Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy

Isolde Smale,a Jon Årtun,b Faraj Behbehani,c Diane Doppel,d Martin van’t Hof,e and Anne M. Kuijpers-Jagtmanf
Nijmegen, The Netherlands, Safat, Kuwait, and Seattle, Wash

Introduction: Individual predisposition might be a major reason for the observed variation in apical orthodontic root resorption. If so, resorption might be expressed during the initial stages of orthodontic therapy in patients at risk.

Methods: To explore this hypothesis, we evaluated standardized, digitized periapical radiographs made before treatment (T1) and at a mean period of 6.4 months (SD 0.9) after placement of maxillary incisor brackets (T2) in 290 patients (age range, 10.1 to 57.1 years at T1). Anamnestic and treatment parameters were recorded according to a protocol, and maxillary incisor irregularity was measured on T1 study models.

Results: The mean average root resorption for 4 incisors was 0.53 mm (SD 0.47), whereas the sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 4.1% of the patients had an average resorption of 1.5 mm or more, and 15.5% had at least 1 tooth with 2.0 mm or more resorption. The maximum amount of resorption was 4.4 mm. Multivariate linear regression showed that deviated root form and increased T1-to-T2 time period were risk factors for apical root resorption of the central incisors; normal root form and wide roots were preventive factors, with an explained variance of 14%. Similarly, long roots, narrow roots, and increased T1-to-T2 time period were risk factors for resorption of the lateral incisors, whereas normal root form was a preventive factor, with an explained variance of 24%. Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors. Use of elastics was not included in the regression analyses.

Conclusions: Root resorption can begin in the early leveling stages of orthodontic treatment. About 4.1% of patients studied had an average resorption of 1.5 mm or more of the 4 maxillary incisors, and about 15.5% had at least 1 maxillary incisor with resorption of 2.0 mm or more from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%. (Am J Orthod Dentofacial Orthop 2005;128:57-67)

Experimental studies conclude that all human teeth develop resorption lacunae on the pressure side of the root surfaces shortly after application of orthodontic forces,1-4 starting at or near the periphery of hyalinized areas.1,2 These lacunae can extend halfway into the pulp canal without being detected on periapical radiographs,4 and they repair with cement once the forces are discontinued.2-4 The fact that all clinical studies document radiographic signs of root shortening of at least 1 tooth in most orthodontic patients after a full period of active appliance therapy suggests reduced potential for repair after apical resorption.

Available clinical studies on apical orthodontic root resorption are almost invariably designed in retrospect relative to the timing of active treatment, selecting pretreatment and posttreatment records to be measured from various patient files. Results about prevalence, severity, and morphologic risk factors are not likely to be different in studies designed before treatment started, if patient materials are representative, radiographs are of sufficient quality, and appropriate records are available for collecting relevant morphologic parameters. In both situations, the experimental designs are identical, analyzing data collected according to a predetermined protocol after all active treatment. Information from large, representative patient samples, based on random measurements of tooth lengths on pretreatment and posttreatment radiographs made ac-
accordance to a standardized paralleling technique, are therefore, likely to be valid. Such studies conclude that the maxillary anterior teeth, particularly the lateral incisors, are the most severely affected and that the sample mean resorption of all 6 maxillary anteriors, of the 4 maxillary incisors, or of each pair of maxillary centrals and laterals, is less than 1.5 mm. Accordingly, apical root resorption is of hardly any clinical significance for the average orthodontic patient. However, about 4% of patients experience generalized resorption of more than 3 mm, and about 5% of adults and 2% of adolescents are likely to have at least 1 tooth that resorbs more than 5 mm during treatment. Similarly, simultaneous subjective scoring of pretreatment and posttreatment panoramic radiographs of a large, representative patient sample suggests that about 3% experience resorption of more than a quarter of the root length of both maxillary central incisors during fixed appliance therapy. Although the resorption process stops when the active appliances are removed, the longevity of severely resorbed teeth might be compromised in patients susceptible to marginal periodontal breakdown. In addition, teeth with abnormally short roots might not be suitable as abutments if bridges are required in the future. The ability to identify the small proportion of patients at risk of severe apical root resorption before or early in treatment might therefore be of clinical significance.

