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Early radiographic diagnosis of apical root resorption during orthodontic treatment: a study of maxillary incisors

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SUMMARY The purpose of this study was to evaluate the sensitivity of digital radiographs for detection of (i) simulated root resorption cavities in an experimental model and (ii) orthodontically-induced apical root resorption *in vivo*. The severity of root resorption after 3 and 6 months treatment was studied in relation to root form. The experimental study cavities, drilled in mandibular roots in a dry skull, were recorded in conventional and digital radiographs. *In vivo* root resorption was evaluated on digital radiographs of 92 maxillary incisors after 3 and 6 months treatment with fixed appliances.

The results showed a similar sensitivity for the two methods. Sensitivity increased significantly with cavity size. After 3 months apical root resorption was detected in only a few teeth. The number had increased significantly after 6 months. There was a higher degree of root resorption in teeth with blunt and pipette-shaped apices. In such teeth a 3-month radiographic control is recommended.

Introduction

Early detection of small root resorptions during orthodontic treatment is essential for identifying teeth at risk of severe resorption (Levander and Malmgren, 1988). Interruption of active treatment can minimize adverse effects during subsequent treatment (Levander *et al.*, 1994). The initial resorption lacunae are small and can be identified only by histological methods. Orthodontically-induced root resorptions after 7 weeks of treatment, verified histologically, are not visible in periapical radiographs (Owman-Moll, 1995). Thus, in film-based radiography, the diagnosis is uncertain during the first months of treatment. After 5–6 months a reliable radiographic diagnosis of apical root resorption can be performed. Most teeth have small resorptions after this period. A few roots, however, are severely resorbed and it has been shown that teeth with blunt or pipette-shaped roots are particularly at risk (Levander and Malmgren, 1988).

The potential advantage of early radiographic examination of root resorption has not yet been evaluated. In order to reduce the radiation dose and cost, the number of controls must be kept to a minimum. With digital intra-oral dental radiography the radiation dose can be decreased to one-third of conventional film-based radiography (Nelvig *et al.*, 1992; Welander *et al.*, 1993).

The diagnostic utility of digital images has been questioned, but Wenzel *et al.* (1991), in a study on occlusal caries detection, found no difference in image quality for digital systems compared with Kodak Ektaspeed film (Eastman Kodak Co., Rochester, NY). In endodontics, Sanderink *et al.* (1994) reported comparable diagnostic results between film and several digital systems in determining root canal length when medium size files were used, but all sensor systems were inferior to film images with thinner files.

The purpose of this investigation was to evaluate the sensitivity of digital radiographs for detection of (i) simulated root resorption cavities in an experimental model and (ii) apical root resorption *in vivo*. Furthermore, the degree of apical root resorption after 3 and 6 months treatment was studied in relation to root form.

Material and methods

Experimental study

The material consisted of 44 conventional radiographs and an equal number of digital radiographic images of premolars in the mandible of a dry skull. During the radiographic examination the mandible was embedded in silicone impression material (Panasil, Kettenbach) and fixed in a device to the cone of a Siemens Heliodent X-ray unit, operating at 65 kVp and 10 mA. Target to object distance was 36.5 cm and object to film/sensor distance was 3.5 cm. The premolars were radiographed before and after artificial defects were drilled in different locations at the cervical, middle and apical thirds of the proximal, oral, and lingual root surfaces of the teeth. In each tooth, two small cavities (diameter 0.6 mm, depth 0.3 mm), two medium (diameter 1.2 mm, depth 0.6 mm), and two large cavities (diameter 1.8 mm, depth 0.9 mm) were made. Cavity locations were distributed to ensure a variation of root surfaces with and without cavities. The exposures were performed in three different views to increase the number of observations: (i) with the premolar orientated so that the central X-ray beam at 0 degrees horizontal angulation was directed orthoradially (i.e. the projection of the central ray that was perpendicular to the tangent of the dental arch) towards the tooth, (ii) with 20 degrees horizontal angulation mesially, and (iii) with 20 degrees horizontal angulation distally. The dental X-ray films and the sensor, respectively, were held in place with a fixed film holder during exposure (Figure 1).

