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The Accuracy of Three Apex Locators in Determining the Location of Strip Root Perforation in Different Environments

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ABSTRACT

Introduction: The purpose of this study was to assess the accuracy of Root ZX (J. Morita USA, Inc., Irvine, CA, USA), Raypex 6 (VDW, Munich, Germany) and *i*-Root (S-Denti Co. Ltd Seoul, Korea) electronic apex locators (EALs) in detecting strip root perforations in dry condition, and in presence of 0.9% saline (NaCl), 2.5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), 17% ethylenediaminetetraacetic acid (EDTA) and blood. **Methods and Materials:** This *ex vivo* study evaluated 30 extracted human mandibular first molars. After mesiobuccal canal preparation, strip perforation was artificially created in the coronal third of the canal. The actual length (AL) of the canal to the perforation site was measured using a # 70 K-file under a stereomicroscope under 20× magnification. The teeth were then mounted in an alginate mold. The electronic length (EL) of the canal to the perforation site was measured by each apex locator in different environments. The difference between the EL and AL was calculated for each tooth. Statistical analyses were performed using the Friedman and post hoc Dunn tests at $P<0.05$ level of significance. **Results:** Most accurate measurements were seen in CHX environment for all three EALs. Root ZX mini in CHX environment showed most accurate reading but no significant difference was observed in three EALs in CHX environment. There was no significant difference between different environment in Root ZX mini ($P>0.05$). The most difference between the EL and AL were observed in NaOCl environment in Raypex and iRoot ($P>0.05$). **Conclusion:** Based on this *ex-vivo* study, the most accurate measurements were seen for all three EALs in CHX medium. The presence of irrigation solution affected the accuracy of all EALs. Root ZX showed better results compared to other EALs in determining the location of perforation in different environments, but this difference was not significant.

Keywords: Electronic Apex Locator; Root Canal Irrigants; Strip Root Perforations

Introduction

Strip perforation of the root is a procedural error and complication of root canal treatment that occurs due to the overuse of instruments and excessive thinning of the lateral wall of the root in the coronal third or below the furcation site [1]. Prompt diagnosis and immediate treatment can improve the prognosis [2, 3].

The suggested techniques for detection of perforation include direct observation of bleeding, indirect evaluation of bleeding by use of paper points, radiographic assessments, cone-beam computed tomography and use of electronic apex locators (EALs) [4]. Radiography is an important part of diagnosis of procedural errors during endodontic treatment such as root perforation. However, conventional radiography cannot aid in detection of buccal and lingual perforations due to the two-dimensional (2D) nature of the image. Risk of superimposition of anatomical structures and subsequent data loss also exists in use of 2D conventional radiography [2]. This technology is highly technique-sensitive in both the exposure and interpretation of results [5].

EALs are efficient, reliable tools for detection of perforations. They are extensively used by dental clinicians due to higher accuracy than radiography and decreasing the need for taking multiple radiographs during the procedure [6]. The most recent generations of EALs measure the changes in impedance in two or more different frequencies. EALs operate in presence of different materials and irrigating solutions in the root canal system [7-9].

Evidence shows that the accuracy of EALs in measuring the working length or determining the location of perforation may vary in presence of different materials/irrigating solutions in the root canal system [7, 10].

To date, no previous study has assessed the diagnostic accuracy of Root ZX, Raypex6 and i-Root EALs in detection of strip perforation of the root in different root canal environments (in terms of content). Thus, this *ex-vivo* study sought to assess the diagnostic accuracy of Root ZX, Raypex6 and i-Root for detection of strip perforation of the root in different root canal environments in terms of content [dry canal, 0.9% saline, 2.5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), 17% ethylenediaminetetraacetic acid (EDTA) and blood]. The null hypothesis was that there would be no significant difference among the three EALs in determining the location of strip perforation of the root.

Materials and Methods

The protocol of this *ex-vivo* study was approved by the ethics committee of Isfahan University of Medical sciences (IR.MUI.RESEARCH.REC.1397.480). Thirty human extracted mandibular first molars were selected. This study had eighteen groups, in each group the same thirty teeth with various intracanal irrigants were assessed. The inclusion criteria were teeth with no resorption, root fracture, root perforation or open apex. The eligible teeth were immersed in 2.5% sodium hypochlorite (Chlora, Cerkamed, Poland) for 5 min for the purpose of disinfection. The soft tissue residues and calculus were removed from the root surface by hand instruments. The teeth were stored in sterile 0.9% saline until the experiment.