Studies that used univariate or multivariate regression and had amount of tooth movement and abnormal root form as variables in the analyses agree that those parameters are risk factors. Similarly, the amount of resorption increases with increased tooth length and reduced root width. Teeth with short, blunt roots are not at increased risk of resorption. Finally, split mouth and intergroup comparisons of representative patient samples conclude that endodontic treatment is a preventive factor. Because the sample variation of these parameters is likely to be similar whether the study is prospective or retrospective relative to fabrication of the records, these findings might be valid. However, valid information on the effect of parameters such as time with square wire or active torque, elastics use, or background variables such as history of trauma, dysfunction, or previous orthodontic treatment might require a concurrent, prospective study design to insure accurate treatment notes.

Studies using multivariate analyses conclude that the explained variance of the parameters included in the final prediction model is less than 20%. This strongly suggests unidentified risk factors. A recent case series suggests that dental anomalies, which had not been variables in previous studies, are major risk factors for apical root resorption during orthodontic treatment. However, another study failed to detect any differences in resorption of maxillary incisors between patient groups with and without dental anomalies, matched for prevalence of known risk factors.

The low explained variance of identified risk factors suggests that the major reason for the variation in orthodontic root resorption could be individual predisposition. If so, predisposed patients might experience root resorption already in the initial leveling stages. Very few studies have explored that hypothesis. One evaluated 390 teeth in 98 patients. However, availability of only nonstandardized periapical radiographs necessitated simultaneous, subjective scoring of the pretreatment and posttreatment radiographs, introducing a risk of bias. Also, the crude scoring scale might not have been sufficiently accurate to depict the small changes likely to occur during the initial treatment stages. In the other study, 92 maxillary incisors in 45 patients were evaluated, the sample was selected according to root morphology and therefore not representative of the population. The relatively small samples in both studies and the lack of additional information precluded meaningful statistical analysis. The aims of our study were to determine the prevalence of apical root resorption during the initial stages of active orthodontic treatment and to test the hypothesis that the ability to predict patients at risk of severe initial resorption is low.

MATERIAL AND METHODS

A total of 302 orthodontic patients were consecutively enrolled between March 2001 and June 2002 at 3 centers—in Kuwait, The Netherlands, and the United States—in a study on parameters associated with apical root resorption. All patients were treated with multibonded, preadjusted appliances, with either .018-in (113 patients) or .022-in (189 patients) bracket slots. After leveling and alignment, typically with round, superelastic or stainless steel wires, space closure and interarch corrections were achieved by using rectangular wires with the exception of any initial retraction of severely proclined maxillary incisors. Lateral expansion was performed only in cases with transverse discrepancies. Periapical radiographs were obtained according to a standardized technique at predetermined stages of treatment. Three radiographic projections were made at each stage: with the central ray between the 2 central incisors and with the ray centered on each lateral incisor. Radiographs made before treatment (T1) and approximately 6 months after placement of maxillary incisor brackets (T2) were evaluated. Patients without radiographs at T2 (n = 5) or whose radiographs
had insufficient quality at T1 or T2 (n = 7) were excluded. No differences were detected in age, sex, extraction decision, incisor irregularity, or follow-up period between the included and rejected patients (P > .05). Thus, the final sample of 290 patients (191 female and 99 male) aged 10.1 to 57.1 years at T1 (mean 19.2, SD 10.6), with a time period ranging from 3.3 to 9.4 months from T1 to T2 (mean 6.4, SD 0.9), was considered representative for the study population. In these patients, 95 teeth (8.2%) were not included in the computerized evaluations, 16 due to unsuccessful reconstruction (see later paragraph) and 79 due to a combination of congenital absence or incomplete radiographic projection. All 4 teeth were measured objectively in 225 patients, 3 teeth were measured in 42 subjects, 2 in 16, and only 1 tooth in 7 patients. The 16 teeth without reconstruction were included in the subjective evaluations of apical root resorption, allowing subjective scoring of all 4 incisors in 239 patients, 3 incisors in 30 patients, 2 in 14 patients, and only 1 incisor in 7 patients.

History of previous orthodontic treatment was recorded as present or absent through patient interviews. Traumatic injuries, through clinical and radiographic examination and patient interviews at T1, were recorded as present or absent. If present, differentiations were made between no apparent dental injury, tooth luxation, tooth exfoliation, crown fracture, and root fracture.

