

Comparative evaluation of accuracy of two electronic apex locators in the presence of various irrigants: An *in vitro* study

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Abstract

Context: The establishment of appropriate working length is one of the most critical steps in endodontic therapy. Electronic apex locators have been introduced to determine the working length. The development of electronic apex locators has helped make the assessment of the working length more accurate and predictable, along with reduction in treatment time and radiation dose. **Objectives:** The aim of this study was to compare the efficacy of electronic apex locators after cleansing and shaping of the root canals and whether there was any alteration in accuracy when used in the presence of irrigants. **Materials and Methods:** Seventy extracted human permanent molars with mature apices were selected. Equal number of maxillary and mandibular permanent molars (35 each) were sectioned at the cemento-enamel junction. Access opening was done and only the mesiobuccal root canal was studied for the purpose of standardization. Electronic working length measurements were taken before and after preparation of the mesiobuccal canal with Root ZX and ProPex II using various irrigants. **Statistical Analysis Used:** The data were statistically analyzed using a paired t-test at 0.05 level of significance. **Results:** *P*-values for actual and final canal lengths for Root ZX employing NaOCl(0.001), CHX(0.006), LA(0.020) and for ProPex II was (0.001) respectively. When the data were compared, results were statistically significant ($P < 0.05$). **Conclusion:** Within the limitations of this study Root ZX can be considered to be an accurate electronic apex locator and CHX as irrigant matched more precisely with the actual canal length measurements.

Keywords: Chlorhexidine digluconate, electronic apex locator, local anesthesia, sodium hypochlorite

Introduction

The establishment of appropriate working length is one of the most critical steps in endodontic therapy. Cleansing, shaping, and obturation of the root canal system cannot be accomplished perfectly unless the working length is determined precisely.^[1] Working length is the distance from a coronal reference point to a point at which the canal preparation and obturation should terminate.^[2] It is generally accepted that root canal procedures should be limited to the confines of the root canal system for which an accurate working length is of paramount importance.^[3]

Apical anatomy determines the termination of root canal instrumentation and filling. The cemento--dentinal junction,

which is also described as the apical constriction, is the anatomical and histological landmark where the periodontal ligament begins and the pulp ends.^[4] Many methods have been put forward for determination of the working length but with varying degree of accuracy.^[5]

Traditional methods for establishing the working length include the use of radiography, anatomical averages and knowledge of anatomy, tactile sensation, and paper point technique.^[4] However, the possibility of radiographic distortion, operator-measuring-error or use of an improper radiographic technique can lead to faulty readings.^[5]

In order to overcome these drawbacks, electronic apex locators have been introduced to determine the working length and form an important adjunct to radiography.

It was not till 1918 that Custer^[5] first put forth the idea that the root canal length could be determined by using electrical conductance. The scientific basis of apex locators originated with research conducted by Suzuki in 1942.^[6]

Sunada (1962)^[7] adopted the principle reported by Suzuki and was the first to describe the detail of a simple clinical device to measure working length in patients. Since then electronic apex locator has become an invaluable tool in modern endodontic practice. These devices were based on electrical resistance and they function by using the human body to complete an electrical circuit. These first-generation apex locators provided rather inaccurate and unstable measurements as a result of the presence of vital pulp tissue,

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excessive blood, exudates or moisture within the canals.^[8] The more recent resistance-based apex locators provided the accurate location of apical constriction in 55--75% of the cases.^[9] However, their accuracy was further diminished by the presence of fluids.^[10]

Second-generation apex locators^[11] -- also known as impedance apex locators -- measure opposition to the flow of alternating current or impedance. Therefore, impedance rather than resistance became the characteristic used to mark the depth of canal penetration. Based on this assumption Inoue's device, the Sono-Explorer was introduced in 1972. The most important disadvantage of this device was the need for individual calibration.^[3]

Shortcomings of first- and second-generation Electronic Apex Locators were overcome by the introduction of third-generation apex locators in the 1990s.^[12]

In 1991, Kobayashi *et al.*^[13] reported on the ratio method for measuring the root canal length, which is the basic working mechanism of Root ZX. The ratio method works on the principle that two electric currents with different sine wave frequencies will have measurable impedances that can be measured and compared as a ratio regardless of the type of electrolyte in the canal. The capacitance of a root canal increases significantly at the apical constriction, and the quotient of impedances reduces rapidly as the apical constriction is reached. This principle forms the basis for operation of Root ZX. The Root ZX simultaneously uses two waveforms of a high (8 kHz) and low (400 Hz) frequency.^[14]

There have been efforts to further increase the accuracy of electronic apex locators with the introduction of fourth generation apex locators. This-generation apex locators take resistance and capacitance measurements separately to compare them with a database to determine the distance to the apex of the root canal.

