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Long-term follow-up of tooth mobility in maxillary incisors with orthodontically induced apical root resorption

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SUMMARY The aim of the study was to evaluate tooth mobility in relation to root length and alveolar bone support in maxillary incisors 10–25 years after orthodontic treatment, and to monitor the development during 5 years in a sub-sample. Thirty-six patients, seven males and 29 females with one or more severely resorbed maxillary incisors, a total of 139 teeth, were examined. At re-examination, 11 patients were older than 40 years, 20 were between 30 and 39, and five younger than 30 years. Root length, alveolar bone height, and crestal alveolar bone level were measured on standardized intraoral radiographs. Tooth mobility was registered using Miller's index and the periotest method. Statistical analysis was undertaken using a *t*-test for dependent and independent samples, and chi-square tests for comparison of the relationship between the periotest values (PTVs) and the variables periodontal pocket depth, gingival index, incisal facets, interferences, and anamnesis.

The majority of the teeth were stable. The correlation between root length and alveolar bone height was high, with minimal changes of marginal bone support. Extremely resorbed incisors with a root length less than 10 mm had significantly higher PTV than teeth with longer roots and greater bone support. In the sub-sample, tooth mobility was followed in 16 patients, two males and 14 females, with 62 maxillary incisors over a 5-year period. The PTV increased significantly on average, particularly in teeth with extreme resorption.

Increasing mobility can be expected with age in teeth with extremely resorbed roots. Teeth with a root length ≥10 mm and a healthy periodontium remain stable.

Introduction

It is well-known from the orthodontic literature that apical root resorption can be seen after orthodontic treatment. It has been recommended that follow-up radiographs should be obtained after 6 months treatment with fixed appliance (Levander and Malmgren, 1988). A treatment pause of approximately 3 months if resorption is detected might minimize the risk of further root shortening (Levander *et al.*, 1994). In spite of such monitoring and careful treatment with light forces, some teeth undergo severe resorption. Little is known of the long-term prognosis of teeth with severely resorbed roots. Some authors have reported that markedly resorbed teeth can function clinically reasonably well several years post-treatment (Remington *et al.*, 1989; Parker, 1997; Desai, 1999). However, the long-term outcome is influenced both by root length and by alveolar bone support. It has been found that treatment with fixed appliance can result in loss of marginal attachment (Sjölien and Zachrisson, 1973; Zachrisson and Alnæs, 1974; Boyd *et al.*, 1989). A reduced attachment in combination with a short root might lead to tooth mobility, which in animal experiments has been shown to increase the risk of further breakdown of alveolar bone (Lindhe and Svanberg, 1974; Nyman *et al.*, 1978). Other animal studies have shown that increased tooth mobility in combination with plaque-induced gingivitis heightens the risk of tooth loss (Ericsson and Lindhe, 1982). A clinical long-term follow-up of maxillary incisors with orthodontically induced severe apical root resorption showed that there was a risk of tooth mobility in incisors with radiographic root lengths of 9 mm or less, 10–15 years after active treatment (Levander and Malmgren, 2000). However, it has not been shown what such enhancement of mobility means for the longevity of a tooth.

The aim of the present study was to evaluate tooth mobility in relation to total root length and alveolar bone support in maxillary incisors with severely shortened roots, 10–25 years after active orthodontic treatment, and to monitor the development of tooth mobility in maxillary incisors over a 5-year period.

Subjects and methods

The study was approved by the ethical committee of Karolinska Institutet.

Sixty patients with one or more severely resorbed maxillary incisors after orthodontic treatment with fixed appliance 10–25 years previously were recalled. Thirty-six of these, seven males and 29 females, who answered the letter of invitation, were examined. Active treatment was finished 10–15 years earlier in 11 patients, 15–20 years earlier in 13, and more than 20 years earlier in 12. At re-examination, 11 patients were older than 40 years with the oldest 43. Twenty patients were between 30 and 39 years and five younger than 30 years.

All patients had worn fixed or removable retainers after active treatment. Four still had 0.0175 twistflex retainers bonded to all incisors (16 teeth). The follow-up period for two of these patients was 20–25 years, and for the other two 10–15 years.

Intraoral radiographs of the four maxillary incisors pre- and post-active treatment were available. One patient had two missing lateral incisors and in one it was only possible to analyse one tooth. The total number of investigated teeth was 139. In 16 patients, tooth mobility tests had been performed 5 years previously. One of these patients had two missing lateral incisors. The total number of reinvestigated teeth was 62.

The patients were examined at the Eastman Institute in Stockholm. An anamnesis concerning general health, medication, and tobacco use (smoking or taking snuff) was performed. Awareness of tooth grinding and use of bite splints were registered.

