European Journal of Orthodontics 22 (2000) 85–92

Long-term follow-up of maxillary incisors with severe apical root resorption

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SUMMARY The purpose of the study was to analyse the mobility of teeth with severe orthodontically induced root resorption, at follow-up several years after active treatment, and to evaluate mobility in relation to root length and alveolar bone support. Seventy-three maxillary incisors were examined in 20 patients, 10–15 years after active treatment in 13 patients (age 24–32 years) and 5–10 years after active treatment in seven patients (age 20–25 years). All had worn fixed or removable retainers; seven still had bonded twistflex retainers. Total root length and intra-alveolar root length were measured on intra-oral radiographs. Tooth mobility was assessed clinically according to Miller´s Index (0–4) and the Periotest method. Crestal alveolar bone level, periodontal pocket depth, gingival, and plaque indices, occlusal contacts during occlusion and function, and dental wear were recorded.

There was a significant correlation ($P < 0.05$) between tooth mobility, and total root length and intra-alveolar root length. No correlation was found between tooth mobility and retention with twistflex retainers. None of the variables for assessment of periodontal status, occlusion and function were related to total root length or tooth mobility. It is concluded that there is a risk of tooth mobility in a maxillary incisor that undergoes severe root resorption during orthodontic treatment, if the remaining total root length is ≤9 mm. The risk is less if the remaining root length is >9 mm. Follow-up of teeth with severe orthodontically induced root resorption is indicated.

Introduction

External apical root resorption in association with orthodontic treatment varies between patients and between different teeth in the same person: there may be severe resorption in a few teeth. It has been reported that once active orthodontic treatment is finished there is no further progression of resorption (Copeland and Green, 1986). Extensive resorption does not usually affect the functional capacity of the teeth. There have been few investigations of the post-treatment stability and prognosis of severely resorbed teeth (Remington *et al.*, 1989; Parker, 1997). The long-term outcome might be influenced by several factors, e.g. root length/bone support ratio and periodontal conditions. Several investigators have reported significantly greater loss of attachment in adolescents who have undergone fixed appliance therapy than in those who have not had orthodontic treatment (Sjölien and Zachrisson, 1973; Zachrisson and Alnæs, 1974; Hollender *et al.*, 1980). In combination, greater loss of attachment and shortened roots might lead to a higher level of tooth mobility, which in animal experiments has been shown to enhance the risk of further breakdown of the alveolar bone (Lindhe and Svanberg, 1974; Nyman *et al.*, 1978; Ericsson 1978).

In earlier studies (Levander and Malmgren, 1988; Levander *et al.*, 1994) severe resorption was found in a number of teeth after orthodontic treatment with fixed appliances and the long-term outcome of these teeth was being monitored in this investigation. The aim was to analyse and evaluate tooth mobility in relation to root length and alveolar bone support.

Subjects and methods

The invited participants were the 30 subjects with severely resorbed maxillary incisors from two earlier studies on root resorption during orthodontic treatment (Levander and Malmgren, 1988; Levander *et al.*, 1994). In those studies, apical root resorption in 672 teeth was evaluated on intra-oral radiographs and a resorption index of 3 (resorption from 2 mm to one-third of the original root length) or 4 (resorption exceeding one-third of original root length) was recorded in 151 roots. From this material, all teeth with a resorption index of 4 and those with the most marked resorption index 3 were selected. Four patients had moved and the new addresses were unknown, four were studying abroad and two refused to participate in the study. The remaining 20 patients had one or more severely resorbed maxillary incisors: 13 subjects (six males, seven females, age 24–32 years) had undergone active treatment 10–15 years previously (total 50 teeth), and seven subjects (two males, five females, age 20–25 years) had undergone active treatment 5–10 years previously (total 23 teeth). All had worn fixed or removable retainers for a minimum period of two years after active treatment, and seven still had twistflex retainers bonded to all incisors (23 teeth). After orthodontic treatment they had received regular annual dental care. In all, 73 maxillary incisors (39 centrals and 34 laterals) were examined. Digital intra-oral radiographs were taken and tooth mobility, periodontal status, occlusion, and function were registered clinically.

