

Research Article



In vivo assessment of accuracy of Propex II, Root ZX II, and radiographic measurements for location of the major foramen

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

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ABSTRACT

Objectives: The aim of this *in vivo* study was to assess the accuracy of 2 third-generation electronic apex locators (EALs), Propex II (Dentsply Maillefer) and Root ZX II (J. Morita), and radiographic technique for locating the major foramen (MF).

Materials and Methods: Thirty-two premolars with single canals that required extraction were included. Following anesthesia, access, and initial canal preparation with size 10 and 15 K-flex files and SX and S1 rotary ProTaper files, the canals were irrigated with 2.5% sodium hypochlorite. The length of the root canal was verified 3 times for each tooth using the 2 apex locators and once using the radiographic technique. Teeth were extracted and the actual WL was determined using size 15 K-files under a $\times 25$ magnification. The Biostat 4.0 program (AnalystSoft Inc.) was used for comparing the direct measurements with those obtained using radiographic technique and the apex locators. Pearson's correlation analysis and analysis of variance (ANOVA) were used for statistical analyses.

Results: The measurements obtained using the visual method exhibited the strongest correlation with Root ZX II ($r = 0.94$), followed by Propex II ($r = 0.90$) and Ingle's technique ($r = 0.81$; $p < 0.001$). Descriptive statistics using ANOVA (Tukey's *post hoc* test) revealed significant differences between the radiographic measurements and both EALs measurements ($p < 0.05$).

Conclusions: Both EALs presented similar accuracy that was higher than that of the radiographic measurements obtained with Ingle's technique. Our results suggest that the use of these EALs for MF location is more accurate than the use of radiographic measurements.

Keywords: Dental pulp cavity; Electronic apex locators; Endodontic; Radiographs; Therapeutics; Working length

INTRODUCTION

Working length (WL) determination is an important step in endodontic therapy, because it defines the point at which root canal preparation and obturation should terminate [1]. A root canal preparation short of the accurate WL can result in incomplete elimination of bacteria

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from the apical third of the root [2], whereas instrumentation beyond the apex results in overfilling and periapical inflammation [3]. The anatomy of the apical foramen has been suggested as presenting an apical constriction (AC) that apically enlarges toward the major foramen (MF) [4]. However, some studies have shown that frequently this configuration is not present [5,6].

Radiographic measurements have been used for WL determination. However, variations in the position of the foramen can lead to incorrect measurements when only radiographs are used. The introduction of electronic apex locators (EALs) for use in endodontic therapy has enabled more predictable and accurate measurements in this regard [1]. Although a recent review suggested that at least one radiograph should be acquired to determine WL [7], some studies have demonstrated that EALs are more reliable than radiographic measurements [8]. An increase in the use of EALs may decrease the excessive use of radiographs [9].

Different methodologies have been used to evaluate the accuracy of EALs. Some studies have tested the ability of EALs to locate AC, while some have tested their ability to locate MF. However, it has been reported that MF is a more reliable landmark [6]. Moreover, some studies have used extracted teeth and some have obtained *in vivo* measurements, followed by comparisons with radiographic measurements [7]. Some *in vitro* studies have shown that the accuracy of EAL devices may vary when tested *in vivo*. Although several studies have evaluated EALs, the majority have been conducted *in vitro* [1].

Third-generation EALs use multiple frequencies, which provide more accurate measurements. Propex II (Dentsply Maillefer, Ballaigues, Switzerland) and Root ZX II (J. Morita, Tokyo, Japan) are 2 examples of third-generation EALs. Propex II works by calculating the ratio of the impedances measured simultaneously at frequencies of 0.5 and 8.0 kHz, while Root ZX II uses the mean square roots of the impedances measured at frequencies of 0.4 and 8.0 kHz [10]. The aim of the present *in vivo* study was to investigate the accuracy of Propex II and Root ZX II and radiographic measurements for locating MF during endodontic treatment.

MATERIALS AND METHODS

In total, 32 maxillary and mandibular premolars with single root canals that required extraction for orthodontic reasons were included in this study. All patients provided written informed consent for participation, and the study was approved by the Institutional Review Board of Faculdade de Odontologia São Leopoldo Mandic (2010/0062). The inclusion criteria were as follows: completely formed apices and a positive response to cold sensitivity tests (Endofrost, Coltene/Whaledent AG, Altstätten, Switzerland). Teeth presenting open apices, signs of root canal calcification, caries, and/or previous restorations were not included. Two radiographs in orthogonal and distal angulations were taken and observed to exclude teeth presenting 2 roots or curvatures of $> 5^\circ$ according to Schneider's technique [11].

