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Accuracy of Working Length Measurement by Raypex 6: Electronic Apex Locator versus Actual Measurements under Stereomicroscope

SUMMARY

Background/Aim: *This study aimed to evaluate the precision of the Raypex 6 apex locator in locating the apical constriction (AC) and major foramen (MF) during a root canal treatment compared with a microscopic evaluation. Another aim of the present study was to evaluate the accuracy of the Raypex 6 in the presence of different irrigating solutions (NaOCl, saline, EDTA, etidronic acid-HEBP).* ***Material and Methods:*** *One hundred and nine patients were included in this study and were randomly assigned into four groups according to the irrigation solution used; NaOCl, EDTA, HEBF and saline. Electronic MF (EMF) and AC (EAC) were measured by using Raypex 6. The teeth were extracted. The apical 3 mm of each canal was trimmed to expose the file tip. The samples were observed under a stereomicroscope, and the actual length of MF (ALMF) and AC (ALAC) were measured. The data were analyzed by using x^2 test, and significance was set at P< 0.05.* ***Results:*** *The Raypex 6 was accurate 71.4% of the time to ±0.5mm and 93.3% of the time to ±1mm in determining the ALAC. While similar ALAC-EAC differences were observed in EDTA, NaOCl, and saline groups (p= 0.230), the highest differences were seen in the HEBP group (p= 1.000). The precision of Raypex 6 in determining the working length measurement depends on the type of irrigation. All solutions allowed reliable detection of AC. However, HEBF significantly increased the risk of overpreparation.* ***Conclusions:*** *Raypex 6 can be recommended for clinical use and its accuracy is not affected by the type of irrigant when locating MF.*

Key words: Raypex 6, Electronic Apex Locators, Working Length Measurement, Irrigation Solutions

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Introduction

Root canal treatment (RCT) procedures should be confined within the root canal system[1]. The working length (WL) is defined as the distance between a coronal reference point and the point at which canal preparation and obturation should terminate[2]. Maintaining a correct working length (WL) during RCT is expected to positively influence the outcome of RCT. Commonly, the minor apical foramen or apical isthmus is considered the end of the area for canal preparation and filling. The minor apical foramen is the border line between the dental pulp and periodontal area, which is approximately 0.5-1 mm from the anatomic apex[3]. Failure to determine the root canal length can result in both over- and underestimation of the root canal length[1,4].

Conventional measurement methods for working length determination are periapical radiographs and electronic apex locators (EALs). Apex locators have advantages over radiographic methods; electronic working length determination (EWL) with apex locators is easier, faster, and can be indefinitely repeated without exposure to radiation[5]. Moreover, modern apex locators can locate not only the apical foramen but also, in contrast to radiographic methods, the apical constriction[6-9], which is an optimal endpoint for root canal preparation and filling[1,10]. The

accuracy of apex locators is higher when compared with radiographic methods[11-13]. In addition, apex locators can diagnose perforations and root fractures[2,14,15]. The use of electronic devices to determine the WL was proposed first by Custer[16] in 1918, and the first EAL was developed following the investigation by Suzuki[17] of the electrical resistance properties of oral tissues. The first generation of EALs was based on resistance, whereas the second generation worked on the basis of impedance. The main drawback of both these types, namely poor accuracy in the presence of electrolytes, was overcome by the introduction of later-generation EALs. Many studies have addressed the benefits and clinical performance of the many different models of EALs that have been developed in recent years[8,9.18-20], among them the Raypex 6 (VDW, Munich, Germany). Raypex 6 (VDW, Munich, Germany) is the last member of the Raypex series and clinical performance was previously found to be successful with the evaluation of Raypex 4 and 5 [21-23]. To our knowledge, no study has compared the accuracy of Raypex 6 in *in vitro* versus *in vivo* models (in a truly clinical condition).

The purpose of the study reported herein was to compare the accuracy of the Raypex 6 in establishing the WL under in clinical and *in vitro* conditions. Another aim of the present study was to evaluate the accuracy of the Raypex 6 in the presence of different irrigating solutions (NaOCL, saline, EDTA, and HEBF).

Material and Methods

This study was approved by the Ethics Review Committee for Research, Istanbul Medipol University, Istanbul, Turkey (#059/2017). One hundred and nine patients who attended the Esenler Dental Clinic of the Istanbul Medipol University, with a need for extraction (e.g. caries or periodontal cause) were screened through periapical clinical and radiographic examination, by a single calibrated operator (BU). Following agreement to participate, the patients signed a statement of informed consent. The study was conducted in accordance with the guidelines of the World Medical Association Declaration of Helsinki, and the Institutional ethical committee. Inclusion criteria involved teeth with closed apex, one single-root, and an intact root. Exclusion criteria involved teeth with previous root canal treatment, root resorption, metallic restorations, fractures, or open apices.