Periapical radiographs (Kodak Co., NY, USA) were obtained from the buccolingual and mesiodistal dimensions to assess the root canal anatomy of the teeth. Access cavity was then prepared and the canal orifices were negotiated. The mesiobuccal cusp tip was beveled to serve as the reference point. Apical patency of the mesiobuccal canal was ensured using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). Teeth that did not have apical patency were excluded and replaced. For working length determination, a #10 K-file was introduced into the canal until its tip was visible at the apex under a microscope. Next, 1 mm was subtracted from this length to obtain the working length of the respective canal.

The mesiobuccal canal was prepared by ProTaper files (Dentsply Maillefer, Ballaigues, Switzerland) in the following sequence: SX, S1, S2 and F1, according to the standard protocol; 2.5% NaOCl was used as the irrigating solution. Next, #3, #4 and #5 Gates-Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) were used in the coronal third of the root to create a strip perforation (oval shape) in the distal surface of the mesiobuccal canal (4 mm below the furcation). Approximately 1.5 mm in size perforations were created [7]. The perforation site was finally checked by passing a #20 K-file (Dentsply Maillefer, Ballaigues, Switzerland) through it. Next, the actual length (AL) to the perforation site was measured by introducing a #70 K-file into the canal and observing the file tip at the most coronal border of the perforation site. The AL was defined as the distance between the rubber stop of the file at flatted mesiobuccal cusp tip and the file tip visible at the most coronal border of the perforation site under a stereomicroscope (Stemi DV4; Carl Zeiss, G€ottingen, Germany) at 20× magnification. All measurements were made using a stainless steel digital caliper (Mitutoyo Absolute Digimatic Sliding Caliper, Tokyo, Japan,) with 0.01 mm accuracy. The teeth were then mounted in an alginate mold. To prevent alginate entering into the canal through the perforation a #70 K-file was inserted into the mesiobuccal canal. One h prior to measurement of electronic length (EL), about 2.5 cc of human blood was collected in a tube containing heparin. Blood was drawn from a volunteer after obtaining his informed consent.

The EALs tested in this study included Root ZX (J. Morita Corp., Tokyo, Japan), Raypex6® (VDW GmbH, Munich, Germany) and i-Root (S-Denti Co. Ltd Seoul, Korea).

The EL to the perforation site was measured by the three EALs according to the manufacturers' instructions in dry root canal environment and also in presence of 0.9% saline (Samen, Iran), 2.5% NaOCl (Chlora, Cerkamed, Poland), 2% CHX (Chlora, cerkamed, Poland), 17% EDTA (Chlora, Cerkamed, Poland) and blood using a #70 K-file (Dentsply Maillefer, Ballaigues, Switzerland). All measurements were performed by one operator blinded to the AL. For assessment of intra-observer reliability, half of the measurements were made again by another observer after 2 days.

In the time intervals between the measurements in presence of different materials, the canals were rinsed with distilled water and dried with paper points (Meta BioMed, Cheongju, Korea) to ensure complete elimination of the previously used material.

For measurements with Root ZX, a #70 K-file with a rubber stop was introduced into the canal until the "OO" signal was displayed. In use of Raypex6, a #70 K-file with a rubber stop was introduced into the canal until the third green line appeared. In use of i-Root, a #70 K-file with a rubber stop was introduced into the canal until the "OO" signal displayed. The rubber stop was adjusted at the reference point, the file was removed from the canal and EL of the perforation site was recorded. All the aforementioned steps were repeated for all three EALs in presence of different materials. All measurements were made by the same operator who was experienced in using all three EALs. All procedures were performed under the supervision of the first author. The difference between the EL and AL of the perforation site was calculated.

Statistical analysis

Because the data were not normally distributed the Friedman test and post hoc Dunn test were applied to assess and compare the diagnostic accuracy of the three EALs in presence of different materials. *P*-value less than 0.05 were considered statistically significant.

