

Ex vivo evaluation of the effectiveness and accuracy of electronic apex locators in the identification of the actual working length

Carlos Alberto Herrero de **MORAIS**¹

Joana Yumi Teruya **UCHIMURA**²

Rosangela Getirana **SANTANA**³

Emerson **BARILI**⁴

Marcos Sergio **ENDO**⁵

DOI: <http://dx.doi.org/10.14436/2358-2545.6.1.015-020.oar>

ABSTRACT

Introduction: The use of electronic apex locators (EALs) is essential to identify the actual working length (AWL), since the radiographic method has limitations. **Objective:** The aim of this study was to compare the effectiveness and accuracy of three EALs: Root ZX™, NovApex™ and Justy II™ in the identification of the AWL. **Methods:** Thirty extracted human incisors were selected. After coronal opening and cervical preparation, a #15 K-file was inserted into the canal until its tip reached the apical foramen. The actual length (AL) was observed using a digital caliper and magnification with an operating microscope (25x). The AWL of each tooth was obtained by subtracting 1 mm from the file length. The teeth were inserted into the cervical level in a sponge of floral arrangement, which was

in a transparent plastic box, soaked in 0.9% saline solution. An experienced and calibrated endodontist performed 30 measurements with each device, with the total of 90 measures. **Results:** Analysis of variance (ANOVA) demonstrated that there was no statistically significant difference ($p = 0.4505$) among devices. Comparing the three EALs in relation to AWL, there was not statistically significant difference among them: Root ZX™ ($p = 0.3418$); NovApex™ ($p = 0.3031$) and Justy II™ ($p = 0.4080$). However, regression analysis carried out by means of the scatter plot showed that NovApex™ had better accuracy than other electronic apex locators, with 93%. **Conclusions:** The EALs used were effective; however, although NovApex™ showed higher accuracy, more studies should be performed.

Keywords: Odontometry. Accuracy. Effectiveness.

How to cite this article: Morais CAH, Uchimura JYT, Santana RG, Barili E, Endo MS. Ex vivo evaluation of the effectiveness and accuracy of electronic apex locators in the identification of the actual working length. *Dental Press Endod.* 2016 Jan-Apr;6(1):15-20.
DOI: <http://dx.doi.org/10.14436/2358-2545.6.1.015-020.oar>

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

¹Associate professor, Universidade Estadual de Maringá (UEM), School of Dentistry, Department of Endodontics, Maringá, Paraná, Brazil.

²MSc in Integrated Dentistry, Universidade Estadual de Maringá (UEM), Maringá, Paraná, Brazil.

³Full professor of Statistics, Universidade Estadual de Maringá (UEM), Maringá, Paraná, Brazil.

⁴MSc in Biostatistics, Universidade Estadual de Maringá (UEM), Maringá, Paraná, Brazil.

⁵Adjunct professor, Universidade Estadual de Maringá (UEM), School of Dentistry, Department of Endodontics, Maringá, Paraná, Brazil.

Submitted: 16/10/2015. Revised and accepted: 01/03/2016.

Contact address: Carlos Alberto Herrero de Morais
Rua Neo Alves Martins, 3176, sala 93, Maringá/PR, Brazil – CEP: 87.013-060
E-mail: caherrero@endodontiamaringa.com.br

Introduction

Root canal therapy aims at cleaning, disinfecting, preparing and three-dimensionally filling the root canal system.¹ However, in order to achieve those objectives, it is essential to identify the actual working length (AWL) of the tooth being treated.

Odontometry is an extremely important step during endodontic treatment. It is at this stage that apical constrictions or AWL are determined. The AWL enables to safely work inside the root canal;² however, because of small diameters of root canals, its clinical and radiographic identification may be difficult to achieve.^{3,4,5} Although several methods have been suggested for this purpose, the electronic method based on the principle of frequency-dependent impedance has demonstrated better effectiveness when compared to radiographic assessments.^{6,7} This is of clinical importance because not always the foraminal patency is obtained. In such cases, the reading observed in the electronic apex locators (EAL) near the apical foramen will be crucial to obtain a safe working length.

