Original Article

Root resorption diagnosed with cone beam computed tomography after 6 months and at the end of orthodontic treatment with fixed appliances

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ABSTRACT

Objective: To investigate the prevalence of orthodontically induced root resorption after treatment and the correlation with resorption found after 6 months of treatment.

Materials and Methods: One hundred fifty-six patients (11–18 years) treated with fixed appliances and extraction of four premolars were examined with cone beam computed tomography before treatment, after 6 months of treatment (n = 97), and at the end of active treatment. The Malmgren Index was used to describe the degree of root resorption.

Results: Severe root resorption (>2 mm, score 3) was found in 25.6% of the patients at the end of treatment. Extreme root resorption was found in one patient. Root resorption was seen more frequently in the maxillary incisor region. There was no correlation between the severity of root resorption after 6 months and the amount observed at the end of treatment. Furthermore, no correlation was seen between treatment duration and the severity of root resorption.

Conclusions: Clinically significant resorption was diagnosed in 25.6% of the patients, but no correlations, either with the resorption seen after 6 months or with the length of treatment, were found. Radiographic examination after 3 to 6 months of orthodontic treatment is too early and will not reduce the number of patients who will have teeth with severe root resorption. (*Angle Orthod.* 2013;83:389–393.)

KEY WORDS: Orthodontics; Fixed appliance; Cone beam computed tomography; Root resorption

INTRODUCTION

Numerous studies have been published identifying orthodontic treatment as a risk factor for external root resorption, with an increased incidence and severity among treated patients[1]; orthodontically induced root resorption (OIRR) incidences ranging from 1% to 100% have been reported.[2,3] The large variation is the result of several factors, including examination methods, definition of root resorption, and type of appliances and forces used.

Radiography is the most commonly used tool for diagnosing root resorption. The majority of clinical studies have used intraoral periapical radiography and/or panoramic radiographs, but these techniques have shortcomings that are difficult to overcome.[4,5] Although numerous studies have been published regarding OIRR, very few published studies have examined all permanent teeth from first molar to first molar with adequate radiographic technique.[6] However, no prospective research projects on OIRR have been carried out with an attempt to standardize patients as well as treatment procedure in a large number of patients.

Cone beam computed tomography (CBCT) was introduced in the late 1990s,[7,8] and studies generally show lower radiation doses from CBCT units than from conventional CT examinations.[9,10] The CBCT technique, in combination with multiplanar reconstructions, has the advantage of optimal visualization of each tooth despite the changes in tooth position that occur during orthodontic treatment,[11] thus enhancing reproducibility.

The literature poses a correlation between root resorption at an early stage of treatment (3–9 months)

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and the occurrence of severe resorption at the end of orthodontic treatment.[1,12,13] Levander et al.[14] reported that, after 3 months of treatment, apical root resorption was detected in only a few teeth, but the number of affected teeth increased significantly after 6 months of treatment. Patients with detectable root resorption during the first 6 months of active treatment have also been reported to be more likely to experience resorption during the following 6-month period.[14,15] In a previous study,[16] the incidence of early root resorption of the present sample was examined, and it was concluded that, after 6 months of treatment, clinically significant resorption was diagnosed in only 4% of the patients.

The aims of the present study were, therefore, to: (1) investigate the prevalence and degree of OIRR after treatment with fixed appliances in all permanent teeth, from first molar to first molar; and (2) investigate the correlation of the severity of root resorption with that seen after 6 months of treatment.

MATERIALS AND METHODS

Subjects

CBCT examinations are not routinely performed on orthodontic patients at the Orthodontic Clinic in Gothenburg, Sweden. However, from March 2005 to June 2008, consecutive incoming patients were invited to take part in a prospective radiographic study. The patients had to meet predefined inclusion criteria: age 11–18 years, Class I malocclusion, crowding, and overjet <5 mm. Further, the treatment plan should comprise extraction of one premolar in each quadrant. Informed consent from the parents and ethical approval from the Ethics Committee and the Radiation Protection Committee, Sahlgrenska Academy at University of Gothenburg, Sweden, were obtained. One hundred seventy-one patients agreed to take part in the investigation, and at the end of the study 156 patients (88 female, 68 male) remained in the study. A randomized subsample of 97 patients (57 female, 40 male) also underwent a radiographic examination 6 months after the start of their orthodontic treatment. The mean age of the patients was 15.4 years (standard deviation [SD] 1.53 years; range, 11.0–18.9 years) and the mean treatment time was 20.9 months (SD 5.8 months). The orthodontic treatment protocol was standardized using an MBT preadjusted appliance with 0.022-inch slots. Space closure was performed with sliding mechanics using Class I and/or Class II traction when necessary.