All teeth were assigned randomly to one of four groups (each of which comprised of approximately 27 teeth); EDTA group (17% EDTA), NaOCl group (2.5% NaOCl), HEBP group (9% HEBF) and saline group (0.9% NaCl isotonic sodium chloride). All clinical procedures and measurements were conducted by a single operator (BU). The teeth were isolated with a rubber dam under local anesthesia. Endodontic access was performed, and the coronal portion of each canal was flared with an SX Protaper file (Maillefer, Ballaigues, Switzerland). Each canal was then irrigated with the irrigation solution according to their assigned group. Excess fluid was removed from the pulp chamber with an air syringe, but no attempt was made to dry the canals. The Raypex 6 apex locator was used in accordance with the manufacturer's instructions. The clip was attached to the patient's lip, and the electrode was connected to a 15 K-file with two silicone stoppers.

Electronic Measurement/Working length determination using electronic apex locators

The file was advanced within the root canal until the red ball began flashing, which indicates the major foramen (according to the manufacturer's instructions). The measurements were recorded as electronic major foramen (EMJ). The same file was again advanced within the root canal until the red ball, and then withdrawn until the LCD display showed a flashing bar[2]. The third green line, just before the yellow lines, which corresponds to 0.5 mm short of the radiographic apex was determined for working length. The measurements were recorded as electronic apical constriction (EAC). Measurements were considered to be valid if they remained stable for at least 5 seconds.

Actual Length Measurement/Actual Working length determinations under stereomicroscope

The teeth were extracted and placed in 5.25% NaOCl for 30 min to remove any residual organic tissue from the root and then stored in 0.9% saline solution. A size 15 K-file was gently inserted into the canal until its tip was visible at the plane of the major foramen using a dental operating microscope at 10x magnification. The rubber stop was adjusted to the occlusal reference, and the distance from the stop to the tip of the instrument was measured by a magnifying glass (x10) and recorded in mm as the actual length major foramen (ALMF). To observe the apical constriction, a window of 3 mm in diameter was made in the apical portion of the root using a diamond bur until the root canal became visible under a stereomicroscope (SZ-TP, Olympus, Tokyo, Japan). Then the same file was advanced again in the root canal up to the major foramen. The apical parts of the specimens were photographed using a digital camera (Ken-A-Vision, Kansas City, MO, USA) after visualization using a stereomicroscope (Meiji Techno, Saitama, Japan) at ×10 magnification (Figure 1a, 1b). On the images of each apex, two investigators determined the minor diameter (dentinocemental junction), the major foramen, and the file tip; the investigators worked together to reach a consensus. We then measured the distance from the minor diameter to the file tip with a computer-based system (Leica Interactive Measurements Dialog, Cambridge, England) (Figure 1c). The measurements were recorded as actual length apical constriction (ALAC).

