

# Accuracy of Four Electronic Apex Locators During Root Canal Length Determination

## Precisión de Cuatro Localizadores de Ápice en la Determinación de la Longitud de Trabajo

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**ABSTRACT:** The apical limit of tooth roots for instrumentation and obturation is a controversial subject due to the high morphological complexity presented by the apical zone of the root. The development of electronic apex locators (EALs) has made working length (WL) determination more predictable, producing more accurate results; however, the interpretation mechanisms of different devices may affect measurements taken under different clinical conditions. One hundred premolars were used to compare the effectiveness of Propex II, Raypex 6, Propex Pixi and Root ZX II in locating the apical foramen (AF). No statistically significant differences were observed when the accuracy of measurement was compared between the different groups of EALs, however Root ZX II and Raypex 6 presented the best overall performance.

**KEY WORDS:** tooth root, anatomy, endodontics, electronic apex locator.

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### INTRODUCTION

The success of endodontic treatment depends on the correct mechanical enlargement, disinfection and sealing of the root canal system (D'Assunção *et al.*, 2007). These objectives can only be achieved with accurate determination of the working length (WL) (Ding *et al.*, 2010). The WL is defined as "the distance from a coronal reference point on the tooth to the point where canal preparation and obturation should terminate" (American Association of Endodontists, 2003). An error in determining the WL may lead to insufficient debridement of the root canal, delaying healing and increasing postoperative pain (Duran-Sindreu *et al.*, 2012).

The apical limit of tooth roots for instrumentation and obturation is a controversial subject due to the high morphological complexity presented by the apical zone of the root. Various authors have suggested that determining the exact location of the apical constriction is extremely complex because it is not present in all teeth (Martínez-Lozano *et al.*, 2001; Lee *et al.*, 2002; de Vasconcelos *et al.*, 2014). As a result the apical

foramen (AF) has been described as the most stable anatomical reference point for taking the measurement (Somma *et al.*, 2012; Oliveira *et al.*, 2017).

The development of electronic apex locators (EALs) has made WL determination more predictable, producing more accurate results (Haffner *et al.*, 2005; Altunbas, *et al.*, 2014). Their action mechanism is based on a resistance in the electrical conductivity between the tissues which surround the root apex and the interior of the root canal (Custer, 1918). One of the main advantages is that it reduces the patient's exposure to ionising radiation by reducing the number of radiographies (Tampelini *et al.*, 2017).

A large number of different models of EALs have been developed in recent years, however, although they work on the same principle, they operate with different mechanisms. Some use the impedance quotient principle, such as Root ZX II (J Morita, Tokyo, Japan) (Altunbas, *et al.*, 2014). The Propex II (Dentsply

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Maillefer, Ballaigues, Switzerland) (Marroquín *et al.*, 2014), the Raypex 6 (VDW GmbH, Munich, Germany) (Marigo *et al.*, 2016) and the Propex Pixi (Dentsply Maillefer) (Üstün *et al.*, 2016) use the square root of the impedances in 2 frequencies. These impedance interpretation mechanisms can affect measurements taken under different clinical conditions (Vaconcelos *et al.*, 2015).

Considering the different models of EALs available in the market and the importance of measuring the WL correctly for successful endodontic treatment, the purpose of the present study was to compare *ex vivo* the effectiveness of Propex II, Raypex 6, Propex Pixi and Root ZX II in locating the AF.

## MATERIAL AND METHOD

One hundred single-rooted mandibular premolars, from both sides, extracted for periodontal or orthodontic indication were selected from the Universidad de La Frontera, Temuco, Chile. Teeth with caries, fracture or root resorption were excluded. Each tooth was cleaned with ultrasound points (Satelec® Zirconium Endo Pro Ultra, Dentsply Maillefer, Ballaigues, Switzerland) to eliminate calculus and periodontal tissue. The teeth were then immersed in 2.5 % sodium hypochlorite (NaOCl) for 2 hours and stored in sterile saline solution at 0.9 % until use. The teeth were decrowned at the cemento-enamel junction with a diamond disc and the coronary third was prepared using an SX file (Dentsply, Maillefer, Ballaigues, Switzerland). The permeability of the apical foramen was verified with a K#10 file (Dentsply, Maillefer, Ballaigues, Switzerland) to discount any obstruction of the canal.

The real length (RL) was determined by stereoscopic microscope (Stemi DV4, Carl Zeiss, Göttingen, Germany) at 20X. A K#15 file (Dentsply, Maillefer, Ballaigues, Switzerland) was introduced into the root canal until it emerged from the AF, then withdrawn until the point of the instrument was tangential to the AF. The distance was measured between the rubber stop and the point of the file, adjusting the measurement to the nearest tenth of a millimetre if necessary.