Three indexes were used to measure the sum of adjacent anatomic contact point displacements from the mesial of 1 maxillary canine to the mesial of the other on the study models at T1. Labiolingual displacement was measured according to a modified irregularity index (IRI), defined as the sum of the distances in the labiolingual direction perpendicular to the dental arch. Spacing was measured according to a proposed spacing index (SPI), defined as the sum of the distances parallel to the dental arch, recording no mesiodistal displacement as 0, interdental overlapping as negative, and interdental spacing as positive. Contact point displacement was measured according to a proposed contact displacement index (CDI), similar to Little’s irregularity index, defined as the sum of the distances between adjacent anatomic contact points, regardless of space or overlapping. IRI and SPI were measured with a transparent millimeter grid; the CDI measurement was obtained by using a digital caliper (Fred V. Fowler, Newton, Mass). All measurements were rounded to the nearest 0.5 mm.

Extraction alternative was recorded as nonextraction, extraction of 4 teeth (various premolar and molar combinations), and extraction of only maxillary teeth.

In addition, number of months from T1 to T2, use of round and square wire, and use of anterior or posterior elastics were recorded.

All periapical radiographs were converted to digital images by using an Scanjet 5470c scanner (Hewlett-Packard, Palo Alto, Calif) at a resolution of 300 dpi. The Windows-based Emago/Advanced version 2.20 software package (SODS, Amsterdam, The Netherlands) was used to correct for differences in projection, density, and contrast between the scanned images at T1 and T2. Corresponding radiographs were evaluated simultaneously on the screen (Fig 1). Four anatomic landmarks were identified on each incisor at T2 (Fig 1, B)—2 on the crown and 2 on the root. The same 4 landmarks were then identified on the T1 image (Fig 1, A). By superimposing on these 4 landmarks, we used the software to reconstruct the T1 image according to the projection of the T2 image. The quality of the
reconstruction was checked by subtracting the reconstructed T1 image from the T2 reference image (Fig 1, C). If only minimal root and crown structures could be discerned on the subtracted image, the reconstruction was considered successful (Fig 1, B, C, and D).

Before identifying measurement points, each pair of reconstructed T1 and original T2 images was evaluated jointly. If the incisal edge was not readily identified on both radiographs, a decision was made whether to use 2 points on the projection of the cementoenamel junction (CEJ; Fig 2, A and B) or the bracket (Fig 2, C and D) as the common incisal measurement point. The latter was the preferred option if the T1 radiograph was made immediately after bracket placement. Then the radiographs were coded and measured in random order with the aid of the Emago software, recording the number of pixels between landmark pairs.\(^{20}\) If the incisal edge could be identified, tooth length (TL) was measured as the distance from the tip of the apex to the midpoint of the incisal edge. In addition, if indicated in the code, modified tooth length (MTL) was measured to a point on the CEJ or the bracket (Fig 2). Root width (RW) was measured from the mesial to the distal outline of the root 4 mm from the apex. Assuming that the enlargement factor was negligible, absolute distances were calculated according to the formula, 1 pixel = 0.085 mm, because all images were scanned at a resolution of 300 dpi.

The original T1 radiographic images were evaluated in random order, and root form was scored subjectively as normal, blunt, eroded, pointed, bent, or bottle shaped (Fig 3). Then each pair of original T1 and T2 radiographic projections was evaluated simultaneously. Signs of root resorption were scored on a scale from 0 to 5 (Fig 4).\(^{21}\)

Reproducibility of the measurements was assessed by statistically analyzing the difference between double measurements taken at least 1 week apart on study models and radiographs at T1 and T2 of 20 randomly selected patients. For the computerized measurements, the reconstruction and landmark identification procedures were repeated. Errors of the continuous variables were 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,\(^{22}\) and according to Pearson’s correlation coefficient (r). The errors of study model measurements were 1.33 mm for SPI (r = 0.71), 1.84 mm for IRI (r = 0.85), and 2.37 mm for CDI (r = 0.64). The errors for measurements of the TL and RW at T1 were 0.46 mm (r = 0.96) and 0.25 mm (r = 0.70), respectively, and the error for calculation of root resorption was 0.46 mm (r = 0.67). Kappa statistics for duplicate, subjective scoring of root shape and root resorption were 0.74 and 0.42, respectively.

