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ORIGINAL ARTICLE

Effectiveness of three electronic apex locators to determine root canal working length.

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Abstract: The aim of this study was to evaluate *in vivo* the accuracy of three electronic apex locators (EALs) in determining working length (WL) using hand files and a wear technique. Thirty two premolars that were completely formed apically and that were scheduled for extraction for orthodontic reasons from patients between ages of 15 and 20 years old were included. Electronic measurement of WL was performed using the EAL according to the manufacturer's instructions. The following three EAL were used: A. Root ZX II; B. Raypex 5, and C. Propex II. There were significant difference (p=0.0002) when comparing median differences among the three EAL. Statistical analysis revealed significant differences between Root ZX II vs. Raypex 5 and Root ZX II vs. Propex II (p=0.0044; p=0.0002), while between Raypex 5 and Propex II, there were no statistically significant differences with respect to the accuracy of the EAL in determining WL (p=0.1087). The present findings suggest that Root ZX II presented the highest agreement rate for determining the final WL.

Keywords: *Electronic apex locator, Working length, Major foramen, Minor foramen, Raypex 5, Root ZX II, Propex II.*

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INTRODUCTION.

The removal of all pulp tissue, necrotic debris, and microorganisms from the root canal system is required for success in root canal treatment[1]. To achieve this objective, the canal end must be detected accurately during canal preparation and precise control of working length (WL) during the process must be maintained. Short measurements of the WL, especially in cases of necrotic pulps and chronic periapical lesion, led to drastically lower success rates compared to cases where an accurate WL was achieved. In addition, a WL established beyond the apical constriction (AC) may cause root perforation and overfilling that can increase presence of postoperative pain and delay the healing process[2].

The apical 3mm of the root canal system has been considered critical zone in the treatment of infected root canal. The cemento-dentinal junction (CDJ), where the pulp tissue changes into the apical tissue, is the most ideal physiologic apical limit of the WL.

It is referred to as the minor foramen or AC. However, the CDJ and AC do not always coincide, particularly in senile teeth as a result of cementum deposition, which alters the position of the minor diameter. Therefore, setting the AC as the apical limit of the WL, where it is easy to clean and shape or fill the canals, is recommended. The major apical foramen (AF) is not always located at the anatomical apex of the tooth. The AF may be located to one side of the anatomical apex, sometimes at distances of up to 3.0mm. It has been reported that the distance between the AC and the AF is 0.659mm in adults, whe-

reas it is 0.524mm in young people.

The problem clinician's face is how to accurately identify and prepare to this landmark the WL and achieve highest success[3].

Usually, WL has been determined radiographically; however, at present electronic apical locators (EALs) have gained acceptance[4]. Studies have demonstrated the limitations of radiographs, which include image distortion, superposition of roots, and adjacent anatomical structures, radiation exposure, and patient management.

The most significant disadvantage of the radiographic method is related with the difficulty of locating the apical foramen and apical constriction. Different generations of EALs have been developed in order to increase the accuracy to determining WL[5-13].

EALs have been used clinically for more than 40 years as an aid to determine the file position in the canal. These devices, when coupled to a file, are able to detect the point at which the file leaves the tooth and enters the periodontium (minor foramen). The first generation of EALs was based on resistance, whereas the second generation was based on impedance properties. However, both types have a main difficulty for use in the presence of electrolytes, resulting in poor accuracy.

This was overcome by the introduction of third-generation EALs. Studies with EALs have been carried out under *in vitro* conditions; but at present, the validity of measurements performed with *in vitro* models remains unknown. As a consequence, extrapolation from *in vitro* studies to the clinical setting might not be appropriate. While modern EALs can locate apical foramen and apical constriction with high precision, to date, few *in vivo* studies have analyzed the accuracy of Root ZX II, Raypex 5, and Propex II for determining WL[14,15].

The aim of this study was to evaluate *in vivo* the accuracy of three electronic apex locators in determining WL using hand files and a wear technique.

MATERIALS AND METHODS.

A clinical trial was conducted according to the ethical guidelines established by the Helsinki Declaration and approved with the number CEIFE-011-011 by the Institutional Research Ethics Committee at the Faculty of Dentistry, San Luis Potosi University, SLP, Mexico. Patients included in this study signed written informed consent, which specified the objectives and benefits of the study, the procedures planned, as well as possible risks.

Thirty two premolars, which a completely formed apically that were scheduled for extraction for orthodontic reasons from patients between the ages of 15 to 20 years old were included in the study. Teeth responded positively to the cold sensitivity test and clinically, all pulps were confirmed to be vital at the moment of entry into the pulp.

