

Comparative Evaluation of Accuracy of Ipex, Root Zx Mini, and Epex Pro Apex Locators in Teeth with Artificially Created Root Perforations in Presence of Various Intracanal Irrigants

 Sakshi BILAIYA,  Pallav Mahesh PATNI,  Pradeep JAIN,  Sanket Hans PANDEY,
 Swadhin RAGHUWANSHI,  Bhupesh BAGULKAR

ABSTRACT

Objective: The study aimed to compare and evaluate the accuracy of iPex, Root ZX mini, and Epex Pro Electronic apex locators (EALs) in diagnosing root perforations in both dry and in different wet conditions: 5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), and 17% Ethylenediaminetetraacetic acid (EDTA).

Methods: Thirty extracted, human single rooted mandibular premolars were artificially perforated with a diameter of 1.5 mm in middle third of root. Actual canal lengths (ALs) in millimetre (mm) were evaluated for all teeth up to perforation location, and alginate mould were used to embed the teeth. After this, the electronic measurements were calculated by all EALs up to perforation site using a 20 K-file in both dry and wet canal conditions. Up to the perforation sites, the ALs were subtracted from the electronic length. Statistical analyses were done using One-way ANOVA with post hoc tukey's test for pairwise comparison and the level of significance was set at 0.05.

Results: All three EALs detected canal perforations which were clinically acceptable. There was significant difference for dry and wet conditions. Most accurate measurement were seen in dry canals for all three EALs. Root ZX mini in dry condition showed most accurate reading and there was a significant difference when compared with other groups. No significance difference was observed in iPex and Epex Pro Apex locator, and between NaOCl and CHX, CHX and EDTA.

Conclusion: Perforations were determined within a clinical acceptable range of 0.03–0.05 mm by all three EALs. Root ZX mini in dry canals gave most accurate measurement. The presence of irrigating solution influenced the accuracy of all the apex locators.

Keywords: Electronic apex locator, root perforations, root ZX mini

Please cite this article as: Bilaiya S, Patni PM, Jain P, Pandey SH, Raghuvanshi S, Bagulkar B. Comparative Evaluation of Accuracy of Ipex, Root Zx Mini, and Epex Pro Apex Locators in Teeth with Artificially Created Root Perforations in Presence of Various Intracanal Irrigants. *Eur Endod J* 2020; 1: 6-9

From the Department of Conservative Dentistry and Endodontics (S.B. ✉ sakshibilaiya8318@gmail.com, P.M.P., P.J., S.H.P., S.R., B.B.) Sri Aurobindo College of dentistry, Indore, India

Received 08 July 2019,
Accepted 22 December 2019

Published online: 19 March 2020
DOI 10.14744/eej.2019.07279

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.



HIGHLIGHTS

- This study evaluated the accuracy of various electronic apex locators in presence of different canal conditions to detect root perforations.
- All three apex locators detect canal perforations within clinical acceptable range.
- There was no significant difference in accuracy of different apex locators when used with different irrigants.
- Root ZX mini in dry conditions gave most accurate reading.

INTRODUCTION

Endodontic failure may occur because of root perforations, which is considered as one of the important reasons for failure (1). These perforations are artificial communication that are formed between root canal and the oral cavity or periodontium (2). These perforations result in periodontal involvement which may further result in the loss of tooth. Perforations may be caused iatrogenically, resorption, or caries (1). Root perforation prognosis depends on size, site, and time elapsed before the perforation is detected and treated (3).

To reduce the chances of irrigating material to extrude into surrounding peri-radicular tissues and to prevent instrumentation going beyond the perforation during root canal treatment, clinical diagnosis of location of perforations is essential (4). Diagnosis of iatrogenically created perforations can be achieved with the aid of clinical findings and radiographic interpretation. Root perforations can be identified by (a) Placing reamer or file into an opening, which get loose rather than snugly fit in a true canal, (b) direct observation of bleeding, (c) indirect observation

of bleeding using paper point, (d) radiography, and (e) an apex locator (5).

