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Comparative "ex vivo" study on working length determination using six apex locators

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ABSTRACT

The aim of this study was to analyse the accuracy, precision, and consequently the reliability of five traditional apex locators (AL) and one integrated AL in determining working length (WL).

Materials and Methods: The lengths of 15 extracted human teeth were measured with six ALs (Dentaport Root ZX, Dual Pex Micro Mega, Root ZX mini, Elements Diagnostic, Woodpex III, and E-connect S) and with digital radiographs (RVG). Electronic measurements were compared with each other and with radiographic measurements under the same experimental conditions.

Results. Repeated measures ANOVA showed a significant difference between the radiographic and the electronic method. The Root ZX achieved the best accuracy and precision in determining the location of the apical foramen compared to other ALs.

Conclusions. ALs are the most reliable method and superior to radiologic methods to determine the WL. Further studies should be performed to assess the differences between different types of ALs.

Keywords: apex locators, working lenght, digital radiographs

INTRODUCTION

The importance of a correct determination of the working length (WL) of the root canal in endodontics is well known, in order to improve the effectiveness of chemical-mechanical disinfection and to avoid over/under-instrumentation. An adequate endpoint of preparation and obturation seems to be the main factor for the success of endodontic treatment [1]. Nowadays, in clinical practice, the methods used to determine WL are electronic and radiographic [2].

In the last three decades, apex locators (ALs) have been the main subject of literature review and they are now considered the ideal method and the first choice of clinicians in therapeutic protocols due to their high reliability. The progress of endomotors with integrated AL represents the latest technological innovation and is therefore the subject of fewer scientific studies [3]. In general, scientific studies on ALs evaluate 'clinical reliability', without consistently defining the concept and the accuracy of the device. The aim of this study was to analyse the accuracy, precision, and consequently the reliability of five traditional ALs: Dentaport Root ZX (J. Morita Corp., Tokyo, Japa), Dual Pex Micro Mega (C. Eighteeth Medical T. Co., Jiangsu, China), Root ZX mini (J. Morita Corp., Kyoto, Japan), Elements Diagnostic (Sybron Endo, Anaheim, CA, USA), Woodpex III (Woodpecker Medical Instrument Co, Guilin, China) and the integrated AL: E-connect S Endo Motor with Built-in Apex Locator (Eighteeth Medical Technology Co, Changzhou, Jiangsu, China). The study evaluated the accuracy of these devices and compared the electronic and the radiographic measurements of the working length under the same experimental conditions.

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MATERIALS AND METHODS

After careful analysis of preliminary radiographs in mesiodistally and buccolingually incidences, 15 monoradicular premolars extracted for orthodontic or periodontal aims, were selected. Teeth with previous carious lesions, conservative, endodontic or prosthetic therapies, immature apex, internal or external root resorption, calcifications, pulpitis, and root fractures were excluded. Access to the pulp chamber was obtained using the 801 ISO 014 spherical diamond bur (Dia-Tessin, Switzerland). The effective length of each root canal was measured by inserting the manual K-File ISO 10, 31 mm (Endostar, Poldent, Poland) under 4.5x magnification to the point where the tip was tangent to the apical foramen and measuring the actual WL with the analog caliper (GNZ Dental). To perform the electronic measurements, the ALs were calibrated according to the manufacturer's instructions, and the condition and charge of the batteries were checked and replaced with new ones as needed. For the clinical simulation of the periodontal ligament, the electroconductive material was prepared using alginate Tropicalgin (Zhermack SpA) and physiological saline solution according to the powder/liquid ratio specified by the manufacturer. Before starting the electronic measurements, the samples were irrigated with 5.25% sodium hypochlorite (Chloraxid, Cerkamed, Poland). For each sample, the first measurement was performed with Root ZX until the last green bar appeared above the "APEX" symbol on the display. In this position, the K-File was fixed and its position remained unchanged for all subsequent measurements with the remaining ALs. This procedure was performed by plugging the measuring wire of the other ALs into the Lip clip and the File clip. Each time the measuring wire of a new AL was plugged in, the measurements shown on the display (electronic WL) were noted. Confirmation X-rays were then taken at two incidences. The K-File was then extracted and the electronic WL of the Root ZX was measured with a caliper. The determination of the digital radiograph WL was obtained by importing the X-rays into MicroDicom software (MicroDicom Ltd, Sofia, Bulgaria). Using the digital ruler, which was previously calibrated, the distance between the tip of the K-File and the base of the stopper (radiographic WL) was measured. The distance between the tip of the file and the radiographic apex was measured using the same procedure. Two-incidence X-rays and measurements were obtained using the ProTrain device (Simit Dental srl, Mantua, Italy). The software jamovi (version 2.2) [4] was used for the statistical analyses.

