**SUMMARY**

The aim of this study was to evaluate in vitro the accuracy of Ray-Pex 5 to determine the working length in teeth with simulated apical root resorption. 40 recently extracted human single rooted teeth with mature apices were used for this study. To simulate apical resorption, we used a #3 carbide round bur (#330 S.S. White) to create an abnormal defect at the root apex of each tooth. 2 operators compared the electronic versus direct visual measurements, and the accuracy of the electronic apex locator was evaluated within ± 0.5, ± 1, and ± 1.5 mm, respectively. Ray Pex 5 was accurate 81.25%, 97.5%, and 100.0% by direct visual measurements within 0.5 mm, 1 mm, and 1.5 mm, respectively. There was no statistically significant difference between the 2 operators (p<0.05).

**Keywords:** Root Resorption, apical; Working Length; Ray-Pex 5

**Introduction**

The exact determination of the tooth root canal working length is one of the most important steps in endodontic treatment, and makes the difference between success and failure. The working length corresponds to the distance between the coronal reference point and the apical constriction. Ideal root canal treatment should terminate at the apical constriction. Kuttler1 showed that the average apical constriction is 0.524 - 0.659 mm coronal to the apical foramen; the determination of this area has traditionally been made by tactile-feedback and radiography.

Traumatic injury and chronic inflammation of the pulp or periodontal ligament, or both, results in apical root resorption, which will make the determination of the working length extremely difficult due to the fact that the apical constriction will be pathologically altered2. Root resorption is either a physiologic or pathologic process which results in the loss of cementum and dentin3. All pathological root resorption of dental origin are inflammatory in nature, and the most common stimulating factor is pulpal infection4. The surrounding periapical bone contains osteoclasts, and following injury to the cementum or dentin, infected dentinal tubules may stimulate the inflammatory process with osteoclastic activity, consequently initiating apical root resorption5.

Most root canals associated with apical root resorption no longer have an apical constriction. Obtaining closure of the apex in these cases is synonymous with the apical closure in the blunderbuss canal. Besides the difficulty in instrumenting to close this type of root canals, there is also a great difficulty in determining the working length6. In these cases, combination of digital-tactile sense and radiography has important limitations.

Nowadays, many electronic apex locators (EAL) have been introduced to the market. Using a ground clip on the patient’s lip and a file-probe inside the canal, the EAL determines the location of the actual anatomic apical foramen. These devices can be very technique-sensitive, leading to inconsistent results and frustration for the device user. However, when used on a consistent basis, they are a quick and accurate way to determine working lengths7,8.

Several research papers have showed that EAL cannot determine accurately the working length in teeth with open apices, and only a few papers report the use of an EAL in teeth with apical resorption. Nguyen et al9 used the Root ZX and were able to identify the location of the
In a wax sheet of 2 mm thickness, 40 holes were made and the specimens were inserted into them up to their neck, and stabilized with sticky wax. A gel of 0.9% NaCl solution and methyl-cellulose was prepared to simulate the periapical tissues, proposed by De Moor et al., and was placed in a plastic box of 20 x 6 x 3 cm. The wax sheet was placed at the top of the plastic box so that the roots of the teeth were embedded into the gel.

The electronic apex locator that was tested in the present study was Ray-Pex 5. Based on the canal size, a K-file was attached to the file holder and was inserted into the root canal until the signal on the display flashed “APEX.” The file was then retracted until the EAL digital display showed 0.5 mm, which generally confirms that the instrument is at the apical constriction. The rubber stop on the inserted file was set to the prepared incisal edge, the standard reference point for the measurements. The files were then removed from the canals and their lengths were measured with a digital caliper (Mitutoyo Corp. Tokyo, Japan) to the nearest 0.5 mm. After the measurements with the apex locator, direct visual ones were performed. The distance from each incisal edge till the point where the tip of the file reached the outer surface of the root, was measured. This direct visual measurement was reduced by 0.5 mm and recorded. 2 operators compared the electronic versus the direct visual measurements, and the accuracy of the EAL was evaluated within ± 0.5, ± 1, and ± 1.5 mm, respectively.

**Results**

The results can be seen on table 1. According to the results obtained by the 2 operators, Ray-Pex 5 measurements were accurate 81.25%, 97.5%, and 100.0% by direct visual measurements within 0.5 mm, 1 mm, and 1.5 mm, respectively. There was no statistically significant difference between the two operators (p<0.05).

**Table 1. Accuracy of Ray-Pex 5 obtained from 40 teeth**

<table>
<thead>
<tr>
<th>Distance to the apical foramen</th>
<th>Operator A</th>
<th>Operator B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of teeth</td>
<td>%</td>
<td>Number of teeth</td>
</tr>
<tr>
<td>± 0.5</td>
<td>33</td>
<td>82.5</td>
<td>32</td>
</tr>
<tr>
<td>± 1</td>
<td>39</td>
<td>97.5</td>
<td>39</td>
</tr>
<tr>
<td>± 1.5</td>
<td>40</td>
<td>100</td>
<td>40</td>
</tr>
</tbody>
</table>

**Discussion**

Although different papers point out that EAL don’t give correct results in teeth with open apices, only a few
papers report the use of an EAL in teeth with apical root resorption\textsuperscript{11,12}. When apical constriction is altered as a result of apical root resorption, it is very difficult to determine the working length by radiographic methods alone.

In this study we followed the methodology of Goldberg et al\textsuperscript{2} who tested the measurement accuracy of Root ZX in teeth with simulated apical root resorption \textit{in vitro}, and found that Root ZX was accurate 62.7\%, 94\% and 100\% by direct visual measurements within \(\pm 0.5\text{mm}, \pm 1\text{mm}, \pm 1.5 \text{mm}\) respectively. In this study, electronic readings obtained with Ray-Pex 5 showed an accuracy of 81.25\%, 97.5\%, and 100.0\% by direct visual measurements within 0.5 mm, 1 mm, and 1.5 mm, respectively. Shabahang et al\textsuperscript{13} suggested that an error tolerance of 1 mm is clinically acceptable. Our results are in agreement with those of Goldberg et al\textsuperscript{2}, who evaluated tolerance of 1 mm is clinically acceptable. Our results are

Only in 1 case in our study the distance to the apical foramen exceeded 1.5 mm, which is in disagreement with the results of Dunlap et al\textsuperscript{14} who found 2 measurements in the necrotic group that were >1.5 mm beyond the apical constriction using the Root ZX, and both came from the same patient whose 2 teeth had periapical radiolucencies, and it is conceivable that these periapical lesions, with their lack of periodontal ligament and periapical bone, might have caused abnormally long readings. It is also possible that apical root resorption may have occurred, thus resulting in the destruction of the apical constriction.

In teeth with incompletely formed roots, the diameter of the apex is wider\textsuperscript{15}. Huang\textsuperscript{16} observed that when the width of the apex is greater than 0.5 mm, electronic measurement have been found to deviate significantly from the actual length. In a clinical study, Suehde and Tulim\textsuperscript{17} showed that the length was correctly determined in only 7 out of 11 cases of teeth with incompletely formed root. Also, Berman and Fleischman\textsuperscript{7} reported 5 such cases where the length measured with an EAL was shorter than the actual length. However, investigating mature teeth with apical root resorption \textit{in vivo} by EAL, the root canal typically has a decreasing taper toward the defect, making it possible to place a file into the canal and have its apical most terminal aspect contact dentin and achieve an electronic measurement. The results of this study showed that the Ray-Pex 5 might be useful in determining the working length in a variety of clinical conditions, including extensive apical root resorption.