European Journal of Orthodontics 32 (2010) 693–697
doi:10.1093/ejo/cjp165
Advance Access Publication 22 March 2010

Root resorption before and after orthodontic treatment: a clinical study of contributory factors

Ruo-ping Jiang*, J.P. McDonald** and Min-kui Fu*
*Department of Orthodontics, Peking University School and Hospital of Stomatology, Beijing, China and
**Orthodontic Department, Glasgow Dental Hospital, UK

Correspondence to: Dr Ruoping Jiang, Department of Orthodontics, Peking University School and Hospital of Stomatology, 22 Zhong Guan Cun Nan Da Jie, Beijing 100081, China. E-mail: Jiangruoping@126.com

SUMMARY This clinical study evaluated factors related to root resorption before (T1) and after (T2) orthodontic treatment. Ninety-six subjects between 9 and 34 years (34 males and 62 females) who had been treated using fixed appliances for at least 1 year and who had panoramic radiographs at T1 and T2 were selected. The relationship between root resorption at T1 and T2, with regard to gender, age, extraction versus non-extraction patterns, specific teeth and treatment duration was investigated.

No statistically significant differences in root resorption were found in relation to gender. Significant differences in root resorption ($P=0.000$, $P<0.01$) and also in treatment duration ($P=0.036$, $P<0.05$) were noted between the extraction and non-extraction groups; extraction and treatment duration correlated with T2 mean root resorption. Patient age correlated with root resorption of the upper incisors at T1 and T2. Using multiple regression analysis, age and duration of treatment were found to be more associated with root resorption than with extractions; the presence of root resorption at T1 was associated with T2 root resorption, especially of the anterior teeth.

Introduction

Root resorption is a common outcome of orthodontic treatment. Harry and Sims (1982) found that some level of root resorption existed in most patients. Most resorption is clinically insignificant, but, if severe, root resorption threatens the longevity of the teeth. With the improvements in orthodontic techniques and the increase in patient expectations, orthodontists need to be aware of this issue.

Most studies (Baumrind *et al.*, 1996; Jiang *et al.*, 2001) on root resorption and its relationship with orthodontic treatment have found that there are multiple factors associated with root resorption. Age, gender, nutrition, genetics, the type of appliance, the amount of force used during treatment, extraction or non-extraction, duration of treatment, and the distance the teeth are moved all have some influence on root resorption. Generally, the causes and mechanism of resorption are still unclear. The purpose of the present study was to research and, if possible, identify factors related to root resorption during orthodontic treatment.

Subjects and methods

Subjects

Ninety-six patients aged from 9 to 34 years (34 males and 62 females) who had undergone at least 12 months fixed appliance orthodontic therapy (straightwire, Roth value) were randomly selected from subjects treated at the Orthodontic Department, Peking University School and Hospital of Stomatology, Beijing, China. Panoramic radiographs before (T1) and after (T2) treatment were available. Patients who required orthognathic surgery or had a cleft lip and/or palate were excluded from the study. Sixty-five of the subjects had undergone extraction therapy (four premolars extracted, including the first or second premolars) as part of their orthodontic treatment. Treatment duration was between 9 and 61 months (average 31 months).

Methodology

The roots of the maxillary and mandibular incisors, canines, premolars, and first molars were examined according to a modified root resorption classification method, based on the root resorption score (Sharpe *et al.*, 1987). Panoramic radiographs were used to score the root resorption level for every patient at T1 and T2. The modified root resorption method is shown in Figure 1.

The mean root resorption score (MRRS) for every patient at T1 and T2 was calculated for the upper anterior and posterior and lower anterior and posterior teeth, using the formula:

$$\text{Mean root resorption} = \frac{\text{Sum of the scores}}{\text{Number of teeth}}.$$

Gender, age, extraction or non-extraction therapy, and treatment duration were recorded.