Periodontal pocket depth was measured with a graduated probe (Hu-Friedy PCP2 Immunity, Chicago, Illinois, USA) at the mesial, buccal, distal, and lingual sites. The depth was recorded in millimeters, from the deepest penetration of the probe to the free margin. Gingival bleeding on probing at the same four sites was also registered and the gingival index (GI; Löe and Silness, 1963) was calculated. The incisal edges of the teeth were checked for signs of grinding and bite interference. Dental wear was registered in teeth with distinct facets. The presence or absence of facets was recorded.

The mobility of the teeth was assessed using Miller's mobility index (Miller, 1938) and the periotest method (Schulte *et al.*, 1983; d'Hoedt *et al.*, 1985). Miller's index is divided into four classes; no movement distinguishable (0), first distinguishable sign of mobility (1), crown deviates within 1 mm of its normal position (2), mobility is easily noticeable and the tooth moves more than 1 mm in any direction or can be rotated in its socket (3).

The periotest (Gulden-Medizintechnik, Bensheim, Germany) is an electronic device that measures the dampening characteristics of the periodontium. A defined impact load is applied to the tooth crown and the mean contact time of 16 reproducible impacts is calculated and converted into a numeric scale ranging from −8 to +50. The scale correlates with Miller's index, with periotest value (PTV) −8 to +9 being no movement distinguishable, PTV +10 to +19 first distinguishable sign of mobility, PTV + 20 to +29 crown deviates within 1 mm of its normal position and PTV +30 to +50 mobility is easily noticeable (Schulte *et al.*, 1992).

The periotest device was used according to the manufacturer's instructions. The patient's head was placed against the headrest with the actual tooth perpendicular to the floor. The hand piece was held in a horizontal position with the start button on top and at a distance of not more than 4 mm from the buccal surface of the incisor. The tooth was out of occlusion and percussed perpendicular to the buccal surface at the midpoint of the crown, orthoradially to the arch (d'Hoedt *et al.*, 1985). All measurements were made twice by the same operator (AJ). The average values were used in the calculations.

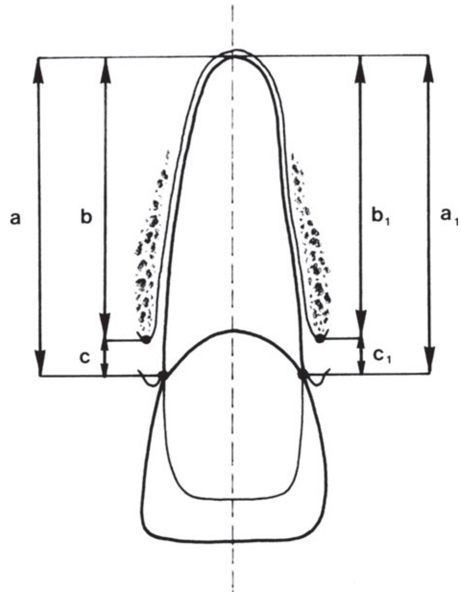

Figure 1 Measurements of root length (a), alveolar bone height (b), and crestal alveolar bone level (c) were performed on intraoral radiographs at the mesial (a, b, and c) and distal (a_1, b_1, and c_1) aspects.

Three conventional standardized orthoradial radiographs (Kodak Ektaspeed) were taken of the maxillary incisors. The radiographic examinations were performed using an Eggen film holder. The film size was 30 × 40 mm. The rectangular collimator of the X-ray machine was orientated in contact with the film holder indicator. The end of the tube was placed 8 cm from the film. The aim was to obtain parallelism between the film and the long axis of the tooth. The radiographs were developed, fixed, and rinsed according to standardized procedures and then digitized and analysed on a computer tablet. The shortest distance from a perpendicular through the apical intersection of the long axis of the tooth to the cemento-enamel junction (total root length) and to the alveolar crest (alveolar bone height) was measured to the nearest 0.1 mm at the mesial and distal aspects of the teeth (Figure 1). The mean distance was used for the calculations. The measurements were made twice and the average values were used.

Statistical analysis

After ranking of the teeth according to the remaining total root length, they were divided into three groups: extreme, severe, and moderate apical resorption (root length <10, 10–12.9, ≥13 mm). A *t*-test for independent samples was used to analyse the difference in PTV in relation to root length and a *t*-test for dependent samples for the development of tooth mobility. Chi-square tests were used for statistical comparisons of the relationship between the PTV and the following variables: periodontal pocket depth, GI, incisal facets, interferences, and the anamnesis variables. The significance level was $P < 0.05$.

