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Original Article

Comparison of the accuracy of three different electronic apex locators used in root canals enlarged in different apical diameters

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Abstract

Aim: This study aimed to evaluate the accuracy of three apex locators in enlarged teeth with different apical diameters using files that are compatible and incompatible with the apical diameters.

Methodology: Sixty lower premolars were used in this study. The actual canal length was determined with a stereo microscope, and the teeth were divided into three different groups (G25, G40 and G50).

The teeth in G25, G40 and G50 were enlarged in actual canal length with apical diameters of 0.25, 0.40- and 0.50-mm using hand files and Reciproc R25, R40, and R50, respectively. In the electronic measurements, a #15 hand file was used in each group, and #25, #40 and #50 hand files that were compatible with the apical diameters of the teeth in the groups were used. An alginate model was created with enlarged teeth. The electronic working length was determined for each tooth using Root ZX Mini, Raypex 6, and Propex Pixi electronic apex locators (EALs).

Results: Electronic measurement results that were shorter by 0.50 mm or longer by 0.05 mm than the actual length were considered unsuccessful; otherwise, they were deemed successful. Analysis of variance was used to evaluate the accuracy of the EALs with different files in the same apical diameter. For the different apical diameters, the chi-square exact test was used to evaluate the accuracy effect of using files that were incompatible with each apical diameter. The level of significance was $p > 0.05$.

In all the groups, the measured lengths were closer to the actual canal length with the use of #25, #40 and #50 hand files that were compatible with the apical diameters. However, there was no significant difference between the measurements with the #15 hand file ($p > 0.05$).

According to the electronic measurement results made with the #15 hand file in teeth with 0.25, 0.40 and 0.50 apical diameters, the use of a file that was incompatible with the apical diameter did not have a significant effect on accuracy ($p > 0.05$).

Conclusion: The use of a file that is compatible with the apical diameter of the tooth in the determination of the working length with measurement of EALs close to the actual canal length. The accuracy of EALs is not affected by the file size in electronic measurements with file sizes smaller than the apical diameter in teeth with apical diameters up to 0.50 mm.

Keywords: electronic apex locator, apical constriction, apical diameter

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Introduction

The distance between the coronal reference and apical constriction is called the working length in endodontics. The working length can be determined using digital tactile sensation, anatomy information, radiograph evaluation and electronic apex locators (EALs) (1). Radiography is the traditional method of obtaining information about the anatomy of the root canal and periodontal tissues (2). However, radiographic working length measurement has several disadvantages, such as radiation exposure, long time consumption and interpretation difficulties (a radiograph is usually a two-dimensional image with overlapping anatomical structures, and reading heavily depends on the observer's interpretation) (3). According to a study on the reliability of determining the working length between EALs and the radiographic method, deviations from the apical foramen with EALs were significantly less than those with the radiographic method, and the determination of the working length was more reliable (4).

A wide apical diameter, morphological features resulting from over-preparation, root resorption or lack of apical root formation may cause difficulties in determining the working length with EALs during root canal treatment (5). The effect of the width of the apical diameter and the file size on the accuracy of measurement with EALs has been investigated in many studies; some studies show that the accuracy of EAL decreases in teeth with an apical diameter of 0.6 mm and above (6). Other works show that the accuracy of EALs is not affected even when the file used is smaller than the apical diameter, whereas some studies state that a file compatible with the apical diameter should be used to ensure accuracy in the use of EALs (7-9).

The literature is inconclusive about how an increase in the apical diameter affects the performance of apex locators and whether the use of files compatible or incompatible with the increasing apical diameter will affect the accuracy of EALs. Hence, the present study aims to investigate the effect of increasing apical diameter and use of files compatible and incompatible with the apical diameter on the accuracy of the EALs Root ZX mini, Raypex 6 and Propex Pixi.

Materials and Methods

This study was approved by the Ethics Committee of Dicle University, Faculty of Dentistry (2020-18).