Doubt exists in the mind of operators as regards the accuracy of different available electronic apex locators. Moreover comparative evaluation of different apex locators under similar clinical/clinically simulated conditions is deficient in the literature. The present study was an effort to compare the reliability and establish the superiority between apex locators used under similar conditions.

The present study was devised to achieve certain objectives that were to determine the efficacy of electronic apex locators after pulp extirpation and whether there was any alteration in accuracy when used in the presence of irrigants.

Materials and Methods

Seventy extracted human permanent molars with mature apices were selected. The teeth were cleaned of calculus, soft

tissues, and debris with hand instrumentation and stored in distilled water until used.

Equal number of maxillary and mandibular permanent molars (35 each) were selected and numbered randomly. The crown of each tooth was sectioned at the cemento--enamel junction using a diamond disk (DFS -- Diamon GmbH Landenstraße, Riepenburg, Germany), revolving at a conventional speed in order to simplify access to the root canal and establish a level surface to serve as a stable reference for all measurements^[15] [Figure 1]. Access cavity was prepared and mesiobuccal canal orifice was located. For the purpose of standardization, only the mesiobuccal root canal was studied [Figure 2].

The actual root canal was measured by inserting a #10 K file (Mani Inc., Japan) into the root canal until the file tip was just visible at the level of apical foramen. This procedure was done under 25× magnification using a dental operating microscope ZOM-3 and photographs were clicked at 24× with Nikon 4500 Coolpix digital camera mounted on a Delta 300 Moller Wedel, Germany operating microscope under direct vision [Figure 3].

A mould was manufactured using cold cure acrylic resin (DPI-RR), natural teeth, and alginate impression material (Velplast), to simulate oral conditions for electronic measurement of the working length of the root canal.

The stopper of the file was adjusted to flush with the coronal reference plane and file withdrawn from the canal; the length was measured with the help of Endobloc (Dentsply Mini-Endobloc) and recorded.

Electronic working length measurements were taken with Root ZX (J. Morita MFG Corps, Japan) electronic apex locator by attaching the lip clip to the conductive gel and other end of the electrode to #10 K file placed into the root canal. All the mesiobuccal root canals were irrigated with 2 ml of 3% sodium hypochlorite solution, Dento-chlor and local anesthetic solution 2% adrenaline 1:200,000. The electronic measurements were recorded from Root ZX. After the use of each irrigant, the root canals were first washed with 2 ml of distilled water They were dried with absorbent paper points before the use of the next irrigant.

The termination point used for Root ZX was the point where the monitor of the apex locator displayed "APEX" which was indicated in a continuous audible tone.^[4] The silicon stopper was adjusted at that length, and the electronic measurements were recorded with the help of Endobloc (Dentsply Mini-Endobloc) [Figure 4].

A similar measurement regime and procedure were carried out with ProPex II (Dentsply Maillefer, Switzerland) as previously described for the Root ZX electronic apex locator. The termination point used for ProPex II was the point where



Figure 1: Decoronated maxillary teeth



Figure 3: File tip flush with apical foramen (viewed under operating microscope)

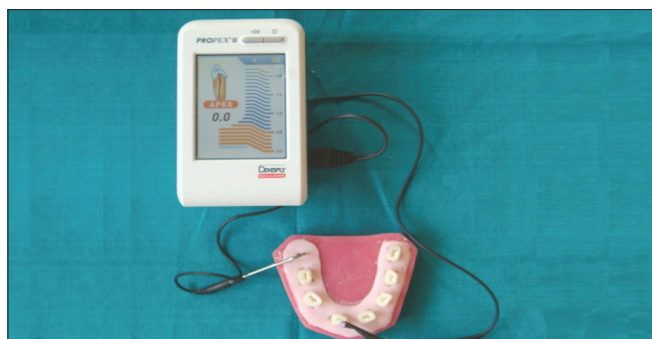


Figure 5: Experimental setup showing ProPex II apex locator connected to teeth

the monitor of the apex locator flashed “APEX” along with “0.0” reading and a constant audible tone.^[4] All measurements thus obtained were recorded [Figure 5].

After the actual root canal length measurements with both the apex locators was recorded the apical third of all mesiobuccal root canals was enlarged and prepared to #35 K-file diameter following the step back technique of biomechanical preparation as described by Ingle. After root canal preparation, electronic working length measurements were again taken using Root ZX followed by ProPex II following similar regime as described earlier. The three irrigants were also employed for the measurements with both electronic apex locators after determining the final length of the root canal.