RESULTS

According to the Shapiro-Wilk test (p>.05), all data were found to have a normal distribution except Diagnostic (W=0.82, p=.008). According to Table 1 Root ZX, Root ZX mini, and Elements Diagnostic were found to be accurate in 100% of measurements (within accepted clinical error of ±0.5), Dual Pex and Woodpex III in 93.3%, and E-connect S in 86.6% of measurements, while buccolingual and mesiodistal incidence radiographic measurements were accurate, respectively, in 39% and 34% of measurements, with a high tendency to overestimate the working length. The methods in order of precision are listed in Table 2. Repeated measures ANOVA showed a significant difference between the measurement techniques used (F[7,98]=23.91, p<.001). Post hoc analysis with Tukey's test revealed a significant difference between the radiographic and the electronic method. Student's t-tests for paired samples showed a significant difference (t(14)=2.27, p=.040) between E-connect S and Woodpex III. The electronic measurement data set was plotted using box-and-whisker plots (Figure 1) to graphically describe the distribution of the measurements with simple scatter and position indices.

DISCUSSION

Modern ALs can determine the position of the apical foramen (AF) in wet canals by calculating the relative impedance measurements using multiple frequencies [3] . Therefore, the canals were kept soaked with hypochlorite during electronic measurements. Anatomical decoronation of the samples by sectioning the dental crowns was avoided in order to keep the test conditions as close as possible to the clinical scenario. This is in disagreement with the methodology of 65% of the studies analyzed by ElAyouti et al.

TABLE 1. Reports the accuracy of the electronic and radiographic methods, determined by the position (mm) of the file tip relative to AF, with the percentage.

Distance from AF	Root ZX		Dual Pex		Root ZX mini		Wood pex		Diagnostic		E-connect S		X-ray B-L		X-ray M-D	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
> 0.5	0	-	1	6	0	-	1	6	0	-	2	13	0	-	0	-
0.5 to 0.1	11	73	8	54	14	94	8	54	9	60	8	53	2	12	0	-
0.0	4	27	3	20	0	-	0	-	6	40	0	-	0	-	0	-
-0.1 to -0.5	0	-	3	20	1	6	6	40	0	-	5	34	4	27	5	34
< -0.5	0	-	0	-	0	-	0	-	0	-	0	-	9	61	10	66

* n: number of measurements, %: percentage of measurement, AF: apical foramen, negative value indicates position of beyond AF.

TABLE 2. The electronic and radiographic methods in order of accuracy

	M	SD	SE	IC 95%	
				Min	Max
Root ZX	0.08	0.04	0.01	0.06	0.10
Diagnostic	0.09	0.11	0.03	0.03	0.43
Root ZX Mini	0.21	0.15	0.04	0.13	0.29
DualPex	0.13	0.22	0.06	0.01	0.24
Woodpex	0.05	0.24	0.06	-0.07	0.17
E-connect S	0.23	0.39	0.10	0.03	0.43
X-ray M-D	-0.67	0.41	0.11	-0.88	-0.47
X-ray B-L	-0.67	0.51	0.13	-0.92	-0.41

*M: average score, SD: standard deviation, SE: standard error, IC: confidence interval