Preparation of teeth and determination of actual canal length

In this study, 60 single straight-root human lower premolars were used for periodontal and orthodontic reasons. After the teeth were kept in a 5.25% NaOCl solution for at least 2 h, attachments on the root and surface were removed and stored in a 0.9% saline solution until they were used for analysis. Calcified teeth with root canal that had more than one canal or apical opening were distinguished by taking radiographs at different angles, and they were excluded from the study.

The access cavity of each tooth was opened through water cooling with an aerator. Pulp tissue was removed using a #10 K-type file (VDW GmbH, Munich, Germany). Measurement was performed using a digital calliper (Aleks Makine, İstanbul, Turkey) and a #10 K-type file at ×10 magnification in a stereo microscope (Leica Z16, Wetzlar, Germany), and the result was recorded as the actual working length (AWL). The measurement was conducted three times, and the values were averaged.

Then, #15, #20, #25 and #30 hand files (VDW GmbH, Munich, Germany); Reciproc R25, R40 and R50 (VDW GmbH, Munich, Germany); and an X-Smart Plus (Dentsply Sirona, Ballaigues, Switzerland) were used at the determined AWL in the root canals. The files were enlarged using double stoppers to keep the AWL constant at the measured values (Fig. 1). Enlargement was completed using Reciproc R25 in the G25 group; #15 and #20 hand files and Reciproc R40 in the G40 group; and #15, #20, #25 and #30 hand files and Reciproc R50 in the G50 group. During the enlargement, 25 mm NaviTip (Ultradent, South Jordan, USA) needle tips were used, and irrigation was performed with 2 ml 2.5% NaOCl at each file change, 2 mm shorter than the working length. After the enlargement, the apical openings of the teeth were reached with a #10 K-type file to prevent dentin smear from blocking them. Final irrigation was performed with 2 ml distilled water.

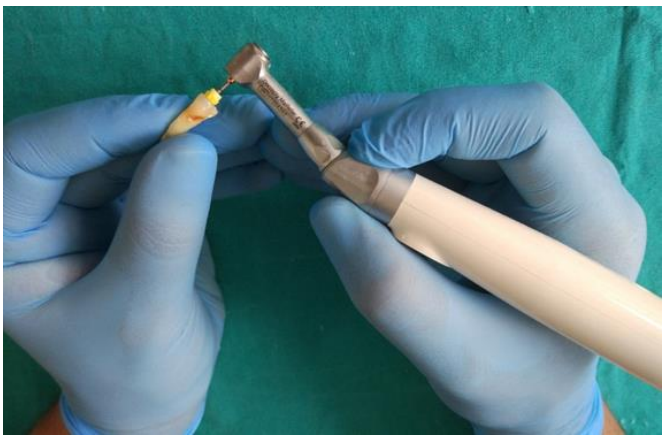

Figure 1. Enlargement of the teeth using files with double stopper

Determination of electronic working length

For the electronic measurements, each tooth was placed in 50 ml acrylic boxes filled with alginate (Cavex, CJ Haarlem, Netherlands), with the roots remaining in the alginate from the enamel-cement border. Before each measurement, each tooth was irrigated with 2 ml 2.5% NaOCl, 2 ml distilled water and 2 ml 17% EDTA; after a minute, they were washed with 2 ml distilled water. Any irrigation solution overflowing from the access cavity was removed with cotton pellets. Root Zx Mini (J. Morita, Tokyo, Japan), Raypex

6 (VDW, Munich, Germany), Propex Pixi (Dentsply, Ballaigues, Switzerland) electronic apex locators were used to determine the working length.

For each tooth, a #15 K-type file was used to determine the electronic working length (EWL). In groups G25, G40 and G50, #25, #40 and #50 K-type files compatible with the apical diameter were used after the #15 K-type file. In the electronic measurements, the display was expected to be constant on the screen for 5 s, and the distance from the lower edge of the rubber stopper of the file extracted from the root canal to the tip of the file was measured with a digital caliper. Measurements were made three times, and the average measurement result was recorded as the EWL.