Following the induction of local anesthesia and rubber dam isolation, the access cavity was prepared using diamond burs and the presence of vital tissue was confirmed. The pulp chamber was irrigated with 5 mL of 2.5% sodium hypochlorite (NaOCl), and a size 10 K-file was used for initial canal negotiation. The tooth was then evaluated under the magnification of a dental operating microscope (DOM) to confirm the presence of a single canal. The pulp tissue was extirpated using size 10 and 15 K-files in a sequential order, with continuous

irrigation using 2 mL of 2.5% NaOCl. S1 and SX rotary ProTaper files (Dentsply Maillefer) were then used at 300 rpm and 3 N to prepare the cervical third of the teeth. Finally, the root canal space was irrigated with 2.5% NaOCl and aspirated to eliminate excess irrigant solution.

Propex II and Root ZX II were used with a size 15 K-file to locate MF. The point at which each EAL maintained the 0.0 measure for 5 seconds was confirmed to be MF. This step was repeated 3 times with both Propex II and Root ZX II. If the same value was obtained with all three measurements, we registered that value. If 2 same and 1 different values were obtained, we used the value that appeared twice. If 3 different values were obtained, we determined the median value. The files were then measured using a digital caliper with a ± 0.01 mm resolution (FNCL, Worker Gage, Esteio, Brazil), and the obtained values were registered in a spreadsheet. Subsequently, radiographic measurements using Ingle's technique were obtained to determine the length of each canal [12]. Based on the initial image a radiograph was taken with a size 15 K-file 2 mm short of the radiographic apex. The difference between the tip of the file and the radiographic apex was added and a new radiograph was taken; the results were recorded. Thus, each tooth was measured a total of 7 times: once with Ingle's technique, 3 times with Propex II, and 3 times with Root ZX. The same experienced operator performed all measurement procedures.

Following *in vivo* measurements, the teeth were extracted and stored in 2.5% NaOCl. The teeth were then held in a manner that the MF could be directly visualized from a lateral view. A size 15 K-file was introduced into the canal until the tip reached MF. The obtained length was registered in the same digital caliper. A DOM under a × 25 magnification was used for accurate measurements.

All results were analyzed using the Biostat 4.0 program (AnalystSoft Inc., Chapel Hill, NC, USA). Pearson's correlation analyses were used to correlate the *in vivo* and *in vitro* measurements. Descriptive statistics using analysis of variance (ANOVA, Tukey's *post hoc* test) were used to evaluate discrepancies among measurements obtained using radiographic technique and the 2 EALs.

RESULTS

Measurements obtained using Root ZX II and Propex II correlated with the extracted tooth measurements for 75% and 59.37% of the cases, respectively. According to Pearson's correlation analyses, the actual measurements obtained using the visual method exhibited the strongest correlation with the measurements obtained using Root ZX II ($r = 0.94$), followed by those obtained using Propex II ($r = 0.90$) and Ingle's technique ($r = 0.81$; $p < 0.001$; **Table 1**).

Table 1. Results of Pearson's correlation analyses to determine the correlation between the measurements obtained using direct visualization and those obtained using Ingle's radiographic technique, Root ZX II, and Propex II for MF location

Measurement correlated	Radiographic vs. direct visualization	Root ZX II vs. direct visualization	Propex II vs. direct visualization
No. (pairs)	32	32	32
r (Pearson's correlation)	0.818	0.941	0.905
95% CI	0.66–0.91	0.88–0.97	0.81–0.95
99% CI	0.59–0.93	0.85–0.98	0.77–0.96
p value	< 0.001	< 0.001	< 0.001

Manufacturer information is follow as; Root ZX II, J. Morita, Tokyo, Japan; Propex II, Dentsply Maillefer, Ballaigues, Switzerland. CI, confidence interval; MF, major foramen.

Table 2. Results of descriptive statistics using ANOVA (Tukey's *post hoc* test) to determine discrepancies among measurements obtained using Ingle's radiographic technique, Root ZX II, and Propex II for MF location

Radiographic technique	Root ZX II	Propex II
0.93 ± 0.84 ^a	0.31 ± 0.59 ^b	0.50 ± 0.67 ^b

Manufacturer information is follow as; Root ZX II, J. Morita, Tokyo, Japan; Propex II, Dentsply Maillefer, Ballaigues, Switzerland.
ANOVA, analysis of variance; MF, major foramen.

