External apical root resorption in retracted incisors

Hallissa Simplício, DDS, MS, PhD
José Sandro Pereira da Silva, DDS, MS, PhD
Sergei Godeiro Fernandes Rabelo Caldas, DDS, MS, PhD candidate
Ary dos Santos-Pinto, DDS, MS, PhD

Aim: To evaluate the occurrence of external apical root resorption (EARR) in the incisors after anterior retraction in corrective orthodontic treatment with first premolar extractions and whether it was related with the type of root apex movement and its inclination. Method: The maxillary and mandibular incisors of 22 patients (12 to 25 years of age; 9 males and 13 females) were treated with fixed appliances and premolar extraction. EARR was defined as the difference in root length before and after incisal retraction on periapical radiographs. Distortion of radiographic images and changes due to incisal tipping were controlled for. Pre- and post-incisal retraction lateral cephalometric radiographs established the relationship between EARR and the tipping of the incisors, along with the vertical, horizontal, and total movement of the root apex. Results: There was significant EARR (1.51 to 2.37 mm) during incisor retraction, but this was not related to the movement or the tipping of the root apex of almost all teeth. It was observed that after the retraction stage, EARR occurred in all evaluated incisors, but it was more significant (P < .05) in the mandibular right lateral incisor. Conclusion: The EARR that did occur was unrelated to movement or tipping of the root apex, except for the vertical root apex movement of the mandibular left central incisor and the inclination of the maxillary right lateral incisor. ORTHODONTICS (CHIC) 2012;13:86–93.

Key words: dental extraction, orthodontic space close, root resorption

Orthodontic corrective therapy is universally accompanied by iatrogenic external apical root resorption (EARR) in almost all teeth and is most evident on the maxillary and mandibular central and lateral incisors. Although this problem has been studied extensively, all previous studies compared changes after orthodontic treatment or the retention phase. Few studies have dealt with the prevalence and severity of EARR during specific stages of orthodontic treatment. Therefore, the aim of this study was to identify and quantify EARR during the incisor retraction phase, after extraction of the first premolars.

METHODS

This research was a prospective study and was approved by the research ethics committee of the Araraquara School of Dentistry, São Paulo State University (UNESP), São Paulo, Brazil.
Twenty-two patients (12 to 25 years of age; 9 males and 13 females) selected for orthodontic treatment with fixed appliances and extraction of the first premolars were evaluated. To be included in the study, patients had to have been undergoing orthodontic treatment with 0.022 × 0.028-inch Roth prescription straight-wire fixed appliances and be indicated for first premolar extraction. All patients’ incisors were tested to confirm pulp vitality and examined to attest to the absence of edema, periodontal pockets, caries, endodontic treatment, and restorations.

Lateral cephalograms and periapical radiographs were taken just prior to and at the end of the orthodontic space closure after bilateral first premolar extraction by retraction of the anterior segment.

Space closure was performed using standard mechanics of closing loops (T or bull loops) to retract the anterior segment (canine to canine), and the amount of applied force was about 300 to 350 g.

By evaluating the radiographs, the occurrence of incisor external apical root resorption (EARR) and its relationship with the amount of inclination and the type of root apex movement performed by the incisor after the anterior segment retraction was determined.

Periapical radiographs of the maxillary and mandibular central and lateral incisors were taken by the long-cone technique using a positioner to obtain one radiograph of two teeth (central and lateral incisors). The radiographs were processed in an automatic processor to ensure standardization of the development and fixation times of all films, so that density, contrast, and clarity were similar in all radiographs.

Reference points were marked on one sheet of transparency film by a single examiner and checked for consistency by a second examiner (Figs 1 and 2).

From the sample (22 patients), measurements were made on 17 maxillary incisors (11 patients had only maxillary incisors retracted and 6 patients had maxillary and mandibular incisors retracted). Measurements were also made on 11 mandibular incisors (5 patients had only mandibular incisors retracted and 6 patients had maxillary and mandibular incisors retracted). The retraction phase of the treatment generally lasted 3 to 10 months.

The reference points were digitized with a digitizing table (TLP 1212, Kurta) and DFPlus 6.5 (Dentofacial Software) by a single examiner. For each incisor, coronal and root lengths were calculated using the DFPlus software. Coronal incisor length was defined as the linear distance between the mean points of the mesial and distal incisal edges, and incisor root length was defined as the linear distance between the mean points of the mesial and distal cervical margin and the root apex point (Fig 2 and Table 1).