Radiographs

The radiographs were taken with the Sens-A-Ray (Regam Medical Systems International AB, Sundsvall, Sweden) dental imaging system. In order to standardize the radiographic technique, a modified film holder was used for fixation of the sensor (Levander *et al.*, 1998). The sensor was placed parallel to the long axis of the tooth. A rectangular collimator was used. All radiographs were taken by the same operator.

The digital peri-apical radiographs were examined at ×5 magnification and analysed on the computer monitor. The total length of the roots and intra-alveolar root length at the mesial and distal aspects of the teeth were measured to the nearest 0.1 mm. A perpendicular line was drawn through the apical intersection of the long axis of the root in all teeth. The shortest distance from the line to the cemento-enamel junction (total root length) and to the alveolar crest (intra-alveolar root length) was measured mesially and distally and the mean distance was used in the calculations for all teeth (Figure 1). The measurements were repeated after a 1-month interval. The average values were used in the calculations.

Tooth mobility

Mobility was assessed clinically, using Miller's 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 movement (1); crown deviates within 1 mm of its normal position (2); mobility is easily noticeable, and tooth moves more than 1 mm in any direction or can be rotated in its socket (3).

The Periotest (Siemens AG, Bensheim, Germany) is an electronic device that measures the damping characteristics of the periodontium. The principle is based on detection of changes in the periodontal structures. The apparatus comprises a microcomputerized measuring and steering device, flexibly connected to a handpiece containing a metal rod. During measurement the rod is accelerated against the object. The rod moves at a constant speed until it contacts the tooth. After impact, the tooth is deflected and the rod is braked. The reaction force returns the tooth to its original position and the rod is drawn into the starting position. Over a period of 4 seconds, 16 reproducible impacts are made with the tooth. A microcomputer calculates the mean contact time, which is converted into a Periotest value. These values vary from –8 to +50 and correlate with Miller's classification of tooth mobility: no movement distinguishable, PTV –8 to +9: first distinguishable sign of movement, PTV +10 to +19; crown deviates within 1 mm, PTV +20 to +29 and mobility easily noticeable, PTV +30 to +50 (Schulte and Lukas, 1993).

All maxillary incisors were examined twice by the same operator, using the same Periotest device throughout. The average values were used in the calculations. The 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 handpiece 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 percussed perpendicular to the buccal surface at the midpoint of the crown, and orthoradially to the arch (d'Hoedt *et al.*, 1985; Chai *et al.*, 1993). The measurements were made with the teeth out of occlusion.

Periodontal status

The crestal alveolar bone level on the mesial and distal aspects of the teeth was determined by calculating the difference between the total root length and the intra-alveolar root length (Figure 1).

Periodontal pocket depth was measured at mesial, distal, buccal, and lingual sites, using a graduated probe (Hu-Friedy PCP2 Immunity, Chicago, IL, USA). The depth was recorded in millimetres, from the deepest penetration of the probe to the free gingival margin. At the same four sites, plaque, and gingival bleeding were also recorded, and Plaque Index (Silness and Löe, 1964) and Gingival Index (Löe and Silness, 1963) were calculated.

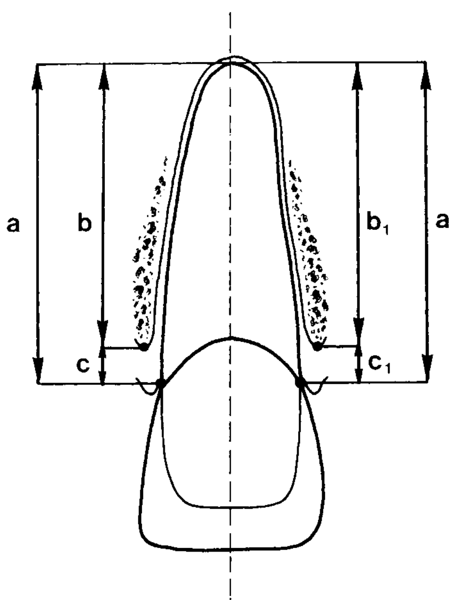

Figure 1 Measurements of (a) total root length, (b) intra-alveolar root length, and (c) crestal alveolar bone level was performed on intra-oral radiographs at the mesial and distal aspect.