CBCT Examination

CBCT was performed on all subjects before and after treatment; CBCT was also performed in 97 randomly selected patients after 6 months of treatment. Randomization of the 6-month subgroup was performed with a list generated in Excel 2003 (Microsoft AB).

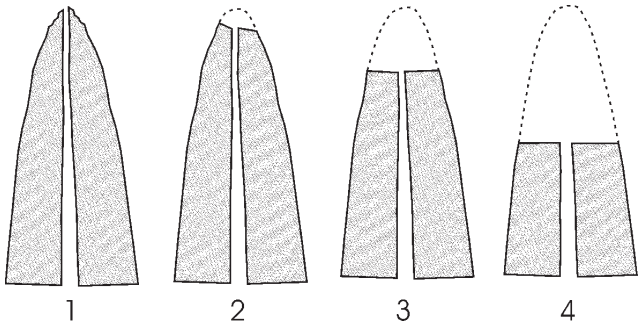

Figure 1. Index for subjective scoring of root resorption according to Malmgren et al.[17] 1 indicates irregular root contour; 2, apical root resorption less than 2 mm of original root length; 3, apical root resorption from 2 mm to one-third of original root length; 4, apical root resorption exceeding one-third of original root length.

The radiographic procedure using multiplanar reconstructions to obtain optimal visualization of the tooth/root in three perpendicular image planes has been described in detail elsewhere.[16] Tooth length was measured in millimeters on the reformatted images parallel to the long axis of the tooth/root and then converted into an index (Figure 1) originally designed for intraoral radiography by Malmgren et al.[17] Only a few roots were unscorable at one or two assessments, but the distal root of the lower first molar was, in many cases, outside the imaged volume (Table 1). All assessments were made by one independent, blinded examiner.

Statistics

The relationship between resorption after 6 months of treatment and at the end of treatment was analyzed with Spearman's rank correlation analysis. Analysis of variance was used to evaluate resorption at end of treatment in conjunction with the number of teeth affected and duration of treatment. $P > .05$ was considered not statistically significant.

RESULTS

An irregular root contour (score 1) was seen in most teeth prior to active treatment. Thus, root resorption was considered to be present only if a score of 2 or higher was registered.

Figure 2 shows the distribution of root-resorbed teeth according to the counts in each tooth group seen at the end of treatment, and Table 1 presents the percentages of resorbed teeth. The extent of root resorption was significantly larger ($P < .05$) in the maxilla than in the mandible, and OIRR was more

Table 1. Percentage of Teeth with a Root Resorption Score of 2 or More at the End of Orthodontic Treatment in 156 Patients

Tooth no.[a]	n	Score 2 (%)		Score 3 (%)		Score 4 (%)	
16/26	310	6.8					
15/25	312	7.7		1.6			
13/23	308	7.5		3.6			
12/22	312	41.0	36.2	10.3	9.5	0.6	0.6
11/21	312	31.4		8.7		0.6	
36/46d	216	3.7					
36/46m	290	3.4					
35/45	312	3.8		0.3			
33/43	304	7.2		4.6			
32/32	312	21.5	17.9	1.3	2.1		
31/41	312	14.4		2.9			

[a] FDI tooth-numbering system used; lower molars are presented with both mesial (m) and distal (d) roots because of the higher number of unscorable distal roots.

common in anterior teeth than in posterior teeth (Figure 2). At the end of treatment, minor resorption (score 2) was noted in 82 patients (52.5%), severe resorption (score 3) was found in 40 patients (25.6%), and extreme resorption (score 4) was found in the lower jaw in one patient. In the lower jaw, severe root resorption (score 3) was detected in eight patients and the most susceptible tooth was the canine, while moderate root resorption (score 2) was most prevalent in the lower incisors. Root resorption was also seen on the posterior teeth, and a score of 2 was reported in several first molars: 11 upper right, 7 upper left, 7 lower left, and 4 lower right. No correlation was found between the severity of root resorption at 6 months and that at the end of treatment ($R = 0.05$, P = NS), and there was no relationship between the length of treatment and the severity of root resorption found in the patients (Figure 3).