Error of the method

The error of the method in measuring root length and alveolar bone height was calculated from double determinations of all radiographs using the formula: $s = \sqrt{\sum d^2 / 2}$, where d is the difference between duplicate determinations and n is the number of determinations (Dahlberg, 1940). The precision was 0.2 mm, which is in agreement with earlier observations (Levander *et al.*, 1994; Levander and Malmgren, 2000).

The reproducibility of the periotest method was based on double recordings. For 117 teeth (84 per cent), the recordings were the same or there was a difference of one unit, and for 15 the difference was two units. The remaining seven incisors had a difference of three to four units. This is also in accordance with Levander and Malmgren (2000).

Results

General health was good in all participants. No allergies or inflammatory conditions were recorded. The only prescribed medications registered were contraceptives. Two patients were smokers. Seven patients had problems with joint crepitation and six reported grinding. Two of these individuals used splints at night. In one patient, a subjective feeling of tooth mobility in the maxillary incisors was registered. None of the anamnesis variables were related to root length, alveolar bone height, or PTV.

Root length, alveolar bone height and PTV in 139 maxillary incisors from 36 patients

The root length at follow-up varied between 7.2 and 20.1 mm, on average 13.5 mm, the alveolar bone height between 5.3 and 16.8 mm, on average 11.5 mm, and the crestal alveolar bone level between 0.6 and 4.3 mm, on average 2.1 mm. The correlation between root length and alveolar bone height was significant ($r = 0.97$). PTV varied from −4 to +22 and correlated well with root length ($r = 0.61$), alveolar bone height ($r = 0.63$), and Miller's index ($r = 0.72$).

For 18 teeth, the root lengths were less than 10 mm, extreme resorption. The PTVs for 11 of these were 10–19, indicating the first sign of tooth mobility according to Miller's index. For two teeth, the PTVs were higher than 19, meaning that the crowns moved within 1 mm. Thirty-eight incisors had a root length from 10 to 12.9 mm, severe resorption. The PTVs for seven of these were 10–19. Of 83 incisors with a root length equal to or longer than 13 mm (moderate resorption), one tooth had a PTV higher than 19. The average PTV in the teeth with extreme resorption was 11.9 [standard deviation (SD) 6.02], for teeth with severe resorption 5.9 (SD 4.28) and for moderately resorbed incisors 2.3 (SD 3.70). The PTV differed significantly between the groups (Table 1).

Teeth with extremely resorbed roots and a follow-up period of 15–20 years had a PTV of 14.8, and those after 10–15 years a PTV on average of 11.2. The difference was not significant. Teeth with severe or moderate resorption had a PTV lower than 10 at all follow-up periods (Table 2).

A high PTV was registered in 10 of the 36 patients. These values were related to individual teeth. In one patient, four maxillary incisors had a PTV equal to or higher than 10. These incisors had extremely shortened roots. Two patients had three teeth and seven one or two teeth with such high values.

For the 16 teeth bonded with twistflex retainers, the average PTV was 3.6 (SD 4.07) and for the other 123 it was 4.7 (SD 5.48). The difference was not significant.

Table 1 Root length for 139 maxillary incisors from 36 patients with severe root resorption after orthodontic treatment, and periotest values at follow-up after 10–25 years.

Severity of root resorption	Number of teeth	Root length in mm		Periotest values				
		Min	Max	<10	10 to 19	>19	Mean	SD
				Number of teeth				
Extreme	18	7.2	9.8	5	11	2	11.9	6.02
Severe	38	10.0	12.9	31	7	0	5.9	4.28
Moderate	83	13.0	20.1	82	0	1	2.3	3.70
	139	7.2	20.1	118	18	3	4.6	5.30

Teeth grouped according to root length at follow-up in 2004; SD, standard deviation.

Table 2 Periotest values (PTV) for 139 teeth in 36 patients.

Severity of root resorption	Follow-up period in years								
	10–15			15–20			20–25		
	Number of teeth	PTV		Number of teeth	PTV		Number of teeth	PTV	
		Mean	SD		Mean	SD		Mean	SD
Extreme	14	11.2	6.2	4	14.8	5.0	—	—	
Severe	14	7.7	4.7	13	5.4	3.9	11	4.3	3.7
Moderate	14	4.2	5.9	36	1.8	2.5	33	2.2	3.7

Teeth grouped according to root length and follow-up periods: 10–15, 15–20, and 20–25 years. SD, standard deviation.