Statistical analysis

Analysis of the data was carried out with SPSS software version 22.0 (IBM Corp., Armonk, NY, USA). In the analysis of the data, the EWL was compared with the AWL. The measurement was deemed unsuccessful when the EWL was shorter by 0.50 mm or longer by 0.05 mm than the AWL. Since the distribution of the data was normal (according to the Shapiro-Wilk test), analysis of variance was used in the evaluations within the groups. The chi-square exact test was used for the evaluations between the groups.

Results

Group G25

In this group, Propex Pixi gives the closest results to the AWL with the #15 file. Raypex 6 gives the closest results to the AWL with the #25 file. However, there is no significant difference between devices in terms of proximity to the AWL ($p > 0.05$). Between the EWLs determined with the #15 and #25 files, the measurements made with the #25 file are closer to the AWL, but there is no significant difference between such measurements ($p > 0.05$) (Table 1).

Group G40

The results of Raypex 6 with the #15 file are the closest to the AWL. Propex Pixi with the #40 file produces the closest result to the AWL. However, there is no significant difference between devices in terms of proximity to the AWL ($p > 0.05$). Between the EWLs obtained with the #15 and #40 files, the measurements made with the #40 file are closer to the AWL, but there is no significant difference between the measurements of the two files ($p > 0.05$) (Table 2).

Group G50

In this group, Root ZX mini shows the closest result to the AWL with the #15 file. Root ZX mini yields the closest result to the AWL with the #50 file. However, there is no significant difference between devices in terms of proximity to the AWL ($p > 0.05$). Between the EWLs identified with the #15 and #50 files, the measurements made with the #50 file are closer to the AWL, but there is no significant difference between these measurements ($p > 0.05$) (Table 3).

Between groups

The success rates in the different groups were assessed in the measurements made with the same EAL and the #15 file. For the three EALs used, there is no relationship between the success of the measurements made with the #15 file and the apical diameter ($p > 0.05$) (Table 4).

Table 1. Data of group G25

		Average of the amount of deviation from the AWL (mm)	EWL was shorter by 0.50 mm than the AWL (n)	EWL was shorter by 0.50 mm than the AWL (n)	Successful Measurements (%)	Anova (p)
#15 File	Root ZX mini	0,274	1	0	%95	0,126
	Raypex 6	0,289	1	0	%95	0,124
	Propex Pixi	0,270	1	0	%95	0,117
#25 File	Root ZX mini	0,236	1	0	%95	0,094
	Raypex 6	0,235	1	0	%95	0,090
	Propex Pixi	0,237	1	0	%95	0,097

Table 2. Data of group G40

		Average of the amount of deviation from the AWL (mm)	EWL was shorter by 0.50 mm than the AWL (n)	EWL was shorter by 0.50 mm than the AWL (n)	Successful Measurements (%)	Anova (p)
#15 File	Root ZX mini	0,311	2	0	%90	0,110
	Raypex 6	0,308	1	1	%90	0,087
	Propex Pixi	0,321	2	0	%90	0,117
#40 File	Root ZX mini	0,272	2	0	%90	0,079
	Raypex 6	0,280	1	0	%95	0,094
	Propex Pixi	0,263	1	0	%95	0,074

Table 3. Data of group G50

		Average of the amount of deviation from the AWL (mm)	EWL was shorter by 0.50 mm than the AWL (n)	EWL was shorter by 0.50 mm than the AWL (n)	Successful Measurements (%)	Anova (p)
#15 File	Root ZX mini	0,314	1	0	%95	0,108
	Raypex 6	0,325	2	0	%90	0,112
	Propex Pixi	0,326	2	0	%90	0,114
#50 File	Root ZX mini	0,274	1	0	%95	0,083
	Raypex 6	0,284	1	0	%95	0,102
	Propex Pixi	0,280	1	0	%95	0,097

Table 4. Measurement data between groups.