Progression of Root Resorption from 6 Months to End of Treatment

In the four patients with the most severe resorption, the condition was unchanged in three subjects and worsened in one by the end of treatment. In the 10 cases with moderate resorption, the severity increased in three patients and was unchanged in seven. In the 83 patients where no noticeable resorption was seen after 6 months, 65 had developed a resorption score of 2 or higher by the end of treatment (Figure 4).

DISCUSSION

Conventional radiographic methods for assessing root length cannot reliably compensate for inherent radiographic distortion,[4,5] and several studies have demonstrated that conventional intraoral radiography is not a reliable technique for detecting external root resorption in its early stages.[18,19] To minimize the errors in radiographic evaluation, this study design included the use of CBCT. The study material comes from a research project that was initiated by a report by the "The Swedish Council on Technology Assessment in Health Care,"[6] and the study design was approved by university ethics and radiation protection committees. CBCT has high sensitivity and specificity in the detection of external resorption lesions,[20,21] and CBCT performs significantly better than digital intraoral radiography.[20] However, the effective radiation dose is much higher than with conventional digital intraoral radiography,[22] and CBCT should therefore never be used on a routine basis in orthodontic practice.

Resorption at the end of treatment was almost only seen in the upper incisor region, in agreement with clinical experience, but rarely shown with appropriate methods[6] apart from a previous publication of the same material[23] and a few older studies (eg, Goldson and Henrikson[24]) and a recent study by Dudic et al.[25] Most studies investigating root resorption have focused on the upper incisors.[26–29] Dudic et al.[25] found, using the same CBCT appliance and root resorption index, moderate root resorption in 19% of the examined teeth, and two maxillary anterior teeth (1%) displayed severe resorption at the end of treatment. The corresponding values in the present study were 15% and 3%. However, the number of investigated patients was much smaller in the study of Dudic et al.[25] ($n = 22$).

Another finding of the present study was that there was no correlation between treatment duration and the

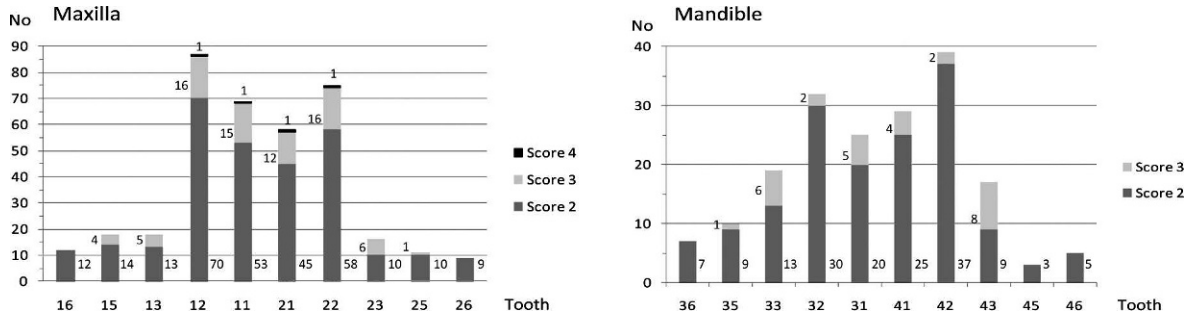

Figure 2. Distribution of root resorbed teeth (scores 2–4) according to the counts in each tooth group at the end of treatment.

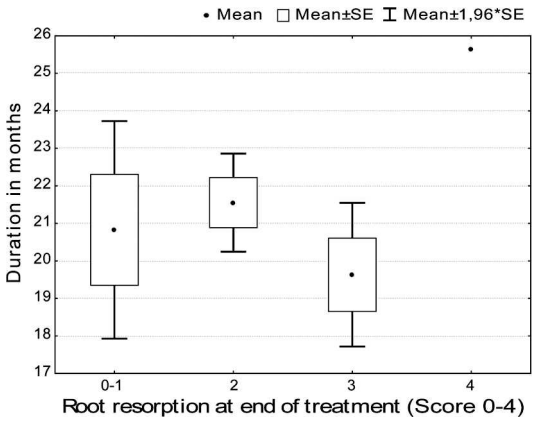

Figure 3. Distribution of patients with different root resorption scores in relation to the treatment duration.