EARR was then expressed as a percent of the effective root reduction (ie, the difference between pre- and postretraction root length divided by the
External apical root resorption in retracted incisors

Scientific Innovation

preretraction length). To eliminate any differences due to size and to correct for any radiographic image distortion, root shortening was calculated using the following formula:

\[ \text{Root shortening (RS)} = iRL_1 - (iRL_2 \times CF) \]

where \( iRL_1 \) = incisors preretraction root length, \( iRL_2 \) = incisors postretraction root length, and \( CF \) = correction factor.

The correction factor used was the ratio of the preretraction coronal length divided by the postretraction coronal length\(^5\) to correct any change of the incisor inclination or radiographic distortions.

Changes in the inclination of the incisors and type of root apex movement (vertical, horizontal, and total) were measured from the patients’ cephalometric radiographs. The maxillary and mandibular central incisors were used because their incisal and apical points provide the most accurate measurements and the apexes of the other teeth move in the same way. The palatal plane (ANS-PNS) was used to obtain the maxillary incisor inclination, and the mandibular plane (Go-Me) was used to obtain the mandibular incisor inclination (Fig 3). Movements of the root apex were calculated relative to the horizontal and vertical axes defined on the preretraction radiograph and transferred to the postretraction one using the Bjork regional superimposition. The horizontal axis was defined as \( SN = -7 \) degrees, and the vertical axis was defined as perpendicular to the horizontal axis using the \( S \) as a registry point (Figs 4 and 5).
Table 1  Means, SDs, and CIs of the variables that represent incisal shortening

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>RULI_RS</td>
<td>17</td>
<td>2.02*</td>
<td>1.61</td>
<td>1.19</td>
<td>2.84</td>
</tr>
<tr>
<td>RUCI_RS</td>
<td>17</td>
<td>2.16*</td>
<td>1.40</td>
<td>1.45</td>
<td>2.88</td>
</tr>
<tr>
<td>LUCI_RS</td>
<td>17</td>
<td>1.74*</td>
<td>1.32</td>
<td>1.06</td>
<td>2.42</td>
</tr>
<tr>
<td>LULI_RS</td>
<td>17</td>
<td>2.04*</td>
<td>1.78</td>
<td>1.12</td>
<td>2.95</td>
</tr>
<tr>
<td>RLLI_RS</td>
<td>11</td>
<td>2.37*</td>
<td>1.44</td>
<td>1.40</td>
<td>3.33</td>
</tr>
<tr>
<td>RLCI_RS</td>
<td>11</td>
<td>1.78*</td>
<td>1.15</td>
<td>1.01</td>
<td>2.56</td>
</tr>
<tr>
<td>LLCI_RS</td>
<td>11</td>
<td>1.51*</td>
<td>0.93</td>
<td>0.88</td>
<td>2.14</td>
</tr>
<tr>
<td>LLLI_RS</td>
<td>11</td>
<td>2.08*</td>
<td>1.23</td>
<td>1.26</td>
<td>2.91</td>
</tr>
</tbody>
</table>

SD, standard deviation; CI, confidence interval; RULI_RS, maxillary right lateral incisor root shortening; RUCI_RS, maxillary right central incisor root shortening; LUCI_RS, maxillary left central incisor root shortening; LULI_RS, maxillary left lateral incisor root shortening; RLLI_RS, mandibular right lateral incisor root shortening; RLCI_RS, mandibular right central incisor root shortening; LLCI_RS, mandibular left central incisor root shortening; LLLI_RS, mandibular left lateral incisor root shortening. *P < .05.

Fig 3  Palatine, mandibular, and cranial base planes in the preretraction lateral cephalogram.

Fig 4  (left)  Maxillary regional overlap to obtain the total apical movement of the incisors.

Fig 5  (right)  Mandibular regional overlap to obtain the total apical movement of the incisors.
Maxillary superimposition was obtained using the nasal floor, key ridge, and hard palate structures and was used to measure the maxillary incisor root movements, avoiding interference of any displacement or bone remodeling of the maxilla (Fig 4 and Table 1). Mandibular superimposition was obtained using the mandibular canal and symphysis and was used to measure the mandibular incisor root movements, eliminating any displacement or bone remodeling of the mandible (Fig 5 and Table 1). The total change in position of the root apex was calculated as the hypotenuse of the triangle formed by the horizontal and vertical changes using the Pythagorean theorem.

A single examiner digitized the reference points from the tracings using a digitizing table and DFPlus. DFPlus was used to calculate the distances and angles that were transferred to SPSS (IBM) to calculate changes and for statistical analysis.

The Student t test at a significance level of 5% was used to test for significant EARR, and the Pearson correlation coefficient was used to calculate incisor shortening and root movements. Method error for root resorption and root movement measurements were determined by intraclass correlation coefficients (ICC), which showed values between 0.995 to 0.999 and 0.995 to 1.0, respectively. Sample-size estimation determined that the statistical analysis had an adequate power of 0.7 for the mandibular incisor sample (n = 11) and 0.83 for the maxillary incisor sample (n = 17).