Recently, many studies have been performed comparing the effectiveness of EALs,^{2-5,8-20} but only a few have focused on their accuracy.^{6,7,21,22,23} In 2002, one of the first studies⁶ to perform accuracy analysis through a calibration curve showed a positive correlation between measurements. In 2006, a study⁷ emphasized the importance of accuracy and suggested a model for this determination with the use of EALs. After that, other studies conducted in 2008;²¹ 2010²² and 2011²³ stressed the importance of conducting comparative analyses among EALs in regard to their effectiveness and accuracy.

Nevertheless, despite the studies mentioned above, more comparative studies on EALs are still necessary. Therefore, the aims of this *ex vivo* study were to compare the effectiveness of three EALs widely used by endodontists in the identification of the AWL and assess the accuracy of these devices. The null hypothesis was that the EALs tested would not present significantly different results under the same conditions.

Material and Methods

This study was reviewed and approved by Universidade Estadual de Maringá (UEM) Ethics Committee (#0498.0.093.000-11).

Teeth selection

Thirty incisors obtained from the human tooth bank of Universidade Estadual de Maringá (UEM) were selected. The teeth were visually examined and radiographed mesiodistally and buccolingually with radiographic films type 2 (Carestream Dental, France) and RX Siemens Heliodont 60B (Siemens S/A - Rio de Janeiro, Brazil). The selected teeth had a single root canal, completely formed roots, and absence of calcifications, internal resorption and prior endodontic treatment.

Teeth preparation

Conventional endodontic access was performed in all teeth with a high-speed handpiece under copious irrigation with distilled water and spherical diamond burs 1014 and 3082 (KG Sorensen, São Paulo, Brazil).

Coronal flaring of the canal was sequentially performed using Gates Glidden drills #4, #3 and #24.10. Canals were irrigated with 1% sodium hypochlorite solution (NaOCl) (Asfer – Indústria Química Ltda., São Caetano do Sul - SP, Brazil).

The actual length (AL) of each tooth was obtained by inserting a #15 K-file (Dentsply Maillefer™, Ballaigues, Switzerland) into the root canal until its tip reached the apical foramen, as observed with the aid of a clinical microscope under 25x magnification (DF Vasconcellos, São Paulo, Brazil).¹⁰ At this point, the silicone stopper on the file was set against the flat anatomical tooth landmark.⁹ The file was removed from the canal and the distance between its tip and the stopper was measured with a digital caliper (Mitutoyo™, Tokyo, Japan). The actual working length (AWL) was obtained by subtracting 1 mm from the file length.

Ex vivo measurements were performed in a transparent plastic box filled with flower sponge moistened with 0.9% saline solution and in which the teeth were inserted until the cervical level.

Electronic measurements were performed by an experienced and calibrated endodontist, using the following apex locators: Root ZX™ (J. Morita Corporation, Tokyo, Japan); Novapex™ (Forum Technologies, Israel); and Justy II™ (Co. Hager-Werken, Duisburg, Germany)/Yoshida, Tokyo, Japan).

Irrigation of the root canal was performed with 1% NaOCl (Asfer – Indústria Química Ltda.,

São Caetano do Sul - SP, Brazil) with an irrigation NaviTip™ needle (Ultradent Products, South Jordan, United States), followed by excess removal of the solution from the pulp chamber. A #15 K-file was inserted into the root canal connected to one electrode of the EAL, while the other electrode (lip) was maintained in the flower sponge, simulating the periodontal ligament. The locators were operated according to the manufacturers' instructions; that is, until the file reached the apical foramen. At this point, the instrument was pulled back until the mark "1.0" was shown on the display of the EAL, thus recording the AWL. We used this method for standardization because the foraminal patency is not always clinically obtained. For each EAL used, 30 readings were obtained, with a total of 90 readings.

In order to check for effectiveness, data were statistically analyzed by analysis of variance (ANOVA) at a significance level of 95% to verify potential significant differences between the electronic measurements obtained with EALs and the AWLs

pre-determined visually. In order to analyze the accuracy of the devices, a calibration curve was performed through simple linear regression model, using the angular coefficient ($\beta = 1$) and the graphical representation of dispersion.

Results

The ANOVA results comparing the working length obtained with the three EALs and the AWL measured showed that the measurements obtained presented no statistically significant differences ($p = 0.4505$).