Electronic apex locator (EAL) can determine root perforations accurately (6, 7). According to Sunada's (8) findings, the electrical resistance between oral mucous membrane and periodontium has a constant relationship; an electronic canal length measuring device can determine perforation, when it communicates with periodontal membrane and it would record a constant value. Recent EALs work by measuring alternating current impedances at multiple frequencies and can give accurate reading in presence of both dry and wet canal conditions.

Root ZX mini (J. Morita Co., Tokyo, Japan), iPex (NSK, Tochigi, Japan), Epex Pro (Eighteeth, Changzhou, China) are three modern EALs. Root ZX mini is one EAL introduced and compared with a number of EALs (9, 10). Measurement of canal length is based on ratio method, which record impedance values at 8 kHz and 0.4 kHz frequencies and by position of file in the canal; it calculates quotient of impedances (11). iPex which is a fourth generation EAL, measures both capacitance, and resistance to evaluate file position in root canal (12). This apex locators uses two or more non-simultaneous continuous frequencies in order to measure the difference or ratio between two currents (7). Epex Pro is an advanced EAL which is based on technology of multiple frequency, and impedance measurement. It has an automatic calibration according to manufacturer. Altunbas (5) assessed the accuracy of Dentaport ZX (J. Morita Co., Tokyo, Japan) and the Rotor electronic apex locators (Meta Biomed, Cheongwon-gun, Korea) in detecting root perforations in dry condition and various wet conditions, and concluded that most accurate reading was obtained in dry canals, content of root canal affected accuracy of both EAL's, and Dentaport ZX was more accurate compared to Rotor in the presence of different irrigants. Recently, Epex Pro manufacturer has achieved great popularity world wide being economic, and claimed by the manufacturer to be highly accurate. To the best of our knowledge, no studies which were published have together compared Root ZX mini, iPex, and Epex Pro EALs in locating root perforations under both canal conditions. The purpose of the study was to compare and evaluate accuracy of three EAL in detecting the perforations in dry conditions and in presence of following irrigating solutions: 5% sodium hypochlorite (NaOCl) (Neelkanth, Boranada, jodhpur, India), 2% chlorhexidine (CHX) (Neelkanth, Boranada, jodhpur, India), and 17% Ethylenediaminetetraacetic acid (EDTA).

MATERIALS AND METHODS

The research design was reviewed and approved by the "Institutional Research Committee and Ethical Committee" of Sri Aurobindo College of Dentistry, Indore (M.P.). The sample size was determined using G*Power 3.1 (Heinrich Heine, Germany) Statistical power analysis software with alpha-type error of 0.05, and power of statistics 0.8. The output indicated a minimal sample size of thirty teeth. Thirty extracted human single-rooted straight mandibular premolars having single canal were selected. Roots with resorption, open apices, or fractures were excluded. To view root canal anatomy Radio Visio Graphy (RVG) (Carestream Dental, Atlanta, GA) were taken from buccolingual and mesial-distal angles. Ultrasonic scaler (Uni-

corn Denmart NSK, New Delhi, India) was used to remove hard tissues, soft tissues, and debris from the surface of root and then all teeth were stored until used in sterile saline solution (NaCl) (0.9%). Carborundum disk (Bharat industrial corporation, Gaziabad) was used to decoronate all teeth at cemento-enamel junction. Barbed broach (VDW GmbH, Munchen, Germany) was used to remove root canal contents and then canals were instrumented up to size of 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and gained apical patency with size of 10 K-file (Dentsply Maillefer, Ballaigues). During the instrumentation, irrigation of canal was done by with 2.5 mL 5% NaOCl followed by 2.5 mL of distilled water. Artificial perforations were created from outside on middle third of root at a 90° angle with a 0.12 size round diamond bur (Medin, Nove Mesto na Morave, Czech Republic) using aerotor hand-piece by same operator. Approximately 1.5 mm in size perforations were created. Stereomicroscope (Stemi DV4; Carl Zeiss, Gottingen, Germany) with 20x magnification was used to determine Actual length (AL) up to perforation site by visualizing tip of 20 K-file (Dentsply Maillefer) through perforation space (Fig. 1). Vernier caliper (Mitutoyo, Japan) was used to measure the distance from rubber stopper to the tip of file at the nearest of 0.05 mm. Then the alginate moulds were use to embed all the teeth.

