Original Article

Accuracy of electronic apex locator in the presence of different irrigating solutions

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ABSTRACT

Aim: The aim of this study was to evaluate the accuracy of the apex locator in the presence of different irrigating solutions.

Materials and Methods: Thirty humans, single canal mandibular premolars were decoronated, and canal orifices were flared with Gates-Glidden drills. Working length (Gold standard [GS]) was measured under 3.5 magnification by inserting a size 10 K file until the tip became visible and deducting 0.5 mm from this length. Teeth were embedded in an alginate mass. Electronic apex locator (EAL) measurements were made with Propex II, while different irrigants were placed in the root canals with 30G needle and groups were made based on the type of irrigating solution used i.e., Group I (3% NaOCl), Group II (5% NaOCl), Group III (2% Chlorhexidine), and Group IV (17% ethylenediaminetetraacetic acid). Statistical analysis was performed.

Results: Statistically insignificant differences were observed between the GS and EAL lengths among all the groups. There were significant differences ($P < 0.05$) only between Group III as compared to Group II and Group I.

Conclusion: EAL can be used to accurately measure the working length, even in the presence of irrigating solutions. Of the irrigating solutions tested, least effect on the accuracy of EAL was seen with 2% chlorhexidine and the highest effect was seen with 5% NaOCl.

Keywords: Apex locators, chlorhexidine, ethylenediaminetetraacetic acid, root canal irrigants, sodium hypochlorite, working length

INTRODUCTION

Successful endodontics is dependent on the correct implementation of all the steps of endodontic treatment. Working length determination being an important step, accuracy of this step will definitely contribute to the success of endodontic treatment.

The use of electronic devices to determine the working length was first proposed by Custer,[1] and the scientific basis of apex locators originated was by Suzuki.[2] Later, devices became more sophisticated and have used the characteristics of impedance gradients and frequency dependency to provide more accurate and reliable measurements under typical clinical conditions.[3] These new electronic apex locators (EALs), in which the problems with canal moisture have been solved, include qualified third-generation apex locators that use single frequencies, fourth-generation apex locators that use two separate frequencies, and fifth-and sixth-generation devices that use multiple frequencies to locate the minor foramen.[4] Thus, leading to proper mechanical debridement of the root canals.

In contemporary endodontics, the main focus is on complete disinfection of the root canal system which requires the use

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of chemical disinfection along with mechanical debridement. Irrigation is presently the best method for the removal of tissue remnants and dentine debris during instrumentation.[5] All over the years, many materials have been used to root canal irrigation, and certainly, sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), and chlorhexidine gluconate (CHX) are the most popular solutions used and most reliable ones. Due to their wide spectrum antimicrobial activity, an irrigation regimen has been proposed, in which NaOCl would be used throughout instrumentation, followed by EDTA, and CHX would be used as a final irrigant. The use of NaOCl followed by CHX has been advocated to enhance their antimicrobial properties.[6-9] NaOCl and chlorhexidine are the most popular irrigation solutions used. CHX can be used as an adjunct to the NaOCl during endodontic treatment.[10] CHX has several advantages, such as its low toxicity, broad antibacterial spectrum, effectiveness against *Enterococcus faecalis* and *Candida albicans*,[11-14] substantivity,[15] tolerable odor and taste and nonbleaching properties.[6] Whereas, EDTA has been used in endodontics as a chelating solution which helps in the removal of inorganic debris and smear layer.[16,17] The effect of the irrigation solutions as factors potentially affecting EAL accuracy has been studied widely. Study results overwhelmingly describe the lack of influence of the content of the root canal on the results of the measurements.[18-22] However, the current research has shown that the accuracy of EAL measurements might depend on the type of irrigation solution used.[17] Ozsezer analyzed ProPex after pulpal excision with three irrigants: 2.5% NaOCl, 0.9% NaCl, and 0.2% chlorhexidine gel, demonstrating that the highest discrepancies occurred with 0.9% NaCl, and the lowest with 0.2% chlorhexidine gel.[23] Therefore, it is evident that there is controversy regarding the effect of various irrigating solutions on the accuracy of EAL.

Thus, the null hypotheses tested were the EAL is accurate in the presence of irrigating solutions and the effect of different irrigating solutions on the accuracy of EAL will be the same. Moreover, the objective of this study was to evaluate the accuracy of the apex locator in the presence of different irrigating solutions to determine the working length of root canals.

MATERIALS AND METHODS

Thirty intact, mature human mandibular premolars were selected from a pool of extracted teeth which were extracted for orthodontic or periodontal reasons. All teeth were inspected under a magnifying loupe at ×3.5 magnification and were radiographed mesiodistally and labiolingually using RVG to eliminate teeth with restorations, caries, root cracks, fractured roots, internal or external resorptions, calcified canals, more than one canal, and canal curvatures >20°.

Tooth root preparation

The crowns were sectioned horizontally with a diamond disc in a slow speed handpiece at 2mm coronal to the cementoenamel junction (CEJ). The orifice and 1/3 of the coronal part of each canal were flared with Gates-Glidden drills (sizes 2–4) (Mani, Tochigi, Japan).