Table 1 shows the accuracy results of each EAL in comparison to the AWL measured, comparing their measurements through the simple linear regression model. There was no statistically significant difference (NovApex™: $p = 0.3039$; Root ZX™: $p = 0.3418$; Justy II™: $p = 0.4080$); however, NovApex™ showed better determination coefficient than the others, with 93% ($R^2 = 0.9287$).

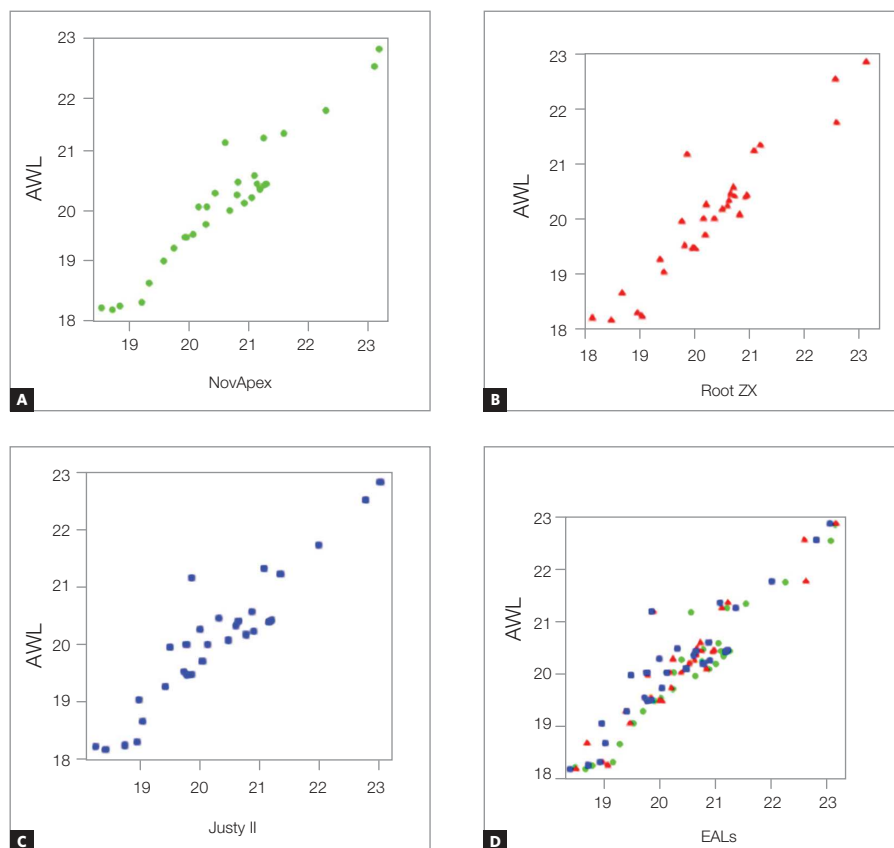


Figure 1. Calibration analysis by plotting dispersion of three devices used in relation to the AWL measured, confirming the best calibration with NovApex™.

Table 1. Accuracy analysis of the three EALs in comparison with the AWL measured.

EAL	R ²	p
NovApex™	0.9287	0.3039
Root ZX™	0.8785	0.3418
Justy II™	0.8734	0.4080

R² = coefficient of determination; p = descriptive level.

Discussion

To the best of our knowledge, this is one of the few studies performed to compare results obtained with EALs and the AWL, demonstrating the effectiveness and accuracy of different locators. Although correlation analysis showed that NovApex™ was slightly more precise than the other locators, effectiveness analysis of EALs supported the null hypothesis.

Analysis of variance showed no statistically significant difference among measurements obtained with EALs: NovApex™, Justy II™ and Root ZX™ in comparison with the AWL measured. The same result was also observed in previous studies comparing different devices: Root ZX™ and NovApex™;⁴ Root XZ™, Elements Diagnostic Unit™, Apex Locator™ and Romi APEX D-30™;⁹ Propex™, NovApex™, Root ZX™ and Elements Apex Locator™;²⁴ Root ZX™, RomiApex D-30™ and Ipex™;¹⁶ and Root ZX™ and i-Root™.²³ In contrast, other studies have also found statistically significant differences among devices: Root ZX™, Endy™ and Endox™;³ Endex™, Propex II™, Root ZX™;¹⁴ and Propex™ and Root ZX™.⁸

