Original Article

In vitro Accuracy Assessment of Electronic Apex Locator: RSUpex

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Abstract

Aim: To evaluate the accuracy of RSUpex, a newly developed electronic apex locator (EAL), by comparing it with a standard apex locator (Root ZX). **Methodology:** Forty single-root lower premolar human teeth with completed apex formation were embedded in alginate model, which simulated tooth-surrounding tissue. The working length (WL) of each tooth was determined by using both Root ZX and RSUpex. The actual working length of each tooth was determined under a microscope. **Results:** The working lengths determined by both electronic apex locators varied ±0.5 mm from the apical foramen, which were within the acceptable criteria. The WLs measured by Root ZX and RSUpex were 0.5 mm short of the apical foramen (AF) of 28 canals (70 %) and 22 canals (55 %) respectively. Eleven canals (27.5 %) and 17 canals (42.5.5 %) were beyond the AF respectively for Root ZX and RSUpex, while WLs of 1 canal (2.5 %) from both EALs were at the AF. The intra-class correlation cofficient of both devices was 0.988, which indicates excellent accuracy. **Conclusion:** The accuracy of RSUpex in working length determination is comparable with Root ZX. Further studies are needed to evaluate the success of RSUpex in clinical settings.

Keywords: Alginate model, Electronic apex locators, Root ZX, RSUpex

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Introduction

Endodontic treatment involves the removal of the infected dental pulp and dentin from the root canal system by mechanical and chemical cleaning and shaping in terms of instrumentation, irrigation and medication. One of the critical steps in the endodontic procedure is the accurate measurement of 'working length' (WL). It has been shown that a densely filled root canal and a good final restoration are important factors that contribute to the success of endodontic treatment.[1] It is accepted that the termination of root canal filling should be at the apical constriction (AC) or at the cemento-dentinal junction (CDJ).

There are several methods for WL determination in endodontic treatment. The tactile perception with a hand file is simplistic but inaccurate when applied to root canals with immature apex, excessive curvature, etc. The radiographic method is the most common practice used in determination of WL.[2] However, accuracy is difficult to achieve with this technique because of difficulties in identification of the AC, variations in angulation of the radiographic technique and image distortion.

Electronic apex locators (EAL) have been used clinically to overcome the drawbacks of the radiographic measurement method. EAL was first developed based on the principle concept that there exists an electrical resistance between the periodontal ligament and the oral mucosa *in vivo*, which has a constant voltage of 6.5 kΩ.[3] Sunada[4] introduced these principles into clinical practice and stated that EAL could be used to indicate the apical area. There are five developmental generations of EAL devices. Each generational device had been developed and modified with a different circuit inside. The first generation devices used the principles of original electrical resistance measurement. However, pain occurred due to high electrical current. The second generation devices, the impedance apex locators, were operated by a single-frequency alternating current. The signal was not stable and inaccurate in the presence of tissue and electro-conductive irrigates in the canal. The third generation devices were operated by using two alternating currents with different frequencies. For the third generation, there are two types of EALs, which are impedance difference type and impedance ratio type. The impedance-difference EAL measures the impedance value at two different frequencies and calculates the difference between the two values, while the impedance ratio type determines the position of the file from the ratio between these two frequncies.[5] Root ZX (J.Morita, Tokyo, Japan) is categorized in this generation. The fourth generation devices use two or more non-simultaneous continuous frequencies for the purpose of measuring the difference or ratio between the two currents.[6] The devices considered in the fifth generation were developed in 2003. They measure the capacitance and resistance of the circuit separately. They use the statistics values to determine the position of the file within the canal.[7]

The operating principle of RSUpex, the novel electrical apex locator device, is based on the measurement of electrical voltage impedance during a root canal procedure. The 50 KHz signal frequency from the device was generated within the canal through the endodontic file. When the file moves through the canal, the canal impedance differs, which is reflected by the alteration of the electrical voltage. From the variation of voltage and the distance between the root apex and the file tip, the calibration graph is created for microcontroller processing and programmed into the microcontroller board. The depth of file tip is shown on an LCD screen as represented by the moving scales and the corresponding numeric value. When the file is at the AC, an audible alarm starts producing rhythmic beeping and sound is continuously generated as it approaches the root apex.

