In Vitro Comparison of Three Electronic Apex Locators

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Abstract

Introduction: The purpose of this study was to compare the accuracy of the Root ZX II Apex Locator (RZX), the Elements Apex Locator (ELE), and the Precision Apex Locator (PAL). **Methods:** Forty single-rooted extracted teeth were decoronated and the root canals coronally flared. Actual canal lengths were determined by inserting a #10 file until the tip was visualized (12.8× magnification) just within the apical foramina. Teeth were mounted in gelatin conducting medium and randomly tested with each electronic apex locator (EAL) to determine the electronic canal length. Differences between the electronic and actual canal lengths were calculated. **Results:** The mean differences were −0.02 mm, 0.13 mm, and 0.15 mm for the RZX, PAL, and ELE, respectively. One-way analysis of variance showed a highly significant difference among EALs (p = 0.003). Student-Newman-Keuls post hoc analysis found significant differences between the RZX and the PAL and between the RZX and the ELE at $p < 0.05$. No significant difference was noted between the PAL and the ELE. The proportion of electronic canal length measurements falling within ±0.5 mm of the actual canal lengths for the EALs was as follows: 97.5% for the RZX, 95% for the PAL, and 90% for the ELE. **Conclusion:** The RZX was the most accurate at locating the apical foramen compared with the ELE and the PAL. *(J Endod 2009;■:1–3)*

Key Words

Electronic Apex Locator, Elements, Precision Apex Locator, Root ZX II

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Accurate determination of the root canal length from the coronal orifice to the apical foramen is critical in the endodontic management of the root canal space. At the apical foramen, the cementodentinal junction (CDJ) or minor constriction is the landmark that anatomically and histologically determines where the pulp ends and the periodontal ligament begins (1).

Root canal preparation techniques attempt to use this natural barrier as the endpoint for canal preparation (2). However, Lee et al. (3) found that almost 50% of teeth evaluated had no distinguishable CDJ. Therefore, the CDJ should be thought of as a histologic and not a morphologic landmark (4).

Instrumenting and obturating the root canal short of the CDJ may leave undebrided bacteria in this critical space. These bacteria have the potential to contribute to subsequent failure of endodontic treatment. On the contrary, a long measurement causing instrumentation past the CDJ will damage the natural anatomy of the root end, making it difficult to obtain an apical seal and maintain the root canal filling within the tooth.

Electronic apex location began in 1942 with studies by Suzuki (5). He discovered that a constant electrical resistance of approximately 6.5 kΩ existed between the periodontium and oral mucous membrane *in vivo*. In 1962, Sunada (6) formulated his principle of “biological characteristic theory,” stating that electrical resistance values between the periodontal ligament and the oral mucosa can be determined by electronic means.

As many as four generations of electronic apex locators (EALs) have been developed since their inception. A third-generation EAL, Root ZX (J. Morita Mfg Corp, Kyoto, Japan) has a reported accuracy ranging from 82% (7) to 100% (8). A study by Shabahang et al. (9) found Root ZX to be 96.2% effective in determining the location of the apical foramen to within ±0.5 mm when used according to manufacturer’s recommendations. Ounsi and Naaman (10) found that Root ZX was 84.72% accurate to within ±0.5 mm of the apical foramen when using the “apex” reading as an apical determination. Root ZX II (RZX) is J. Morita’s updated version of the original Root ZX with original electronic components being used with the addition of a new external casing.

The Elements Apex Locator (ELE) (SybronEndo, Sybron Dental Specialties, Anaheim, CA) is a manufacturer-claimed fourth-generation EAL with a reported accuracy of 94.28% by Plotino et al. (11). The Precision Apex Locator (PAL) (Brasseler USA, Savannah, GA) is a new EAL whose accuracy has not been tested and reported in the literature to date. The purpose of this study was to compare the accuracy of the RZX, the ELE, and the PAL.

Materials and Methods

The study design used was similar to that of Cunha D’ Assunção et al. (12). Forty single-rooted extracted teeth were obtained and stored in a 0.2% sodium azide solution until use. Gross debris was removed from the root surfaces with a 10-minute soak in 6% NaOCl (The Clorox Company, Oakland, CA). The root surface and apical portion of each tooth were examined for the absence of fractures and the presence of a mature apex under a dental operating microscope (Global Surgical Corp, St Louis, MO) at 12.8× magnification. All samples met these inclusion criteria. The crown of each tooth was then sectioned at the cement-enamel junction with a diamond disk to provide unrestricted access to the canal space and to provide a constant reference point for all measurements. The coronal portion of each canal was flared by using sequential Gates Glidden drills #4, #3, and #2 in a crown-down fashion. Irrigation was then performed with 3 mL 6% NaOCl followed by 3 mL sterile saline to remove gross debris from the canal space. A #10 FlexoFile (Dentsply Maillefer, Johnson City, TN) was then used to verify patency of the canal space and the apical foramen under the dental operating microscope.

TABLE 1. Mean Differences between Electronic and Actual Length Measurements

Group	N	Mean	Standard Deviation
ELE	40	0.145	0.2734
PAL	40	0.1283	0.2048
RZX	40	-0.02375*	0.2197

RZX, Root ZX II Apex Locator; ELE, Elements Apex Locator; PAL, Precision Apex Locator.
Positive values indicate means longer than the actual canal lengths. Negative values indicate means shorter than the actual canal lengths.
*Denotes a significant difference between Root ZX II and the other two groups at $p < 0.05$.

TABLE 2. Sample Values Falling Short, Long, or within ±0.5 mm from the Actual Canal Lengths

Group	<0.5 mm	±0.5 mm	>0.5 mm
ELE	0	36	4
PAL	0	38	2
RZX	1	39	0

RZX, Root ZX II Apex Locator; ELE, Elements Apex Locator; PAL, Precision Apex Locator.

