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Distance from file tip to the major apical foramen in relation to the numeric meter reading on the display of three different electronic apex locators

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Abstract

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Aim To establish and compare the relationship between the distance from the file tip to the apical foramen and the numeric meter reading on the display of three different electronic apex locators (EALs).

Methodology A total of 12 extracted intact, straight, single-rooted human teeth with complete roots were used. The actual root canal length (AL) was determined after access preparation. For the electronic measurements with each EAL, silicon stops were fixed with auto-polymerizing resin to size 15 K-files at AL and 0.5, 1, 2, 3, 4 mm short of AL. The data was analysed by two-way ANOVA and Tukey's honestly significant difference (HSD) test for multiple comparisons amongst EALs. Additionally, one-way ANOVA and Tukey's HSD test were carried out for multiple comparisons amongst the measurements of each EAL.

Results There was a statistically significant difference amongst all EALs in indicating the position of file tips in relation to the major foramen (P < 0.05). The correlation between the meter reading and the position of the file tip from the apical foramen was statistically significant in the three EALs. There were significant differences amongst the measurements at distances from 0 to 2 mm in Justy III. In Dentaport, significant differences were found from 0 to 1 mm. However, the E-Magic Finder showed significant differences from 0 to 0.5 mm.

Conclusions Justy III was more capable of displaying the intracanal position of the file tip from the major foramen in mm whilst advancing through the root canal during electronic measurements than the Dentaport and E-Magic Finder Deluxe.

Keywords: distance to apical foramen, electronic apex locator, meter reading display, root canal length determination.

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Introduction

Working length determination is an essential step in root canal treatment. The apical constriction is the recommended end-point of instrumentation and obturation (Ricucci & Langeland 1998). The tooth pulp is narrow at the apical constriction; therefore the wound is minor, potentially providing optimal healing conditions (Kuttler 1955). The location of the apical constriction is considered to be 0.5–1 mm short of the anatomical apex (Kuttler 1955, Tselnik *et al.* 2005). Over-instrumentation and over-filling has been reported to cause tissue destruction, inflammation and foreign body reaction in the periapical tissue area (Kuttler 1955, Seltzer *et al.* 1968, 1969).

The development of electronic apex locators (EALs) has helped to make the assessment of working length

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more accurate and predictable (Pratten & McDonald 1996, Fouad & Reid 2000, Hoer & Attin 2004, Plotino *et al.* 2006). Modern EALs determine distance from the end of the apex by comparing impedances, which are measured by using different current frequencies (Gordon & Chandler 2004). The difference in impedance is calculated in order to determine a position of the file in the canal (Kobayashi & Suda 1994, Azabal *et al.* 2004).

The Justy III (Yoshida Co., Tokyo, Japan) and the E-Magic Finder Deluxe (DESTI S-Denti Co., Ltd, Chungnam, Korea) are new EALs. The Justy III uses 500 Hz and 2 kHz as measuring frequencies. It is presented as a foldable LCD display, and when the meter value of the scale becomes 2.5, a larger image is shown on the screen. On the other hand, the E-Magic Finder Deluxe uses 500 Hz and 5 kHz as measuring frequencies. Also designed with a foldable LCD display, it can be connected to a computer which allows a vivid graphic display. Both the Justy III and the E-Magic Finder Deluxe claim that their numeric meter reading display show the distance in mm from the apical foramen during their measurements.

Several studies have evaluated the accuracy of different apex locators by calculating the distance from the file tip to the apical foramen or apical constriction using apex or 0.0, apical constriction or 0.5, and 1 reading marks (Martinez-Lozano *et al.* 2001, Tselnik *et al.* 2005, D'Assunção *et al.* 2007). However, few studies have considered the display of all meter readings on the display.

The aim of this laboratory study was to establish and compare the relation between the distance from the file tip to the major apical foramen and the numeric meter reading on the display of three different apex locators: Justy III, Dentaport and E-Magic Finder Deluxe.

Materials and methods

Extracted intact, straight, single-rooted human teeth with complete root formation were selected randomly. Teeth with resorption or fracture were excluded. Preoperative digital radiographic images in both buccolingual and mesiodistal directions were taken to evaluate root canal anatomy and teeth with accessory canals or invisible main canals were excluded. Twelve teeth were finally selected. All teeth were soaked in tap water for 2 h before use. Standard access preparation was carried out using a high speed diamond fissure bur (Mani, Tochigi, Japan) under water-cooling. The incisal or occlusal edges were ground to create a flat surface to facilitate length measurements. The actual root canal length (AL) was determined by introducing a size 10 or 15 K-file (Zipperer, Munich, Germany) into the canal until the tip of the file emerged through the major apical foramen under a digital microscope (VH-S30; Keyence, Osaka, Japan) at 20× magnification. The long axis of the tooth was placed perpendicular to the line of sight and the tip of the file was positioned tangential to the major apical foramen (Fig. 1). A rubber stop was carefully adjusted to the reference point and the distance between the file tip and the rubber stop was measured with a digital caliper (Sankin; Mitutoyo Co, Kanagawa, Japan) to the nearest 0.5 mm. The measurements were repeated three times and the mean was taken as the definitive length.