Root canal length measurements

The gold standard (GS) measurement of root canal length was carried out using a visual method aided by the use of a magnifying loupe of ×3.5 magnification, a size 10 K file was inserted into each canal until the tip became visible at the major apical foramen and a rubber stop was then positioned at the coronal reference point and measured with a digital caliper (INSIZE, Mumbai, India) to the accuracy of 0.01 mm and recorded. The working length was then established as 0.5 mm shorter than the measured distance. All the GS measurement was done by the first endodontist.

Then, teeth were embedded up to the CEJ in an alginate mass, which was prepared according to the manufacturer's instructions and poured into a plastic container, the exposed surface of container was covered with a cling film to keep alginate moist. For every tooth, a new preparation of alginate mass was made. A metal lip clip was also placed into the alginate mass by making a hole in the cling film to complete the current circuit. The measurements were always performed in the moist alginate mass, according to the model developed by Kaufman and Katz, i.e., within 15–20 min for one tooth. Teeth were irrigated with four different irrigating solutions and four groups (n = 30) were made based on the type of irrigating solution used i.e., Group I (3% NaOCl), Group II (5% NaOCl), Group III (2% Chlorhexidine), and Group IV (17% EDTA). Irrigants were placed into the canal using an irrigation syringe and needle 0.3 mm (30 ga) (Appli-Vac Irrigating Needle Tip; Vista Dental, Racine, WI, USA). Each canal was irrigated with 2 ml of irrigant, and the excess fluid was dried with a cotton pellet. All measurements were made directly after placement of the irrigant into the canal. Measurement was made using EAL: ProPex II (Dentsply Maillefer, Ballaigues, Switzerland). The apex locator was turned on, and the file was advanced apically into the canal. The file progressed until "0.0" appeared on the screen, suggesting that the tip of the file was at the apical constriction. The rubber stop on the file was set to the reference point. If the measurement remained constant for 5s, the file was withdrawn carefully and the distance between the rubber stop and the tip of the file was measured with a digital caliper (INSIZE, Mumbai, India) and

0.5 mm was deducted from this length which was recorded. For each tooth and the type of irrigant, three measurements were made and the mean of these measurements was taken as the reading. For each tooth, after every measurement with an irrigant, the canals were flushed with 10ml of distilled water and dried with paper points. Moreover, the next type of irrigant was similarly used for measurement with EAL. All the measurements using EAL were done by the second endodontist who was blinded about the type of irrigant used and the GS lengths.

Statistical analysis was performed using the SPSS version 20 (IBM Corp. Armonk, NY, USA). To evaluate differences between values, the following statistical tests were used: Independent *t*-test and Friedman's ANOVA. A probability of <0.05 was considered significant.

OBSERVATIONS AND RESULTS

Independent *t*-test and one way ANOVA were used for statistical analysis.

EAL was reliable for working length determination when compared with the GS method [Table 1].

Among different experimental groups, highly statistically significant difference was observed when EAL lengths were compared between 2% chlorhexidine solution with 3% NaOCl ($P = 0.005$) and 5% NaOCl ($P = 0.027$) solutions [Table 2].

EAL showed the most reliable working length determination method when it was used with 2% chlorhexidine solution, as the least amount of error was observed.

DISCUSSION

Early-generation EALs were often inaccurate in the presence of conductive fluids.[24] However, manufacturers of new-generation EALs claim that these new devices are not adversely affected from the irrigation solutions.[22] New-generation EALs determine the root canal length using two or multiple frequencies, which enable them to work accurately in the presence of various electrolytes. However, there is still a concern as to whether high electro-conductive irrigants such as blood, saline, anesthetic solution, irrigant fluids, and NaOCl can affect the accuracy of the EAL performance.[25] Due to their antibacterial and lubricating features, as well as the ability to dissolve vital tissue, using a wide range of irrigation solutions have been used for endodontic treatment. However, the presence of any fluid may hinder the use of apex locators and obtaining accurate measurements. The effects of various irrigants, such as saline, hydrogen peroxide, NaOCl solution, and EDTA solutions on EAL performance have been studied. Numerous studies indicate that endodontic measurement can be performed in the presence of any conductive fluid, but the type of irrigant solution might affect the accuracy of the EAL. The opinions of researchers regarding this issue are mixed. Some authors[18,20,22,26] believe that the least significant impact is achieved when using the NaOCl solution regardless of its concentration. It comes from the fact that it is a solution characterized by high electrical conductivity and with the potential to penetrate into dentinal tubules and decrease the electrical impedance of the root canal walls as well as generate better electrical contact with periapical tissues.[20,27,28]

In the present study, measurements of the working length were performed with various irrigating solutions to determine their influence on the accuracy of the results of apex locators. In the present study, when the GS lengths and EAL lengths were compared then no significant difference was observed in all the groups tested. This finding suggests that EAL can be safely used with all the irrigants tested in this study to accurately determine the working length.[22] Hence, the first hypotheses tested were accepted.