**STATISTICAL ANALYSES**

Amount of apical root resorption was calculated by subtracting TL (or MTL) of the original T2 radiographic image (TL-2) from the corresponding value of the reconstructed T1 image (TL-1). Root resorption of each of the 4 incisors was averaged. Sample means of averaged amount of resorption of all incisors, of each pair of central and lateral incisors, and of the most
Fig 3. Criteria for subjective scoring of root form. N, normal; A, blunt; B, eroded; C, pointed; D, deviated; E, bottle shaped. Adapted from Mirabella and Årtun.11

Fig 4. Criteria for subjective scoring of root resorption. 0, no resorption; A, 1, irregular root contour; B, 2, apical root resorption less than 2 mm of original root length; C, 3, apical root resorption from 2 mm to 1/3 of original root length; D, 4, apical root resorption exceeding 1/3 of original root length. Adapted from Malmgren et al.21
severely resorbed tooth per patient were calculated. Also, the number of patients with 1, 2, 3, or 4 teeth with subjective signs of root resorption according to each score was calculated. Linear regression analyses were used to identify predictors for resorption. Initially, univariate linear regression was used to test for any association between resorption and the different anamnestic, occlusal, and treatment parameters and measurements of the reconstructed T1 radiographic images (Table I). Then stepwise multiple linear regression with forward selection was used to develop a prediction model. Variables were successively entered into the model if their effects were significant at $P < .05$. At each step, the variable with the lowest $P$ value was included. Separate analyses were made for the central and lateral incisors, by using the most severely resorbed tooth for each pair as the dependent variable.

### RESULTS

#### Prevalence

Computerized evaluation of apical root resorption showed that the mean averaged root resorption was 0.53 mm (SD 0.47) for all 4 incisors; the average for the central incisors was 0.48 mm (SD 0.53); the laterals averaged 0.59 mm (SD 0.68). The sample mean of the most severely resorbed tooth per patient was 1.18 mm (SD 0.86). A total of 13.4% (95% CI 9%-17%) of the patients had an average resorption of 1 mm or more; 4.1% (95% CI 2%-7%), 1.5 mm or more; and 0.7% (95% CI 0%-3%), 2.0 mm or more of all 4 incisors (Figs 5 and 6). The maximum amount of average resorption was 2.7 mm. Similarly, 50.3% (95% CI 45%-56%) of the patients had at least 1 tooth with resorption of 1.0 mm or more, 29.0% (95% CI 24%-34%) had 1 or more teeth resorbed by at least 1.5 mm, and 15.5% (95% CI 11%-20%), had at least 1 tooth with at least 2.0 mm resorption (Figs 7 and 8). The maximum resorption at the tooth level was 4.4 mm (Fig 8). A total of 13.8% of the teeth were calculated to have tooth elongation, at a maximum value of 0.91 mm. As a result, 4.48% were calculated to have an average amount of tooth elongation of all 4 incisors (Fig 5), but no patient was calculated to have a negative value for the most severely resorbed tooth (Fig 7). Only 17.5% of the subjects had no subjective signs of resorption on any tooth, whereas 34.0% had a

### Table I. Results of univariate and multivariate regression analyses with forward selection using most severely resorbed maxillary central and lateral incisors (mm) as dependent variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate</th>
<th>Multivariate</th>
<th>Univariate</th>
<th>Multivariate</th>
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<td>Univariate</td>
<td>Multivariate</td>
<td>Univariate</td>
<td>Multivariate</td>
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<tr>
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<td>$P$</td>
<td>Effect</td>
<td>$P$</td>
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<td>.53</td>
<td>.13</td>
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<td>Time T1-T2 months</td>
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<td>.12</td>
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<tr>
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<td>.26</td>
<td>.25</td>
<td>.12</td>
</tr>
<tr>
<td>Previous tx yes/no</td>
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<td>.29</td>
<td>.68</td>
<td>.08</td>
</tr>
<tr>
<td>Square wire months</td>
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<td>.31</td>
<td>.08</td>
</tr>
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<td>.71</td>
<td>.04</td>
</tr>
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<td>SPI mm</td>
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<td>.78</td>
<td>.65</td>
<td>.08</td>
</tr>
<tr>
<td>CDI mm</td>
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<td>.75</td>
<td>.04</td>
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<tr>
<td>Tooth length mm</td>
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<td>&lt;.05</td>
<td>.06</td>
<td>.31</td>
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<tr>
<td>Trauma yes/no</td>
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<td>.44</td>
<td>.57</td>
<td>-0.06</td>
</tr>
<tr>
<td>Root width mm</td>
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<td>&lt;.001</td>
<td>-0.20 (.07)</td>
<td>.001</td>
</tr>
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<td>Root form</td>
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<td></td>
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<tr>
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<td>&lt;.001</td>
<td>-0.19 (.09)</td>
<td>&lt;.01</td>
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<td>.46</td>
<td>.06</td>
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<td>.20</td>
<td>.96</td>
<td>.07</td>
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<td>&lt;.01</td>
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<td>Deviated yes/no</td>
<td>0.14</td>
<td>&lt;.05</td>
<td>0.18 (.33)</td>
<td>&lt;.01</td>
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</table>