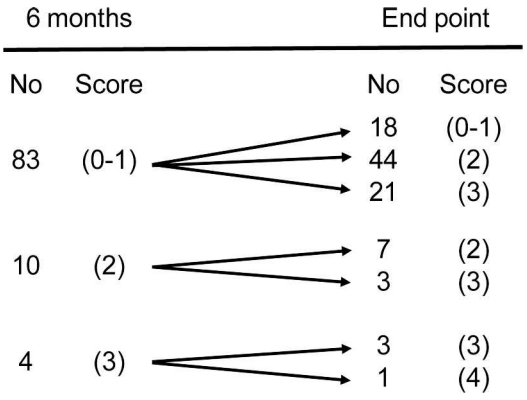

Figure 4. Flow chart of patients with different root resorption scores at 6 months and changes until the end of treatment.

severity of root resorption. This is in agreement with the results of some studies and contradicts others.[1] One explanation of the lack of agreement may be that the current patient sample was fairly homogenous and the amount of tooth movement was fairly similar.

The current and earlier[16] studies confirmed, in agreement with other studies,[14,15] that some patients developed OIRR during the first stage of treatment with fixed appliances. However, we could not confirm any correlation between the degree of resorption at 6 months and that seen at the end of treatment (Figure 4). Of the four subjects with the most severe resorption (score 3) seen after 6 months of treatment, a temporary halt of 3 months was performed in three of them. However, even in one of the patients whose treatment was temporarily halted, the resorption continued, and extreme resorption (score 4) was diagnosed at the end of treatment. Twenty-one of the 27 patients (of those examined at 6 months) who had teeth with severe resorption (score 3) at the end of treatment did not show any tendency toward root resorption after 6 months (Figure 4). A weak relationship between the degree of resorption after 6 months and that at the end of treatment was noted in a previous publication of the present material.[23] However, these results were based on exact numeric measurements in millimeters. In a clinical situation where periapical radiographs are used, it is not possible to make exact measurements of each tooth during orthodontic treatment; therefore, a cruder (but more clinically relevant) instrument as an index is closer to reality.

The results of this study clearly demonstrate that there is no advantage in taking radiographs as early as after 6 months of treatment to reduce the number of patients with severe or extreme root resorption. Radiographs at 6 months only expose patients to unnecessary radiation. Intermediate radiographs, if used, should be obtained at a later stage of treatment; perhaps 1 year after the start of an orthodontic treatment would be feasible. The results of this study also show that one or two radiographs of the upper incisors should be sufficient for detecting resorption of the most vulnerable teeth. However; even then, it is uncertain whether severe root resorption can be avoided.

CONCLUSIONS

- At the end of orthodontic treatment, minor resorption (score 2) was noted in 82 patients (52.5%), severe resorption (score 3) was found in 40 patients (25.6%), and extreme resorption (score 4) was found in only one patient.
- There was no correlation between the severity of root resorption seen after 6 months and the findings at the end of treatment.
- Treatment duration did not have any impact on the amount of resorption at the end of treatment.
- Radiographic examination after 3–6 months of orthodontic treatment is too early and will not reduce the number of patients who will have severe root resorption.

REFERENCES

1. Weltman B, Vig KW, Fields HW, Shanker S, Kaizar EE. Root resorption associated with orthodontic tooth movement: a systematic review. *Am J Orthod Dentofacial Orthop*. 2010; 137(4):462–476; discussion 412A.
2. Mayoral G. Treatment results with light wires studied by panoramic radiography. *Am J Orthod*. 1982;81(6):489–497.
3. Harry MR, Sims MR. Root resorption in bicuspid intrusion. A scanning electron microscope study. *Angle Orthod*. 1982; 52(3):235–258.
4. Katona TR. Flaws in root resorption assessment algorithms: role of tooth shape. *Am J Orthod Dentofacial Orthop*. 2006; 130(6):698 e619–627.
5. Katona TR. The flaws in tooth root resorption assessment algorithms: the role of source position. *Dentomaxillofac Radiol*. 2007;36(6):311–316.