Results

Most accurate measurements were seen for all three EALs in CHX medium. Root ZX mini in CHX environment showed most accurate reading but there was no significant difference in three EALs in CHX environment. No significant difference was observed between different environment in Root ZX mini (*P*>0.05). The most difference between the EL and AL were observed in NaOCl environment in Raypex and iRoot.

Mean difference between EL and AL of perforation with standard deviation (SD) for each EAL in different canal medium are summarized in Table 1.

Discussion

Strip perforation of the root is an unwanted event during root canal treatment, which adversely affects the prognosis. The mesiobuccal root of the maxillary molars and the mesial root of the mandibular molars have a thin dentinal wall and are therefore susceptible to strip perforation of the root. Inappropriate root canal preparation and use of large-size instruments for preparation of thin root canal walls can lead to strip perforation. Strip perforation is different from other types of perforations due to larger size, irregular borders, and difficult sealing of the perforation site [11].

It should be noted that in all previous studies, perforations were artificially created by a round bur in the middle or apical third of the root [7, 10, 12, 13]. However, in this study, strip perforation was created in the coronal third at 4 mm distance from the furcation using a Gates-Glidden drill. The main advantage of this method is gradual thinning of the root canal dentinal wall by use of Gates-Glidden drills, which eventually leads to perforation. It seems that this method of creation of an artificial perforation better simulates the clinical setting than induction of perforation on the external root surface using a round bur. Perforation sizes of 1, 0.60, 0.40, 0.30, and 0.27 mm were used in various previous studies [10, 14, 15]. In this study, perforations with a larger size of about 1.5 mm were created, which are similar to perforations created by using larger files, or coronal shapers.

In wide open apexes and blunder buss canals to determine the working length using the apex locator, when the foramen size is larger than 60 .The size of the instrument should be the largest size that coincide with the size of the foramen. Placing smaller files in such canals leads to shorter working length [16]. In this study a #70 K-file was used to measure EL because it was most consistent with the canal walls which was more coronal than the perforation area.

Gomide de Morais *et al.* [17] used CBCT, PA radiography and apex locator to determine the working length. They concluded that the mean value for working length was not statistically significant from apex locator, PA radiography, and CBCT. The working length obtained with CBCT was accurate compared to radiographic and apex locator [17].

Table 1. The mean difference between the electronic length (EL) and the actual length (AL) of the perforation with the standard deviation (SD) for each electronic apex locator (EAL) in different canal conditions (mm)

	iRoot	Raypex	Root ZX	*P*-value**
Dry	0.91 (0.88)^{Aa}	1.18 (0.89)^{Aa}	0.97 (0.62)^{Aa}	0.239
Saline	1.27 (0.97)^{Aa}	1.03 (0.66)^{Ca}	0.77 (0.73)^{Ab}	0.036
NaOCl	1.54 (1.39)^{Ba}	1.38 (1.03)^{Ba}	0.90 (0.93)^{Ab}	0.039
CHX	0.77 (0.71)^{Ca}	0.66 (0.50)^{Ca}	0.66 (0.41)^{Aa}	0.662
EDTA	1.19 (0.96)^{Aa}	0.80 (0.62)^{Ca}	0.95 (0.62)^{Aa}	0.393
Blood	0.83 (0.85)^{Da}	0.81 (0.71)^{Ca}	0.85 (0.86)^{Aa}	0.792
P*-value	0.018	0.003	0.353	

NaOCl: Sodium hypochloride, CHX: chlorhexidine, EDTA: Ethylene diamine tetraacetic acid, Different superscript uppercase letters in the same column indicate a statistically significant difference (P<0.05). Different superscript lowercase letters in the same row indicate a statistically significant difference (P<0.05); P-value: Between different canal conditions; P-value**: Between EALs*

Jafarzadeh *et al.* [18] compared the working length in the C-shaped mandibular second molars using conventional radiography and apex locator. They concluded that in determining the working length, the apex locator is more accurate than conventional radiography [18].