**Fig 5.** Percentage of patients with average amount of apical root resorption of all 4 maxillary incisors within each 0.5-mm interval.
maximum score of 1; 40.0% had a maximum score of 2; and a score of 3 was observed in 8.5%. Score 4 was never observed. Although 21% of the subjects had subjective signs of resorption on only 1 tooth, 25% had 2 teeth with signs of resorption, 21% had 3 teeth, and 16% had subjective signs of resorption on all 4 teeth examined (Table II). At the tooth level, 47% had score 0, 30% had score 1, 20% had score 2, and 4% had score 3 (Table II).

**ASSOCIATIONS**

Univariate linear regression revealed that an increase in TL (P < .05; Fig 9), as well as pointed (P < .01) and deviated (P < .05) root forms, was associated with an increase in root resorption of the central incisors from T1 to T2 (Table I). Wider central incisor roots and normal root form reduced the risk of resorption (P < .01; Table I). Of these variables, only deviated root form was included in the final model as a risk factor, and normal root form and wide roots remained as preventive factors (Table I). In addition, increased observation period from T1 to T2 was included as a risk factor (Table I). The $r^2$ (explained variance) for these independent variables was 0.14. TL was close to meeting the inclusion criteria, with a $P$ value of .057 at the time of the last step (Table I).
Univariate analyses detected an association between reduced age at T1 (\(P < .05\)), increased time from T1 to T2, male sex, increased TL, reduced RW, and pointed and deviated root forms (\(P < .001; \text{Fig 10}\)) and apical resorption of the lateral incisors (Table I). History of previous orthodontic treatment and normal root form were negatively associated with resorption of these teeth (Table I). Only increased TL, reduced RW, and increased time from T1 to T2 were included in the final model as risk factors, and only normal root form was included as a preventive factor (Table I), with \(r^2 = 0.24\). Sex was not included as a variable in the multivariate analyses because of a colinearity between TL and sex, with males having longer lateral incisors.

Parameters associated with use of rectangular wire, presence of incisor irregularity, and history of trauma were not identified as risk factors (Table I). Use of anterior or posterior elastics was recorded only for periods ranging from 0 to 2.8 months and from 0 to 5.8 months in 1% and 10% of the patients, respectively, and therefore not included as parameters in the regression analyses.

**DISCUSSION**

In keeping with Levander and Malmgren, we confirmed that most orthodontic patients develop visible signs of apical root resorption of the maxillary incisors during the initial stages of fixed appliance therapy. However, the resorption is typically expressed only as a slight change in apical contour without actual root shortening. Although we judged 24.0% of the teeth...
to express root shortening, only 3.6% had shortening of more than 2 mm. Comparable figures by Levander and Malmgren were 34.4% and 1.3%, respectively. However, the wide range in severity of resorption among teeth with subjective score 3, which is from 2 mm to one third of initial tooth length, makes direct comparisons of severity between the 2 studies difficult. The low kappa for our duplicate subjective scoring of root resorption could be interpreted as support of a previous finding of low agreement when scoring intact versus irregular root contour.