^{a,b}The different superscript letters indicate statistically significant differences ($p < 0.05$).

Descriptive statistics using ANOVA (Tukey's *post hoc* test) showed significant differences between the radiographic measurements and the 2 EAL measurements ($p < 0.05$; **Table 2**).

DISCUSSION

This study aimed to evaluate the accuracy of 2 third-generation EALs, namely Propex II and Root ZX II, and a radiographic technique for locating MF during endodontic treatment. Several recent studies have evaluated the accuracy of different EALs *in vitro* [13] and *in vivo* [14,15]. An *in vivo* study presents a great challenge for evaluation; however, it simulates an actual clinical situation more closely. One challenge is the standardization of specimens. We selected maxillary and mandibular premolars with a single canal and comparable estimated lengths for our study. In addition, the patients were of a similar age, thus ensuring similar root development and avoiding anatomical variations due to cement deposition in older patients. Each specimen was measured by both EALs and radiographic technique, which eliminated intergroup differences in apical sizes. A recent meta-analysis showed that EALs are not influenced by the pulp status [1], whereas another study showed that the results are influenced by the pulp tissue status [16]. To avoid any possible bias, we only included teeth with vital pulp tissue.

We chose MF as a reference point in the present study on the basis of a report showing greater anatomical consistency for this landmark than for AC [6] and a report showing the higher accuracy of EAL in locating MF [17]. Following *in vivo* location of MF, we compared the measurements with those obtained *in vitro* using direct visualization. In the present study, both EALs presented better results compared with radiographic technique. A recent study comparing 2 different EALs and a radiographic technique, but found no difference in measurements [18], while another study showed that EAL was more accurate [8]. Kim *et al.* [19] conducted an *in vivo* study and showed that the combined use of EALs and radiographs provide the most accurate measurements.

In the present study, measurements obtained using Root ZX II and Propex II precisely correlated with the extracted tooth measurements for 75% and 59.37% cases, respectively. These values were lower than those obtained by Plotino *et al.* [20] (84.22%) and Real *et al.* [18] (91.9%) for Root ZX. However, it is important to emphasize that these previous studies were *in vitro* studies that selected AC as the reference landmark. In addition, one study considered a variation of 0.5 mm as acceptable, while another study allowed a deviation of 1.0 mm within an accurate measurement. In our *in vivo* study, we used MF as the reference landmark and strictly followed an error-free protocol; by selecting these points, which may have influenced the results, we can consider our correlation rate to be accurate.

Parente *et al.* [21] have shown a 100% accuracy for MF location by both devices. Our results are in agreement with their finding that there is no significant difference in accuracy between the 2 devices, although our accuracy values were lower for both. Vasconcelos *et al.*

[17] presented an accuracy of 73.5% for Root ZX and 67.6% for Propex II with regard to MF location; these values are similar to ours. One *in vivo* study [22], however, has presented less accurate results compared with those obtained *in vitro*. Specifically, only 40% of MF measurements obtained using Propex II were accurate.

In the present study, the accuracy of both third-generation EALs were superior to that of Ingle's radiographic technique. When interpreting and comparing the results of different studies, clinicians should consider the design (*in vivo* or *in vitro*), the adopted reference landmark, and the error tolerance for measurements.

CONCLUSIONS

Both third-generation electronic apical locators assessed in this study located MF with a similar accuracy that were higher than that of the radiographic measurements. Our results suggest that the use of these EALs for MF location is more accurate than the use of radiographic measurements.