Electronic measurements were determined according to the recommendations of manufacturer after AL up to the perforations were obtained, by all three EAL in dry conditions and in various wet canal conditions: 5% NaOCl, 2% CHX, and 17% EDTA using 20 K-file. Between measurements with different irrigants, canals were irrigated were distilled water and then dried using paper points. For the Root ZX mini device, a 20 K-file with a rubber stopper was gradually taken within the root canal till liquid crystal display (LCD) showed the apex reading. Then file was withdrawn from the canal until flashing bar between "Apex-mark and 1-mark" on LCD (Fig. 2).

For iPex, file was gradually advanced until LCD display apex signal and then file was withdrawn until "0.5-mm-mark".

With Epex Pro apex locator, the file was advanced until the "00-mark" reading and "green indicated strips" was obtained

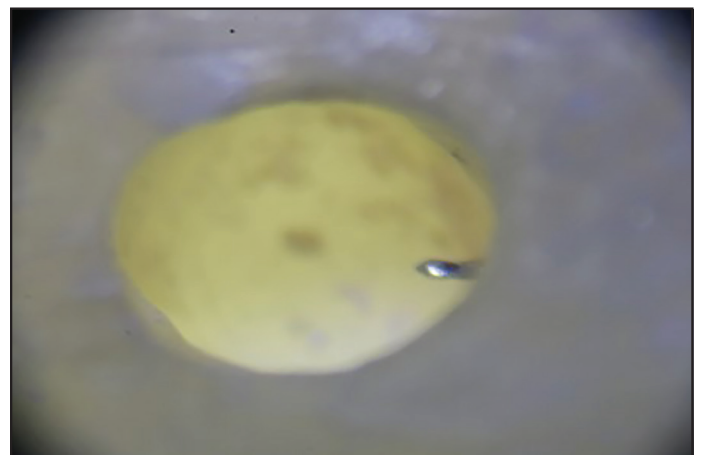


Figure 1. Figure showing tip of a 20K - file at the perforation seen under a stereomicroscope at 20x

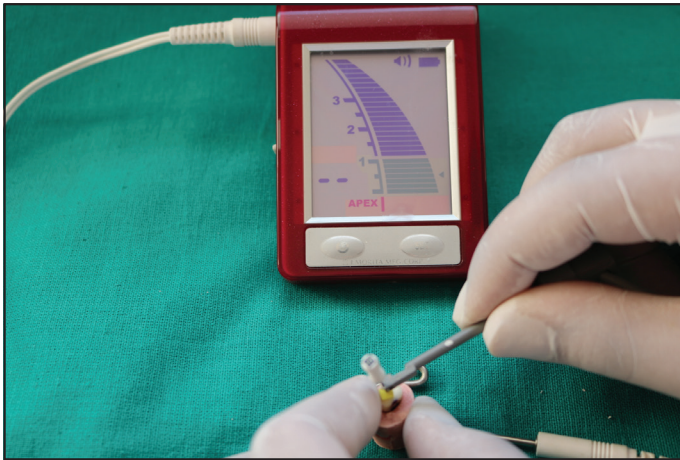


Figure 2. Root ZX mini device, attached to a 20 K-file showing the apex reading between “Apex-mark and 1-mark” on liquid crystal display (LCD)

near perforations. Rubber stopper was adjusted and the file was taken out from canal, and then electronic length (EL) were recorded up to the perforations in both the dry and wet conditions. Measurement of all teeth was done by the same experienced operator. Difference between ELs and the ALs was calculated. Clinically acceptable EL measurements was ± 0.5 mm of AL

The data was collected in Microsoft excel sheet and was cross checked for any errors. The data was then subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS, IBM version 20.0, New York, United States). The level of significance was set at 5% and p value ≤ 0.05 was considered statistically significant. Statistical Analysis were done using One-way ANOVA with post hoc Tukey's HSD for pairwise comparison.