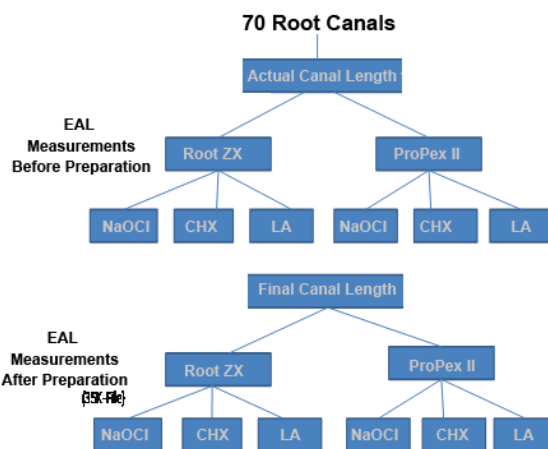


Figure 2: Algorithm of methodology



Figure 4: Experimental setup showing Root ZX apex locator connected to teeth

The data was statistically analyzed using

1. one-way analysis of variance (ANOVA) at 0.05 level of significance and
2. comparison between actual and electronic measurements before and after the preparation of the root canal in the presence of various irrigants (paired t-test) after verifying the correlation for the paired sample test.

Results

Table 1 shows the mean and standard deviation differences between actual (AL) and final length (FL) and electronic lengths before (EAL1) and after preparation (EAL3) with Root ZX using the various test irrigants. *P*-values for actual and final length (0.001) and for EAL1-EAL3 employing NaOCl (0.001), CHX (0.006) and LA (0.020) were statistically significant ($P < 0.05$).

Table 2 shows the mean and standard deviation differences between actual (AL) and final length (FL) and electronic lengths before (EAL2) and after preparation (EAL4) with ProPex II using the various test irrigants. *P*-values for actual and final length (0.001) and for EAL2-EAL4 employing all the test irrigants were statistically significant ($P < 0.05$).

Table 3 depicts the paired difference value for the actual and final lengths (ACL) and electronic lengths for both apex locators employing the test irrigants. *P*-values obtained were NaOCl (0.209), CHX(0.924), LA (0.083) respectively.

The results so obtained were statistically insignificant (*P* > 0.05). Chlorhexidine digluconate showed best results out of the three test irrigants used.

Discussion

Establishment of the correct working length is an important stage in root canal treatment, because sufficient evidence suggests that instrumentation either beyond or too short of apex can adversely affect success.^[16] Various schools of thought exist for the termination of the root canal working length. Though the importance of staying inside the root canal with the obturation and avoiding extrusion of material into the periapical tissues in order to obtain a higher success

rate was stated by various research workers.^[17] Schilder declared that his aim was to debride and obturate till the apex, lateral canals, and apical ramifications. Schilder opposed limitation of preparation at the CDJ or at the apical constriction because he considered these as variables. Thus, it is too approximate to apply a mathematical or statistical formula (0.5, 1 or 2 mm).

Whatever may be the terminus of root canal instrumentation and obturation, the gold standard is the exact location of the apex. For that reason, in this study, calculations were based upon the total length of the root canal.

Historically, conventional radiography has been the primary means for determining the working length in endodontic therapy. However radiographs have inherent limitations like providing only two-dimensional images of three-dimensional objects.^[18]

Controversy remains about the working length and the termination point of the root canal treatment. Some recent investigations have determined the accuracy of measurement of electronic apex locators. However, only few investigations have been carried out to compare the electronic root canal length measurements with that of the actual root canal length.^[19]

In this *in vitro* study two modern electronic apex locators namely Root ZX and ProPex II were used to calculate the length of the root canal.

There has been controversy as to whether EALs are able to determine the minor constriction or the major foramen. According to the manufacturers, the Root ZX meters 0.5 reading indicates that the tip of the file is in the apical constriction. Shabahang *et al.* used the 0.5 reading in testing the Root ZX's accuracy. However, Mayeda *et al.* had previously concluded that EALs are only capable of detecting the major foramen.^[18]

Modern EALs to which these apex locators belong have the advantage that they measure two impedances thereby establishing a ratio between the two and thus give more accurate readings even in the presence of root canal irrigants.

This study was designed to evaluate the precision of these two different electronic apex locators in determining the working length of teeth using small and large size files, along with various root canal irrigants.

An *in vitro* model was used in the study to obtain accurate measurements. The advantages of the model was its simplicity, ease of use, and the ability to have strict control over the experimental conditions tested. This alginate model embedded with extracted teeth provides electrical resistance corresponding to that of periodontium. These *in vitro* models

Table 1: P-value for Root ZX

		Paired differences		
		Mean	Std. deviation	P-value
Root canal length	AL-FL*	0.19996	0.49927	0.001
NAOCL*	EAL1 EAL3	-0.20714	0.41479	0.001
CHX	EAL1 EAL3	-0.10714	0.31442	0.006
LA	EAL1 EAL3	-0.10700	0.37732	0.020