EAL	Grup	Average of the amount of deviation from the AWL (mm)	Successful measurments (n)	Unsuccessful measurements (n)	Successful (%)	Chi-square (p)
Root ZX mini	G25	0,274	19	1	%95	0,765*
	G40	0,311	18	2	%90	
	G50	0,314	19	1	%95	
Raypex 6	G25	0,289	19	1	%95	0,804*
	G40	0,308	18	2	%90	
	G50	0,325	18	2	%90	
Propex Pixi	G25	0,270	19	1	%95	0,804*
	G40	0,321	18	2	%90	
	G50	0,326	18	2	%90	

Discussion

The factors affecting the accuracy of EALs have been the subject of many studies (10-12). The width of the apical diameter and the selection of a diameter-compatible file are among these factors (5, 8, 9).

The use of files compatible with the apical diameter has been investigated by many researchers (5, 8, 9). Studies state that the file size should be as close as possible to the apical diameter to increase the accuracy of electronic length measurements made with EALs (13, 14). Ekici et al. enlarged apical diameters with a ProTaper F1, F2 and F3 and made electronic measurements with #25, #30 and #35 hand files compatible with the apical diameters (15). Briseño-Marroquín et al. investigated the accuracy of measurement in non-enlarged teeth with #08, #10 and #15 hand files (8). Aydın et al. compared electronic measurements with #30, #55 and #70 hand files; they expanded the apical foramen in teeth with diameters of 0.32, 0.57 and 0.72 mm (6). Herrera et al. evaluated the accuracy of Root ZX for teeth with diameters of 0.6-1 mm with all files from #10 that can fit the apical diameter (14). Fan et al. performed electronic measurements with a #15 hand file on glass tubules of different diameters imitating root canals (16). In our study, electronic measurements were performed using #15 hand files that were compatible and incompatible with the apical diameters in teeth with enlarged apical diameters.

Meares et al. stated the advantages, such as ease of conducting in vitro studies and controlling experimental conditions (17). Ebrahim et al. stated that in vitro studies provide an objective evaluation of EALs with different variables, and they are more useful than in vivo studies (9). Huang proposed in vitro models in studies of EALs because more samples could be studied in a shorter time (18).

Ex vivo studies on EALs report that the rubber stoppers of files should be fixed on a flat surface on the tooth to minimize errors in measurement (19, 20). Vieyra and Acosta used two stoppers on the file to ensure measurement invariance (21).

Alginate models have been preferred in many in vitro studies on EALs (18, 22-24). Baldi et al. compared the effect of 1% agar, gelatin, alginate, saline solution and flower sponge dipped in a saline solution on the experimental conditions. They found no significant difference between the media, but alginate was superior (25).

Tınaz et al. examined the effect of NaOCl at different concentrations (5.25%, 2.65%, 1% and 0.50%) on the accuracy of Root ZX and reported that the concentrations had no significant effect on measurement accuracy (26). Saito et al. stated that the choice of irrigation solution, such as saline, 5% NaOCl, 14% EDTA and 3% H_2O_2, does not affect the detection of the apical foramen, regardless of the file size and the apical foramen (27). Dunlap et al. reported that 82.3% of electronic length measurements made with a Root ZX using 2.5% NaOCl were at a distance of ± 0.5 mm from the apical constriction (28). Venturi and Breschi reported that electronic measurements made with Root ZX are inaccurate and inconsistent due to the low conductor conditions in dry canals (29). Altunbaş et al. used 2.5% NaOCl, 0.9% saline and 17% EDTA; they found that the most accurate result was obtained in dry canals with DentaPort ZX and Rootor EALs (11). In a study on glass tubules with different lengths and diameters that imitate root canals, Fan et al. stated that an increase in the tubule diameter did not affect electronic length measurements when the tubules were

dry or filled with a small amount of electroconductor. However, when the tubules were filled with 0.9% saline, 3% H_2O_2, 5% NaOCl and 17% EDTA irrigation solutions, the accuracy of Root ZX decreased as the tubule diameter increased (16). Marigo et al. stated that electronic measurement results obtained using DentaPort ZX did not change in the presence or absence of 5.25% NaOCl (30). However, the effect of anaesthetic solutions, blood and saline and irrigation solutions on the accuracy of EALs remains unclear in the literature. In our study, the last wash was done with distilled water to minimize the effect of the irrigation solution.

