49	
All individuals	625	3.0 (±1.5)	

*Most patients had more than one type of appliance during their active treatment.

The degree of root resorption was assessed using grades from 0 to 2 (Figure 1) with quarters as grade 1 or 2 according to the most resorbed tooth within each tooth group. A reliability test had been undertaken for control group used in the previous study of the same patients (Peltola *et al.*, 1997). The kappa values for the intra-examiner variation in dental findings were 0.75–0.9.

Statistics

A standard chi-square test was used to determine differences in the prevalence of root resorption between genders. Since most of the patients had more than one type of appliance during active treatment, the correlation of root resorption with treatment modality and duration was undertaken using multinomial logistic regression analysis.

Results

Seventy-nine (31 per cent) males and 120 (34 per cent) females developed root resorption (not significant). Root resorption was significantly ($P < 0.001$) correlated with fixed appliance treatment. Fifty-six per cent of the patients treated with fixed appliances showed root resorption. In addition, the duration of treatment with fixed appliances was found to contribute significantly to the degree of root resorption: patients with the longest treatment periods presented with significantly ($P < 0.01$) more grade 2 resorption. The mean duration of treatment in patients without root resorption was 1.5 years, whereas in those with grade 2 resorption it was 2.3 years. The mean treatment durations with fixed appliances in relation to resorption grades are given in Table 3.

Of the patients with root resorption in any of the tooth groups, 68 per cent had mild or moderate resorption (grade 1), while 32 per cent presented with severe resorption (grade 2); and these were usually patients with the longest fixed appliance treatment times. The maxillary incisors exhibited resorption most frequently, followed by the mandibular incisors (Table 4). Of the patients with apical root resorption of the maxillary incisors, 37 per cent showed grade 2 resorption of at least one incisor. Root resorption of the premolars was seen in 8.5 per cent of the patients. The degree of resorption was assessed as grade 2 in almost half (45 per cent) of those patients with their premolars affected. No significant differences in the degree of root resorption were found between the malocclusion Classes or other pre-treatment features.

Discussion

The duration of treatment with Class II or intermaxillary elastics as well as with rectangular archwires has been suggested to contribute significantly to apical root resorption (McFadden *et al.*, 1989; Linge and Linge, 1991; Levander *et al.*, 1998; Mavragani *et al.*, 2000; Brin *et al.*, 2003). In the

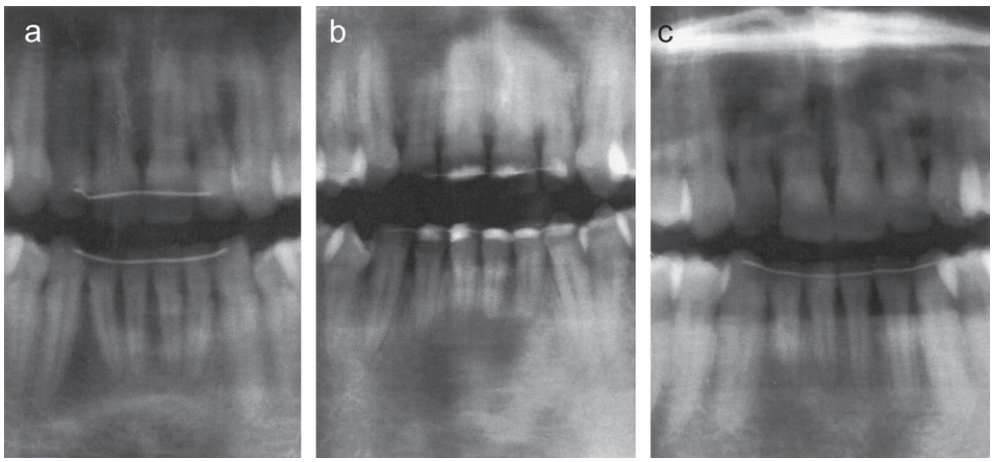

Figure 1 Index for evaluating the degree of root resorption. Grade 0, no radiographically visible root resorption; grade 1, mild resorption with rounding of root apex to about one-quarter of the root length, and grade 2, moderate to severe resorption with loss of one-quarter or more of the root length. (a) Grade 0 resorption of mandibular incisors, (b) grade 1 resorption of mandibular incisors, and (c) grade 2 resorption of maxillary incisors.

Table 3 Mean treatment duration in months (±standard deviation [SD]) with fixed appliances in relation to resorption grade.

	Mean treatment time in months (±SD)			Group total
Resorption grade	0	1	2	
Fixed appliance treatment				
Maxilla (n = 265)	17 (±9.2)	22 (±10)	27 (±13)	21 (±11)
Mandible (n = 246)	19 (±9.2)	24 (±11)	29 (±14)	23 (±11)

present study, the finding that patients who had longer banding times showed significantly more grade 2 apical root resorption is in agreement with earlier findings and indicates that the duration of fixed appliance treatment contributes significantly to the degree of resorption. Although active treatment duration evidently increases the risk of accentuated root resorption, it is obvious that the amount and type of tooth movement are also determinants of root resorption. In addition, the resorptive potential seems to vary between orthodontic patients and even between different teeth in the same patient. Individual biological factors, e.g. alveolar bone density, vascularity, and tooth structure, may explain these variations.