After anesthesia (2% mepivacaine, Scandonest®, Septodont, Mexico), a rubber dam was set in place. Endodontic access was performed with number 4 carbide bur under water irrigation; an Endo Z bur (Dentsply Maillefer, Ballaigues, Switzerland) was used to refine the pulp chamber walls. The coronal/middle third of each canal was flared with SX and S1 Protaper files (Protaper Universal, Dentsply Maillefer, Ballaigues, Switzerland).

Teeth were irrigated with 3mL of 1% NaOCl after the use of each rotator instrument, and the excess of solution was removed from the pulp chamber utilizing an aspirator. All steps were conducted by an experienced specialist in Endodontics.

Teeth were assigned sequential numbers in the order of enrollment and received their allocated EAL according to a computer-generated randomization schedule prepared before the start of the study. Electronic measurement of WL was performed according to the manufacturer instructions as follows: for all devices, the clip was placed on the patient's lip and a K-Flexofile (Dentsply Maillefer, Ballaigues, Switzerland) 21mm in was length selected according to the apical size of each canal and attached to the EAL. Three EALs were used: A: Root ZX II (J. Morita Corp., Tokyo, Japan); B. Raypex 5 (VDW, Munich, Germany), and C. Propex II (Dentsply Maillefer, Ballaigues, Switzerland).

The file was gently inserted into the root canal until the display showed a stable reading of 0.5. The K-files were fixed at the WL determined electronically by the rubber stop shifted to the occlusal reference edge, and the file was then removed. The occlusal reference point was defined and recorded for each canal. This procedure was performed three times for each canal. The K-files were recorded and stored according to the teeth and the EAL employed for each of these.

Following electronic measurement, the rubber dam was removed and the tooth was extracted, assuring that the samples showed no sign of fracture. Each sample was placed in 3% NaOCl for 15min to remove any residual organic tissue from the root and then stored in 10% neutral formalin.

The 4-mm apical portion of each root was trimmed in a longitudinal direction using a fine diamond bur under a Leica EZ40 microscope (Leica Microsystems, Wetzlar, Germany) at X16 magnification to expose the file tip. The remaining tooth structure was removed carefully with a #15 scalpel blade until the file tip and the root

Figure 1. Example of measurement from file tip to major foramen (AF).

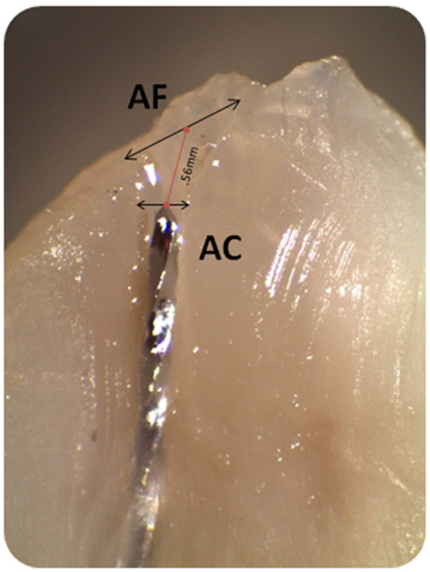
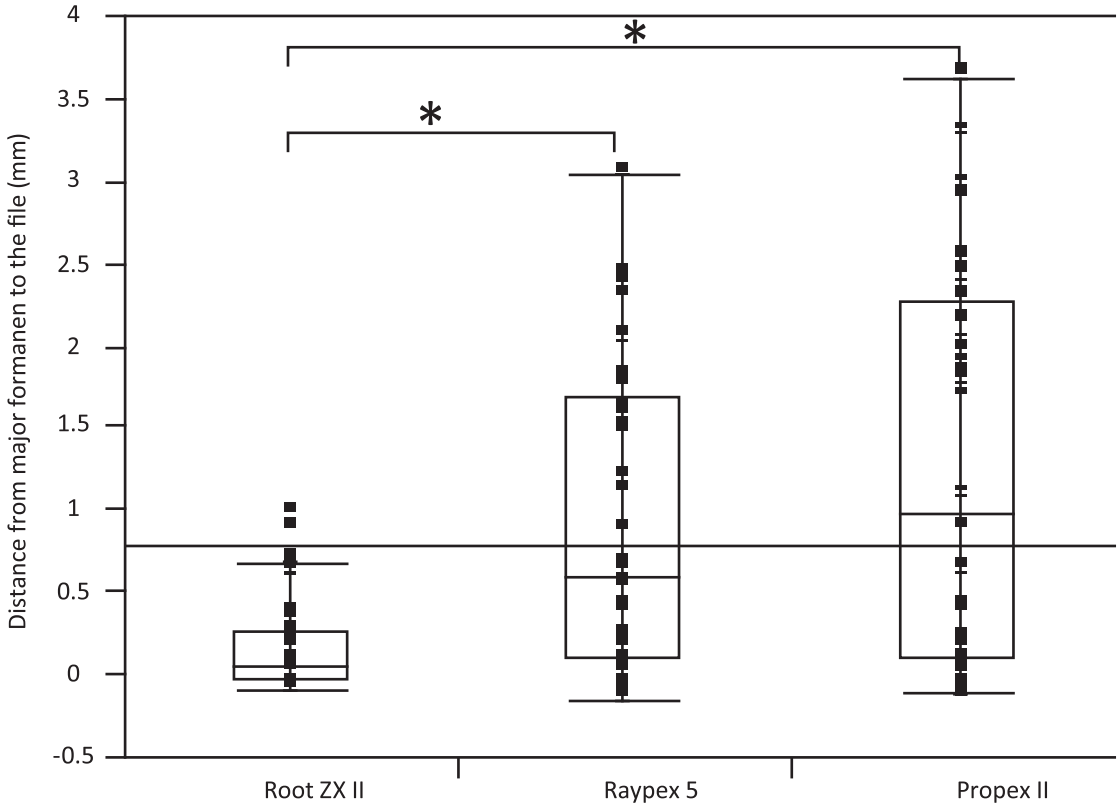