Kodak Ektaspeed film was used for the conventional radiographs. All films originated from

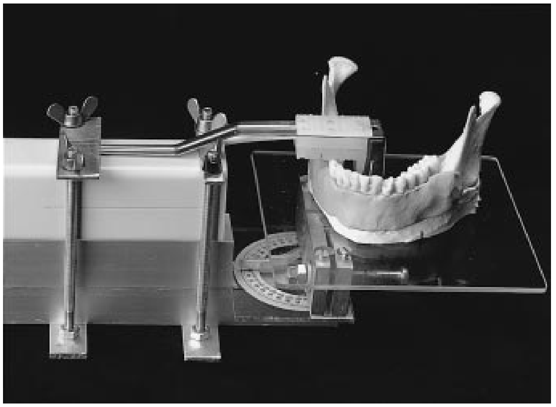

Figure 1 Experimental device for the radiographic examination of the dry skull mandible.

the same package. The radiographs were processed with the use of fresh chemicals in a Durr Periomat automatic processor.

The direct digital radiographic images were obtained by using the Sens-A-Ray system (Regam Medical Systems, Sundsvall, Sweden). The digital radiography used the same projection technique as the film-based. The images were recorded by an electronic sensor and displayed on a computer monitor (Nelvig *et al.*, 1992).

All radiographs and digital images were evaluated by three experienced observers, who were unaware of the experimental design. They were instructed to record presence and location of cavities observed in the premolar roots. They had access to the whole radiographic material with the images randomly arranged. The conventional radiographs were examined with an X-ray viewing box with a ×2 magnification and the digital X-ray images on a high resolution monitor with ×5 magnification.

Analysis of the experimental study

The cavities registered were classified as either: positive (P), a cavity was present and detected, or negative (N), a cavity was present, but not recorded. The sensitivity of the evaluation is expressed by the ratio: $P/(P + N) \times 100$, that is the percentage of correct observations out of the total number of cavities.

Clinical study

The material consisted of 92 maxillary incisors in 45 consecutive patients treated with fixed edgewise, straight wire appliances. At the start of treatment the teeth were separated into two groups according to radiographic appearance: group I (ordinary risk) comprised 56 teeth with normal apical root form, and group II (enhanced risk) comprised 36 teeth with blunt or pipette-shaped roots. The teeth in group II were recorded in 18 patients: five patients had one tooth, and 13 had two or three teeth with enhanced risk.

Radiographic follow-up method

With the digital dental imaging system, instant intra-oral radiographic images of the teeth were obtained before treatment, and after 3 and 6 months. In order to standardize the radiographic technique, a modified film holder was constructed for fixation of the sensor. Thus, the sensor could be placed parallel to the long axis of the incisors. A rectangular collimator was used. All radiography was performed by the same operator.

The digital intra-oral radiographs were displayed with ×5 magnification and analysed on the computer monitor. The distance from the cervical border of the bracket bases to the tooth apices was measured to the nearest 0.1 mm (true value) with a ruler for measuring distances in the software program. The amount of root resorption was evaluated as the difference between the measurements. The measurements were performed twice with an interval of 1 month.

Error of the method

Test model. The precision of the ruler function included in the software program for measuring root length was evaluated in a test model. An extracted premolar embedded in an acrylic cylinder was used as a test object. The anatomical length of the tooth was compared with the length measured in digital radiographs exposed before and after shortening of the root. In all, 20 radiographs were evaluated.

The premolar was shortened in four steps, one step at a time. In each step, 0.2 mm of the apex was milled using a lathe. The milled surface was plane and perpendicular to the long axis of the tooth. The length of the tooth in each step was measured three times with a calliper to the nearest 0.1 mm and the average was used as the anatomical length.

The digital radiographs were performed with the tooth mounted in the same device as shown in Figure 1 with the sensor parallel to the long axis and the central X-ray beam perpendicular to the tooth.

To increase the number of observations the tooth was radiographed in four different horizontal views before and after each shortening: perpendicular to the buccal surface, with 30, 60, and 90 degrees horizontal angulation. The length of the tooth was measured with the ruler function in all images. The measurements were performed twice at an interval of 1 month. The differences between the measurements of the anatomical length and the length measurements on the radiographs were calculated. The mean difference was 0.1 mm (SD 0.05).

Clinical study

The total error of the method in measuring the distances in the digital images in the clinical study was calculated from double determinations of 60 randomly chosen digital radiographs. Calculation was performed with the formula,

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

where d is the difference between duplicate determinations and n the number of determinations (Dahlberg, 1940). The error was 0.1 mm.

Statistical methods

The chi-square test was used for statistical comparison of the number of true observations of cavities within and between the two groups in the experimental study. The arithmetic means (mean) and standard deviations (SD) for tooth length changes were calculated in the clinical study, and the Mann–Whitney U-test was used to assess group differences. A significance level of $P = 0.05$ was used.

Table 1 Sensitivity in evaluation of cavities simulating resorption in digital images and radiographs.