RESULTS

All three EALs detected canal perforations which were clinically acceptable. Results were significant for dry and wet conditions. Most accurate measurement were seen in dry canals for all three EALs. Root ZX mini in dry condition showed most accurate reading and there was a significant difference when compared with other group. No significant difference was observed in iPex and Epex Pro Apex locator, and between NaOCl and CHX, CHX and EDTA.

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

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)

	Dry condition Mean \pm SD	NaOCl Mean \pm SD	Chlorhexidine Mean \pm SD	EDTA Mean \pm SD
Root ZX mini	0.03 \pm 0.01 ^{Aa}	0.06 \pm 0.02 ^{Ab}	0.08 \pm 0.02 ^{Ac}	0.09 \pm 0.02 ^{Ac}
IPEX	0.23 \pm 0.10 ^{Ba}	0.39 \pm 0.14 ^{Bb}	0.36 \pm 0.12 ^{Bb}	0.38 \pm 0.10 ^{Bb}
Epex pro	0.24 \pm 0.13 ^{Ba}	0.39 \pm 0.11 ^{Bb}	0.35 \pm 0.15 ^{Bab}	0.43 \pm 0.18 ^{Bb}

NaOCl: Sodium hypochloride, 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 ($P < 0.05$)

DISCUSSION

A successful root perforations treatment is based on identification of the defect location, size of the defect, time elapse between perforation and treatment, and its sealing (1). Even for skilled endodontists, it is difficult to radiographically diagnose root perforations present in buccal or lingual surfaces of root (13). With the help of EAL site of apical foramen, apical constriction, apical root resorption, and root fracture can be precisely determined (14-17). Older EALs worked under impedance principle, whereas newer apex locators work under different principles like ratio method. Apex locator displays apex reading as soon as reamer or file contact periodontal ligament (2).

Electrical method of detecting apical foramen was first demonstrated by Cluster (2). According to Sunada's findings, electrical resistance between oral mucosa membrane and periodontal ligament has a 6.5 k Ω constant value; which led to the development of the first EAL.

A recent method for evaluating root canal length before initiating root canal treatment is by measuring canal length on pre-existing cone-beam computed tomography (CBCT) scans. Shemesh et al. (11) showed that periapical radiographs has very limited ability to diagnose perforations and CBCT was not able to detect strip perforations in endodontic treated teeth. This limitation of CBCT introduce the importance of more accurate method to diagnose root perforation, so as to avoid bone destruction and to prevent poor prognosis.

In the present study, alginate was used as the embedding medium to simulate periodontium because it has appropriate physical properties. The firm consistency of an alginate prevents tooth mobility and possible material ingress into the artificial perforation. It also presents suitable electroconductivity (18). For an in vitro study of EALs in perforated teeth, other materials such as agar, gelatin, and a saline solution have been used which are electroconductive in nature (3, 11, 19, 20). Perforation sizes of 1, 0.60, 0.40, 0.30, and 0.27 mm were used in various previous studies (3, 4, 19). In one study simulated perforation of size 1 mm was considered unrealistic (20). In the present studies, larger perforation size of approximately 1.50 mm was created, which simulate perforations because of resorption, usage of large files, or coronal shapers, or during different intracanal procedures for post placement.

In this study, dry or wet canal conditions, influenced the accuracies of Root ZX mini, iPex, and Epex Pro in perforated teeth, but under various irrigants, no significant difference was de-

tected. Literature showed similar results in which irrigants had no effect on the precision of different EALs such as Root ZX (Morita Co), Propex (Dentsply Maillefer), and Raypex 5 (VDW GmbH) in determining perforations of root canal (19, 21). In contrast, one study (19) showed that the canal content had an impact on accuracy of Root ZX apex locator. Different devices, irrigants, and methodologies used in many studies can explain this discrepancy. Duran- Sindreu et al. (22) reported that NaOCl and chlorhexidine did not influence the measurements obtained with Root ZX and iPex.