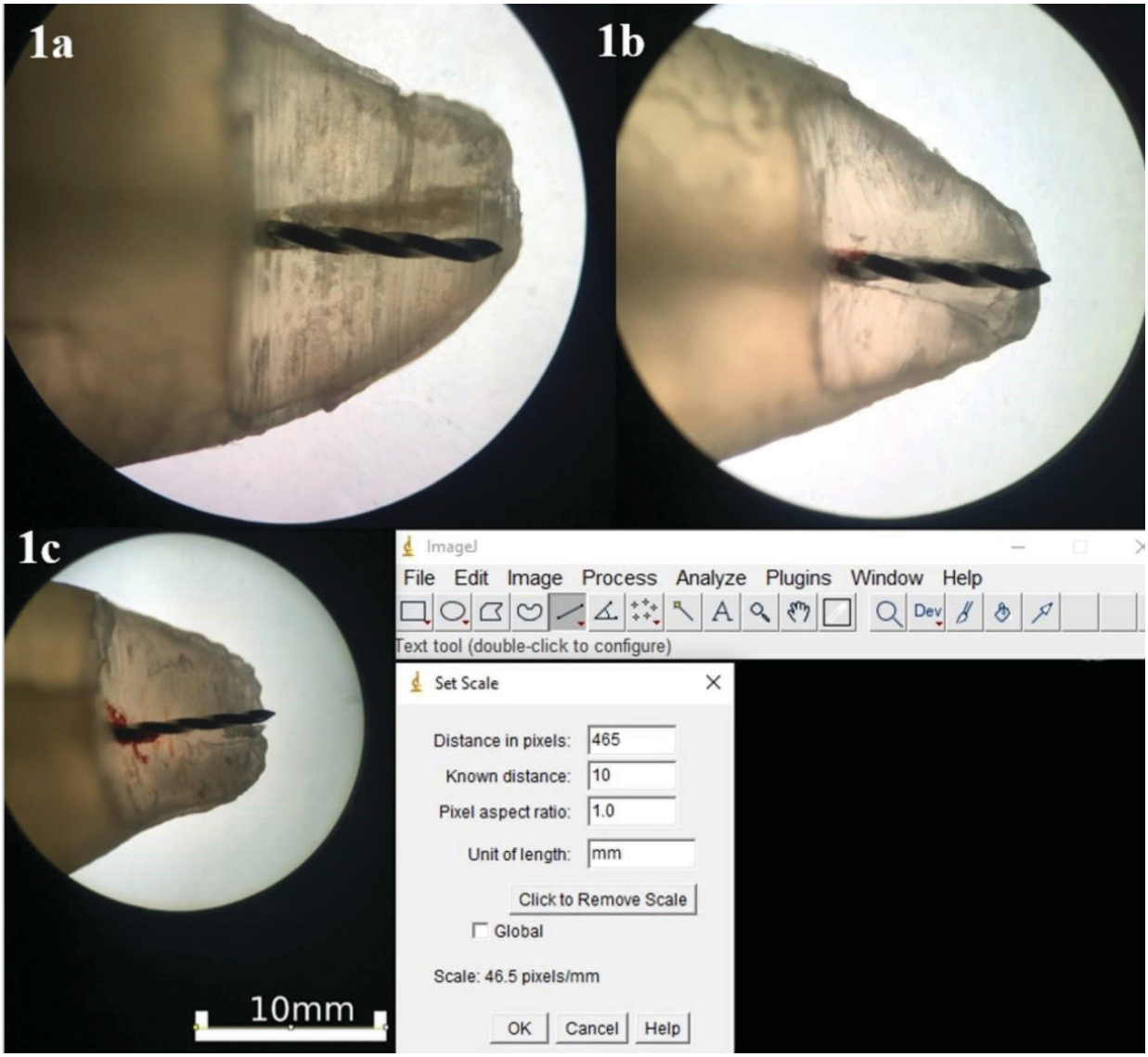

Figure 1. 1a) and 1b) Photographs of the specimens' apical parts under a stereomicroscope at ×10 magnification; 1c) Measurement of the distance from the minor diameter to the file tip with a computer-based system

Differences between electronic and actual length measurements were calculated. Negative and positive values indicated measurements that respectively fell long and short of the AL, whilst 0.0 indicated coinciding measurements. The distance of the file tip from the AC/MF were measured and recorded as being -1.0 or -0.5 mm from the AC/MF, respectively; at the AC/MF, or +0.5 mm or +1.0 mm from the AC/MF, respectively. A minus symbol (-) indicated a file was through the AC/MF; A plus symbol (+) indicated it was short of the AC/MF. Since the insertion length was already known, the actual length was determined by adding or subtracting the distance of the file tip from the AC/MF to the insertion length.

Statistical Analysis

Power analysis was estimated using a GPower 3.1.9.4 program. The sample size was estimated as 27 teeth per group (α= 0.05, β= 0.05, with a minimum value for clinical relevance of 0.5). Kolmogorov-Smirnov test was used to evaluate normality distribution. The dependent two-sample *T* test was used. Statistical significance was set at $P < 0.05$.

Results

Four teeth were excluded, because of broken tooth structure during extraction (one in the saline group and three in the HEBF group). Electronic measurements for apical constriction (EAC) were found to be significantly higher than the actual length measurements for apical constriction (ALAC) (p= 0.007; Table 1). When the mean difference between the EAC and ALAC was evaluated, the

saline group yielded the lowest mean value (p= 0.0000; Table 2). Electronic measurements for major foramen (EMF) were found to be significantly higher than that of the actual length measurements for the major foramen (ALMF) (p= 0.007; Table 1). No significant difference was observed between the test groups according to the mean difference between the EMF and ALMF.

