Prevalence and severity of apical root resorption of maxillary anterior teeth in adult orthodontic patients

A. Davide Mirabella* and Jon Årtun**

*Private Practice, Catania, Italy, and **Department of Orthodontics, University of Washington, Seattle, Washington, USA

SUMMARY The purpose of this study was to evaluate prevalence and severity of apical root resorption of maxillary anterior teeth in a large sample of adult orthodontic patients, to analyse any difference between subgroups of patients with and without a history of earlier orthodontic treatment, and to test the hypothesis that endodontically treated teeth are less likely to experience apical root resorption. Differences in tooth length measurements of standardized periapical radiographs made before and after treatment of 343 adults, representing groups of consecutively treated patients from four orthodontic practices, were calculated. Sample means of averaged root resorption of all six anterior teeth and of the most severely resorbed tooth per patient were 0.94 mm (SD 0.88) and 2.39 mm (SD 1.43), respectively. Forty per cent of the adults had one or more teeth with 2.5 mm resorption or greater. The subsample of 31 patients with a history of earlier orthodontic treatment had less root resorption than the remaining patients ($P<0.001$). Evaluation of the 39 contralateral pairs of teeth with and without endodontic treatment in 36 of the patients revealed less resorption of the endodontically treated teeth ($P<0.05$).

Introduction

Histological findings indicate the presence of small areas of surface resorption on the pressure side of all roots shortly after application of orthodontic forces (Stuteville, 1938; Reitan, 1974; Rygh, 1977). Uncalcified cementum is resistant to resorption (Henry and Weinmann, 1951; Rygh, 1977), which may explain why the alveolar bone surface is readily resorbed whereas the root surface is not. However, in situations with undermining bone resorption, part of the protective cementoid layer adjacent to the hylainized areas appears to be removed, producing a root surface area vulnerable to resorption (Henry and Weinmann, 1951; Rygh, 1977). Adult patients have narrower periodontal ligament spaces, denser alveolar bone, and fewer bone marrow spaces where osteoclasts can differentiate (Weiss, 1972; Liu et al., 1977). Accordingly, undermining resorption may be more common in adults than in adolescents and root surface areas characterized with resorption may be more frequent. Resorption lacunae on lateral root surfaces repair with cementum after discontinuation of the forces, whereas loss of apical root structure is permanent (Stuteville, 1938; Henry and Weinmann, 1951; Reitan, 1974; Rygh, 1977; Langford and Sims, 1982). In the apical area pressure zones and surface resorption of the root have been observed on the periodontal aspect as well as within the pulp canal (Reitan, 1974; Rygh, 1977). Accordingly, apical root resorption may be the result of tissue reactions in both the pulp and the periodontal ligament, rendering teeth with successful endodontic treatment more resistant to apical root resorption.

Several studies have documented a small amount of apical root resorption in the average orthodontic patient, with a wide individual variation (Ketcham, 1929; Phillips, 1955; DeShields, 1969; Hollender et al., 1980). However, the resorption process ceases after removal of active appliances (VonderAhe, 1973; Copeland and Green, 1986; Remington et al., 1989). The majority of the studies have been performed in adolescent patients, and few studies have utilized samples of sufficient size (Linge and Linge, 1983, 1991). An increasing number of adults seek orthodontic treatment, and several may have experienced an earlier treatment phase.
resulting in blunting and shortening of the roots. Information is very limited regarding apical root resorption of such teeth (Harris and Baker, 1990).

The purpose of this study was to evaluate prevalence and severity of apical root resorption in a large sample of adult orthodontic patients, to analyse any differences between subgroups of patients with and without a history of earlier orthodontic treatment, and to test the hypothesis that endodontically treated teeth are less likely to experience apical root resorption.