Most research has focused on maxillary incisors because they are regarded as more susceptible to root resorption than other teeth (Newman, 1975; Levander and Malmgren, 1988; Remington *et al.*, 1989; Janson *et al.*, 2000). In the present investigation, of all the tooth groups, the maxillary incisors were affected most frequently. Earlier studies have reported radiographically clearly visible apical root resorption (more than 2 mm to one-third of root length) in 1.4–17 per cent of incisors (Levander and Malmgren, 1988; Remington *et al.*, 1989; Janson *et al.*, 2000), whereas

Table 4 Number and percentage of patients presenting with grade 1 or grade 2 post-treatment apical root resorption in different tooth groups.

	Number of females (%; n = 348)		Number of males (%; n = 253)	
	Grade 1	Grade 2	Grade 1	Grade 2
Maxilla				
Incisors	60 (17)	35 (10)	38 (15)	17 (6.7)
Canines	8 (2.3)	7 (2.0)	3 (1.2)	1 (0.4)
Premolars	10 (2.9)	8 (2.3)	3 (1.2)	4 (1.6)
Molars	11 (3.2)	1 (0.3)	8 (3.2)	0
Mandible				
Incisors	20 (5.7)	18 (5.2)	29 (11)	8 (3.2)
Canines	16 (4.6)	12 (3.4)	13 (5.1)	2 (0.8)
Premolars	9 (2.6)	9 (2.6)	6 (2.4)	2 (0.8)
Molars	17 (4.9)	2 (0.6)	10 (4.0)	0

extreme resorption with loss of more than one-third of the original root length was seen in only 1 to 0.4 per cent of incisors (Remington *et al.*, 1989; Janson *et al.*, 2000). In the present study, 37 per cent of the patients with apical root resorption of the maxillary incisors showed grade 2 resorption of at least one incisor, indicating severe resorption with loss of one-quarter or more of root length. However, the number of maxillary incisors was not determined, thus the percentage is not comparable with those found in other studies. The differences in the resorption scale make the comparison even more difficult. Maxillary incisors are the first teeth to respond when subjected to fixed appliance activation, which may at least partly explain the high resorption potential of these teeth.

Root resorption in premolars was observed in 8.5 per cent of the patients. The study group included a total of 309 patients who were treated with premolar or molar extractions, and in these patients the extracted teeth could

not be included in the analysis. In almost half of the patients with their premolars affected, the degree of resorption was assessed as grade 2 for at least one premolar. It has been suggested that patients requiring premolar extractions show greater resorption potential because of significant tooth movement (Beck and Harris, 1994; Janson *et al.*, 2000). This may at least in part explain the high percentage of severe resorption of premolars in the present study. The median age for root completion for the upper second premolar is 12 years for boys and 11.3 years for girls, with a range of 3.3 years for boys and 3.0 years for girls (Haavikko, 1970). Thus, for a normally developing boy, the latest age for root completion could be up to 15.3 years. Since the average age of the patients at the start of treatment was 11 years, some of the premolars would still have had growth potential at the time of pre-treatment evaluation. It has been suggested that teeth with incomplete root formation have a higher resistance to root resorption than those with complete roots (Mavragani *et al.*, 2002).

Most authors have evaluated root length changes from panoramic or periapical radiographs using the long-cone parallelling technique. In the present study, root length changes were evaluated from panoramic radiographs. This is because periapical radiographs are not routinely taken during orthodontic treatment and because of the high quality of the panoramic images. The use of panoramic radiographs for assessing root resorption and root shape has, however, some drawbacks. It has been suggested that the use of this technique may overestimate the extent of root loss by 20 per cent (Sameshima and Asgarifar, 2001). In the present study, however, instead of measuring the absolute values of apical root loss, the degree of root resorption was assessed by comparing the pre- and post-treatment root lengths. The angulations of the incisors may change during orthodontic treatment, which may affect the length of the radiographic image of the tooth. Nevertheless, with the panoramic technique, buccolingual inclinations affect the root length only to a limited extent: a 10-mm distance from the sharply depicted layer causes only a 5 per cent difference in root length (Tronje *et al.*, 1985; Langland *et al.*, 1989). Earlier studies indicate that comparing vertical and angular measurements on panoramic radiograph taken at different times is sufficiently accurate to determine changes in root length (Stratomas *et al.*, 2002). The importance of correct patient positioning is, however, stressed. This is also important in order to avoid distortion in the incisor region (McDavid *et al.*, 1995). In the present investigation, all the radiographs were taken by one experienced radiographer, and those in which the roots were distorted and not clearly visible were rejected.

Conclusions

The findings of the present study indicate that a significant correlation exists between the duration of fixed appliance treatment and the degree of apical root resorption. A radiographic control should therefore be carried out routinely. In patients with fixed appliance treatment exceeding 6 months, a follow-up interval of 6 months during treatment is recommended. Panoramic radiography is the method of choice for evaluating root length changes in orthodontic practice.

Address for correspondence

Satu Apajalahti
Department of Dental Radiology
Institute of Dentistry
P.O. Box 41
00014 University of Helsinki
Helsinki
Finland
E-mail: satu.apajalahti@helsinki.fi

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