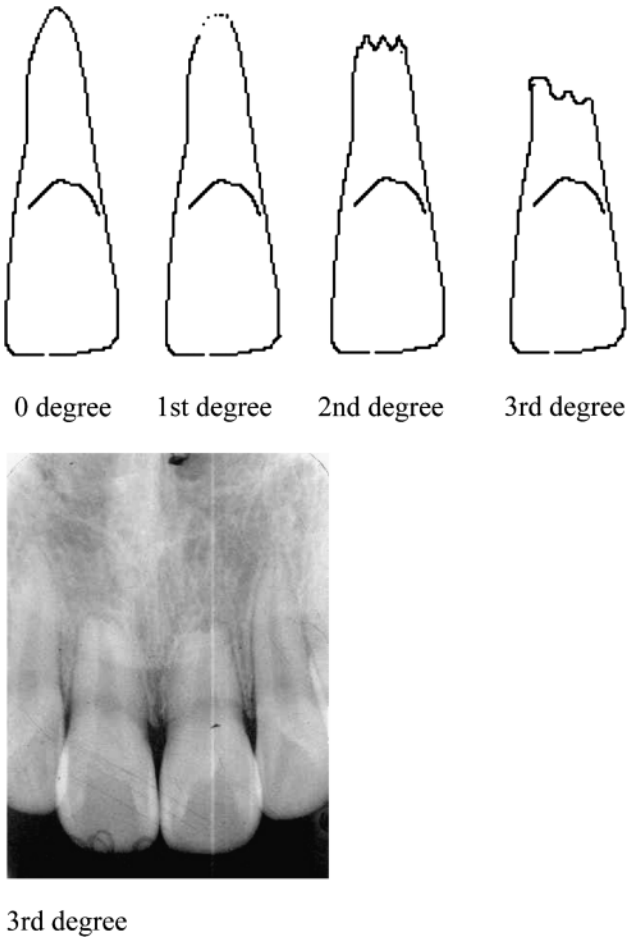

Figure 1 The modified root resorption classification method. 0 degree: no visible root resorption. 1st degree: mild resorption, the root apex is blunted and diffuse. 2nd degree: moderate resorption, the root apex disappears, the root apex looks more like a half circle not a taper. The contour is sometimes discontinuous or not smooth; the amount of root resorption is about approximately one-quarter of the root. 3rd degree: severe resorption, the end of the root shows excessive blunting; the contour of the root apex is more likely to be discontinuous; root resorption is more than one-quarter of the root.

Statistical analysis

The patients were divided into different groups depending on gender and whether extractions had been undertaken. A *t*-test was performed between the MRRS of male and female, and extraction and non-extraction groups. Bivariate correlation analysis was undertaken between extraction, duration, and MRRS after treatment. Using the MRRS as the dependent variable, and age, gender, extraction, and duration as the independent variables, multifactorical regression analysis was performed. When using the T2 MRRS as the dependent variable, the T1 score of the same group was used as the independent variable.

Error study

Assessment of root resorption on the panoramic radiographs was performed by a single examiner (RPJ). To determine reliability, 20 panoramic radiographs were rechecked by the same examiner after a 10 day interval. The MRRS between these two examinations were compared using a paired Wilcoxon test. The difference between the first and second measurements was not significant.

Results

Gender

Statistical analysis did not demonstrate a significant gender difference at T1 and T2.

Extraction therapy

Root resorption values were compared between the extraction (65 patients) and non-extraction (31 patients) groups using a *t*-test. There was no statistically significant difference between the extraction and non-extraction groups at T1. At T2, the MRRS in the extraction group was higher than in the non-extraction group; the difference was statistically significant ($P=0.000$, $P<0.01$).

Treatment duration

The average treatment duration in the extraction group was 32.1 ± 9.7 months, somewhat longer than in the non-extraction group (27.6 ± 9.8 months). *t*-test analysis showed that the difference was statistically significant ($P=0.036$, $P<0.05$).

Bivariate correlation analysis

Bivariate analysis showed that there was no correlation between age and extraction, or between age and treatment duration. The relationship between age and MRRS score was inconclusive—there was a positive correlation between age and root resorption with respect to the upper teeth at T1 and T2, but no correlation was found between age and lower anterior and posterior teeth before or after treatment (Table 1).

The correlation coefficient between extraction and treatment duration was −0.21 ($P<0.05$), hence treatment duration in extraction cases was longer.

With the exception of the upper anterior teeth, extractions had a statistically significant relationship with root resorption after treatment (T2).

There was a positive relationship between T2 root resorption and treatment duration, the correlation coefficients ranging from 0.21 to 0.39. This indicated that the longer the treatment, the more severe the root resorption.

Multiple regression analysis

MRRS were used as the dependent variable and gender, age, extraction, and duration as the independent variables. The results are shown in Table 2.

Table 1 Correlation coefficients of the bivariate correlation analysis between extraction, duration, age and mean root resorption score (MRRS) after treatment for the upper and lower anterior and posterior teeth.

Correlation coefficients	MRRS	MRRS	MRRS	MRRS	Age	Extraction	Duration
	Upper posterior	Upper anterior	Lower posterior	Lower anterior			
Age	0.25*	0.28*	0.19	0.15	1.0	−0.09	−0.17
Extraction	−0.23*	−0.19	−0.25*	−0.34**	−0.09	1.0	−0.21*
Duration	0.21*	0.23*	0.29**	0.39**	−0.17	−0.21*	1.0

*$P<0.05$, **$P<0.01$.