Cavities	Total number of cavities	Number of true observations	
		Digital images	Radiographs
Small	216	59 (27%)	63 (29%)
Medium	144	94 (65%)	87 (60%)
Large	72	54 (75%)	59 (83%)
Total	432	207 (48%)	209 (49%)

Table 2 Apical root resorption in 92 maxillary incisors after 3 and 6 months of treatment with fixed appliance.

Apical root resorption during initial 6 months (mm)	Distribution of teeth in total sample (n = 92)			
	Apical root resorption during initial 3 months (mm)			
	<0.5	0.5–0.9	1.0–1.4	Total
<0.5	45	0	0	45
0.5–0.9	18	7	0	25
1.0–1.4	5	8	2	15
≥1.5	2	3	2	7
Total	70	18	4	92

Results

Experimental study (Table 1)

There were no significant differences in the number of true observations of cavities between the two radiographic methods. Sensitivity increased significantly with cavity size from 27 to 75 per cent for digital images and from 29 to 83 per cent for conventional radiographs.

Clinical study (Tables 2–4)

After 3 months of treatment 70 teeth with no or minimal resorption (<0.5 mm) were found. Eighteen teeth had a resorption of 0.5–0.9 mm and four were resorbed by 1.0–1.4 mm. Mean resorption was 0.3 mm (SD 0.3). Root resorption in group I (ordinary risk) was 0.2 mm (SD 0.2) and in group II (enhanced risk) 0.5 mm (SD 0.4). The difference was significant.

After 6 months of treatment 45 teeth with little or no resorption (<0.5 mm) were recorded. Twenty-five had resorption of 0.5–0.9 mm, fifteen 1.0–1.4 mm and seven more than 1.5 mm. The mean resorption was 0.6 mm (SD 0.5). Root resorption in group I was 0.4 mm (SD 0.4) and 0.8 mm (SD 0.6) in group II. The difference was significant.

Table 3 Apical root resorption in 36 maxillary incisors with an enhanced risk of root resorption after 3 and 6 months of treatment with fixed appliance.

Apical root resorption during initial 6 months (mm)	Distribution of teeth with an enhanced risk of root resorption*, group II (n = 36)			
	Apical root resorption during initial 3 months (mm)			
	<0.5	0.5–0.9	1.0–1.4	Total
<0.5	11	0	0	11
0.5–0.9	5	3	0	8
1.0–1.4	5	5	2	12
≥1.5	1	2	2	5
Total	22	10	4	36

*Blunt and pipette-shaped roots (Levander and Malmgren, 1988).

Table 4 Apical root resorption in 56 maxillary incisors with an ordinary risk of root resorption after 3 and 6 months of treatment with fixed appliance.

Apical root resorption during initial 6 months (mm)	Distribution of teeth with an ordinary risk of root resorption, group I (n = 56)			
	Apical root resorption during initial 3 months (mm)			
	<0.5	0.5–0.9	1.0–1.4	Total
<0.5	34	0	0	34
0.5–0.9	13	4	0	17
1.0–1.4	0	3	0	3
≥1.5	1	1	0	2
Total	48	8	0	56

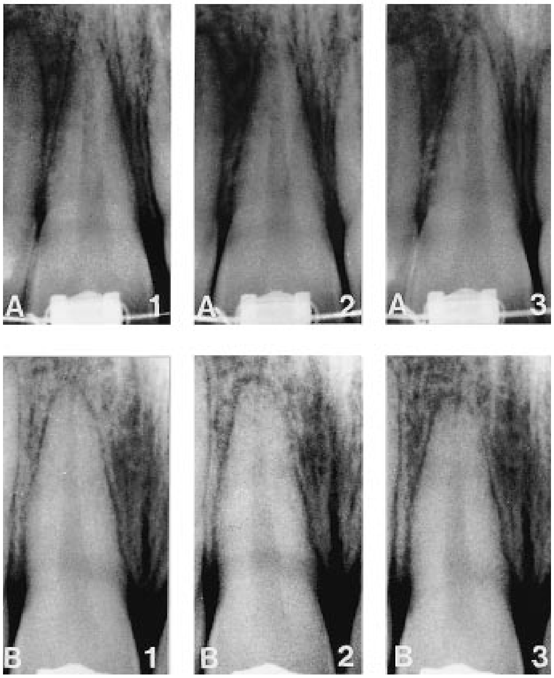

Figure 2 Root resorption after 3 and 6 months in: (A) A tooth with an ordinary risk of root resorption: (1) at the start of treatment; (2) after 3 months; (3) after 6 months. (B) A tooth with an enhanced risk of root resorption: (1) at the start of treatment; (2) after 3 months; (3) after 6 months.