Materials and methods

Sample

Periapical radiographs of maxillary anterior teeth made before \( (T_1) \) and after \( (T_2) \) treatment and charts of 500 adults, representing groups of consecutively treated patients from four orthodontic practices, were examined. (Adult was defined as a minimum of 20 years of age at \( T_1 \).) Multibonded appliances with 0.022 x 0.028-inch bracket slots were used in all cases. The radiographs were made in the same radiographic facility using a paralleling long cone technique. Patients with incomplete records were omitted. A total of 343 patients, aged 20.0–70.1 years at \( T_1 \) (mean 34.5, SD 9.0) and treated for 0.5–5.2 years (mean 2.0, SD 0.7) were included in the study.

Examination of periapical radiographs

Following random coding for identification, the radiographs were projected onto a screen at approximately \( \times 7 \) magnification. Linear measurements were made with a transparent ruler to the nearest fourteenth-hundredth of a millimeter, the nearest whole millimeter on the magnified image. Tooth length was measured from the incisal edge to the root apex. Crown length was measured from the incisal edge to the cemento-enamel junction (Fig. 1). Both measurements were obtained at the same time with the ruler held along the pulp canal to follow as accurately as possible the tooth long axis. Presence of a root canal filling was also recorded.

Examination of charts

History of earlier orthodontic treatment was recorded as present or absent. The recording was based on examination of the anamnestic records and interview with the orthodontist.

Error of the method

The reproducibility of the measurements was assessed by statistically analysing the difference between double measurements taken at least one week apart on 40 series of periapical radiographs selected at random (21 at \( T_1 \) and 19 at \( T_2 \)). The measurement error was calculated from the equation:

\[
S_x = \sqrt{\frac{\sum D^2}{2N}}
\]

where \( D \) is the difference between duplicated measurements and \( N \) is the number of double measurements (Dahlberg, 1940).

The mean error for the tooth length measurements was 0.34 mm with a range of 0.27 mm (right lateral incisor) to 0.42 mm (right canine). The mean error for the crown length measurements was 0.41 mm with a range of 0.30 mm (right central incisor) to 0.52 mm (right canine).

Data analysis

The amount of apical root resorption was calculated by subtracting each tooth length measurement at \( T_2 \) from the corresponding measurements at \( T_1 \) (Method I). Similarly, root resorption was calculated after adjusting each tooth length measurement at \( T_2 \) by multiplying with the corresponding crown length at \( T_1 \) and dividing with the corresponding crown length at \( T_2 \) (Method II, Fig. 1). Root resorption of all six anterior teeth in each patient was averaged. Root resorption for each contralateral pair of central and lateral incisors and canines was also averaged into one value per pair. Sample means were calculated according to each method. In addition, sample means of the most severely resorbed tooth per patient were calculated.

Sample means of averaged root resorption of all six anterior teeth, of averaged root resorption for each pair of central and lateral incisors and canines, and of the most severely resorbed tooth per patient were calculated separately for the two subgroups of patients with and without a history of earlier orthodontic treatment. Student's \( t \)-test for unpaired data was used to test for any statistically significant differences. Differences in root resorption were calculated between contralateral pairs of teeth with and without the presence of endodontic treatment. Student's \( t \)-test for paired data was used to test for any statistical significance.
APICAL ROOT RESORPTION IN ADULTS

Figure 1 Calculation of apical root resorption according to Method I and Method II.

Results

_Differences between calculations according to Method I and Method II_

The mean averaged root resorption of all six anterior teeth and the mean of the most severely resorbed tooth per patient was 0.94 mm (SD 0.88) and 2.39 mm (SD 1.43) according to Method I, and 0.35 mm (SD 1.08) and 2.67 mm (SD 1.87) according to Method II, respectively. A higher proportion of the patients were calculated to have tooth elongation according to Method II than according to Method I (Figs 2 and 3). The mean averaged root resorption for each pair of teeth was consistently larger, and the standard deviation consistently smaller when calculated according to Method I than according to Method II (Table 1).

Figure 2 Percentage of patients with averaged amount of apical root resorption of all six anterior teeth within each millimeter interval calculated according to Method I and II.
Table 1 Sample means of averaged apical root resorption for each pair of central incisors (11–21), lateral incisors (12–22), and canines (13–23) calculated according to Method I and II.

