Accuracy of the Raypex-4 and Propex Apex Locators in Detecting Horizontal and Vertical Root Fractures: An In Vitro Study*  

Abstract  
Unforeseen root fractures during endodontic therapy are often difficult to diagnose and treat. Apex locators have been shown to be accurate in measuring the working lengths of root canals, and it was postulated whether they could also be used to determine the position of root fractures. This study was undertaken to assess the accuracy of two different apex locators in determining the position of fractures. Ninety six single rooted teeth were randomly divided into two groups. One group had simulated horizontal fractures cut into them and the other group had vertical fractures. All fractures were detected in both groups using both a Propex (third generation) and a Raypex-4 (fourth generation) apex locators. The actual lengths of the fractures were then measured under 2.5 times magnification, and the results subjected to statistical analysis. Both locators produced similar results and were found to be very accurate, with measurements that correlated closely to the actual lengths. Clinically, treatment options for root fractures vary depending on their location. Thus apex locators may be a valuable aid in not only determining the presence of a root fracture, but also its exact location, which will help the clinician decide on the most appropriate management.

Key words: Endodontics, Apex locator, Root fracture, Raypex-4, Propex.

Introduction  
Many studies using apex locators to determine the working lengths in root canals, showed them to be very accurate and reliable.1-5 In most of these reports “Third generation apex locators” such as the Root ZX (Morita Crop, Tokyo, Japan) apex locator were used. These instruments are also termed “comparative impedance apex locators” as they are influenced by two alternating currents of differing frequencies flowing through the tissue.6 Recently, a new apex locator, Bingo 1020 (also known as Raypex-4), (Forum Engineering Technologies, Rishon Lezion, Israel) has been introduced. The manufacturers claim this to be a fourth generation apex locator, in that it also uses two separate frequencies of 400 Hz and 8 KHz, but unlike the third generation locators, it uses only one frequency at a time. The use of a single frequency signal eliminates the need for filters that separate the different frequencies which helps prevent the noise inherent in such filters, and increases the measurement accuracy. In addition; these newer apex locators work in the presence of electrolytes, so there is no need to dry the canals before use.6 In use, a file is inserted onto the root canal and an electrical contact is made with the shank of the instrument. The device has a second electrode, which is placed in contact with the patient’s oral mucosa. A digital display or audible signal shows when the tip of the instrument reaches the apical foramen.8

A recent in vitro study compared the accuracy of a new fourth generation (Bingo 1020) locator with a third generation (Root ZX) locator when measuring canal lengths, and then evaluated these results against radiographic measurements. Both locators were equally accurate and reliable, and even though the measurements obtained using the Bingo 1020 were closer to the actual lengths than those obtained by the Root ZX, the differences were not statistically significant.9

One of the more perplexing problems in endodontic therapy is unforeseen horizontal or vertical fractures of the root canal wall, which are often difficult to diagnose and to treat. It has been postulated that apex locators could be used to determine the position of a fracture, if it communicates with the periodontal membrane. However, until now only one study has been done to detect root fractures using an apex locator.10 The authors found that the locator could accurately determine horizontal fractures, but was unreliable in detecting vertical fractures.

Objectives  
The aim of this study was to measure the positions of simulated horizontal and vertical fractures...
using a third generation apex locator, Propex (J. Morita Corp, Tokyo, Japan) and a fourth generation apex locator, Raypex-4 (Forum Engineering Technologies, Rishon Lezion, Israel), and to compare these figures with each other and with the actual measurements of the fractures.

Materials and Methods

Ninety-six recently extracted, single rooted permanent human teeth were used in this study. Only teeth with sound roots and no evidence of root resorption or fractures were used. All of the teeth were placed in 10% formalin immediately after extraction. Access cavities were prepared and the working lengths were determined radiographically using a size 10 K-File (Dentsply, Tulsa, Okla). Teeth were numbered and randomly divided into two groups of 48 each. One group had simulated vertical fractures prepared (group V) and the other had horizontal fractures (group H), cut using a 0.2 mm thick diamond disc (Fig. 1). In group V, a cut was made vertically through the entire length of the root until the root canal was exposed, while in group H, the roots were incompletely cut horizontally until the root canal was exposed.