Several comparative analyses have been performed using the mean of measurements obtained with different EALs,^{2,3,8,13,14,16,17} and also the percentage in relation to the actual measurements.^{2,3,8,9,13,16,17} These studies concluded that Endex™ and Propex II™ presented better results than Root ZX™ in determining the AWL;¹⁴ while Justy II™ showed higher accuracy than Root ZX™, Endy™ and Endox™.³ Additionally, Propex™ provided better findings than Root ZX™ and Elements™.⁸ In this study, NovApex™, Justy II™ and Root ZX™ were used. A recent study showed that Root ZX™ demonstrated precision up to 90%.² Other studies have also shown its effectiveness when compared to other devices. Root ZX™ was proved to be more accurate than Justy II™ and digital radiography;¹⁷ RomiApex D-30™ and Ipex™;¹⁶ Elements Diagnostic Unit™ and Apex Locator™;⁹ Root ZX-II™, Mini Apex Locator™ and NovApex™.¹³

Although widely used by clinicians due to easy handling, NovApex™ has been poorly studied. A recent *in vivo* study comparing NovApex™ with the radiographic method demonstrated no significant

differences between them.²⁵ Another study analyzing the same devices used in our study showed significant differences between the AWL and AL obtained with Justy II™ and NovApex™; however, Root ZX™ showed greater similarity to the AWL; that is, it clinically obtained more accurate file position in the constriction and apical foramen.¹⁸ Unlike our study they did not carry out calibration curve analysis.

Devices need to be accurate as well as precise.²³ Thus, to compare different devices, besides analysis of variance, the calibration curve is also required.

A few previous studies have used graphic representation to compare different devices: Root ZX™ and i-Root™, by analyzing the distribution of measures and outliers using box plots, which showed no significant differences between the two devices tested;²³ Dentaport ZX™, Root ZX mini™, Elements Diagnostic Unit™, Apex Locator™ and Raypex 5™, noting that Dentaport™ and Root ZX mini™ demonstrated higher precision in their measurements;²² and the present study, which compared NovApex™, Justy II™ and Root ZX™, demonstrating better accuracy of NovApex™ with the AWL, using the scatter plot.

Furthermore, taking into account the limitations of *in vitro* studies, some studies have been performed *in vivo*.²⁵ However, due to difficulties encountered to perform *in vivo* analyses, which demand methodological

standardization, as well as analyses and readings that require previous preparation, *ex vivo* analysis is still widely used.^{2,12,14,16,17} The EALs used showed different interfaces: pointer, LCD and LED. However, when analyzing their effectiveness, they showed no differences. As they are all 3rd generation devices, they have similar operation and are capable of providing the clinician with adequate precision in determining the AWL, regardless of their presentation.³

The apparatus used to simulate the periodontal ligament in this study may not always represent the actual clinical situation. Therefore, further studies should be undertaken in order to clarify these limitations, as well as to create models that are more approximate to the actual clinical situation. We used, in our study, flower sponge to simulate the periodontal ligament. Although some studies have shown better results with the use of alginate,^{13,26} the difference found was not statistically significant when compared with 1% agar with saline and flower sponge.²⁶

Conclusions

Based on the results of this study, we may conclude that all electronic apex locators (Novapex™, Root ZX™ and Justy II™) proved to be effective, with similar results in AWL measurements. Although NovApex™ showed higher accuracy, more studies are needed.