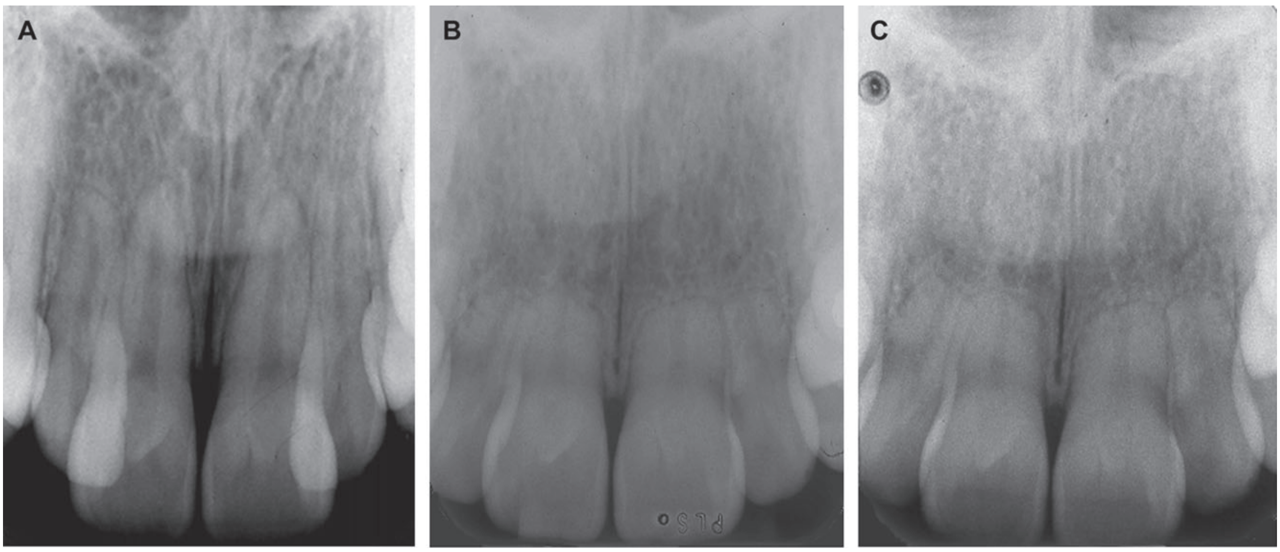

Figure 2 Radiographs of a 37-year-old patient with extreme apical root resorption. The root lengths were less than 10 mm. The follow-up period after orthodontic treatment was 20 years. The periotest values of the maxillary incisors were at follow-up: right lateral 14, right central 18, left central 17, and left lateral 18, indicating the first sign of mobility. (A) Before treatment, (B) after treatment and (C) at follow-up.

Development of PTV during 5 years follow-up in relation to root length in 62 maxillary incisors from 16 patients

In 1998, the average PTV was 5.3 (SD 4.16) and 7.1 (SD 6.10) in 2004. The increase was significant ($P = 0.003$). For 17 teeth, with extreme resorption, the average PTV increased from 9.7 to 12.8 (Figure 2). The increase was significant ($P = 0.036$). For the teeth with severe or moderate resorption, the average value also increased, but the difference was not significant (Table 3).

An increased PTV was found in 39 teeth in 12 patients: in eight subjects four incisors, in one three incisors, and in three two incisors. The increased PTV was related to the severity of root resorption.

Periodontal status, occlusion and function

No probing depths exceeded 4 mm. The GI index varied from 0 to 1. Seventy per cent of the teeth, 94 out of 139, had distinct incisal facets showing signs of dental wear. Bite interference was recorded for two incisors. None of the variables for measurements of periodontal status, occlusion, or function were significantly related to the PTV.

Discussion

Pronounced orthodontically induced apical root resorption of maxillary incisors has been reported in a number of studies (Levander *et al.*, 1994; Levander and Malmgren, 1988, 2000). From that material, 60 subjects, still residing in the Stockholm area, were recalled. Twenty-four did not answer the letter of invitation. Since the maxillary incisors in these individuals had similar amounts of root resorption as the included patients, it can be presumed that the material was representative.

All examined patients had good general and oral health with no known illnesses and none had periodontal disease.

Table 3 Development of periotest values during 5 years, 1998 to 2004, for 62 maxillary incisors from 16 patients analysed in relation to severity of root resorption.

Severity of root resorption	Number of teeth	Periotest values				P value
		1998		2004		
		Mean	SD	Mean	SD	
Extreme	17	9.7	4.72	12.8	4.92	0.036*
Severe	16	4.5	2.62	6.9	4.76	0.069 NS
Moderate	29	3.1	2.02	3.9	4.98	0.277 NS
	62	5.3	4.16	7.1	6.10	0.003**

Teeth grouped according to root length at follow-up in 2004.
*$P < 0.05$; **$P < 0.01$; NS, not significant

The study has a follow-up period of 10–25 years, but the patients were still fairly young. Only two were smokers. Smoking is a significant risk factor for periodontal disease (Jansson *et al.*, 2002).