The aim of this study was to evaluate the accuracy of RSUpex, while comparing it with Root ZX, which has

been a widely used EAL in clinical practice within the alginate model.

Materials and methods

Forty single-root lower premolar human teeth with completed apex formation and without fractures were used in this study. Each tooth had been extracted for the purposes of periodontal or orthodontics reasons under the protocol approved by the Ethics Committee of Rangsit University (RSEC 3/2559). The teeth were collected at the Oral Surgery Clinic, Faculty of Dental Medicine, Rangsit University and were kept in a 0.1 % thymol solution until used for the study. The crown of each tooth was sectioned at 5 millimeters above the cementoenamel junction (CEJ) level from the buccal aspect by a high-speed cylinder diamond bur to make a flat surface as a precise reference area for the rubber stop. The canal was irrigated with 2.5 % sodium hypochlorite. A Hand K-file, snugly fitted to the canal, was selected and inserted through the canal until the tip of file appeared at the AF under the operating microscope (x5.1) (Carl Zeiss, Oberkochen, Germany). Then the rubber stop was adjusted to make contact at the reference level on the tooth surface. The file was then removed from the root canal. The actual length between the rubber stop and the file tip was measured by using a digital vernier caliper (Mitutoyo corporation, Kawasaki, Japan).

After the initial procedure, the tooth was embedded within an alginate model for tooth-surrounding tissue simulation. The type II alginate impression material (Kerr, California, USA) was placed in small plastic cups with one cup containing one tooth each. Then each tooth and the labial clip were inserted in the alginate before it set as shown in Fig.1. The tooth's CEJ was one mm above the alginate level. Each model was used for both EALs measurement within thirty minutes to ensure sufficient humidity during the procedure.

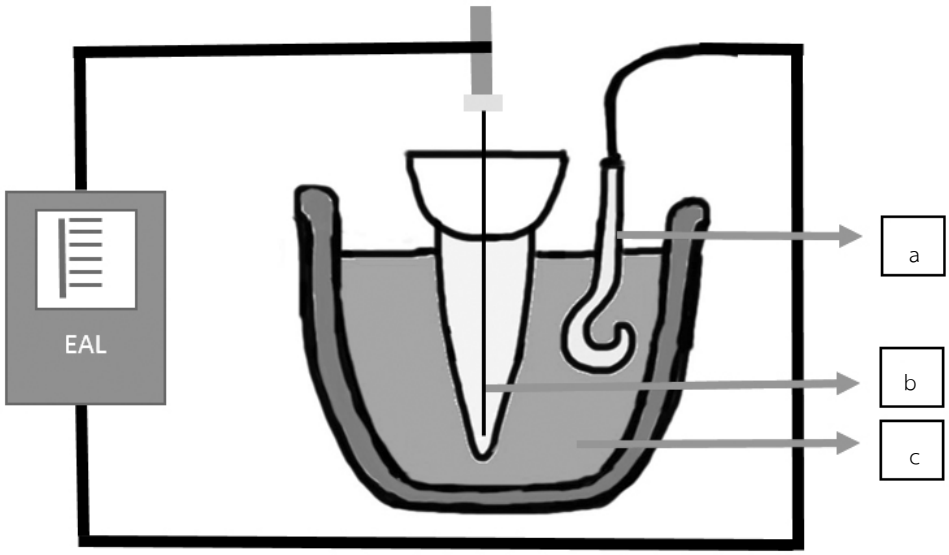

Figure 1 *Tooth embedded in alginate model for which simulated tooth-surrounding tissue. (a = labial clip, b = file, c = alginate)*

The root canal was irrigated with 2.5 % NaOCl and the excess irrigant was absorbed by a paper point. The appropriate size of file, which was snugly fitted within each canal, was selected then a file was connected to the apex locator. The file was slowly inserted into the root canal and the scale on the EAL display was shown the AC point as indicated by each EAL as the following resulting output~ Root ZX: The liquid crystal moves to the green area and a digital output of '00' is shown. RSUpex: The lowest scale measurement showed concurrently followed by an audible beep notification.