A Propex and a Raypex-4 apex locator were used in this study. A master plastic jaw in a phantom head model (Fig. 2) was used to hold the tooth specimens during the testing. All the anterior teeth were removed from their sockets, and the sockets were then enlarged with a bur until the human teeth could be adapted and easily fitted into them. The teeth were placed in the plastic jaw, and embedded with a layer of irreversible hydrocolloid (Blue-print, De Trey, Surrey, UK). Additional alginate was placed under the master model where the lip clip electrode of the apex locator was to be inserted. Four teeth were tested at the same time, and a new mix of alginate was used for every set.

All the fractures were detected in both groups using the Propex and the Raypex-4 apex locators, and all measurements were carried out by one operator to ensure standardization of the experimental technique. Eight teeth from each group were randomly re-tested to verify the accuracy and repeatability of the testing.

In group H, after the lengths of the simulated fractures had been recorded using both apex locators, the teeth were removed from the model, and the fractures were completed with the disc. The actual lengths were then measured using a size 10 K-File under 2.5 times magnification, using a radiographic viewer designed to eliminate extraneous light and magnify the image (Fig. 3). In group V, the lengths were determined up to the coronal end of the simulated fracture with the locators. They too were removed and the lengths of the fractures determined using a size 10 K-file under 2.5 times magnification.

Statistical Analysis

The Pearson correlation co-efficient and regression analysis was used to determine the differences between all the test samples. Agreement between the two locators was measured by the Kappa statistic. Horizontal and vertical fractures were analyzed and compared to the actual values separately, and also with both sets of results combined. Closeness of the Raypex-4 and Propex measurements to the actual length was compared by the paired t-test, based on their deviations from the actual lengths. All statistical procedures were conducted on SAS and p values ≤ 0.05 were considered significant.

Results

In both groups V and H, the mean values (mm), standard deviations, and minimum and maximum values were calculated separately for the Raypex-4 and Propex apex locators as well as for the actual measurements. The differences between Raypex-4 and Actual, Propex and Actual and Raypex-4 and Propex were then calculated and used in the statistical analysis.

Results are shown in Tables 1 and 2 respectively. Table 3 shows the results obtained when both the V and H measurements were combined.

Discussion

Apex locators are capable of accurate measurement and can determine the exact location of the apical foramen especially in cases where the outline of the canal on the pre-operative film is indistinct, or where the canal curves towards or away from the radiographic beam. They have also been used as an alternative to working-length radiographs in cases where patients request to have a minimum number of radiographs taken, however an initial pre-operative film should still be used to obtain an estimated figure. Carrotte (2004) cautioned that there is a learning curve associated with the use of apex locators, thus the pre-operative radiograph is an essential guide as to whether the measurements are in accordance with the original radiographic estimated lengths. In this study, when comparing the two different apex locators,
the operator found that both systems needed an initial practice period before repeatable accurate results could be obtained, however the Raypex was easier to use and detected the fracture lines more readily. Azabat et al. (2004) found apex locators to be more accurate in determining horizontal than vertical fractures, however, in this study although both locators were slightly more accurate when measuring horizontal fractures, the differences were not significant statistically, and both locators were found to be very accurate in determining the actual position of all the fractures.