To determine the location of the AF electronically, the teeth were assigned at random to four groups of 25 teeth each: (I) Propex II, (II) Raypex 6, (III) Propex

Pixi, (IV) Root ZX II. The radicular apex portions were immersed in recently prepared alginate to simulate periodontal ligament; the labial clip was also immersed in the alginate to complete the circuit. The canals were irrigated with 2.5 % NaOCl and sterile cotton rolls were used to eliminate the excess irrigant. To take the electronic measurements, a K#15 file (Dentsply, Maillefer, Ballaigues, Switzerland) was introduced into the canal with Roane movements. The file was advanced with gentle apical pressure until Propex II and Propex Pixi indicated 0.0, Raypex 6 the last red line and Root ZX II the last green line. The measures were considered valid if the EAL remained stable for at least 5 seconds. Then the silicon stop was adjusted to the reference and the file was removed. The distance between the rubber stop and the point of the file was measured with an endodontic ruler, adjusting the measurement to the nearest tenth of a millimetre if necessary. The measurements were taken during a period of two hours by a single operator, who was an endodontic specialist and had previously been calibrated in the use of different apical locators.

To determine the effectiveness of the different EALs in determining the position of the AF, the difference between the RL and the electronic length (EL) of each tooth was calculated. Positive values indicated that the apical foramen had been passed, whereas negative values indicated that the AF had not been reached and a value of 0 indicated coinciding measurements. The measurement lengths were assigned as follows: 1: <-1 mm ; 2:-0.99 to -0.51 mm ; 3: -0.50 to -0.01 mm; 4: 0 to 0.49 mm; 5: 0.50 to 0.99 mm; 6: >1mm.

The data collected were recorded in a Microsoft Office Excel spreadsheet. Data were analysed using the SPSS Statistics programme (version 23.0, IBM), with descriptive analysis of the data determining the mean and standard deviation. The Shapiro-Wilk normality test, Kruskal-Wallis test and Chi-squared test of categoric variables were applied with confidence intervals of 95 % for the population mean. A value of  $p < 0.05$  was selected as the threshold of statistical significance.

## RESULTS

The Kruskal-Wallis test showed no statistically significant differences in the comparison of the accuracy of measurements between the different

groups of EALs (Propex Pixi, Root ZX II, Propex II and Raypex 6),  $p=0.830$ . The Root ZX II had an accuracy of 92.00 % at  $\pm 0.5$  mm and 97.05 % at  $\pm 1$  mm, while the Raypex 6 had an accuracy of 92.00 % at both  $\pm$

0.5 mm and  $\pm 1$  mm. They were followed by Propex II with 80 % accuracy at  $\pm 0.5$  and 88 % at  $\pm 1.0$  mm. The last was Pixi with accuracy of 76 % at  $\pm 0.5$  and 85 % at  $\pm 1.0$  mm (Table I). The mean distances from the file point to the AF are shown in Table II.

Table I. Frequency of distance (mm) between the file and the apical foramen (AF).

CATEGORY	GROUP				
	Pixi	Root ZX II	Propex II	Raypex 6	Total
< -1	2 (8 %)	1 (4 %)	1 (4 %)	1 (4 %)	5 (5 %)
-0.99 to -0.51	2 (8 %)	1 (4 %)	1 (4 %)	0 (0 %)	4 (4 %)
-0.50 to -0.01	10 (40 %)	12 (48 %)	11 (44 %)	12 (48 %)	45 (45 %)
0 to 0.49	9 (36 %)	11 (44 %)	9 (36 %)	11 (44 %)	40 (40 %)
0.5 to 0.99	0 (0 %)	0 (0 %)	1 (4 %)	0 (0 %)	1 (1 %)
>1	2 (8 %)	0(0 %)	2 (8 %)	1 (4 %)	5 (5 %)
Total	25 (100 %)	25 (100 %)	25 (100 %)	25 (100 %)	100 (100 %)

Table II. Median and standard deviation of the distance (mm) between the file and the apical foramen (AF).

Electronic apex locators	Median	Sd
Pixi	-0.106	0.601
Root ZX II	-0.166	0.293
Propex II	0.061	0.789
Raypex 6	-0.156	0.55

\* Negative signs indicate a more coronal position to the AF. Sd: Standard deviation.