Occlusion and function

Occlusal contacts between the maxillary and mandibular incisors were recorded in intercuspal position, and in lateral and protrusive excursions. Dental wear was registered in teeth with distinct incisal facets by recording the presence or absence of facets.

Statistical methods

After ranking of the teeth according to the remaining total root lengths the teeth were divided into three groups: (1) less than or equal to 8.0 mm; (2) more than 8.0 mm, but less than or equal to 9.0 mm; and (3) more than 9 mm. The chi-square test ($P < 0.05$) was used to analyse the variation in total root length in relation to the following variables: tooth mobility; Periotest value; type of incisor (lateral/central); crestal alveolar bone level; periodontal pocket depth; plaque index; gingival index; occlusal contacts in intercuspal position, and in lateral and protrusive excursions; dental wear; retention with twistflex archwire; and follow-up period.

Error of the method

The error of the method in measuring the total root length and the intra-alveolar root length was calculated from double determinations, using the formula

$$s = \sqrt{\Sigma d^2/2n}$$

where d is the difference between duplicate determinations and n is the number of determinations (Dahlberg, 1940). The precision was 0.1 mm for total root length and 0.2 mm for intra-alveolar root length, which is in accordance with earlier observations (Levander *et al.*, 1994). The reproducibility of the Periotest method was also based on double recordings. In 50 teeth the recordings were the same; there was a difference of one unit in 21 teeth and 2 units in two teeth.

Results

Root length and tooth mobility (Table 1, Figures 2 and 3)

The total root lengths of the incisors varied from 5.5 to 18.1 mm. In the teeth with extreme resorption, a root length of 8.0 mm or less was recorded in 15, and between 8.1 and 9.0 mm in 12 teeth. In the remaining 46 teeth, root length varied from 9.1 to 18.1 mm. The intra-alveolar root length varied from 4.1 to 16.6 mm and correlated well with total root length (r = 0.99).

A mobility rating of 1 on Miller's Index was recorded clinically in 15 teeth: nine with root length ≤8.0 mm, five with root lengths 8.1–9.0 mm, and one with root length 12.1 mm. None of the teeth had mobility recordings >1.

The Periotest values varied from –4 to +19: high values, ≥10, were recorded in 12 teeth with total root lengths ≤8.0 mm, and seven with root lengths 8.1–9.0. A Periotest value of 10 was recorded in only one tooth with a longer root (12.1 mm).

The relationship between root length, and Periotest value and tooth mobility was statistically significant, but no significant difference between centrals and laterals, or between the length of the follow-up periods was found. No significant relationship was found between tooth mobility or Periotest value and the use of a twistflex retainer. Twelve of 23 teeth bonded with twistflex archwire had Periotest values ≥10.

Periodontal status, occlusion and function

The crestal alveolar bone level on the mesial and distal aspects of the teeth varied from 0.3 to 2.0 mm in 61 teeth, and from 2.1 to 3.6 mm in 12 teeth. Sixteen incisors with a crestal alveolar bone level <2 mm and three with >2 mm had Periotest values ≥10.

The variation in pocket depth was 1–3 mm, plaque index varied from 0 to 2 and gingival index varied from 0 to 1. Occlusal contacts in intercuspal position were recorded in 45 teeth and during lateral and protrusive excursions in 33, 22, and 38 teeth, respectively. Dental wear was recorded in 41 teeth.

None of the variables for measurements of periodontal status, occlusion and function were related to root length, Periotest value, or tooth mobility.

Discussion

The outcome of orthodontic treatment may be jeopardised by severe apical root resorption. In terms of severity, the most frequently affected teeth are the maxillary lateral and central

Table 1 Tooth mobility and Periotest value in relation to total root length and retention with twistflex retainer in 73 maxillary incisors with root resorption in association with orthodontic treatment.

Total root length (mm)	Number of teeth with:						
	Retention with twistflex retainer		Tooth mobility Miller's Index*		Periotest value		
	No	Yes	0	1	–4–9	10–19	Total
5.5–8.0	11	4	6	9	3	12	15
8.1–9.0	6	6	7	5	5	7	12
9.1–18.1	33	13	45	1	45	1	46
Total	50	23	58	15	53	20	73

*Miller's Index: no movement distinguishable (0), first distinguishable sign of movement (1).