Venturi and Breschi (23) found that in low conductive dry conditions, the measurements were unstable and less accurate for Root ZX. In another study, Root ZX gave more accurate reading in the presence of saline and EDTA than in dry canals, or in the presence of xylol (24). However, according to the present study, Root ZX mini, iPex, Epex Pro gave no significant differences under different wet conditions and were more accurate in dry conditions.

To measure accuracy of the EALs, +/-0.5 mm difference has been considered accurate in various studies (11, 19, 24, 25, 26). Others considered an acceptable range of +/-1.0 mm (19, 27). Since relation between rubber stopper and reference point, rubber stopper and caliper, or file tip and caliper was difficult to control visually, therefore in the present study, average values were considered for accuracy and clinical acceptability. In this study, results obtained with all three devices were acceptable because the largest average difference value was 0.48 mm.

CONCLUSION

All three EALs detected canal perforations within 0.03–0.5 mm range which is clinically acceptable. Root ZX mini gave most accurate measurement among three apex locator. The presence of irrigating solution influenced the accuracy of all the apex locators. The most accurate measurements were obtained in dry canals.

Disclosures

Conflict of interest: None declared.

Ethics Committee Approval: The research design was reviewed and approved by the "Institutional Research Committee and Ethical Committee" of Sri Aurobindo College of Dentistry, Indore (M.P.).

Peer-review: Externally peer-reviewed.

Financial Disclosure: None declared.

Authorship contributions: Concept – S.B., P.M.P., P.J.; Design – P.M.P., S.H.P.; Supervision – S.R., B.B.; Funding – S.B., P.M.P.; Materials – B.B., P.J., S.R.; Data collection &/or processing – S.H.P., P.J.; Analysis and/or interpretation – B.B., S.H.P., S.R.; Literature search – P.M.P., B.B.; Writing – S.B., P.M.P., S.H.P.; Critical Review – P.J., S.R., B.B.