Figure 2. Distance from apical foramen to file tip values.



. (*)Statistically significant.

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Table 1. Position of file tip relative to apical foramen as determined by different electronic apex locators.

Electronic apex locator	Distance from AF to tip file (mm)	Accuracy (%)
Root ZX II	0.5	87.5
	1.0	100
Raypex 5	0.5	50
	1.0	59.4
Propex II	0.5	46.9
	1.0	56.2

canal were both visible.

The apical portion of the specimen was observed under the Leica EZ40 stereoscopic at X35 and was photographed with LAS-EZ software (Leica Microsystems, Wetzlar, Germany) each specimen.

Following this, MOTIC 3.0 software (Motic Deutschland GmbH, Germany) was employed to measure the distance between AF and file tip (Figure 1). An independent investigator carried out the evaluation and was blinded regarding group assignments.

Measurements of WL values were recorded in both groups as the distance from AF to the file tip and graphically as box plots. Test normality of data was evaluated by Shapiro-Wilk test.

For comparing differences among the three EALs, and view of a non-parametric distribution a Kruskal-Wallis test was used, while to identify possible significant differences among the results from the study groups, a non-parametric Mann-Whitney U test was performed, with a significance level set at 0.05, using JMP IN software (Cary, NC, USA).

RESULTS.

The Kruskal-Wallis test shows a significant difference (p=0.0002) when comparing median differences among the three EALs. Root ZX II was accurate 87.5% of the time at ±0.5mm, and 100% of the time ±1.0mm from AF.

Raypex 5 II was accurate 50% of the time at ±0.5mm and 59.4% of the time ±1.0mm from AF.

Propex II was accurate 46.9% of the time at ±0.5mm and 56.2% of the time ±1.0mm from AF (Table 1).

Statistical analysis revealed significant differences between Root ZX II vs. Raypex 5 (p=0.0044) and between Root ZX II vs. Propex II (p=0.0002), while between Raypex 5 vs. Propex II, there were no statistically significant differences respect to their accuracy in determining foramen localization (p=0.1087) (Figure 2).

DISCUSSION.

Numerous studies have reported the accuracy of EALs with respect to determination of the location of apical constriction of the root canal at AF[4]. Root ZX II, Raypex 5, and Propex II were used in the study because they employ the same current frequencies and determine WL via an impedance ratio. In this study, Root ZX II exhibited greater accuracy than Raypex 5 and Propex II. Ex vivo studies have been found that report that Root ZX II was significantly more accurate than Raypex 5 in locating the AF[7,9,16].

EALs are usually utilized in the clinic to establish WL in root canals; its use possesses advantages over other methods such as radiography because EALs do not require radiation. Current studies have shown that apex locators employed with hand-held files are quite accurate in determining the ideal WL[17].