Figure 2 Radiographs of a patient, aged 21 years, with severe apical root resorption. Follow-up period 7 years. Twistflex retainer 13–23. (A) Before treatment. (B,C) After treatment. Severe apical root resorption of all maxillary incisors. (D,E) At the follow-up control. Total root length 12, 21, 22 >9 mm; 11 <9 mm. Increased mobility in 11. Periotest values 12 = 1; 11 = 10; 21 = 5; 22 = –3.

incisors (Phillips, 1955; DeShields, 1969; Goldson and Henrikson, 1975; Sharpe *et al.*, 1987). The subjects of the present study had discontinued active orthodontic treatment several years previously, and had participated in two earlier studies of orthodontically induced apical root resorption in maxillary incisors (Levander and Malmgren, 1988; Levander *et al.*, 1994). For the present study, 30 patients met the inclusion criteria and 10 did not participate. The degree of root resorption was similar in these patients. They had 13 teeth with index 3 and two with index 4. Thus, it is not likely that drop-out has influenced the results.

Although it is claimed that extensive root resorption does not affect the functional capacity of a tooth (Jacobson, 1952; Brezniak and Wasserstein, 1993), Pao *et al.* (1984) and Kalkwarf *et al.* (1986) have shown an approximately linear relationship between root length and the percentage of periodontal attachment. Little information is available about the long-term prognosis for teeth with markedly shortened roots. Studies based on radiographic evidence have shown that

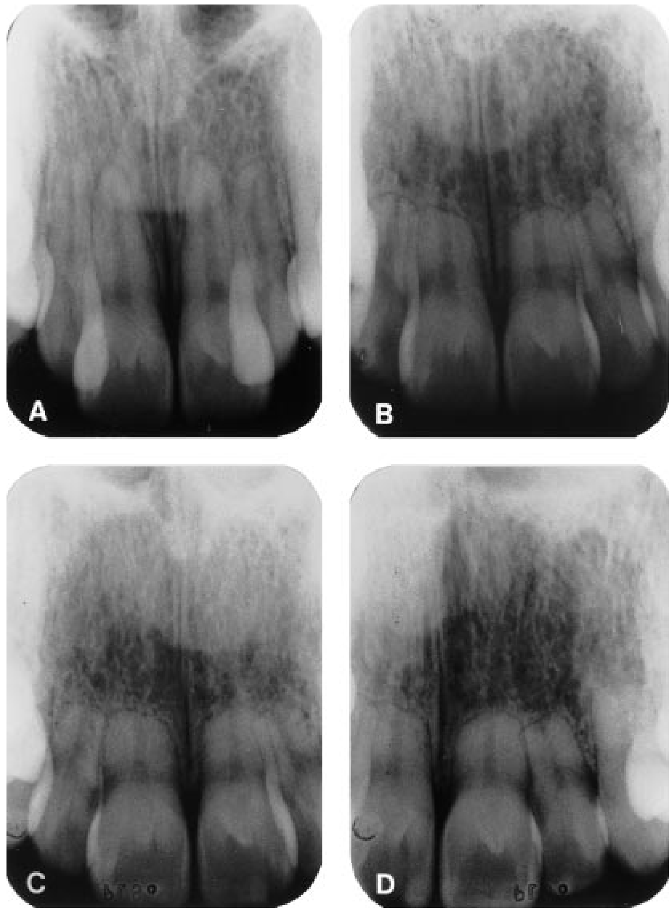

Figure 3 Radiographs of a patient, aged 31 years, with severe apical root resorption. Follow-up period 15 years. Retention with removable plate for 1 year after treatment. (A) Before treatment. (B) After treatment. Severe apical root resorption of maxillary incisors. (C,D) At the follow-up control. Total root length 12 to 22 <9 mm. Increased mobility of all four incisors. Periotest values 12 = 14; 11 = 12; 21 = 18; 22 = 18.

orthodontically induced root resorption does not usually progress after appliance removal (Copeland and Green, 1986; Remington *et al.*, 1989) and histological investigations show repair of resorption cavities after treatment (Owman-Moll, 1995).