**RESULTS**

Significant root shortening was seen in all four maxillary and mandibular incisors (Table 1). Figure 6 shows the mean resorption in each group of teeth and their lower and upper limits in our sample.

The mean percentage of root shortening in the maxillary arch, relative to the initial root size, was 12.8% for the right lateral incisor, 13.5% for the right central incisor, 10.8% for the left central incisor, and 12.0% for the left lateral incisor (Fig 7). In the mandibular arch, the mean percentage of root shortening was 15.5% for the right lateral incisor, 12.4% for the right central incisor, 10.5% for the left central incisor, and 13.5% for the left lateral incisor (Fig 7).
To determine if the EARR was related to intrabony tooth movements, we looked for correlations between the amount of root shortening, the amount of apical movement, or the change of incisor inclination at the end of tooth retraction (Table 2). The EARR that occurred was unrelated to the movement or the tipping of the root apex, except for the vertical root apex movement of the mandibular left central incisor and the inclination of the maxillary right lateral incisor (Tables 3a and 3b).

**Fig 6**  Mean and range of root shortening of the maxillary and mandibular incisors.

**Fig 7**  Root shortening percentage in relation to the initial root length of incisors after its retraction.
DISCUSSION

Orthodontics produces tooth movement by applying force to the dentoalveolar system and facial skeleton. However, one common adverse effect is EARR of the teeth, especially the incisors. Periapical radiographs were chosen to quantify the resorption because they are most accepted in this type of study. Periapical radiographs are superior to panoramic, occlusal, or lateral radiographs for studying root structures, especially when the periapical films are obtained by the parallelism technique. This technique provides more information and produces less image distortion than panoramic and cephalometric radiographs. The mean amount of root reduction we observed is within reported ranges of 1.0 to 2.9 mm for the maxillary incisors and 0.5 to 1.4 mm for the mandibular incisors. Our results also agree with previously reported percentages of root shortening of 9.4% to 14.0% for the maxillary incisors and 4.6% to 7.3% for the mandibular incisors.

Previous studies found no correlation between the amount of EARR and the amount of apical movement. Our study found significant correlations for only the maxillary right lateral incisor and the mandibular left central incisor. In the same way, Sameshima and Sinclair showed a positive correlation between EARR and horizontal apical displacement of the anterior teeth. With the Tweed, Begg, and Roth techniques, Parker and Harris found a strong correlation between EARR and apical and incisal vertical movements as seen in intrusion with incisal lingual root torque. In contrast, they showed no discernible effect in distal bodily retraction, extrusion, or lingual crown tipping.

The different mean amounts of EARR found in different teeth may have been due to measurement error because of the difficulty in determining the cementoenamel junction (CEJ) of the incisors or because different teeth have different tendencies for root resorption. Mirabella and Artun reported on the difficulty of determining the incisor CEJ when compared with the apex and incisal edge. We also noticed this difficulty, which could have contributed to the variability in resorption between different teeth. According to Massler and Malone, the resorption potential varies among individuals and different teeth of the same person. However, our results did not show any significant differences of the resorption level between the central and lateral incisors.

Both our results and the literature indicate a mean EARR in each tooth group of approximately 2 mm. However, it is important to emphasize that previous studies considered the amount of resorption during the entire orthodontic treatment. In contrast, our results refer to only an intermediate phase during the retraction of the anterior teeth. These results show resorption levels similar to reported levels seen in treatment as a whole, suggesting that the greatest amount of resorption in extraction cases occurs during the retraction phase.
Some authors\textsuperscript{3,9–11} have suggested that cases with extraction result in a greater amount of resorption than cases treated without extractions. If so, it would be expected that most of the resorption would occur during the retraction phase.\textsuperscript{2,4} The distribution of resorption gaps is directly related to the quantity of applied force, and the speed distribution of these gaps increases with an increase of applied force. The greater forces used with the patients in this study may be associated with the amount of resorption.\textsuperscript{13,14,20} These forces were reactivated in about 21 days, but this can be shorter for tissue reorganization and to receive a new reactivation, because the tissue reaction may be not the same in all the patients.

CONCLUSION

The following conclusions were drawn from this study:

- EARR happens in all incisors after the retraction stage.
- The tooth that showed larger levels of EARR was the mandibular right lateral incisor; the mandibular left central incisor showed the smallest levels of EARR.
- No significant correlation between EARR and horizontal, vertical, and total root apex movement was found, except for the vertical root apex movement of the mandibular left central incisor.
- No significant correlation was found between EARR and the change in the inclination of incisors, except for the maxillary right lateral incisor.

REFERENCES