The rubber stop was slid down to contact the reference area. The file was carefully removed from the canal and the length from the rubber stop to the file tip was measured by a digital vernier caliper. The WL of each tooth was determined three times with the EAL.

Data Analysis

The length of the file, which was measured by RootZX or RSUpex apex locator, was subtracted by the AL of each tooth. The positive difference value represents the determined length by the EAL that is beyond the AF. Conversely the negative difference represents the determined length by the EAL that is short of the AF. The mean WLs of both EALs was analyzed by Intra-class Correlation Coefficient (ICC)[8] and the percentage for acceptability regarding root canals (the acceptable criterion of WL determination by EALs is short or beyond the AF ± 0.5 mm) was calculated at a 95 % confidence interval.

Results

The WLs of forty teeth were obtained with both RSUpex and Root ZX. The measurements were evaluated on whether they are within the acceptable range (± 0.5 millimeters from AF). The WLs measured by Root ZX and RSUpex was 0.5 mm short of the AF of 28 canals (70 %) and 22 canals (55 %) respectively. Eleven canals (27.5 %) and 17 canals (42.5.5 %) were beyond the AF respectively, while WLs of one canal (2.5 %) from both EALs were at the AF as shown in Table 1.

Table 1 *The percentage of acceptable measurements (±0.5 mm from apical foramen) by both EALs*

Distance from the AF (mm)	Root ZX	RSUpex
- 0.5	70.0 % (n=28)	55.0 % (n=22)
0.0	2.5 % (n=1)	2.5 % (n=1)
+ 0.5	27.5 % (n=11)	42.5 % (n=17)

AF : Apical Foramen

The Intra-class Correlation Coefficient of two EALs was equal to 0.988. The strength of accuracy agreement was excellent as shown in Table 2 and Table 3.

Table 2 *Descriptive statistics of WL measured by both EALs*

Working length	Mean ± SD	Min, Max	ICC	95 % CI	*p*
Root ZX	18.54 ± 1.22	17.32, 19.76			
RSUpex	18.61 ± 1.23	17.38, 19.84			
Difference (RSUpex-RootZX)	0.05 ± 0.21	-0.16, 0.26	0.988	0.978 – 0.994	0.000

Table 3 *Criteria for grading the strength of accuracy agreement[8].*

ICC	Strength of agreement
<0.25	Poor
0.25 – 0.50	Fair
0.50 – 0.75	Moderate
0.75 – 0.90	Good
>0.90	Excellent

ICC : Intra-class Correlation Coefficient

Discussion

The accuracy of EALs has been proven both in the laboratory and in clinical settings. EALs using the impedance ratio principle, such as Root ZX, have demonstrated high accuracy values of 80-90.[9-11] In the present study, the newly developed EAL (RSUpex) was compared with Root ZX in the laboratory settings before the clinical use.

The experimental model that simulates the periodontal tissue is an important factor in the laboratory evaluation. Huang[12] indicated that EALs use the electrical principles more than the biological properties of the periapical tissue. The *in vitro* model for tooth embedding should have a similar electrical resistance with the periodontal tissue.

There are various types of embedding media used for accurately measuring the EAL, which include alginate, gelatin, saline, sponge, and agar. According to Chen *et al*.[13] and Baldi *et al.*[14], it is suggested that alginate is the material of choice as an embedding media because of the colloidal gel properties it possesses. Alginate is placed in the cup to surround the root surface. As a result, the electrical circuit is complete. Alginate is a perfect embedding media due to its level of electro-conductivity as the composition of alginate is comprised of salt (sodium alginate), calcium sulfate, and magnesium oxide that simulate the periodontal ligament tissue. So alginate was selected in our study as it is easy to use, convenient for study protocols, and inexpensive. It provides more accurate measurements for evaluation of EALs when compared with other embedded media. However, the disadvantage of alginate is dehydration. The alginate model should be kept moist or refrigerated and used within thirty minutes after preparation. Longer waiting periods will result in incorrect measurements as the alginate becomes dry.