REFERENCES

1. Tsesis I, Blazer T, Ben-Izhack G, Taschieri S, Del Fabbro M, Corbella S, Rosen E. The precision of electronic apex locators in working length determination: a systematic review and meta-analysis of the literature. *J Endod* 2015;41:1818-1823.
[PUBMED](#) | [CROSSREF](#)
2. Ricucci D. Apical limit of root canal instrumentation and obturation, part 1. literature review. *Int Endod J* 1998;31:384-393.
[PUBMED](#) | [CROSSREF](#)
3. Siqueira JF Jr, Rôças IN, Favieri A, Machado AG, Gahyva SM, Oliveira JC, Abad EC. Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. *J Endod* 2002;28:457-460.
[PUBMED](#) | [CROSSREF](#)
4. Kuttler Y. Microscopic investigation of root apexes. *J Am Dent Assoc* 1955;50:544-552.
[PUBMED](#) | [CROSSREF](#)
5. Ponce EH, Vilar Fernández JA. The cemento-dentino-canal junction, the apical foramen, and the apical constriction: evaluation by optical microscopy. *J Endod* 2003;29:214-219.
[PUBMED](#) | [CROSSREF](#)
6. Dummer PM, McGinn JH, Rees DG. The position and topography of the apical canal constriction and apical foramen. *Int Endod J* 1984;17:192-198.
[PUBMED](#) | [CROSSREF](#)
7. Martins JN, Marques D, Mata A, Caramês J. Clinical efficacy of electronic apex locators: systematic review. *J Endod* 2014;40:759-777.
[PUBMED](#) | [CROSSREF](#)
8. Kobayashi C, Suda H. New electronic canal measuring device based on the ratio method. *J Endod* 1994;20:111-114.
[PUBMED](#) | [CROSSREF](#)
9. Kara Tuncer A, Gerek M. Effect of working length measurement by electronic apex locator or digital radiography on postoperative pain: a randomized clinical trial. *J Endod* 2014;40:38-41.
[PUBMED](#) | [CROSSREF](#)
10. de Vasconcelos BC, Veríssimo Chaves RD, Vivacqua-Gomes N, Candeiro GT, Bernardes RA, Vivan RR, Duarte MA. *Ex vivo* evaluation of the accuracy of electronic foramen locators in root canals with an obstructed apical foramen. *J Endod* 2015;41:1551-1554.
[PUBMED](#) | [CROSSREF](#)
11. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol* 1971;32:271-275.
[PUBMED](#) | [CROSSREF](#)

12. Ingle JI, Beveridge EE. Endodontics. 2nd ed. Philadelphia (PA): Lea & Febiger; 1976. p179.
13. Guise GM, Goodell GG, Imamura GM. *In vitro* comparison of three electronic apex locators. J Endod 2010;36:279-281.
[PUBMED](#) | [CROSSREF](#)
14. 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;41:201-204.
[PUBMED](#) | [CROSSREF](#)
15. Pagavino G, Pace R, Baccetti T. A SEM study of *in vivo* accuracy of the Root ZX electronic apex locator. J Endod 1998;24:438-441.
[PUBMED](#) | [CROSSREF](#)
16. Haffner C, Folwaczny M, Galler K, Hickel R. Accuracy of electronic apex locators in comparison to actual length--an *in vivo* study. J Dent 2005;33:619-625.
[PUBMED](#) | [CROSSREF](#)
17. Vasconcelos BC, Bueno Mde M, Luna-Cruz SM, Duarte MA, Fernandes CA. Accuracy of five electronic foramen locators with different operating systems: an *ex vivo* study. J Appl Oral Sci 2013;21:132-137.
[PUBMED](#) | [CROSSREF](#)
18. Real DG, Davidowicz H, Moura-Netto C, Zenkner Cde L, Pagliarin CM, Barletta FB, de Moura AA. Accuracy of working length determination using 3 electronic apex locators and direct digital radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:e44-e49.
[PUBMED](#) | [CROSSREF](#)
19. Kim E, Marmo M, Lee CY, Oh NS, Kim IK. An *in vivo* comparison of working length determination by only root-ZX apex locator versus combining root-ZX apex locator with radiographs using a new impression technique. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:e79-e83.
[PUBMED](#) | [CROSSREF](#)
20. Plotino G, Grande NM, Brigante L, Lesti B, Somma F. *Ex vivo* accuracy of three electronic apex locators: Root ZX, Elements Diagnostic Unit and Apex Locator and ProPex. Int Endod J 2006;39:408-414.
[PUBMED](#) | [CROSSREF](#)
21. Parente LA, Levin MD, Vivan RR, Bernardes RA, Duarte MA, Vasconcelos BC. Efficacy of electronic foramen locators in controlling root canal working length during rotary instrumentation. Braz Dent J 2015;26:547-551.
[PUBMED](#) | [CROSSREF](#)
22. Somma F, Castagnola R, Lajolo C, Paternò Holtzman L, Marigo L. *In vivo* accuracy of three electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II. Int Endod J 2012;45:552-556.
[PUBMED](#) | [CROSSREF](#)