<table>
<thead>
<tr>
<th>Teeth</th>
<th>n</th>
<th>Method I mean, SD (mm)</th>
<th>Method II mean, SD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11–21</td>
<td>330</td>
<td>1.06, 1.37</td>
<td>0.49, 1.79</td>
</tr>
<tr>
<td>12–22</td>
<td>321</td>
<td>1.17, 1.25</td>
<td>0.45, 1.93</td>
</tr>
<tr>
<td>13–23</td>
<td>324</td>
<td>0.56, 1.56</td>
<td>0.10, 2.48</td>
</tr>
</tbody>
</table>

Differences between subgroups with and without a history of earlier orthodontic treatment

The mean averaged root resorption of all six anterior teeth and the mean of the most severely resorbed tooth per patient was 0.98 mm (SD 0.92) and 2.47 mm (SD 1.44) for the subgroup of patients without a history of earlier orthodontic treatment, and 0.59 mm (SD 1.15) and 1.62 mm (SD 1.07) for the patients with a history of earlier orthodontic treatment, respectively (Method I). The differences were statistically significant ($P<0.001$). Similarly, mean averaged root resorption for each pair of central and lateral incisors was higher in the subgroup of patients without a history of earlier orthodontic treatment than in the subgroup of patients who were previously treated (Method I, Table 2).

Differences between contralateral pairs of teeth with and without endodontic treatment

The teeth with a root canal filling resorbed less than the vital contralaterals (Fig. 4). The mean difference in root resorption between the 39 contralateral pairs of teeth with and without endodontic treatment in 36 of the patients was 0.45 mm (SD 1.21, $P<0.05$, Method I).

Discussion

Errors due to variations in radiographic projection and enlargement are likely to be small and

Table 2 Sample means of averaged apical root resorption for each pair of central incisors (11–21), lateral incisors (12–22), and canines (13–23) in the two subgroups of patients with (Ortho Y) and without (Ortho N) a history of earlier orthodontic treatment according to Method I.

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Ortho Y</th>
<th>Ortho N</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean, SD (mm)</td>
<td>n</td>
</tr>
<tr>
<td>11–21</td>
<td>31</td>
<td>0.50, 0.93</td>
<td>299</td>
</tr>
<tr>
<td>12–22</td>
<td>31</td>
<td>0.59, 0.95</td>
<td>290</td>
</tr>
<tr>
<td>13–23</td>
<td>30</td>
<td>0.31, 1.15</td>
<td>294</td>
</tr>
</tbody>
</table>
randomly distributed in this material, since all periapical radiographs were made in one radiographic facility according to a standardized technique. However, in an attempt to correct for differences in object enlargement within pairs of radiographs made at \( T_1 \) and \( T_2 \), we also calculated the amount of root resorption after adjusting the tooth length measurement at \( T_2 \) by correcting for any change in the crown length measurement from \( T_1 \) to \( T_2 \) (Method II) (Linge and Linge, 1991). Use of this method consistently reduced the estimate for apical root resorption (Table 1). It also produced a higher number of teeth calculated to have root elongation (Figs 2 and 3). Continued root development during treatment may not be unusual in a group of pre-adolescent patients (Linge and Linge, 1991), but is highly unlikely in adults. The discrepancy between results obtained according to Methods I and II may reflect the different effects of any incisal and cuspal equilibration or wear on the estimates for root resorption. A crown reduction will cause an overestimation of root resorption when calculated according to Method I. However, this overestimation will be considerably smaller than the corresponding amount of underestimation calculated with Method II. In addition, the results of our method error study indicate that the midlabial aspect of the cemento-enamel junction is more difficult to locate on periapical radiographs than the incisal edge and apex, which in part may explain the wider variation in root resorption according to Method II than I. The mesial and distal aspects of the cemento-enamel junction may be identified with a higher degree of accuracy provided the teeth are well aligned. However, the projections may be distorted in situations with tooth overlappings and rotations, and impossible to identify with the presence of large interproximal restorations. We consider Method I more valid than Method II, and will use the data calculated according to Method I when we discuss the results.