*AL- actual length, i.e., before preparation, FL - final length, i.e., after preparation to size 35K file, EAL 1 -- electronic length with Root ZX before preparation, EAL 3- electronic length with Root ZX after preparation to size 35 K, file. NAOCL -- sodium hypochlorite, CHX -- chlorhexidine digluconate, LA - local anesthesia

Table 2: P-value for ProPex II

		Paired differences		
		Mean	Std. deviation	P-value
Root canal length	AL - FL	0.19996	0.49927	0.001
NAOCL	EAL2* EAL4	0.20357	0.37420	0.001
CHX	EAL2 EAL4	0.19643	0.35837	0.001
LA	EAL2 EAL4	0.23929	0.33632	0.001

*EAL 2 -- electronic length with ProPex II before preparation, EAL 4 -- electronic length with ProPex II after preparation to size 35 K file

Table 3: P-value for actual and final length and electronic lengths for both apex locators before and after preparation employing the test irrigants

		Paired differences		
		Mean	Std. deviation	P-value
ACL* - NAOCL		-0.03837	0.51027	0.209
ACL - CHX		-0.00270	0.47211	0.924
ACL - LA		-0.05084	0.48935	0.083

*ACL -- Actual length + final length

do provide a valuable insight into the function of EALs and enable objective examination of a number of variables that can not be practically tested clinically.

Previous studies have shown that EALs often yield inaccurate results in the presence of fluids. However the use of irrigants and their benefits in endodontics have been clearly proven, and most clinicians use irrigants for their antimicrobial and tissue dissolving capabilities. The manufacturers of the new generation EALs have said that these models are, in fact, accurate in the presence of irrigants, including NaOCl.

Jenkins J. A. *et al.*^[14] evaluated the accuracy of Root ZX in the presence of variety of endodontic irrigants, 2% lidocaine with 1: 100,000 epinephrine, 5.25% sodium hypochlorite, RC Prep, liquid EDTA, 3% hydrogen peroxide and Peridex. The results showed that the Root ZX reliably measured the canal lengths to within 0.31 mm, regardless of the irrigants. However, the largest deviation from the actual canal length was obtained with NaOCl.

In our study when 3% NaOCl was used as an irrigant the mean difference in length with Root ZX and ProPex II before and after enlargement was -0.03837 ; however, the difference between measurements obtained with two apex locators was statistically insignificant ($P > 0.05$).

When local anesthetic was used as an irrigant the mean difference in length with Root ZX and ProPex II before and after enlargement was (-0.05084) ; however, the difference between measurement obtained with two apex locators was statistically insignificant ($P > 0.05$).

Chlorhexidine digluconate is antiseptic and has an affinity to hydroxy apatite. It has been suggested as an irrigant and as an intracanal medication (Kuruvilla & Kamath 1998, Lindskog *et al.* 1998, Segura *et al.* 1999). To date, no study has been conducted to test the effect of this solution on electronic measurements. When 2% chlorhexidine digluconate was used as an irrigant the mean difference in length with Root ZX and ProPex II before and after enlargement was 0.00270 ; however, the difference between measurement obtained with two apex locators was statistically insignificant ($P > 0.05$). The results of the present study indicate that the electronic measurement in the presence of chlorhexidine can be performed safely and out of the three irrigants tested best results have been shown by this irrigant.^[20]

The size of the root canal is another factor to affect the accuracy of the EALs. Ebrahim *et al.*^[21] reported that as the diameter of the root canal increased, the electronically measured length with the smaller size files became shorter. Fan *et al.*^[22] reported that when the tubules were dry or filled with less conductive electrolyte, the increase in tubule diameter did not influence the results. However, when the tubules were filled with strong electrolytes, the results of

ProPex were negatively affected from the increase in tubule diameter.

When the apex was enlarged to a size 35 K file a statistically significant difference was found between the EALS measurements before and after preparation for both Root ZX (-0.05533) and ProPex II (0.20981) electronic apex locators. The reason for the difference may be that the overall canal patency was compromised due to blockage of canal by dentinal shavings limiting the ability of the measuring device to determine the location of apical foramen. Similar views have been expressed by Ibarrola *et al.*^[23]

Although there is not much difference between Root ZX and ProPex II, under the conditions of our *in vitro* study Root ZX was more accurate in locating the apical foramen and determining the actual working length of the root canal.

Conclusion

Within the limitations of this study Root ZX can be considered to be an accurate electronic apex locator across a variety of irrigants commonly used in the practice of endodontics for measurement of the length of the root canal.

The contents of the root canal influenced the results of the measurements with both the EALs, but the differences were not statistically significant.

The alginate model was found to be an effective and suitable method for testing electronic apex locators *in vitro*.

Within the different variables tested in the present study, measurements recorded after using chlorhexidine digluconate as an irrigant matched more precisely with the actual canal length measurements.

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