The periotest method is well established for evaluation of tooth mobility. It is objective and highly reproducible for measurements of the damping characteristics of healthy teeth (Schulte *et al.*, 1983). A distinction should be made between tooth mobility and the damping characteristics of the periodontium. Rosenberg *et al.* (1995), however, found a highly statistically significant relationship between PTV and tooth mobility measured with Mühlemann's Periodontometer.

The precision of the periotest measurements in the present investigation was in agreement with earlier studies (Schulte *et al.*, 1992; Levander and Malmgren, 2000). The time interval between the double recordings was a few minutes. Andresen *et al.* (2003a) investigated the test–retest reliability of the periotest method. They found that a time interval of 15 minutes between the readings was of importance. No other studies have reported similar findings.

The relationship between the maxillary incisors, the film, and the central X-ray beam is of significance for radiographic precision (Brezniak *et al.*, 2004). In the present follow-up study, a metallic film holder was used to obtain standardized orthoradial radiographs. The film holder indicator orientated the collimator so that the central X-ray beam was directed at a right angle to the long axis of the tooth with the film parallel to the long axis. The film holder prevented the film from bending against the palate.

The majority of the teeth, 118 of 139 with severe, moderate, or extreme resorption after orthodontic treatment, were stable 10–25 years after treatment. The correlation between root length and the alveolar bone height was high ($r = 0.97$) and the crestal alveolar bone level was on average 2.1 mm, indicating minimal changes of marginal bone support. Therefore, only root lengths were used in the present study for comparison with tooth mobility. Incisors with markedly shortened roots and reduced alveolar bone support had higher mobility than teeth with longer roots and more bone support. Loss of root length moves the centre of resistance coronally so that the same amount of force will have a greater impact than on an intact root. This result strengthens the earlier findings of Levander and Malmgren (2000). D'Hoedt *et al.* (1985) determined the PTV for periodontally healthy teeth with normal root length. For central maxillary incisors, the average PTV was 7 and for laterals 6. In comparison, the average PTV in the present study was 11.9 for 18 extremely resorbed incisors (Table 1) and 12.8 for 17 teeth in the 5-year follow-up group (Table 3). Sixteen teeth had bonded retainers. They showed similar mobility as those without retention, indicating that twistflex retainers do not inhibit normal mobility.

The length of the follow-up period did not influence tooth mobility in teeth with severe and moderate resorption. The average PTV was in accordance with normal values (d'Hoedt *et al.*, 1985) even after 20–25 years. Teeth with extreme resorption at the end of orthodontic treatment and a normal crestal bone level had a higher PTV after 15–20 years than after 10–15 years (Table 2). This strengthens earlier conclusions that these teeth are at risk for increased mobility in spite of good oral hygiene and healthy periodontium.

A number of teeth with increased PTV were recorded as not mobile with Miller's index. Andresen *et al.* (2003b) found a significant difference between tooth mobility detected with periotest and traditional palpation methods. Thus, the periotest method seems to be sensitive for detecting early signs of tooth mobility. Only one patient had noticed the mobility subjectively.

Increased PTV was recorded in the majority of patients in the 5-year follow-up study. The increase was minimal for incisors with moderate and severe resorption (Table 2) and the values corresponded well with the normal values given by d'Hoedt *et al.* (1985). A greater increase was found for teeth with extreme resorption and the values were considerably higher than normal.

Hypothetically, distinct incisal facets and grinding might be associated with overloading of teeth resulting in tooth mobility. However, none of the variables for occlusion and function were significantly related to increased PTV.

For patients, in whom orthodontic treatment has led to a severe shortening of the roots, additional alveolar bone loss can be a problem. According to Lavstedt *et al.* (1986), Janson *et al.* (2000), and Hugosson and Laurell (2000), natural alveolar bone loss is approximately 0.1 mm per year (i.e. 1 mm per 10 years). The oldest patient in the present study was 43 years of age. The good oral health had preserved the alveolar bone minimizing the tooth mobility during the 10- to 25-year follow-up. The increased PTV indicating tooth mobility was not detected by the patients. Professional information about the necessity of periodontal prophylaxis is thus mandatory.

Conclusion

In teeth with extremely resorbed roots with a root length less than 10 mm, increasing mobility can be expected with age. Teeth with longer root lengths ≥10 mm and a healthy periodontium remain stable.

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