(2022) [3], in which specimens were coronally modified for convenience and to simplify the methodology. WL was measured using the AF as the reference point, which was electronically marked with the symbol 'APEX' or '0.0' on the AL display. This is due to the greater impedance change at the level of the AF detected by the ALs and also to the greater accuracy of Root ZX in locating this point compared with the apical constriction [6]. In addition, the pre-setting of WL on the display to a distance of 0.5mm above the zero value was avoided, in the expectation of detecting apical constriction [6]. This is in agreement with Ponce et al. (2003) [7] and Leonardo et al. (2007) [8], according to which apical constriction cannot be identified in clinical practice and is rarely present in its classic form. It is considered that in clinical practice the AF should be taken as a reference point on the ALs display, then 0.5-1mm should be subtracted and finally the WL should be determined according to the quality guidelines of the European Society of Endodontology (ESE 2006) [9]. Due to the standardization of the measurement methodology, it was possible to reproduce the '0.0' reading of the Root ZX by fixing the K-File inside the canal on all the devices analyzed, for a total of 90 electronic measurements. This procedure, confirmed by the correspondence between the Root ZX measurements and the real measurements, made it possible to study the reliability of the other ALs in reproducing the position of the AF on the displays (under the same experimental conditions and on the same tooth). Since its introduction, Root ZX has received considerable attention in the literature and has become the "gold standard" to which other ALs are compared [10]. The Root ZX achieved the best accuracy and precision in determining the location of the AF compared to other Als (Figure 1). The reproducibility results of electronic measurements with the Root ZX are superior to those of Miletic et al. (2011) [10] who achieved 100% accuracy within the clinical range of ±1.0mm. The radiographic method gave unsatisfactory results in detecting the position of the AF. It showed a high tendency to overestimate the WL and failed to determine its position within the acceptable clinical limit of ±0.5 mm. Although the radiographic apex can be misleading when it is used as an apical reference point, one should remember that it is an important clinical parameter in the evaluation of periapical control radiographs [11]. Finally, Eighteeth's AL integrated within endodontic motor E-connect S proved to be less reliable than conventional ALs. In terms of accuracy, the Eighteeth's AL appears to be the least accurate electronic device with two electronic measurements outside the accepted clinical error of ±0.5 mm from the AF. In terms of precision compared to other ALs with: the widest confidence interval (CI(95%): 0.03; 0.43), the average score, standard error, and standard deviation (M=0.23; SE=0.10; SD=0.39), it proved to be the least precise electronic device.

CONCLUSIONS

All ALs investigated in this study were able to detect the AF with reasonable accuracy and precision, confirming electronic measurement as the most reliable method and superior to radiological methods. Further studies should be performed to assess the differences between different types of ALs.

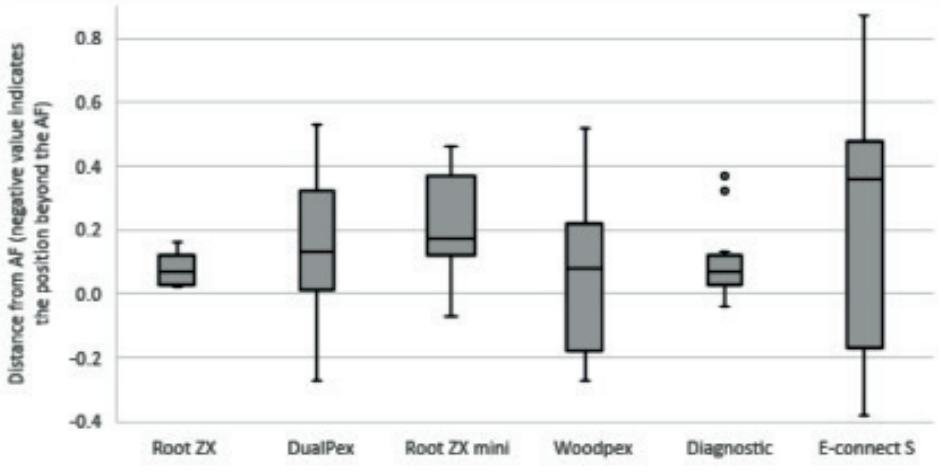

FIGURE 1. Box-and-whisker plots provide a graphical representation of the degree of dispersion and skewness of electronic measurements

*AF: Apical foramen, small circles indicate the outliers of diagnostic (individual values more than 1.5 interquartile range).

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