Root ZX mini is a modified Root ZX; they operate in the same way, but the former is smaller (31). Root ZX is used as the gold standard in many studies (32). The accuracy of this EAL ranges from 56.2% to 95% in in vitro studies (31, 33).

Raypex 6 is a recent model in the Raypex series, and its clinical performance is as successful with the evaluation of Raypex 4 and 5 (34). Moscoso et al. evaluated the accuracy of Raypex 6 and found that all cases detected the apical foramen at ± 0.5 mm with 88.22% success, and at ± 1 mm with 100% success (35). Hilú found Raypex 6 to be 96.4% successful (36). In the work of Demiriz et al., Raypex 6 was 77% successful at ± 0.5 mm (37).

Propex Pixi is a small, multi-frequency EAL. The device works similarly to two-frequency devices; using more than two frequencies, it measures the rapid impedance change when the apical constriction is reached (38). In in vitro studies, the accuracy of Propex Pixi has been reported to be 87%–93% at the apical foramen, 63%–67% at 1 mm shorter than the apical foramen and ± 0.5 mm at the apical constriction (39).

Herrera et al. conducted measurements with different files in enlarged apical diameters. Root ZX showed accurate results when measuring with any file with a diameter of 0.6 mm. According to their study, it is necessary to use a file compatible with the apical diameter when such diameter is 0.7 or 0.8 mm. Their findings showed that Root ZX showed wrong results in diameters of 0.9 mm and above (14).

Akisue et al. compared five EALs in teeth with apical diameters of 0.27, 0.47 and 0.72 mm. They stated that the accuracy of Root ZX did not change between these diameters, but the accuracy of Propex II decreased with increasing apical diameter (5).

In teeth whose apical diameters were enlarged to 0.6, 0.7 and 0.8 mm, Kolanu et al. stated that Propex Pixi succeeded in the 0.6 mm apical diameter but failed in the other apical diameters (40).

Aydın et al. compared Raypex 6 and Root ZX in teeth enlarged to 0.32, 0.57 and 0.72 mm. Although both devices showed excellent results in the apical diameter of 0.32 mm, their performance decreased in diameters of 0.57 mm and above (6).

Ekici et al. compared Raypex 5, Raypex 6 and iPex EALs in teeth with 0.27, 0.33- and 0.39-mm apical diameters which they enlarged with ProTaper F1, F2 and F3, by making measurements with #25, #30 and #35 hand files. The measurements were clinically successful, and there was no significant difference between the three EALs (15).

Ebrahim et al. evaluated the accuracy of Root ZX with small-sized files and different irrigation solutions in teeth that they enlarged up to 0.4, 0.6 and 0.8 mm apical diameters. As the diameter of the root canal increased, length measurements made with smaller files became shorter. The authors reported that when blood was used as irrigation, a file with a size close to the canal diameter prepared for electronic length measurement should be used. Furthermore, in the presence of NaOCl, Root ZX gave successful results, even when the file was much smaller than the diameter of the canal (9).

Conclusions

As the apical diameter increases, the EWL measured using a file smaller than the apical diameter is found to be shorter than the AWL. When a file compatible with the apical diameter is used in determining the EWL, the results are close to the actual length. Nonetheless, there is no significant difference in whether the file used in electronic measurements is compatible with the apical diameter in teeth whose apical diameter is up to 0.5 mm.

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