In this study, for the group H, both locators correlated very closely to the actual measurements with Raypex-4 being slightly more accurate than Propex, but not significantly so (p = 1.00 and p = 0.739 respectively). The difference between the two locators was also not statistically significant (p = 0.339). Thus, where root fractures are detected within the upper third of the root (± upper 4 mm), then forced eruption can be attempted to allow for restoration with physiologic gingival conditions, eliminating the need for surgical crown lengthening, marginal osteotomies or tooth extraction. Clinically, it is more important to be able to diagnose the exact location of a fracture rather than its mere presence, as this can impact on the treatment options and eventual fate of the tooth. Contrary to popular belief, not all teeth with fractured roots need to be extracted. Rintaro et al. (2004) reported that when a root fracture is located very close to the gingiva, the chance of healing with calcified tissue is the poorest. However, in these cases as an alternative to extraction, the coronal fragments can be removed followed by orthodontic or surgical extrusion of the remaining root. This will allow for elevation of the fracture line above the epithelial attachment, and will bring the margins to a visible level, allowing for prosthetic restoration of the tooth. This is a more conservative treatment choice in young children compared to the prosthetic restorations that would be needed after an extraction.

<table>
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<th>N</th>
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<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>-2.7</td>
<td>2.5</td>
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Teeth diagnosed with fractures in the middle third of the root are usually unsavable, although some authors have suggested that if these teeth are repositioned such that the displacement of the segments does not exceed 1mm, and then splinted for 4 weeks,
they may be salvaged. The repair process involves interposition of either hard tissue or periodontal ligament between the fragments, while the pulp may heal or undergo necrosis, in which case endodontic treatment would be required. Many different endodontic techniques have been proposed to determine which method will be the most successful in treatment of teeth with fractures in the middle or apical thirds of the root. One study found that root canal filling with GP of the coronal fragment only, with or without surgical removal of the apical fragment, can be successful in selected cases. Treatment of the root canal with or without surgical removal of the apical fragment, can be successful in selected cases. Treatment of the root canal with calcium hydroxide followed by GP filling was recommended for root-fractured, non-vital teeth, and in those vital teeth where the fracture had caused pulp exposure, partial pulpotomy of the exposed pulps showed similar results to those obtained following pulpotomies in root-unfractured teeth where pulp exposures had been similarly treated. Fractures involving the apical third of the root may also be saved by performing endodontics followed by an apicectomy to remove the fractured segment.

Vertical fractures are more difficult to diagnose. Patients may present with mild symptoms and it may appear as if the root canal treatment has not been successful. The diagnosis can be suspected when a radiograph shows bone loss extending all around a root, or a tooth, where the vertical fracture has led to bacterial contamination of the entire tooth surface. There has been no particular treatment established to preserve vertically fractured teeth. A recent study evaluated the long-term prognosis of intentional replantation of vertically fractured roots after they had been reconstructed with 4-META/MMA-TBB dentin-bonded resin. Results showed longevity of 88.5% at 12 months after replantation, 69.2% at 36 months and 59.3% at 60 months. All of the failures occurred in the premolars and molars, while those teeth where the fracture extended more than 2/3 of the way from the cervical towards the apical area had significantly shorter survival times than roots where the fractures were shorter. The authors concluded that replantation of vertically fractured roots reconstructed with dentin-bonded resins may be considered for incisors as an alternative to extraction, but cautioned that the long-term success was not optimal.

Both of the apex locators tested in this study were not only able to detect the presence of root fractures, but were also able to determine their exact locations. They could prove to be of great value clinically in determining the treatment options for fractured teeth especially in cases where the fractures are impossible to detect on routine radiographs. However, there are some other factors to consider when using apex locators. Most of them perform better when used in wet canals as they rely on the presence of electrolytes to transmit the electrical signals. Errors may occur if the canals are too dry (in dry canals the Raypex-4 was more accurate than the Propex in this investigation), if there are large coronal restorations or metallic crowns that can cause a short circuit, if there is an open apex with a larger peri-radicular lesion, or if there is a perforation of the apex. These are usually apparent and then further measures will need to be taken.

**Conclusion**

Both the third generation and the fourth generation apex locators were found to be equally accurate in determining the exact position of horizontal and vertical root fractures. The fourth generation locator however did have advantages in that it was easier to use, performed better in wet and dry canals, and was slightly more accurate, although not significantly so. Either systems may be of value clinically in not only detecting the presence of a root fracture, but in determining its exact location, which can help the clinician decide on the best treatment option for that particular tooth.

**References**