However, when the influence of different irrigating solutions on the accuracy of apex locators were evaluated, it was observed that the 2% CHX had the least effect followed by 17% EDTA while 3% and 5% NaOCl had significantly more effect on the accuracy of EAL, hence the second hypotheses were rejected. This is in accordance with the study by Khattak *et al.*[29] and Khursheed *et al.*[30] obtained the best results in the 0.2% chlorhexidine environment and in the

Table 1: Comparison between the gold standard and electronic apex locator length of all the groups

Group	Mean	SD	SEM	Paired difference 95% interval of the difference (lower–upper)	*T*	df	Significant (two-tailed)
Group 1: GS lengths and EAL lengths with 3% NaOCl solution	0.12400	0.08476	0.01547	0.09235-0.15565	8.013	29	0.000
Group 2: GS lengths and EAL lengths with 5% NaOCl solution	0.22867	0.08468	0.01546	0.19705-0.26029	14.791	29	0.000
Group 3: GS lengths and EAL lengths with 2% chlorhexidine solution	0.03900	0.01971	0.00360	0.03164-0.04636	10.836	29	0.000
Group 4: GS lengths and EAL lengths with 17% EDTA solution	0.13133	0.10550	0.01926	0.09194-0.17073	6.819	29	0.000

GS: Gold standard, EAL: Electronic apex locator, EDTA: Ethylenediaminetetraacetic acid, NaOCl: Sodium hypochlorite, SD: Standard deviation, SEM: Standard error of mean

Table 2: Multiple comparisons between the mean difference of the gold standard and electronic apex locator lengths of different groups

Group	Mean difference	SE	Significance	95% CI for mean (lower bound–lower bound)
Group 1: EAL lengths with 3% NaOCl				
EAL length_17%EDTA	−0.22167	0.20050	0.271	−0.6188-0.1755
EAL length_2% CHX	−0.57967*	0.20050	0.005	−0.9768-−0.1825
EAL length_5% NaOCl	−0.12933	0.20050	0.520	−0.5265-0.2678
Group 2: EAL lengths with 5% NaOCl				
EAL length_17% EDTA	−0.09233	0.20050	0.646	−0.4895-0.3048
EAL length_2% CHX	−0.45033*	0.20050	0.027	−0.8475-−0.0532
EAL length_3% NaOCl	0.12933	0.20050	0.520	−0.2678-0.5265
Group 3: EAL lengths with 2% chlorhexidine solution				
EAL length_17% EDTA	0.35800	0.20050	0.077	−0.0391-0.7551
EAL length_3% NaOCl	0.57967*	0.20050	0.005	0.1825-0.9768
EAL length_ 5% NaOCl	0.45033*	0.20050	0.027	0.0532-0.8475
Group 4: EAL lengths with 17% EDTA solution				
EAL length_2% CHX	−0.35800	0.20050	0.077	−0.7551-0.0391
EAL length_3% NaOCl	0.22167	0.20050	0.271	−0.1755-0.6188
EAL length_5%NaOCl	0.09233	0.20050	0.646	−0.3048-0.4895

*The mean difference is significant at the 0.05 level. EAL: Electronic apex locator, EDTA: Ethylenediaminetetraacetic acid, NaOCl: Sodium hypochlorite, SE: Standard error, CHX: Chlorhexidine gluconate, CI: Confidence interval

environment of a 3.0% solution of NaOCl, the difference between the measured and the actual length was significantly larger. Furthermore, the studies by Shin noted that the measurements taken in the presence of CHX were the most consistent.[17] This means that the CHX solution resulted in the least variability in the performance of the devices. This study confirms this observation. Furthermore, Ozsezer *et al*.[23] concluded that ProPex was more accurate when the root canal was full of chlorhexidine, compared to NaOCl solution. This could be explained on the basis that the presence of conductive fluids in the canals decreased the accuracy of apex locators. In an *in vivo* study, Venturi and Breschi[31] showed that measurement accuracy was related to the contents of the canal. According to Reynoso *et al*. NaOCl had higher conductivity than CHX.[32] In another study by Pilot and Pitts[28] in 1997, in which conductivity testing of some irrigants was done found out that NaOCl was the most conducting endodontic solution. The conductivity of root canal irrigants from most to least are as following. 5.25% NaOCl solution, 17% EDTA solution, 2% chlorhexidine, normal saline and finally RC-prep, and 70% isopropyl alcohol.[33] As in many other studies, in this present study, 2% chlorhexidine and 17% EDTA were found to be more reliable solutions for carrying out electronic canal measurements than with the more commonly used solutions such as 3% NaOCl.

CONCLUSION

Within the limitation of this study, it could be concluded that:

1. EAL can be used to accurately measure the working length, even in the presence of irrigating solutions
2. NaOCl in different concentrations of 3% and 5% did not have significantly different effects on the accuracy of EAL
3. Of the irrigating solutions tested in the study, the least effect on the accuracy of EAL was seen with 2% chlorhexidine followed by 17% EDTA, 3% NaOCl, and the highest effect was seen with 5% NaOCl.

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Conflicts of interest

There are no conflicts of interest.

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