Table 2 Correlation coefficients of the multiple regression analysis of mean root resorption score (MRRS).

MRRS								
	Before treatment				After treatment			
	Upper posterior	Upper anterior	Lower posterior	Lower anterior	Upper posterior	Upper anterior	Lower posterior	Lower anterior
Gender	−0.02	−0.06	0.13	0.06	0.04	−0.07	−0.13	−0.08
Age	0.52**	0.23*	−0.04	−0.06	0.29**	0.23*	0.21*	0.19*
Extraction	—	—	—	—	−0.15	−0.07	−0.17	−0.25**
Duration	—	—	—	—	0.26*	0.25**	0.28**	0.34**
Cor-values	—	—	—	—	0.15	0.42**	0.13	0.19*

Cor-values: when the mean MRRS values post-treatment were used as the dependent variable, the corresponding values pre-treatment were added to the independent variables.
*$P<0.05$; **$P<0.01$.

At T1, patient's gender had no statistically significant correlation with root resorption. Patient's age only had a correlation with root resorption for the upper teeth (0.52), but no correlation with the lower teeth. The results show that at T1, in the upper posterior dentition, older patients tended to have more severe root resorption. At T2, all factors, apart from gender, had a correlation with root resorption. Age and treatment duration had a statistically significant correlation with resorption in all parts of the dentition. Extraction only had a statistically significant correlation with resorption of the lower anterior teeth. The degree of root resorption at T1 only had a statistically significant correlation with that of the anterior teeth at T2. No statistically significant correlation was found in the posterior region between T1 and T2 resorption.

Discussion

Panoramic radiographs, cephalometric head films, and periapical films have been used to study root resorption and the relationship with orthodontic treatment. When designing this study, these radiographs were compared and it was initially decided that as cephalometric radiography is the only technique that uses localization, this would be the best method to compare the length of incisal roots before and after treatment. However, patients with malocclusions often have crowding in the incisor region, which makes it difficult to identify the position of root apices before treatment. In addition, a previous study (Kennedy *et al.*, 1983) has shown that most resorption is in the region of 1–2 mm, hence the margin of error is extremely small. The advantage of a panoramic radiograph is that a single film gives information on all teeth, as well as the dentoalveolar bone and jaws. It is not, however, a localized film and has varying distortion of different teeth, for example, in upper incisor retraction where the incisal root length after treatment may appear to be much longer than before treatment on a panoramic radiograph. Periapical film obtained using the crown parallel projective technique (Linge and Linge, 1983, 1991; Levander *et al.*, 1998) is localized and accurate, but the patient is subjected to an increased amount of radiographic exposure. It was therefore decided that panoramic radiography was the choice for the present study, but with some modifications of the MRRS.

Two methods are used to assess root resorption: one measures the length of the root directly to determine the amount of root resorption; the other marks the degree of root resorption. The method classifying the degree of root resorption used in most previous research (Remington and Joondeph, 1989) was similar to the four degree standard of

Sharpe *et al.* (1987): 0 degree = no root resorption (0 mm); 1 degree = root apex blunted slightly (1–2 mm); 2 degree = moderate blunting, resorption up to one-quarter of the root (2–4 mm); and 3 degree = severe blunting, resorption more than one-quarter of the root (greater than 4 mm). It is believed that this method is accurate when used with a localized film but not suitable for panoramic radiographs. The modified classification method in this study used the change in shape of the root apex but not the length of root and is similar to the method of Sharpe *et al.* (1987). In a previous study (Jiang *et al.*, 2001), the same modified method was used to investigate the endemic features of root resorption; the findings were in agreement with others who used periapical film (Sameshima and Sinclair, 2001a,b), which supposedly is more accurate than panoramic film.

No statistically significant difference in root resorption was found between male and female patients. This is contrary to the studies of Spurrier and Hall (1990) and Kjær (1995) who found females to have more resorption than males but is in agreement with most other research (Sameshima and Sinclair, 2001a,b; Kaley and Phillips, 1991; Linge and Linge, 1991). No statistically significant difference in treatment duration between male and female patients was found.

