The effect of irrigation solutions and file types on the accuracy of electronic apex locator: an *in vitro* study

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Abstract

Background: To achieve success in endodontic treatment, working length can be accurately determined using an electronic apex locator. However, the accuracy of the apex locator is not always stable across different root canal environments. This study aims to evaluate the accuracy of the Apex ID, 4th generation of apex locator, under various irrigation solutioans and types of measuring files. **Materials and methods:** a total of 40 extracted lower premolars were instrumented using size 15-30 K-files. The teeth were then divided randomly into 4 groups of 10 teeth each, to evaluate the working length by the Apex ID apex locator in 4 different conditions. Four irrigation solutions, two concentrations of irrigation solution, six K-file sizes, and two file types were used to assess the accuracy of the Apex ID. **Result:** This study showed no statistically significant difference in working length and deviation from the actual canal length values between different measurement conditions. However, the accuracy of the Apex ID varied among different irrigation solutions, file sizes, and file materials. NaOCl and NaCl solution, K-file size 25-30 with the Apex ID showed 100% accuracy. **Conclusion:** The accuracy of the Apex ID apex locator varies under different conditions of measuring the working length. Using the NaOCl solution and selecting file sizes close to the size of the root canal is recommended to achieve high accuracy.

Keywords: *working length, electronic apex locator, irrigation solutions, file types.*

1. INTRODUCTION

To achieve success in endodontic treatment, working length (WL) must be accurately determined and maintained throughout the preparation process [1]. Since appearing, electronic apex locators (EALs) have marked a breakthrough in endodontics, aiding in the quick and precise determination of WL while avoiding the influence of radiation on both patients and operators [2, 3].

With the advancement of science and technology, EALs have evolved to the 6th generation, incorporating numerous improvements for higher accuracy. The Apex ID apex locator (Sybron Endo, USA) is a widely used device in dental practices in Vietnam. Belonging to the 4th generation, the Apex ID measures both resistance and capacitance values, providing accurate WL even in the presence of blood and other fluids. A previous study showed that the Apex ID achieved an accuracy of 93% at position 00 [4].

However, the accuracy of EALs is not always stable across different root canal environments. Some studies have reported that the WL determination results obtained with these devices can be influenced by various factors [5, 6]. AK Ebrahim et al. (2006) studied the effect of root canal file size, NaOCl solution, and blood on the accuracy of EALs, concluding that all these factors significantly affect the measurement error [6]. A study by Janeczek et al. (2016) on two types of EALs showed that NaOCl solution and file size did not affect the accuracy of root canal measurements, while other solutions reduced the measured length [5]. However, there has been no study evaluating the accuracy of the Apex ID apex locator under different irrigation conditions and types of measuring files.

Therefore, to clarify the factors affecting the accuracy of the Apex ID apex locator and provide guidance for clinical practice in endodontics, we conducted this study with the following objectives:

1. To evaluate the accuracy of the Apex ID EAL under different irrigation solutions.

2. To sssess the accuracy of the Apex ID EAL with various types of measuring files.

2. MATERIALS AND METHODS

2.1. Tooth Selection

To evaluate the influence of various factors on the accuracy of the apex locator, 40 extracted lower premolars were randomly divided into 4 groups related to the following factors (10 teeth/group): irrigation solution concentration, irrigation solution

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type, file size, and file material. The working length was determined using the Apex ID apex locator after canal preparation.

Forty mandibular premolars were extracted due to orthodontic treatment, ensuring the following selection and exclusion criteria:

- Selection criteria:

+ Single-rooted teeth with intact crowns and roots, free from cracks, fractures, internal or external resorption, and calcification of the root canal.

+ Completely sealed and relatively straight root canals (root curvature not exceeding 5 degrees on periapical radiographs).

- Exclusion criteria:

+ Teeth with abnormal root shapes or previously treated root canals.

+ During WL determination, the size 15 K-file did not reach the full length of the root canal.

2.2. Preparation of Tooth Samples

Forty teeth meeting the research criteria were cleaned, disinfected, and softened. Subsequently, the root canals of the tooth samples were prepared, and the true length of the root canal was measured using an electronic caliper [7].

- Root canal preparation: The WL was determined using the Apex ID with a size 15 stainless steel file in a 2% sodium hypochlorite (NaOCl) solution. The WL value was the average of 3 measurements. Canal preparation was performed sequentially with K-files sizes 15, 20, 25, and 30 using the step-back technique, with the size 30 file as the final working file (Master apical file) at the determined WL. The root canals were irrigated with 2% NaOCl solution and dried with size 30 absorbent paper points.

- Measurement of actual canal length: A size 15 K-file with a silicone stopper was inserted into the root canal, and gently moved towards the apex until the tip of the file was visible at the apical foramen. The stopper was fixed on the coronal part of the tooth, and the length from the stopper to the tip of the file was measured using an electronic caliper. Subsequently, 0.5mm was subtracted from this measurement to obtain the true length of the root canal [7].

2.3. Evaluation of the Influence of Irrigation Solution and Measuring Files on the Accuracy of the Apex ID EAL

- **Group 1:** Evaluation of the influence of 2 concentrations of sodium hypochlorite (NaOCl) 2% and 5.25% (n=10).

+ Using a size 30 stainless steel K-file, the WL of each root canal was sequentially measured using the apex locator in a NaOCl solution environment with two different concentrations: 2% and 5.25%.