In the majority of the studies root resorption has been scored subjectively (Phillips, 1955; DeShields, 1969; Newman, 1975; Goldson and Henrikson, 1975; Hollender et al., 1980; Levander and Malmgren, 1988; Kaley and Phillips, 1991) making direct comparisons with our data difficult. However, comparison of our results with those from a large sample of adolescents (Linge and Linge, 1991) does not indicate an increased tendency for root resorption in adults. This supports a recent study (Harris and Baker, 1990) showing no differences in the amount of apical root resorption between adults and adolescents treated for Class II division 1 malocclusions. In fact, some reports have found more resorption in adolescent patients than we found (Phillips, 1955; Sjölien and Zachrisson, 1973; Rönnerman and Larsson, 1981; Copeland and Green, 1986; Dermaut and De Munck, 1986; Goldin, 1989; McFadden et al., 1989). However, the sample sizes were generally small and may not be representative for the population of orthodontic patients (Sjölien and Zachrisson, 1973; Rönnerman and Larsson, 1981; Copeland and Green, 1986). In addition, some samples were selected to test the effects of specific treatment modalities and tooth movements that are thought to predispose to root resorption (Dermaut and De Munck, 1986; Goldin, 1989; McFadden et al., 1989). Our sample of adults had a higher mean value for the most severely resorbed tooth per patient than the comparable group of adolescents (Linge and Linge, 1991). Also, 40 per cent of the adults had one or more teeth with 2.5 mm
resorption or more (Fig. 5), as opposed to only 16.5 per cent of the adolescents. This data indicates a wider variation of apical root resorption in adults than in adolescents.

The subgroup of patients with a history of previous orthodontic treatment was limited to only 31 patients in our sample. For that reason, our finding of less apical root resorption in this subgroup than in the remaining patients should be evaluated with care. A likely explanation for the finding may be that patients seeking retreatment in general need less tooth movement to correct the malocclusion. Also, the orthodontists may have decided to limit the treatment objectives in patients judged to be at high risk due to evidence of resorption from the first treatment period (Fig. 6). Finally, patients who have experienced severe root resorption may not seek retreatment. Accordingly, we cannot rule out an over representation of patients who are resistant to apical root resorption in our subsample.

In keeping with a previous study (Spurrier et al., 1990), we found that endodontically treated teeth are more resistant to root resorption than vital teeth, although Wickwire et al. (1974) have reached different conclusions.

However, the majority of the teeth in their study had been subjected to injury. There are indications that periapical inflammation of pulpal origin may cause apical root resorption, and that successful endodontic treatment can reverse the resorption process and encourage healing (Kaffe et al., 1984). Therefore, excess resorption observed during orthodontic movement of endodontically treated teeth may be due to unsuccessful endodontic therapy rather than the orthodontic treatment per se. In conclusion, the average adult orthodontic patient may not be at greater risk of apical root resorption than adolescents. However, the resorption pattern may be more extreme in adults, and a higher proportion may be severely affected. Endodontically treated teeth are more resistant to apical root resorption than vital teeth.

Address for correspondence
Dr Jon Årtun
Department of Orthodontics SM-46
University of Washington
Seattle
Washington 98195
USA
Acknowledgements

The authors would like to thank Don Joondeph, Vince Kokich, Doug Ramsay, and Peter Shapiro for their support. They also would like to thank Vince Kokich, Peter Shapiro, John Moore, and Gina Trask for providing the sample. Special thanks goes to Mrs Elisa Mirabella for her clerical assistance. This research was supported by Washington Dental Service Foundation Grant No. 65-7973 and the University of Washington Alumni Association.

References


Rygh P 1977 Orthodontic root resorption studied by electron microscopy. Angle Orthodontist 47: 1–16


Stovin O H 1938 Injuries caused by orthodontic forces and the ultimate results of these injuries. American Journal of Orthodontics 24: 103–116