Teeth were numbered 1 to 40 and randomly selected for measurement using a #10 FlexoFile (Dentsply Maillefer) with double stoppers. Double stoppers were used to decrease the chance of stopper movement during measurements. The file was advanced until the tip of the file could be visualized just within the apical foramen under 12.8× magnification using the dental operating microscope. This length was then measured with a digital caliper to within one hundredth of a millimeter and recorded as the actual length. Files and stoppers were used for only five measurements and discarded.

The teeth were placed in a conducting medium of gelatin (Kraft Foods North America, Inc, Rye Brook, NY). A random number generator was used to assign the sequence of which tooth was to be measured with which EAL for the electronic length.

Each EAL was used according to manufacturers' recommendations for detecting the major apical foramen. For RZX, this was the "apex" reading, which was indicated by a solid audible tone. For the ELE, this was the solid "apex" bar appearing on the EAL screen. For the PAL, this was the "0.0" mark and a constant audible tone. One hundred twenty electronic measurements were recorded.

Differences between the electronic and actual canal lengths were calculated. Positive values indicated measurements that were long of the apical foramen, negative values indicated measurements that were short of the apical foramen, and 0.0 values were considered coinciding measurements. One-way analysis of variance followed by the Student-Neumann-Keuls test and chi-square analysis were used to analyze the data with the significance level set at $\alpha = 0.05$.

Results

Mean differences between electronic and actual lengths were −0.02 mm, 0.13 mm, and 0.15 mm for the RZX, the PAL, and the EAL, respectively. Analysis of variance showed a highly significant difference among EALs at p = 0.003. Student-Newman-Keuls post hoc analysis found significant differences between the RZX and the PAL and between the RZX and the EAL at $p < 0.05$. No significant difference was noted between the PAL and the EAL (Table 1). Chi-square analysis found no significant difference among the EALs in the proportion of measurements within a ±0.5 range of clinical acceptability at $p = 0.190$. However, the minimum acceptable proportion of electronic canal lengths that should fall within this arbitrary range has not been established. The actual within-range proportions were as follows: 97.5% for the RZX, 95% for the PAL, and 90% for the EAL. Table 2 shows where sample measurements were short, long, or within this range.

Discussion

Historically, radiographs have been the primary means for determining the working length in endodontic therapy. However, radiographs have inherent limitations, the most important being they are two-dimensional images of three-dimensional objects. This is further complicated by situations in which superimposition of anatomic structures such as the zygomatic arch or adjacent roots occur over the roots of teeth requiring endodontic therapy (13). Variation in root-end morphology as studied in the works of Kuttler (4) in 1955, Green (14) in 1956, and Dummer et al. (15) in 1984 showed that radiographic interpretation alone cannot be depended on alone to establish the working length and that electronic determination is necessary.

There has been controversy as to whether EALs are able to determine the minor constriction or the major foramen. According to the manufacturer (16), the RZX meter's 0.5 reading indicates that the tip of the file is in the apical constriction. In what many consider to be the benchmark for testing apex locators, the *in vivo/vitro* method of Shabahang et al. (9) used the 0.5 reading in testing the Root ZX's accuracy. However, Mayeda et al. (17) had previously concluded that EALs are only capable of detecting the major foramen. Ounsi and Naaman (10) confirmed this point in 1999, concluding that "The Root ZX is not capable of detecting the '0.5 mm from the foramen' position and thus, should only be used to detect the foramen (major diameter)." Lee et al. (3) found that file tips ended in the area of the major foramen regardless of the CDJ presence and that the major foramen is a better level to test for EAL accuracy. Recently, Herrera et al. (18) found that the diameter of the files used to determine working lengths with Root ZX had no significant effect until the apical widths were instrumented to a diameter of 1.02 mm. ElAyouti et al. (19) reported that after removing roots with obstructions to the apex, Root ZX was significantly more consistent in its readings (98.2%) than the Raypex 5 (VDW, Munich, Germany) (92.6%). Finally, Hassanien et al. (20) recently found that "[The] CDJ and apical constriction are not the same point, the apical constriction was always found coronal to [the] CDJ," and, when using the apical constriction bar in the Root ZX display, the measurement obtained is closer to the CDJ than to the apical constriction. This is not surprising, considering the findings of Ounsi and Naaman (10). Therefore, the current study used the major foramen as the measuring point for all three EALs.

Considered to be a useful guide for clinical acceptability, the ±0.5 mm range from actual canal length was also used to test accuracy in this study (21, 22). The large majority of EAL measurements were within the ±0.5-mm range for all three electronic apex locators. However, the RZX had no measurements long of this range and only one measurement short of this range. The PAL had two measurements long of the range and the EAL had four measurements long of this range.

Concern over overextended preparations and subsequent compromised obturations has produced differing opinions as to how to use these EALs correctly. The manufacturers suggest determining the working length by using the EAL to determine the major foramen and subtracting approximately 0.5 mm (16, 23, 24). Many practitioners believe this may still violate the minor constriction and suggest subtracting 1.0 mm from what is determined electronically as the major foramen. Using descriptive statistics, the present study suggests that subtracting only 0.5 mm would likely produce overextended preparations in 10% of EAL and 5% of PAL electronic measurements. It is ultimately the responsibility of the practitioner to determine how these devices are used.

Under the conditions of this *in vitro* study, the Root ZX II Apex Locator was the most accurate at locating the apical foramen compared with the Elements Apex Locator and the Precision Apex Locator. When using a clinical acceptability range of ±0.5 mm from actual canal lengths, the Root ZX II also had the highest in-zone proportion of acceptable measurements at 97.5%.

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