Shin *et al.* [10] assess the accuracy of Root ZX (J. Morita Corp., Tokyo, Japan) for detection of root perforation. They showed that 5.25% NaOCl had the highest and 2% CHX and RC-Prep had the lowest electrical conductivity. In other words, different intracanal materials (due to their variable electrical conductivity) may differently affect the accuracy of EALs in detection of perforations [10]. They found no significant difference in the accuracy of Root ZX in presence of different solutions. In our study, the accuracy of Root ZX in detection of strip perforations was not influenced by different environments (unlike the other two EALs). Another study assessed the diagnostic accuracy of working length determination using ProPex apex locator (Dentsply, Tulsa Dental, Tulsa, OK, USA) and revealed minimum difference between EL and AL in presence of CHX while maximum difference was noted in presence of NaOCl. They added that NaOCl had the highest electrical conductance and could therefore affect the accuracy of apex locators [19]. In presence of an intracanal solution with higher electrical conductivity, the apex locator would underestimate the working length to a greater extent [20]. In comparison of NaOCl, CHX and saline, NaOCl had maximum electrical conductance while CHX had minimum electrical conductance [10]. In our study, most accurate measurements were made in presence of CHX by all three EALs and the most difference between the EL and AL were observed in NaOCl environment in Raypex and iRoot.

A previous study reported that the accuracy of Mini, Root SW (Dailymag International Limited, Chenjia, China) and Root ZX II (J. Morita Corp., Tokyo, Japan) EALs in detection of root perforation in presence of 2.5% NaOCl was 97.1%, 100% and 91.4%, respectively. The results showed that in presence of NaOCl, all three EALs had excellent diagnostic accuracy for detection of root perforations *ex vivo* [12]. Our results, however, revealed the diagnostic accuracy of Root ZX was higher than that of i-Root and Reypex6 for detection of root perforation in presence of NaOCl; however, no significant difference was noted between i-Root and Reypex6.

Altunbaş *et al.* [7] compared the diagnostic accuracy of Dentaport ZX (J. Morita Corp., Tokyo, Japan) and Rootor (Meta Biomed,Cheongwon-gun, Korea) for detection of artificially created perforations in the middle-third of the root of mandibular premolars. They compared dry environment, NaOCl, saline, and EDTA and concluded that Dentaport ZX was more accurate than Rootor, and the contents of the root canal can affect the diagnostic accuracy of apex locators in detection of root perforations. Most accurate measurements were made in dry canal environment.

Marek *et al.* [21] concluded that the EALs Raypex 5 (VDW, Munich, Germany) and ApexDal (Septodont, Saint-Maur-des-Fossés, France) in the apical root foramen containing CHX (gel or solution) were more accurate than NaOCL. No significant differences were observed between the Raypex 5 and ApexDal in CHX solution, 2% CHX gel and 2% NaOCl [21]. Khatri *et al.* [22] in determining the length of strip root perforation, compared VDW gold (GmbH, Munchen, Germany) to iPex (NSK, Tochigi, Japan). In dry condition, VDW gold showed better results than iPex. In the presence of 2% CHX, both apex locators accurately measured the perforation site, while in the presence of 3% NaOCl, both apex locators showed a significant difference from the actual length [22]. Bilaiya *et al.* [23] evaluated the accuracy of iPex (NSK, Tochigi, Japan), Root Zx Mini (J. Morita Co., Tokyo, Japan), and Epex Pro (Eighteeth, Changzhou, China) apex locators in teeth with root perforation in dry condition, NaOCl and CHX, CHX and EDTA. The most accurate measurements were seen in the dry canals with all three EALs. The most accurate result was seen with the Root ZX mini in a dry condition and was significantly different from the other groups. With iPex and Epex Pro, there was no significant difference between NaOCl and CHX media and CHX and EDTA media [23]. The results of this study were different from our study, perhaps because in Bilaiya's study to create perforation, a round diamond bur was used and perforarion site had a sharp area but in our study we used Gates-Glidden drills to create perforation and perforation site had a strip about.

Analyzing the standard deviation values can help ensure the accuracy of the obtained data [7]. The analyses in this study showed that Root ZX had minimum standard deviation, which indicates that measurements related to the location of perforation made by this apex locator were not influenced by the root canal content.

Conclusion

In case of strip perforation most accurate measurements were seen in CHX environment for all three EALs. The presence of irrigation solution influenced the accuracy of all the apex locators. Root ZX showed better results compared to other EALs in determining the location of perforation in different environments, but this difference was not significant.

Conflict of Interest: 'None declared'.

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