Gates Glidden drills (size 1–4, Mani) were used to prepare the coronal portion of the canals. Each canal was irrigated using 2 mL of 6% sodium hypochlorite solution (NaOCl) through a 27-gauge needle (Nipro, Osaka, Japan) during cleaning. Patency was constantly checked using a size 10 K-file.

The lid of a polystyrene specimen bottles (20 mL, Iuchi, Osaka, Japan) was used to fix each tooth. The bottles were filled with alginate (GC Corporation, Tokyo, Japan) and, upon setting the root of the corresponding tooth was embedded in it, leaving



Figure 1 Actual canal length determination. A size 15 K-file was introduced into the canal until the tip of the file emerged through the major apical foramen. The tip of the file was positioned tangential to the major apical foramen.

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Figure 2 Experimental set-up used in this study.

approximately 2 mm of the cervical root surface exposed for stabilization using auto-polymerizing resin. The tooth was kept in that position until the alginate had completely set (Fig. 2).

The three EAL used to measure the twelve teeth in this experiment: the Dentaport ZX (J. Morita Co., Kyoto, Japan), the Justy III and the E-Magic Finder Deluxe. Each device was used according to the manufacturers' instructions. Size 15 K-files were used with the EALs. Silicon stops were fixed with autopolymerizing resin to the files at the following distances: AL and 0.5, 1, 2, 3, 4 mm short of the AL. A file was gently inserted into the root canal until the signal was emitted by the corresponding EAL. All the electronic measurements were performed three times and the mean was calculated.

Two-way analysis of variance (ANOVA) and Tukey's HSD test were used to evaluate differences amongst EALs. One-way ANOVA and the Tukey's HSD test were used to evaluate differences amongst the measurements of each EAL. In addition, the correlation between the file tip-apical foramen distance and electronic measurements, meter reading mean values, was analysed with the Pearson Correlation Coefficient. The analysis was carried out with JMP 7 software (SAS Institute, Cary, NC, USA).

Results

Table 1 illustrates one-way ANOVA and Tukey's HSD test results. The mean and standard deviation of the meter readings with three EALs at different distances of the file tip from the apex are shown. The indicated mean meter reading of Justy III were significantly different except at 3 and 4 mm (P < 0.05). For the Dentaport, the mean readings at 0, 0.5 and 1 mm were significantly different (P < 0.05). The mean reading of the E-Magic Finder Deluxe at 0.5, 2, and 3 mm showed

no significant difference with 1, 3, and 4 mm respectively (P < 0.05).

Two-way ANOVA and Tukey's HSD test showed significant differences amongst the three EALs (P < 0.05). The correlation between distance of the file tip from the major apical foramen and mean meter readings was statistically significant (P < 0.001). The Pearson Correlation Coefficient was 0.88 for Justy III, 0.83 for Dentaport and 0.74 for E-Magic Finder Deluxe.

Discussion

Many studies have reported the accuracy of EALs to determine root canal length (Hoer & Attin 2004, Lucena-Martin et al. 2004, ElAvouti & Löst 2006, Plotino et al. 2006, Smadi 2006, Bernardes et al. 2007, D'Assunção et al. 2007, Wrbas et al. 2007). In addition, it is common knowledge that the numbers on the display of the EALs do not correspond to the actual distance in millimetres to the minor or major foramen. Rather, they are arbitrary units indicating if the file tip is moving closer or further from the foramen (Tselnik et al. 2005). However, two new devices on the market, Justy III and E-Magic Finder Deluxe, claim that the readings on the display do show the distance in millimetres from the apical foramen during measurements. The purpose of this study was to evaluate the capability of EALs to determine the distance in mm from the apical foramen whilst the file tip is advancing through the root canal.

Laboratory studies on EALs have made use of different media in which the teeth are embedded to simulate the clinical situation. The alginate model was chosen for this experiment for its good electroconductive properties, ease of preparation, stability and firm consistency (Baldi *et al.* 2007, Herrera *et al.* 2007).

The actual canal length was determined before the flaring with Gates Glidden drills. Owing to the fact that flaring with Gates Glidden files might alter the root canal length, measurements were performed before and after flaring and no difference was found largely because teeth with straight roots were used.

The Dentaport ZX is comprised of two modules: the Root ZX and the Tri Auto ZX, a rotary canal preparation handpiece with a nickel titanium instrument. The Root ZX has become the benchmark to which other EALs are compared (Plotino *et al.* 2006, Bernardes *et al.* 2007). No data about the Justy III and E-Magic Finder Deluxe could be found. Six percent NaOCl was selected as the irrigant solution for this experiment. Previous studies reported that NaOCl irrigation

Intracanal position of			
file tip from major apical foramen (mm)	Justy III	Dentaport	E-Magic Finder
Meter readings			
0	0.08 ± 0.12 A	+0.09 ± 0.33 A	0.13 ± 0.33 A
0.5	0.72 ± 0.27 B	0.90 ± 0.49 B	0.59 ± 0.13 B
1	1.60 ± 0.61 C	2.13 ± 0.53 C	0.85 ± 0.38 B
2	3.32 ± 0.93 D	2.93 ± 0.13 D	1.50 ± 0.75 C
3	3.86 ± 0.86 E	2.93 ± 0.21 D	1.93 ± 0.96 C D
4	4.12 ± 0.94 E	$3.01 \pm 0.04 \text{ D}$	$2.24 \pm 1.02 \text{ D}$

Table 1 Mean \pm SD of meter readings atdifferent intracanal positions of file tipfrom the major apical foramen

Different alphabet letters (A, B, C, D and E) indicate statistically significant differences (P < 0.05) amongst measurements within each EAL.