REFERENCES

- Alhadainy HA. Root perforations. A review of literature. *Oral Surg Oral Med Oral Pathol* 1994; 78(3):368–74.
- Srivastava V, Jain N, Bagchi S, Negi MPS. Evaluation of the Use of Sixth Generation Apex Locators as a Diagnostic Tool to Detect Root Perforations. *Int J Dent Med Spec* 2015; 2(4):10–14.
- Zmener O, Grimberg F, Banegas G, Chiacchio L. Detection and measurement of endodontic root perforations using a newly designed apex-locating handpiece. *Endod Dent Traumatol* 1999; 15(4):182–5.
- Fuss Z, Assouline LS, Kaufman AY. Determination of location of root perforations by electronic apex locators. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1996; 82(3):324–9.
- Altunbaş D, Kuştarıcı A, Toyoğlu M. The Influence of Various Irrigants on the Accuracy of 2 Electronic Apex Locators in Locating Simulated Root Perforations. *J Endod* 2017; 43(3):439–42.
- Nahmias Y, Aurelio JA, Gerstein H. Expanded use of the electronic canal length measuring devices. *J Endod* 1983; 9(8):347–9.
- Mosleh H, Khazaei S, Razavian H, Vali A, Ziaei F. Electronic apex locator: A comprehensive literature review – Part I: Different generations, comparison with other techniques and different usages. *Dental Hypotheses* 2014; 5(3):84–97.
- Sunada I. New method for measuring the length of the root canal. *J Dent Res* 1962; 41(2):375–87.
- Alothmani OS. The accuracy of Root ZX electronic apex locator. *Saudi Endod J* 2012; 2(3):115–30.
- de Vasconcelos BC, do Vale TM, de Menezes AS, Pinheiro-Junior EC, Vivacqua-Gomes N, Bernardes RA, et al. An ex vivo comparison of root canal length determination by three electronic apex locators at positions short of the apical foramen. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010; 110(2):e57–61.
- D'Assunção FL, Sousa JC, Felinto KC, de Medeiros TC, Leite DT, de Lucena RB, et al. Accuracy and repeatability of 3 apex locators in locating root canal perforations: an ex vivo study. *J Endod* 2014; 40(8):1241–4.
- Stöber EK, Duran-Sindreu F, Mercadé M, Vera J, Bueno R, Roig M. An evaluation of root ZX and iPex apex locators: an in vivo study. *J Endod* 2011; 37(5):608–10.
- Tsesis I, Rosenberg E, Faivishevsky V, Kfir A, Katz M, Rosen E. Prevalence and associated periodontal status of teeth with root perforation: a retrospective study of 2,002 patients' medical records. *J Endod* 2010; 36(5):797–800.
- Saraswathi V, Kedia A, Purayil TP, Ballal V, Saini A. Comparative evaluation of the accuracy of two electronic apex locators in determining the working length in teeth with simulated apical root resorption: An in vitro study. *J Conserv Dent* 2016; 19(5):402–5.
- Ebrahim AK, Wadachi R, Suda H. Accuracy of three different electronic apex locators in detecting simulated horizontal and vertical root fractures. *Aust Endod J* 2006; 32(2):64–9.
- Vieyra JP, Acosta J. Comparison of working length determination with radiographs and four electronic apex locators. *Int Endod J* 2011; 44(6):510–8.
- Altunbas D, Kustarci A, Arslan D, Er K. In vitro comparison of four different electronic apex locators to determine the major foramen using the clearing technique. *Niger J Clin Pract* 2014; 17(6):706–10.
- Baldi JV, Victorino FR, Bernardes RA, de Moraes IG, Bramante CM, Garcia RB, et al. Influence of embedding media on the assessment of electronic apex locators. *J Endod* 2007; 33(4):476–9.
- Shin HS, Yang WK, Kim MR, Ko HJ, Cho KM, Park SH, et al. Accuracy of Root ZX in teeth with simulated root perforation in the presence of gel or liquid type endodontic irrigant. *Restor Dent Endod* 2012; 37(3):149–54.
- Marroquín BB, Fernández CC, Schmidtman I, Willershhausen B, Goldberg F. Accuracy of electronic apex locators to detect root canal perforations with inserted metallic posts: an ex vivo study. *Head Face Med* 2014;10:57.
- Li YH, Zhou Z, Zheng YQ, Gan N, Tang YY, Li R, et al. Accuracy of three different electronic apex locators in determination of perforation with various conditions in vitro. [Article in Chinese]. *Hua Xi Kou Qiang Yi Xue Za Zhi* 2011; 29(3):272–5.
- Duran-Sindreu F, Gomes S, Stöber E, Mercadé M, Jané L, Roig M. In vivo evaluation of the iPex and Root ZX electronic apex locators using various irrigants. *Int Endod J* 2013; 46(8):769–74.
- Venturi M, Breschi L. A comparison between two electronic apex locators: an ex vivo investigation. *Int Endod J* 2007; 40(5):362–73.
- Kaufman AY, Keila S, Yoshpe M. Accuracy of a new apex locator: an in vitro study. *Int Endod J* 2002; 35(2):186–92.
- Çalışkan MK, Kaval ME, Tekin U. Clinical accuracy of two electronic apex locators in teeth with large periapical lesions. *Int Endod J* 2014; 47(10):920–5.
- Khandewal D, Ballal NV, Saraswathi MV. Comparative evaluation of accuracy of 2 electronic Apex locators with conventional radiography: an ex vivo study. *J Endod* 2015; 41(2):201–4.
- Herrera M, Ábalos C, Lucena C, Jiménez-Planas A, Llamas R. Critical diameter of apical foramen and of file size using the Root ZX apex locator: an in vitro study. *J Endod* 2011; 37(9):1306–9.