Tooth stability is of fundamental importance for function. A new apparatus for clinical assessment of tooth mobility, the Periotest, has been used in several studies (Schulte *et al.*, 1983, 1992; Schwarze *et al.*, 1995; Rosenberg *et al.*, 1995). The method is a dynamic measuring procedure that assesses the resistance of the periodontium to a defined impact load. The Periotest value depends mainly on the damping characteristics of the periodontium, but also to a minor degree on the mobility of the tooth. It has been shown, however, that Periotest values correlate closely with tooth mobility assessed by the Mühlemann Periodontometer (Rosenberg *et al.*, 1995). The best correlation between tooth deflection and Periotest value was found for teeth with some degree of clinical mobility. Rosenberg *et al.* (1995) found that when mobility was clinically detectable by means of the Miller method, it correlated well with the Periotest score.

In clinical interpretation, it is important to realize that the Periotest apparatus measures the contact time between the tapping rod and the object in milliseconds, and that the values are based on a numerical scale from –8 to +50. This scale is calculated by means of two different formulas, one for values <13 and one for values >13, i.e. the clinical importance of a rise of one unit is not constant along the whole scale. Sensitivity decreases with increasing values from +13 to +50. Only four of the most extremely resorbed incisors had values exceeding 13. In accordance with d'Hoedt *et al.* (1985) and Schulte *et al.* (1992), double determinations showed good precision of the method. The numerical Periotest values obtained in the study are therefore considered to be clinically relevant for assessment of mobility.

Crestal alveolar bone level is conventionally determined by calculating the distance between the cemento-enamel junction and the crest of the alveolar bone (Källestål and Matsson, 1989; Lupi *et al.*, 1996). In subjects with no history of periodontal disease, the normal range is reported to be 0–2 mm. For 12 teeth in the present study, the crestal alveolar bone level was 2.1–3.6 mm, indicating minor loss of alveolar bone, but increased Periotest values were recorded in three teeth and only one showed clinical evidence of mobility. Thus, no correlation between crestal alveolar bone level and tooth mobility could be shown. No increased pocket depth was found, the plaque level was low, and gingival inflammation was recorded at very few sites. Dental wear was registered on a number of the incisors, but was not associated with increased mobility. Thus, the increased mobility in the teeth with extremely resorbed roots was attributable to root length, and not to periodontal disease or occlusal trauma.

Schwarze *et al.* (1995) showed that a highly flexible multi-stranded 0.0155 retainer reduces tooth movement. Twenty-three incisors in the present study had lingually bonded twistflex archwire retainers. There was no significant difference in the Periotest values for these teeth and those without retainers. Increased mobility was recorded in 12 of the teeth with retainers.

As tooth mobility had not previously been assessed in the subjects, it was not possible to monitor any progression during the follow-up period. Further investigation is warranted to pursue this question and the development of increased mobility in severely resorbed teeth.

Conclusions

1. If orthodontic treatment leads to severe root resorption in a maxillary incisor, leaving a remaining total root length of 9 mm or less, there is a risk of tooth mobility. Less risk is associated with a remaining root length >9 mm, with a healthy periodontium.
2. After orthodontic treatment, teeth with severe root resorption should be followed-up, clinically and radiographically.

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Acknowledgements

The authors would like to thank Professor Jan Huggare for his invaluable support of this project and critical evaluation of the manuscript. This study was supported by grants from the Stockholm County Council, Sweden, and the Sigrid de Verdier Memorial Fund.