Table 1. Mean and standard deviations (mm) of differences between electronic measurements (EAC, EMF) and actual length (ALAC, ALMF)

Group	N	Average	S.D	*p*
ALAC – EAC	105	-0.289	0.051	**0.007***
ALMF – EMF	105	-0.483	0.050	

ALAC: Actual apical constiriction; EAC: Electronic apical constriction; ALMF: Actual major foramen; EMF: Electronic major foramen; SD: Standard deviation

Table 2. Mean and standard deviations (mm) of differences between electronic measurements (EAC) and actual length (ALAC) with regard to irrigation solutions

		N	Average	S.D	p
ALAC-EAC	NaOCI	28	-0.093	0.063	0.000*
	EDTA	29	-0.305	0.106	
	Saline	25	-0.060	0.086	
	HEBP	23	-0.756	0.098	
ALMF-EMF	NaOCI	28	-0.501	0.092	0.259
	EDTA	29	-0.349	0.084	
	Saline	25	-0.481	0.126	
	HEBP	23	-0.633	0.089	

ALAC: Actual apical constiriction; EAC: Electronic apical constriction; ALMF: Actual major foramen; EMF: Electronic major foramen S.D: Standard deviation

Table 3. Frequency and percentages of EAC measurements that prove short and long with respect to ALAC

	Solutions	n	Shorter than AL (1.0 mm to 0.5 mm; %)	Shorter than AL (0.5 mm to 0.0 mm; %)	Longer than AL (0.0 mm to -0.5 mm; %)	Longer than AL (-0.5 mm to -1 mm; %)	Longer than AL (<-1 mm; %)
ALAC-EAC	**NaOCI**	28	3 (10.7%)	4 (14.3%)	21 (75%)	0 (0%)	0 (0%)
	EDTA	29	0 (0%)	7 (24.1%)	17 (58.7%)	3 (10.3%)	2 (6.9%)
	Saline	25	2 (8%)	5 (20%)	15 (60%)	3 (12%)	0 (0%)
	HEBP	23	0 (0%)	1 (4.3%)	5 (21.7%)	12 (52.2%)	5 (21.7%)
ALMF-EMF	**NaOCI**	28	1 (3.5%)	1 (3.5%)	11 (39.3%)	12 (42.9%)	3 (10.7%)
	EDTA	29	0 (0%)	6 (20.7%)	14 (48.3%)	7 (24.1%)	2 (6.9%)
	Saline	25	2 (8%)	1 (4%)	7 (28%)	11 (44%)	4 (16%)
	HEBP	23	1 (4.3%)	1 (4.3%)	4 (17.4%)	15 (65.3%)	2 (8.7%)

ALAC: Actual apical constiriction; EAC: Electronic apical constriction; ALMF: Actual major foramen; EMF: Electronic major foramen
Chi-Square (Crosstab) relationship test, Chi-Square Value (ALAC - EAC) = 49,141; Chi-Square Value (ALMF - EMF) = 19,431

Table 4. Frequency (%) of measurements ±0.5 mm of the AC

		Shorter than ALAC (0.5 mm to 0.0 mm; %)	Longer than ALAC (0.0 mm to -0.5 mm; %)
ALAC-EAC	**NaOCI**	4 (16%)	21 (84%)
	EDTA	7 (29.2%)	17 (70.8%)
	Saline	5 (25%)	15 (75%)

ALAC: Actual apical constriction ALAC: Actual apical constriction EAC: Electronic apical constriction

In determining the MF, the Raypex 6 was accurate 42.9% of the time to ±0.5 mm and 89.5% of the time to ±1 mm. In determining the AC, the Raypex 6 was accurate 71.4% of the time to ±0.5 mm and 93.3% of the time to ±1 mm (Table 3). Table 3 shows the percentages of ±0.5 and ±1.0 mm measurements obtained. The AC (±0.5 mm) was determined in 89.3%, 82.7%, 80% and 26.1% for NaOCl, Saline, and EDTA (Table 3). Among the four irrigation solutions tested, EDTA, Saline, and NaOCl showed similar accuracy in detecting AC (Table 4).

Discussion

The aim of this study was to evaluate the precision of Raypex 6 apex locator in locating the apical

constriction (AC) and major foramen (MF) during a root canal treatment compared with that of a microscopic evaluation. Accuracy of the Raypex 6 in the presence of different irrigating solutions was also evaluated. The accuracy of EALs with respect to the determination of the location of the apical constriction of the root canal or the major foramen has been examined by various methods that include radiographic method, cone bean computerized tomography, *in vitro* study models[25-28]. But the present study aimed to evaluate Raypex 6's accuracy under clinical conditions. First, WL determination by Raypex 6 in the mouth was determined and these values were measured again after tooth extraction under a stereomicroscope. Numerous studies have reported the accuracy of EALs in determining the location of the apical constriction of the root canal or the major foramen[8,9,18]. However, various authors have suggested that the precise location of the apical constriction cannot be determined[29,30]. Only histological evaluation can determine the precise location of this detected point in the root canal[1]. In the present study, the apical constriction was examined under stereomicroscope after extraction of the tooth. After extraction of the teeth, the distance between the instrument and the MF was measured after a longitudinal window had been performed on the apical portion of the root[31-33]. Therefore, clinical accuracy of Raypex 6 for AC evaluation is correctly correlated with the AC's accurate/actual position. MF was visualized after extraction of the tooth and this value was also correlated with clinical measurements.