Objective evaluation of root resorption requires radiographs made according to a standardized parallelizing technique to minimize errors due to differences in projection and magnification. However, interpretation of the whole range of root resorption estimates on such radiographs shows that some teeth are judged to have tooth elongation even though continued root growth can be ruled out, suggesting that projection and magnification errors might still occur. Attempts have been made to reduce such biases by adjusting for differences in crown length measurements. When we compared the 2 techniques, we found that greater tooth length was calculated more frequently and estimated resorption was less and more varied, probably because of errors associated with locating the CEJ. Projection errors are likely to be random and evenly distributed with standardized radiographs, so they might not affect mean values. However, individual cases might be inaccurately recorded. The minor amount of resorption likely to occur early in treatment could be particularly difficult to record. Attempting to minimize this problem, we used a recently introduced digital reconstruction technique, which could be a reliable method of adjusting projection errors when comparing pretreatment and posttreatment radiographic projections. The fact that maximum enlargement in our study was 0.9 mm as opposed to 2 mm or more without reconstruction confirms the usefulness of the technique.
The patients in our study were recruited from 3 different centers in 3 countries. Regardless of possible racial differences and any differences in treatment mechanics, no differences in resorption were detected among the subsamples, justifying our combining the patients into 1 group for statistical analysis.

About 4.1% of the subjects in our sample had an average resorption of more than 1.5 mm, with a maximum value of 2.7 mm. Even though such amounts of resorption are usually of minor clinical significance at the end of treatment, it might be of concern at this early stage if it is progressive. Although Levander and Malmgren\textsuperscript{17} concluded that even teeth with an irregular root contour 6 to 9 months into active treatment are at risk of severe resorption by the end of treatment, the predictive value of that finding is rather limited because 71% of the teeth fell into that category. Our aim was to explore the predictive value of early signs of resorption in detail once all treatment is completed. Of particular significance might be the final amount of resorption among the 13.4% of the patients in our study who had at least 1 tooth with apical root loss of 2.0 mm or more at this stage.

We confirmed previous findings of an association between greater tooth length and amount of root resorption.\textsuperscript{11,12} We could also confirm an association between narrow,\textsuperscript{11-13} pointed,\textsuperscript{11,12} and deviated\textsuperscript{11,12} roots and resorption. Because such root forms are more common in maxillary lateral incisors than in centrals, the common finding that maxillary lateral incisors are resorbed more than other teeth during orthodontic treatment\textsuperscript{5-7} should not be unexpected. In keeping with previous studies,\textsuperscript{11,12} we found no indication that teeth with short, blunt roots are at increased risk of resorption.

We used 3 different estimates of tooth irregularity as surrogate variables for tooth movement in our study but detected no associations between either measurement and amount of root resorption. This might be because typical tooth movements during initial leveling are in the form of crown tipping rather than root movement. Our material might therefore not have been suitable for confirming previous findings of an associ-
ation between apical root resorption and amount of root movement.\textsuperscript{11,12} However, we did find an association between initial treatment time and resorption. Our results suggest that 1 month of extra treatment time causes 0.1 and 0.2 mm of additional root resorption of the most severely resorbed central and lateral incisor, respectively (Table I). The findings in previous studies are inconclusive regarding any association between treatment length and amount of resorption at appliance removal.\textsuperscript{8,9,11-13} One explanation could be that treatment time might include periods when the appliances are passive and that variables that might be correlated with treatment time, such as amount of root movement, are not always accounted for in analyses.

We did not use anterior or posterior elastics as independent variables in the regression analyses because of insufficient use at this early stage of treatment. Neither did we include malocclusion parameters such as overjet and overbite because any active corrections were unlikely to have started at this early stage. However, we did confirm previous findings that the explained variance of the identified risk factors was low,\textsuperscript{8,11,13} only 14% for the central and 24% for the lateral incisors. This strongly supports the notion that the major risk factors for apical root resorption during orthodontic treatment are related to individual predisposition.

CONCLUSIONS

Root resorption can be detected even in the early leveling stages of orthodontic treatment. About 4.1% of patients have an average resorption of at least 1.5 mm of the 4 maxillary incisors, and about 15.5% have 1 maxillary incisor or more with resorption of at least 2.0 mm from 3 to 9 months after initiation of fixed appliance therapy. Although teeth with long, narrow, and deviated roots are at increased risk of resorption during this early stage, the explained variance of these risk factors is less than 25%.

REFERENCES