6. Statens beredning för medicinsk utvärdering. Bettavvikelser och tandreglering i ett hälsoperspektiv. En systematisk litteraturöversikt. *Bettavvikelser och tandreglering i ett hälsoperspektiv. En systematisk litteraturöversikt*. Stockholm: Statens beredning för medicinsk utvärdering (SBU); 2005. English summary and conclusion available at: http://www.sbu.se/upload/Publikationer/Content1/1/Malocclusions_Orthodontic%20.pdf. Accessed September 20, 2012.
7. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol*. 1999 Jul; 28(4):245–248.
8. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *Eur Radiol*. 1998; 8(9):1558–1564.
9. Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. *Dentomaxillofac Radiol*. 2004 Mar;33(2):83–86.
10. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. Dose reduction in maxillofacial imaging using low dose cone beam CT. *Eur J Radiol*. 2005 Dec; 56(3):413–417.
11. Lund H, Gröndahl K, Gröndahl HG. Cone beam computed tomography for assessment of root length and marginal bone level during orthodontic treatment. *Angle Orthod*. 2010 May;80(3):466–473.
12. Smale I, Artun J, Behbehani F, Doppel D, van't Hof M, Kuijpers-Jagtman AM. Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy. *Am J Orthod Dentofacial Orthop*. 2005 Jul;128(1):57–67.
13. Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. *Eur J Orthod*. 1988 Feb;10(1):30–38.
14. Levander E, Bajka R, Malmgren O. Early radiographic diagnosis of apical root resorption during orthodontic treatment: a study of maxillary incisors. *Eur J Orthod*. 1998 Feb;20(1):57–63.
15. Artun J, Smale I, Behbehani F, Doppel D, Van't Hof M, Kuijpers-Jagtman AM. Apical root resorption six and 12 months after initiation of fixed orthodontic appliance therapy. *Angle Orthod*. 2005 Nov;75(6):919–926.
16. Makedonas D, Lund H, Gröndahl K, Hansen K. Root resorption diagnosed with cone beam computed tomography after 6 months of orthodontic treatment with fixed appliance and the relation to risk factors. *Angle Orthod*. 2012 Mar;82(2):196–201.
17. Malmgren O, Goldson L, Hill C, Orwin A, Petrini L, Lundberg M. Root resorption after orthodontic treatment of traumatized teeth. *Am J Orthod*. 1982 Dec;82(6):487–491.
18. Chapnick L. External root resorption: an experimental radiographic evaluation. *Oral Surg Oral Med Oral Pathol*. May 1989;67(5):578–582.
19. Andreasen FM, Sewerin I, Mandel U, Andreasen JO. Radiographic assessment of simulated root resorption cavities. *Endod Dent Traumatol*. 1987 Feb;3(1):21–27.
20. Durack C, Patel S, Davies J, Wilson R, Mannocci F. Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. *Int Endod J*. 2011 Feb;44(2):136–147.
21. Estrela C, Bueno MR, De Alencar AH, et al. Method to evaluate inflammatory root resorption by using cone beam computed tomography. *J Endod*. 2009 Nov;35(11):1491–1497.
22. Helmrot E, Thilander-Klang A. Methods for monitoring patient dose in dental radiology. *Radiat Prot Dosimetry*. 2010 Apr–May;139(1–3):303–305.
23. Lund H, Gröndahl K, Hansen K, Gröndahl HG. Apical root resorption during orthodontic treatment. *Angle Orthod*. 2012 May;82(3):480–487. Epub 2011 Sep 16.
24. Goldson L, Henrikson CO. Root resorption during Begg treatment; a longitudinal roentgenologic study. *Am J Orthod*. 1975 Jul;68(1):55–66.
25. Dudic A, Giannopoulou C, Leuzinger M, Kiliaridis S. Detection of apical root resorption after orthodontic treatment by using panoramic radiography and cone-beam computed tomography of super-high resolution. *Am J Orthod Dentofacial Orthop*. 2009 Apr;135(4):434–437.
26. Blake M, Woodside DG, Pharoah MJ. A radiographic comparison of apical root resorption after orthodontic treatment with the edgewise and Speed appliances. *Am J Orthod Dentofacial Orthop*. 1995 Jul;108(1):76–84.
27. DeShields RW. A study of root resorption in treated Class II, Division I malocclusions. *Angle Orthod*. 1969 Oct;39(4):231–245.
28. Mavragani M, Boe OE, Wisth PJ, Selvig KA. Changes in root length during orthodontic treatment: advantages for immature teeth. *Eur J Orthod*. 2002 Feb;24(1):91–97.
29. Taithongchai R, Sookkorn K, Killiany DM. Facial and dentoalveolar structure and the prediction of apical root shortening. *Am J Orthod Dentofacial Orthop*. 1996 Sep; 110(3):296–302.