As mentioned above, the accuracy of EAL devices depends on both the electrical principle and biological properties of periapical tissues. Some studies used the standard model of glass tubule instead of the extracted tooth for an accurate measurement of the EAL. Fan *et al.*[15] used glass tubules for purposes of evaluating the accuracy of RootZX, Propex (Dentsply – Maillefer, Ballaigues, Switzerland), and Neosono (Satelec Inc., NJ, USA) in different electrolyte conditions within the root canal. Canal curvature, canal taper, and lateral canal are the variable factors for WL determination that directly affect the results of the study. Our study used the natural extracted teeth for better clinical simulation.

The acceptable range for EAL accuracy determination in many studies has two levels; ± 0.5 and ± 1.0 mm from apical foramen or major foramen. The study by Wu *et al.*[16] demonstrated that utilizing the location of the minor foramen or the AC was unreliable when there was physiological cementum deposition of 0.5 – 1.0 mm on the sample teeth. Therefore, an evaluation of EAL accuracy at level ± 0.1 mm from the AF was acceptable in the clinical investigation due to the wide range observed in the shape of the apical zone. But in this study, the acceptable criteria was specified at level ± 0.5 mm from AF because over

instrumentation or root canal filling affect the healing process as explained in the study by Sjogren *et al*.[17]

Huang[12] and Wu *et al*.[18] suggested that two factors that affect the accuracy of EAL are the electrolyte levels within the root canal and the diameter of the AF. In this study, 2.5 % NaOCl was used to irrigate the root canal for simulating clinical practice environmental duplication appropriately. Excessive irrigation results in inaccurate readings while using the EAL device. Ebrahim *et al*.[19] proposed that NaOCl irrigation results in a higher level of accuracy during measurement. Huang [12] found that if the diameter of the apical foramen is larger than 0.2 mm, the WL determination by EAL would be shorter than the accurate one. In the current study, forty mature teeth with complete root formation were used. Open apex or root fracture was in the exclusive criteria of the sample selection in this study.

The size of the file is another factor that influences the accuracy of EAL results. The size of a root canal should be evaluated before choosing the appropriate file size. Ideally a snug-fitting file, which is equally not too loose should be selected for WL determination by the EAL. The accuracy of the EAL is reduced if the file used for WL determination is too small within a canal with a large AF, by comparison with the appropriate file size ($p < 0.05$).[20] Our study utilized hand files with a size range of 08-10 for WL determination and the procedures were performed by one operator, who would identify the working length determination by both EALs.

In the present study, the factors, which would impact the accuracy of evaluations of EALs were controlled. The comparative results between RSUpex and Root ZX were excellent with a ICC score of 0.988, which indicates almost parallel readings from both devices. The WL determination, which was obtained from both EALs, was compared to the AL and were in the acceptable criteria of ± 0.5 mm. However, during the experimental period, there were some defects that came to light regarding the RSUpex design, which need to be addressed. The RSUpex was powered by an alternating electrical current, which prevented the device from being 'portable' as it required a power socket and certain length of cable to operate. The display was not visible and the audible beeping notification was not at an appropriate audible pitch when compared to the Root ZX, which might lead to misinterpretation during the use of the device. Development of a portable solution equipped with a high capacity battery with a more visually responsive and contrasting display would greatly improve the next generation of RSUpex devices.

Conclusion

The accuracy of RSUpex was studied in comparison with Root ZX, which is accepted as the gold standard EAL, by using the alginate model. Their correlation between two devices was excellent and parallel. RSUpex can be used for WL determination. However, further clinical studies is needed before using this new device in clinical practice.

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