Relationship between root form and resorption (Figure 2)

As defined radiographically prior to orthodontic treatment, teeth with blunt or pipette-shaped roots were placed in group II. There were 36 teeth in this group. Root resorption increased significantly more in these teeth than in the 56 teeth in group I both after 3 and 6 months.

From Table 3 it can be seen that after 3 months 14 of the teeth in group II showed resorption greater than 0.5 mm, and 11 of these had resorption of more than 1.0 mm after 6 months (79 per cent). In the remaining 22 teeth minimal or no resorption was found after 3 months and at the 6-month control six of these showed resorption more than 1.0 mm (27 per cent).

Table 4 shows that of 56 teeth with ordinary risk for root resorption (group I), eight were resorbed after 3 months. Progression of root resorption could be seen in four of these (50 per cent). In the remaining 48, minimal or no resorption was registered after the initial 3 months. One root was shortened during the following period (2 per cent).

Discussion

Although conventional intra-oral radiography is the standard method used by orthodontists to detect apical root resorption during treatment it has some inherent disadvantages. Intra-oral radiographs do not accurately diagnose early resorption (Chapnick and Endo, 1989), and often fail to reveal surface resorption lacunae on the lingual and buccal aspects of the roots (Andreasen *et al*., 1987).

Orthodontically induced apical root resorption is progressive during treatment (Levander and Malmgren, 1988), and follow-up radiographs are therefore mandatory. Hollender *et al*. (1980) advocate a limited radiographic examination every 3 months during active treatment. With such frequent check-ups, the radiation dose to the patient must be minimized. In this context digital imaging is preferable to conventional radiography.

In an evaluation of the diagnostic accuracy of digital images by McDonnell and Price (1993), it was reported that successful identification of a pattern of holes in a test object was reduced in Sens-A-Ray images in comparison to Kodak Ektaspeed intra-oral films. The observers, however, were not allowed to manipulate the original digital images, to enhance contrast and brightness. Other studies have found that the diagnostic accuracy might be increased if the contrast on the videoscreen is altered (Wenzel, 1988; Wenzel and Fejerskov, 1992; Wenzel and Hintze, 1993). The observers in the present study were instructed to use the contrast and brightness enhancement facilities to achieve the subjectively best image quality on the videoscreen. This careful examination might have contributed to the result of the experimental study. The same technique was used in the clinical part of the investigation.

Neither radiographic technique revealed many of the small cavities. This is in accordance with Andreasen *et al*. (1987). For larger cavities sensitivity was 75 per cent for the digital images and

83 per cent for the film-based radiographs. Similar findings have been reported for evaluation of cavities simulating caries in enamel with another digital system, RadioVisioGraphy (Dagenais and Clark, 1995).

The precision of the measurements of maxillary incisors on the digital images in this study was 0.1 mm. A previous study (Levander *et al.*, 1994) reported similar precision in measuring tooth lengths in standardized radiographs. In clinical practice, root resorption is assessed visually and loss of root length <0.5 mm is difficult to detect in conventional radiographs. In the Sens-A-Ray digital system the distance measurement function makes it possible to quantify small alterations in root length, and for early diagnosis of apical root resorption this is an advantage over conventional radiographs. Standardized images are a prerequisite for the assessments.

Individual response is a main factor for root resorption and the rate of resorption might be a consequence of this reaction pattern (Zachrisson, 1976; Linge and Linge, 1980, 1983; Owman-Moll, 1995). At the 3-month control, resorption >0.5 mm was detected in only a few teeth. Such an early examination might therefore seem to be of little value. However, a large proportion of these teeth showed further resorption 3 months later. Among teeth with blunt and pipette-shaped apices, included in the group with an enhanced risk at the preliminary evaluation, 69 per cent progressed. Apart from teeth with a deviating root form it has been claimed in the literature that teeth with previous root resorption and traumatized teeth are at increased risk of resorption during orthodontic treatment (Stenvik and Mjör, 1970; Linge and Linge, 1983). A high correlation between the amount of root resorption present before and after treatment has been found (Massler and Malone, 1954), and therefore the early radiographic control might serve as a risk management procedure in such teeth.

Conclusions

The sensitivity of digital radiographs for diagnosis of apical root resorption during orthodontic treatment is comparable to conventional film-based radiographs. The method offers the benefits of image processing and a reduction in radiation dosage.

To monitor apical root resorption associated with orthodontic treatment with fixed appliances the standard procedure is a radiographic examination after 6 months of treatment. In teeth with an enhanced risk, a 3-month follow-up is recommended.

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