EAL, electronic apex locator; +, measurements are beyond the apical foramen.

improved the accuracy of measurements with Root ZX (Meares & Steiman 2002, Ebrahim *et al.* 2006).

The present study showed that, as the distance of the file tip from the apical foramen increased, the differences amongst the mean of the numeric meter readings became larger. The greatest differences were noticed when the distance between the file tip and the apical foramen was 4 mm. According to previous reports, the accuracy of measurements increases as the file tip approaches the foramen (Kobayashi & Suda 1994, Venturi & Breschi 2007).

ElAyouti & Löst (2006) suggested that accuracy and repeatability should be considered in the evaluation of EALs. The Dentaport provided the most stable electronic measurements when considering the mean standard deviation (SD) of the meter readings of the distance of the file tip from the apical foramen. The maximum and minimum SD (max SD and min SD) were 0.53 at 1 mm and 0.04 at 4 mm, respectively. On the other hand, Justy III and E-Magic Finder Deluxe showed min SD at 0 mm and 0.5 mm, respectively, and max SDs were close to 1 at 4 mm. Although SDs at 0 mm are greater than the average at the same distance, all the measurements were within the acceptable clinical range of AL ± 0.5 mm. Similar results were reported by Meares & Steiman (2002) and Venturi & Breschi (2005).

If the estimated working length is considered to be AL \pm 0.5 mm, which is clinically acceptable, then the measurements made with the three EALs at 0.5 mm from apical foramen were acceptable. The results are in agreement with the previous reports that EALs can accurately determine root canal length within \pm 0.5 mm from the apical constriction (Fouad *et al.* 1989, Czerw *et al.* 1995, Vajrabhaya & Tepmongkol 1997, Plotino *et al.* 2006). When the position of the file tip was at the major apical foramen, some of the measurements by the three EALs were positive as the

file tip was beyond the major foramen. According to Wrbas *et al.* (2007) and D'Assunção *et al.* (2007), the apical constriction should be used as a benchmark for working length determination instead of the major apical foramen to reduce overpreparation.

Clinically, the measurement of root canal length with the use of EAL in conjunction with tactile sensation has better results than radiographs (Pilot & Pitts 1997). However, for inexperienced dental clinicians, the numeric meter reading values of EALs could become a useful guide if they indicate the file tip position within the root canal whilst developing tactile sensitivity skills. In the present study, the relationship between the numeric meter readings and the position of the file was based on correlation analysis, and significant differences were found amongst the mean numeric readings within each EAL. The Pearson Correlation Coefficient indicated that the three EALs revealed a statistically significant correlation between the numeric meter reading and the distance of the file tip from the major apical foramen. The Justy III presented a higher level of correlation followed by the Dentaport and the E-Magic Finder Deluxe. On the other hand, the mean numeric meter readings by Justy III at different distances from the apical foramen were significantly different at 0, 0.5, 1 and 2 mm. The Dentaport readings were significantly different at 0, 0.5 and 1 mm. This result shows discrepancy with the previous study. Oishi et al. (2000) reported that the Root ZX showed correlation between measurements and file tip position whilst the file is up to 5 mm from the apex. The E-Magic Finder Deluxe results showed that mean meter readings at 0.5, 2, and 3 mm were not significantly different from the 1, 3, and 4 mm ones, respectively. According to the results obtained in the present study, the Justy III correlates the distance and the numeric meter reading display when the file is within 2 mm from the apical foramen whilst the

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Dentaport shows correlation when the file is within 1 mm. These results disagree with the claims made in Justy III and E-Magic Finder's catalogue that state the numeric reading on the display shows the distance in millimetres from the apical foramen.

Conclusion

The accuracy of monitoring root canal length varies amongst EALs. The Justy III was more capable of displaying the intracanal position of the file tip to the major foramen in mm whilst advancing through the root canal during electronic measurements than the Dentaport and E-Magic Finder Deluxe.

The relation between the distance from the major apical foramen and the numeric meter reading display was proved in Justy III when the file was within 2 mm from the apical foramen whilst in the Dentaport when the file was within 1 mm.

The readings '0.0' or 'apex' and '0.5' showing the intracanal position of the file tip at the major and the minor foramen was satisfactory by Justy III, Dentaport and E-Magic Finder Deluxe.

Further studies are needed to evaluate the three EALs clinically. The locators developed to date have their own internal circuit and characteristics to process and establish the file tip intracanal position from the major apical foramen and to express this numerically on the LCD display of the meter.

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