In *in vitro* studies, electrically conductive materials, such as alginate, gel, or saline, have been used to simulate clinical situations. Also, in *in vivo* studies, after electronic measurements, the tooth is extracted and different points, such as apical foramen, apical constriction, and radiographic apex are compared with the point where the apex locator marked the end of the root canal system[18].

In the present study all measurements of the EALs were conducted at ±0.5mm. No statistically significant differences were obtained by taking apex locator readings. We attribute this to the age of the teeth, because they were young teeth with no restorations, which resulted in the canals being very spacious and hardly any obstructions were found.

Regarding the range of ±0.5mm, the latter is considered the strictest acceptable range, and the measurements obtained within this range were considered highly accurate. However, some authors prefer the range of ±1mm[19,20].

In our study, the Root ZX II locator gave an accuracy of 87.5% at a distance of 0.5mm from AF and 100% accuracy at a distance of 1.0mm from AF. Siu *et al.*[17] reported accuracy of 50% with Root ZX II at ±0.5mm and of 92.86% at ±1.0mm, with the highest percentage of locators in the study performed *in vitro*, similar to ours.

Welk *et al.*[7] demonstrated accuracy with Root ZX II of 90.7% in determining AF at ±0.5mm. On the other hand, Guise *et al.*[8] reported an effectiveness of 97.5% with Root ZX II; under *in vitro* conditions, Root ZX II was the most accurate in locating AF compared with the EAL and the precision apex locator, which agrees our data based on the results of our study.

Ravanshad *et al.*[18] informed an accuracy of 90.4% with Raypex 5, with which we differ, because we reported in our study 50% accuracy at a distance of ±0.5mm from AF and 59.4% accuracy at a distance of ±1.0mm distance from AF. Ding *et al.*[21] reported an average 67.7% accuracy for Raypex 5; however, in their study, the authors concluded that Root ZX possess greater accuracy for detecting AF, compared with Raypex 5 and the Elements.

Pascon *et al.*[22] reported that the Raypex 5 locator had 31% accuracy at ±0.5mm and at ±1.0mm, 82% accuracy, which differs from our study, and the authors concluded that DentaPort ZX and Raypex 5 were similar in terms of accuracy. Cianconi *et al.*[9] reported 82.2% accuracy at ±0.5mm with Propex II, compared with Root ZX and Endex; we differ with these authors because in our study, the Propex II locator presented an accuracy of 46.9% at a distance of ±0.5mm from AF and 56.2% accuracy at ±1.0mm from AF.

The use of the EAL to determine WL has still not gained extensive acceptance worldwide. This may in part be due to early devices that suffered from poor accuracy and did not function properly in the presence of common irrigants; cost of the instruments and exposure to the technology are also factors.

Clinical limitations should be taken in consideration; other conductors that can cause short-circuiting are metallic restorations, caries, saliva and instruments in a second canal. Also, clinically it might be prudent to confer with the patient's cardiologist prior to treatment.

CONCLUSIONS.

The results of this study showed statistically significant differences among Root ZX II, and Raypex 5 and Propex II, while between Raypex 5 and Propex II, no statistically significant differences were found. The present findings suggest that Root ZX II possessed the highest agreement rate for determining the final WL. There was no significant difference between Raypex 5 and Propex II for determining the final WL.

Efectividad de tres localizadores apicales electrónicos para determinar la longitud radicular de trabajo.

Resumen: El objetivo del presente estudio fue evaluar *in vivo* la exactitud de tres localizadores apicales electrónicos (LAEs) para determinar la longitud de trabajo (LT) usando instrumentos manuales y una técnica de desgaste. Treinta y dos premolares con formación apical completa e indicados para extracción por razones ortodóncicas de pacientes de edad entre 15 y 20 años fueron incluidos en el estudio. Se usaron tres LAE; A. Root ZX II; B. Raypex 5, y C. Propex II. Se encontraron diferencias significativas (p=0.0002) cuando se compararon las medianas entre los tres LAE. El análisis mostró diferencias entre Root ZX II vs. Raypex 5 y Root ZX II vs. Propex II (p=0.0044; p=0,0002), mientras que entre Raypex 5 y Propex II, no se encontraron diferencias

estadísticamente significativas en la determinación de la LT (p=0.1087). Los presentes hallazgos sugieren que Root ZX II mostró la mayor exactitud para determinar la LT final.

Palabras clave: *Localizador apical electrónico, longitud de trabajo, foramen mayor, foramen menor, Raypex 5, Root ZX II, Propex II.*

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