## DISCUSSION

The purpose of this study was to compare the accuracy of AF location by third generation (Propex Pixi, Root ZX II) and fourth generation (Propex II, Raypex 6) electronic devices using a methodology similar to that of D'Assunção *et al.* (2007), Altunbas, *et al.* (2017) and Oliveira *et al.*

One of the most-studied locators is the Root ZX. Duran-Sindreu *et al.* determined that no significant differences were observed in its accuracy *ex vivo* or *in vivo*, with excellent performance in both cases. Guise *et al.* (2010) in an *ex vivo* study, showed that the Root ZX II located the apical foramen more accurately than Apex Locator and Precision Apex Locator. It has also been shown that the Root ZX II is effective in avoiding overestimation of the working length (D'Assunção *et al.*, 2007) and for locating root perforations (D'Assunção *et al.*, 2014). The results of these works agree with the findings in our study, in which the Root ZX II proved to be the most accurate of the devices tested.

Akisue *et al.* (2014) compared the accuracy of different locators according to the size of the apical foramen, observing that the MiniApex, Root ZX II and Elements Apex Locator were accurate in determining WL in all foramen sizes investigated, whereas the accuracy of iPex and Propex II was reduced in cases of larger foramina. Uneven results were obtained with Root ZX and Raypex 5, with the file point passing the principal foramen in some cases (Wrbas *et al.*, 2007); the study authors therefore recommended withdrawing the instruments by 0.5 mm to reduce over-instrumentation.

The effect of pre-flaring or widening prior to determination of the WL has been studied, for example in the study of Brito-Júnior *et al.* (2012), who assessed the performance of the Root ZX and the Novapex. This study found greater accuracy in the electronic measurements taken by the devices, both of which presented acceptable results in the palatine canals of upper molars. Similar results were reported by Ibarrola *et al.* (1999), who suggests that pre-flaring of the canals gives the files more uniform access to the apical foramen, improving the accuracy of the Root ZX. In our study, pre-flaring was carried out with SX files, which may have improved the accuracy results of the devices tested.

Another factor which may affect the behaviour of electronic locators is the irrigation solution selected. It has been suggested that third and fourth generation EALs perform better in clinical practice when accompanied by a highly conductive solution, unlike second generation devices (Venturi & Breschi, 2005;

Carvalho *et al.*, 2010). In our study, the use of 2.5 % NaOCl, a highly conductive irrigant, did not have a negative affect on the results obtained using third and fourth generation EALs, and even improved the performance of the devices in clinical practice. Furthermore, the accuracy of fourth generation devices (Propex II) was not affected by pulp vitality (Milanovic *et al.*, 2015).

Oliveira *et al.* assessed various devices, as well as protocols for their use. This author found that EALs produce the best results when the electronic measurements are taken as far as but not beyond the AF; for this case, there were no differences between the devices assessed (Root ZX II, Raypex 6, Apex ID, Propex II and Propex Pixi). These results are similar to those of the present study, in which there were no significant differences between the locators tested.

One limitation of this *ex vivo* study is that the results obtained cannot be extrapolated directly to clinical practice; however it offers the advantage of allowing all the samples to be standardised, for example the type of tooth used, work protocol, and chemical-mechanical preparation carried out by a single operator, thus ensuring a truer comparison between the devices. In 2012, Duran-Sindreu compared the readings obtained *ex vivo* and *in vivo*, finding no statistically significant differences; this enhances the validity of *ex vivo* studies of this kind.

In conclusion, the results obtained suggest that there are no significant differences in the accuracy of Propex II, Raypex 6, Propex Pixi and Root ZX II; however Root ZX II and Raypex 6 present better overall performance.

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**RESUMEN:** El límite apical radicular para la instrumentación y obturación es un tema controversial, debido a la alta complejidad morfológica que presenta la zona apical de la raíz. El desarrollo de localizadores de ápice electrónicos (EALs) ha hecho la determinación de la longitud de trabajo (WL) más predecible y con resultados más precisos. Sin embargo, el mecanismo de interpretación de cada dispositivo puede afectar la determinación de las mediciones en diferentes condiciones clínicas. Cien premolares fueron utilizados para comparar la efectividad de Propex II, Raypex 6, Propex Pixi y Root ZX II en localizar el foramen apical

(AF). No se observaron diferencias estadísticamente significativas cuando se comparó la precisión de medición entre los diferentes grupos de EALs, sin embargo, Root ZX II y Raypex 6 mostraron un mejor desempeño global.

**PALABRAS CLAVE:** raíz dentaria, anatomía, endodoncia, localizador electrónico apical.

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