References

- Schilder H. Cleaning and shaping the root canal. *Dent Clin North Am*. 1974 Apr;18(2):269-96.
- Vasconcelos BC, Araújo RBR, Silva FCFA, Luna-Cruz SM, Duarte MAH, Fernandes CAO. In vivo accuracy of two electronic foramen locators based on different operation systems. *Braz Dent J*. 2014;25(1):12-6.
- 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 Sept;33(8):619-25.
- D'Assunção FL, Albuquerque DS, Queiroz Ferreira LC. The ability of two apex locators to locate the apical foramen: an in vitro study. *J Endod*. 2006 Jun;32(6):560-2. Epub 2006 Apr 4.
- Siu C, Marshall JG, Baumgartner JC. An in vivo comparison of the Root ZX II, the Apex NRG XFR, and Mini Apex Locator by using rotary nickel-titanium files. *J Endod*. 2009 Jul;35(7):962-5.
- Kaufman AY, Keila S, Yoshpe M. Accuracy of a new apex locator: an in vitro study. *Int Endod J*. 2002 Feb;35(2):186-92.
- ElAyouti A, Löst C. A simple mounting model for consistent determination of the accuracy and repeatability of apex locators. *Int Endod J*. 2006 Feb;39(2):108-12.
- 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 May;39(5):408-14.
- Bernardes RA, Duarte MA, Vasconcelos BC, Moraes IG, Bernardineli N, Garcia RB, et al. Evaluation of precision of length determination with 3 electronic apex locators: Root ZX, Elements Diagnostic Unit and Apex Locator, and RomiAPEX D-30. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2007 Oct;104(4):e91-4.
- Venturi M, Breschi L. A comparison between two electronic apex locators: an ex vivo investigation. *Int Endod J*. 2007 May;40(5):362-73.
- Wrbas KT, Ziegler AA, Altenburger MJ, Schirmeister JF. In vivo comparison of working length determination with two electronic apex locators. *Int Endod J*. 2007 Feb;40(2):133-8.
- Pascon EA, Marrelli M, Congi O, Ciancio R, Miceli F, Versiani MA. An ex vivo comparison of working length determination by 3 electronic apex locators. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009 Sept;108(3):e147-51.
- D'Assunção FL, Albuquerque DS, Salazar-Silva JR, Santos VC, Sousa JC. Ex vivo evaluation of the accuracy and coefficient of repeatability of three electronic apex locators using a simple mounting model: a preliminary report. *Int Endod J*. 2010 Apr;43(4):269-74.
- Cianconi L, Angotti V, Felici R, Conte G, Mancini M. Accuracy of three electronic apex locators compared with digital radiography: an ex vivo study. *J Endod*. 2010 Dec;36(12):2003-7.
- Guisse GM, Goodell GG, Imamura GM. In vitro comparison of three electronic apex locators. *J Endod*. 2010 Feb;36(2):279-81.
- Vasconcelos BC, Vale TM, 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 Aug;110(2):e57-61.
- Real DG, Davidowicz H, Moura-Netto C, Zenkner CL, Pagliarin CM, Barletta FB, et al. Accuracy of working length determination using 3 electronic apex locators and direct digital radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011 Mar;111(3):e44-9.
- Vasconcelos BC, Matos LA, Pinheiro-Júnior EC, Menezes AST, Vivacqua-Gomes N. Ex vivo accuracy of three electronic apex locators using different apical file sizes. *Braz Dent J*. 2012 Jan;23(3):199-204.
- Puri N, Chadha R, Kumar P, Puri K. An in vitro comparison of root canal length determination by DentaPort ZX and iPex apex locators. *J Conserv Dent*. 2013 Nov;16(6):555-8.
- Vasconcelos BC, Bueno M de 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 Mar-Apr;21(2):132-7.
- Leonardo MR, Silva LA, Nelson-Filho P, Silva RA, Raffaini MS. Ex vivo evaluation of the accuracy of two electronic apex locators during root canal length determination in primary teeth. *Int Endod J*. 2008 Apr;41(4):317-21.
- Stoll R, Urban-Klein B, Roggendorf MJ, Jablonski-Momeni A, Strauch K, Frankenberger R. Effectiveness of four electronic apex locators to determine distance from the apical foramen. *Int Endod J*. 2010 Sept;43(9):808-17.
- Jung IY, Yoon BH, Lee SJ, Lee SJ. Comparison of the reliability of "0.5" and "APEX" mark measurements in two frequency-based electronic apex locators. *J Endod*. 2011 Jan;37(1):49-52.
- Goldberg F, Frajlich S, Kuttler S, Manzur E, Briseño-Marroquín B. The evaluation of four electronic apex locators in teeth with simulated horizontal oblique root fractures. *J Endod*. 2008 Dec;34(12):1497-9.
- Shahi S, Rahimi S, Milani AS, Asghari Jafarabadi M, Djoorabaf Naghsh GR. Comparison between the accuracy of NovApex Apex Locator and radiographs in determining radiographic Apex. *Iran Endod J*. 2011 Spring;6(2):65-8.
- Baldi JV, Victorino FR, Bernardes RA, Moraes IG, Bramante CM, Garcia RB, et al. Influence of embedding media on the assessment of electronic apex locators. *J Endod*. 2007 Apr;33(4):476-9.