References

Brezniak N, Wasserstein A 1993 Root resorption after orthodontic treatment: Part 2. Literature review. American Journal of Orthodontics and Dentofacial Orthopedics 103: 138–146

Chai J, Yamada J, Pang I O 1993 *In-vitro* consistency of the Periotest instrument. Journal of Prosthodontics 2: 9–12

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

Dahlberg G 1940 Statistical methods for medical and biological students. Interscience Publications, New York

De Shields R W 1969 A study of root resorption in treated Class II Division 1 malocclusion. Angle Orthodontist 39: 231–245 d'Hoedt B, Lukas L, Mühlbradt F, Scholz F, Schulte W, Quante F, Topkaya A 1985 Das Periotestverfahren-Entwicklung und klinishe Prüfung. Deutsche Zahnärztlische Zeitung 40: 113–125

Ericsson I 1978 Periodontal tissue reactions to jiggling and orthodontic forces. Thesis, University of Gothenburg, Sweden

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

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

Jacobson O 1952 Clinical significance of root resorption. American Journal of Orthodontics 38: 687–696

Kalkwarf K L, Krejci R F, Pao Y C 1986 Effect of apical root resorption on periodontal support. Journal of Prosthetic Dentistry 56: 317–319

Källestål C, Matsson L 1989 Criteria for assessment of interproximal bone loss on bitewing radiographs in adolescents. Journal of Clinical Periodontology 16: 300–304

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

Levander E, Malmgren O, Eliasson S 1994 Evaluation of root resorption in relation to two orthodontic treatment regimes. A clinical experimental study. European Journal of Orthodontics 16: 223–228

Levander E, Malmgren O, Bajka R 1998 Early radiographic diagnosis of apical root resorption during orthodontic treatment: a study of maxillary incisors. European Journal of Orthodontics 20: 57–63

Lindhe J, Svanberg G 1974 Influence of trauma from occlusion on progression of experimental periodontitis in beagle dogs. Journal of Clinical Periodontology 1: 3–14

Löe H, Silness J 1963 Periodontal disease in pregnancy. I. Prevalence and severity. Acta Odontologica Scandinavica 21: 533–563

Lupi J E, Handelman C S, Sadowsky C 1996 Prevalence and severity of apical root resorption and alveolar bone loss in orthodontically treated adults. American Journal of Orthodontics and Dentofacial Orthopaedics 109: 28–37

Miller S C 1938 Textbook of periodontia. Blakiston Company, Philadelphia

Nyman S, Lindhe J, Ericsson I 1978 The effect of progressive tooth mobility on destructive periodontitis in the dog. Journal of Clinical Periodontology 5: 213–225

Owman Moll P 1995 Orthodontic tooth movement and root resorption with special reference to force magnitude and duration. A clinical and histological investigation in adolescents. Thesis, Göteborg University, Sweden

Pao Y, Reinhardt R A, Krejci R F, Taylor D T 1984 Computer graphics in aided instruction of three-dimensional dental anatomy. Journal of Dental Education 48: 315–317

Parker S P 1997 Root resorption—long-term outcome. American Journal of Orthodontics and Dentofacial Orthopedics 112: 119–123

Phillips J R 1955 Apical root resorption under orthodontic therapy. Angle Orthodontist 25: 1–22

Remington D N, Joondeph D R, Årtun J, Riedel R A, Chapko M K 1989 Long-term evaluation of root resorption occurring during orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics 96: 43–46

Rosenberg D, Quirynen M, Steenberghe D, Naert I, Ticio J, Nys M 1995 A method for assessing the damping characteristics of periodontal tissues: goals and limitations. Quintessence International 26: 191–197

Schulte W, Lukas D 1993 Periotest to monitor osseointegration and to check the occlusion in oral implantology. Journal of Oral Implantology XIX: 23–32

Schulte W *et al.* 1983 Periotest- neues Messfahren der Funktion des Parodontiums. Zahnärztliche Mitteilungen 73: 1229–1240

Schulte W, d'Hoedt B, Lukas D, Maunz M, Steppeler M 1992 Periotest for measuring periodontal characteristics—correlation with periodontal bone loss. Journal of Periodontal Research 27: 184–194

Schwarze J, Bourauel C, Drescher D 1995 Frontzahnbeweglichkeit nach direkter Klebung von Lingualretainern. Ein Vergleich von *In-vitro* und *In-vivo* Messungen. Fortschritte der Kieferothopädie 56: 25–33

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

Silness J, Löe H 1964 Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. Acta Odontologica Scandinavica 22: 121–135

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

Zachrisson B U, Alnæs L 1974 Periodontal condition in orthodontically treated and untreated individuals. II. Alveolar bone loss: radiographic findings. Angle Orthodontist 44: 48–55