Seventy-nine of the 96 patients were under 15 years of age. In a trial test, root resorption was compared between two groups subdivided at the age of 15 years, using *t*-test analysis. No statistically significant difference was found. When correlation analysis was introduced, a strong correlation was found between age and root resorption at T2; at T1, there was also a correlation between age and root resorption of the upper teeth. This indicated that the older the patient, the more severe the root resorption. This is contrary to the findings of Sameshima and Sinclair (2001a,b) who found no correlation between age and resorption of the maxillary anterior teeth but that adults had significantly more resorption of the mandibular anterior teeth. Linge and Linge (1983) found that patients starting treatment after 11 years of age experienced significantly more root resorption than those starting earlier. It is believed that age is an important factor related to root resorption because of the reduced ability to repair root resorption in the older patient. Rietan (1974) found that 'in younger patients the anatomical environment constitutes an important factor, existing cementoid on the root surface may delay the onset of root resorption, and if there is a thick layer of predentine, any apical or apical side resorption can hardly prevent further development of the root'. Therefore, the protective mechanism of precementum and predentine located at young apices may also be an influencing factor.

There were some interesting findings on the relationship between extraction, treatment duration and root resorption. Baumrind *et al.* (1996) and McFadden *et al.* (1989) found patients who undergo extraction treatment tended to have more root resorption. Sameshima and Sinclair (2001a,b) also found that extraction pattern was a significant factor in root resorption. However, after performing multiple regression correlation analysis, only the resorption of lower anterior teeth had a correlation with extraction in the present study; resorption of upper and lower posterior teeth had no relationship with extraction. This implied that if other factors were included, such as gender, age, treatment duration, and pre-treatment resorption, extraction became less important for resorption than previously believed. It was noted that extraction and treatment duration had a statistically significant correlation, and the duration between the extraction and non-extraction groups was significantly different. Furthermore, treatment duration itself had a statistically significant correlation with root resorption.

In relation to the mandibular incisors, however, cases involving extractions tended to have more root resorption even with the same treatment duration. This may be due to the difference between various areas within the mouth because of the anatomical structure of this complex mandibular area—the distance between the cortical plates is narrow and when the incisors are retracted after premolar extractions, the root apices tend to contact the cortex. The contact between root and cortex was found to be an important factor in root resorption after orthodontic treatment (Horiuchi *et al.*, 1998).

The presence of previous resorption had an influence on resorption after treatment but only for the anterior teeth, especially the maxillary incisors. Hence a patient who has root resorption without orthodontic treatment may well be susceptible to root resorption as a result of orthodontic treatment. However, in a case–control study (Kaley and Phillips, 1991), it was found that evidence of previous root resorption was present as frequently in control patients as in those with severe resorption.

Conclusions

The findings of this study suggest that:

1. Gender was not an influencing factor in root resorption and treatment duration in this Chinese sample.
2. Patient's age would appear to be an influencing factor in root resorption. Older patients tend to have significant root resorption after orthodontic treatment and an element of upper root resorption before treatment.
3. Extraction has some influence on treatment duration and root resorption. Extraction cases have a longer treatment duration and more severe root resorption than non-extraction cases. The influence of extraction on root resorption may be a consequence of treatment duration.
4. Treatment duration has a statistically significant correlation with post-treatment root resorption; the longer the duration, the more severe the root resorption.

5. The degree of pre-treatment root resorption seems to influence root resorption after orthodontic treatment in the maxillary dentition.

Funding

Peking University Stomatology Research Fund.

References

Baumrind S, Korn E L, Boyd R L 1996 Apical root resorption in orthodontically treated adults. American Journal of Orthodontics and Dentofacial Orthopedics 110: 311–323

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

Horiuchi A, Hotokezaka H, Kobayashi K 1998 Correlation between cortical plate proximity and apical root resorption. American Journal of Orthodontics and Dentofacial Orthopedics 114: 311–318

Jiang R P, Zhang D, Fu M K 2001 A clinical study of root resorption before and after orthodontic treatment. Chinese Journal of Orthodontics 8: 108–110

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 extractions and orthodontic treatment on dentoalveolar support. American Journal of Orthodontics 84: 183–190

Kjær I 1995 Morphological characteristics of dentitions developing excessive root resorption during orthodontic treatment. European Journal of Orthodontics 16: 25–34

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

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

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

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

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

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

Sameshima G T, Sinclair P M 2001a Predicting and preventing root resorption Part 1: diagnostic factors. American Journal of Orthodontics and Dentofacial Orthopedics 119: 505–510

Sameshima G T, Sinclair P M 2001b Predicting and preventing root resorption Part 2: treatment factors. American Journal of Orthodontics and Dentofacial Orthopedics 119: 511–515

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

Spurrier S W, Hall S H 1990 A comparison of apical root resorption during orthodontic treatment in endodontically treated vital teeth. American Journal of Orthodontics and Oral Orthopedics 97: 130–134