The diameter of the AC and MF and the location of the MF are factors affecting the accuracy of EALs. In order to avoid the effects of these factors, only single-rooted premolars and incisors were included in the present study. Pre-flaring of root canals before measurement with EALs can increase the precision of WL determination[34]. Thus, the canals were pre-flared in the current study before WL measurement. In the present study, only teeth that were extracted from adult patients for periodontal or caries reasons were included. Different results might have been obtained for teeth with periradicular periodontitis, which in most cases presents with some degree of root resorption[35]. In addition, as explained in the Material and Methods section and as in other studies[15,36], determination of the actual working length at the major foramen was made by observing the latter with a magnifying glass (x2.5). However, because identification of the apical constriction required higher magnification, a stereomicroscope (x10) was used. This methodological difference may have implied less precision in the measurements of the actual length to the major foramen. Diverse studies have usually considered the electronic measurements for the AC to be between the 0.5 mm mark[8,19,37,38], which is considered highly accurate[39], and the 1 mm mark[14,22,40]. One reason cited for accepting a 1.0 mm margin of error is the wide range seen in the shape of the apical third[37,41]. Thus, this variation is clinically acceptable[37], because microscopic studies revealed that this landmark might be positioned within this range[1,41].

In 71.4% (75 of the 105) and 93.3% (92 of the 105) of the measurements made, the margin of error in locating AC was ±0.5 and ±1.0 mm, respectively. These results are in line with previous findings[25,26,42]. A recent found that Raypex 6 was accurate 71.43% of the time to ±0.5 mm in measuring AC, nearly the same value with the present findings[43]. Moreover, no significant difference between Raypex 6 and Root ZX was found in another study[25]. These results indicate that the manufacturer enhanced the accuracy with Raypex 6 compared to Raypex 4. The manufacturer claims that Raypex 6 utilizes the latest multi-frequency apex locator technology and displays precise results. Among the four irrigation solutions tested, EDTA, Saline, and NaOCl showed similar and higher accuracy then with HEBP in detecting AC. This study showed a higher but not statistically significant rate of acceptable results (100%, ±1 mm) in the saline and NaOCl groups, which is in agreement with previous studies[25,42]. In a recent study by Chukka RR[44], NaOCl does not affect the WL determination of the EAL, similar with the present findings. HEBP's overestimated measurements in detecting AC can be explained by the fact that HEBP's ionization degree in liquids is lower than that of the other three solutions[45]. The lower ionization degree in HEBP explains its lower ion mobility and its weak conductiveness. It was stated that inconsistent or false measurements of EAL is due to the low conductivity of irrigants in root canals[46]. Since there has been no study studying the effect of HEBP on EAL's accuracy, the present results are the first documented. Although HEBP has some advantages like smear layer removal, not affecting the efficacy of NaOCl in clinical conditions, it can be cautiously used in AC determination.

In 42.9% (75 of the 105) and 89.5% (92 of the 105) of the measurements made, the margin of error in locating MF was ±0.5 and ±1.0 mm, respectively. Raypex 6 can cause over instrumentation in detecting MF regardless of the type of irrigant. These results are in contrast with the findings of Lucena *et al.*[26]. This difference can be due to the selection of the red ball as the reference point for MF in the present study, while Lucena *et al.*[26] used the third yellow bar as the reference point for MF. In addition to the reference point selection, the use of different types of irrigation solutions could have caused different results. Raypex 6 was found to be more reliable in detecting AC than detecting MF.

Conclusions

Under the conditions of this *in vivo* study, Raypex 6 was found to be more reliable in detecting AC

than detecting MF. The 2 electronic measurements (EAC and EMF) give an overestimation of the actual working length (ALAC and ALMF). The present study revealed that electronic working length determination by Raypex 6 is not influenced by the presence of irrigation solutions, except for HEBP. Only HEBP have a statistically significant influence on the accuracy of the EAL in detection of apical constriction, but there was no statistically significant difference between all four irrigation solutions in detecting the major foramen.

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