+ Between the two different solution concentrations, the root canals were irrigated twice with distilled water and dried with absorbent paper points.

- Group 2: Evaluation of the influence of different irrigation solutions (NaOCl 2%, sodium chloride (NaCl) 0.9%, ethylenediaminetetraacetic acid (EDTA) 17%, chlorhexidine (CHX) 2%) (n=10).

+ Using a size 30 stainless steel K-file, the WL of each root canal was sequentially measured using the apex locator in four different solutions: NaOCl 2%, NaCl 0.9%, EDTA 17%, CHX 2%.

+ The root canals also were irrigated and dried between the two different solutions.

- Group 3: Evaluation of the influence of different sizes of measuring files (n=10).

+ Using stainless steel K-files (Mani, Japan) sizes 08, 10, 15, 20, 25, and 30 in a 2% NaOCl solution environment, the WL of each root canal was sequentially measured using the Apex ID.

- Group 4: Evaluation of the influence of different materials on measuring files (n=10).

+ Using stainless steel K-file size 30 and NiTi K-file (Mani, Japan) size 30 in a 2% NaOCl solution environment to sequentially measure the WL with the Apex ID.

The WL was measured three times under each condition, and the mean WL value was compared with the actual length to calculate the deviation of WL from the actual length (ΔWL). The accuracy of the Apex ID EAL under each condition was determined as the percentage of measurements within ±0.5mm of the true canal length [8].

Figure 1. The irrigation solutions used in the study (from left to right): 2% sodium hypochlorite (Cerkamed, Poland), 5.25% sodium hypochlorite (Cerkamed, Poland), 2% chlorhexidine (Cerkamed, Poland), 17% ethylenediaminetetraacetic acid (Cerkamed, Poland), 0.9% sodium chloride (Vinh Phuc Medicine, Vietnam).

2.4. Data processing

All data were calculated using Microsoft Excel 2016 software and then processed using SPSS 20.0 software. Student's t-test and one-way ANOVA were used to compare the mean values, with a confidence level of 95%, and statistical significance was considered when p<0.05.

3. RESULTS

3.1. Effect of NaOCl concentration on WL measured by the Apex ID apex locator

Table 1. Mean values of WL and deviation of WL from the actual length of the root canal (ΔWL) in NaOCl solutions with different concentrations.

Values Irrigation solutions	WL Mean ± SD (mm)	ΔWL Mean ± SD (mm)
NaOCl 2% solution	20.55 ± 0.99	-0.32 ± 0.12
NaOCl 5.25% solution	20.56 ± 0.99	-0.31 ± 0.12
*p**	0.423	0.42

(-) Value: WL shorter than the actual length of the root canal.

** Student's t-test*

The mean WL and deviation from the actual length of the root canal measured by the Apex ID EAL in two NaOCl solutions, 2%, and 5.25%, showed no statistically significant difference (p*>0.05).

3.2. Effect of different irrigation solutions on WL values measured by the Apex ID apex locator

Table 2. Mean values of WL and deviation of WL from the actual length of the root canal (ΔWL) in different irrigation solutions

Values Irrigation solutions	WL Mean ± SD (mm)	ΔWL Mean ± SD (mm)
NaOCl 2% solution	20.17 ± 1.11	-0.001 ± 0.09
NaCl 0.9% solution	19.97 ± 1.16	-0.21 ± 0.09
EDTA 17% solution	19.62 ± 1.09	-0.56 ± 0.12
CHX 2% solution	19.71 ± 1.10	-0.47 ± 0.13
*p**	>0.05	0.714

(-) Value: WL shorter than the actual length of the root canal.

** One-way ANOVA*

The mean WL and deviation from the actual length of the root canal measured by the Apex ID EAL in four irrigation solutions (NaOCl, NaCl, EDTA, CHX) showed no statistically significant difference (p*>0.05).

3.3. Effect of K-file size on WL values measured by the Apex ID apex locator

Table 3. Mean values of WL and deviation of WL from the actual length of the root canal (ΔWL) when measured by K-files of different sizes

Values File sizes	WL Mean ± SD (mm)	ΔWL Mean ± SD (mm)
K-file size 08	19.43 ± 1.38	-0.74 ± 0.14
K-file size 10	19.60 ± 1.41	-0.57 ± 0.11
K-file size 15	19.79 ± 1.40	-0.38 ± 0.10
K-file size 20	19.93 ± 1.41	-0.24 ± 0.08
K-file size 25	20.01 ± 1.44	-0.15 ± 0.11
K-file size 30	20.13 ± 1.39	-0.04 ± 0.07
*p**	>0.05	0.886

(-) Value: WL shorter than the actual length of the root canal.

** One-way ANOVA*

The mean WL and deviation from the actual length of the root canal measured by the Apex ID apex locator with K-files of sizes 08, 10, 15, 20, 25, and 30 showed no statistically significant difference (p*>0.05).

3.4. Effect of K-file size on WL values measured by the Apex ID apex locator

Table 4. Mean values of WL and deviation of WL from the actual length of the root canal (ΔWL) when measured by K-files of different materials.

Values File types	WL Mean ± SD (mm)	ΔWL Mean ± SD (mm)
Steel K-file size 30	20.27 ± 1.53	-0.14 ± 0.33
Niti K-file size 30	19.96 ± 1.46	-0.46 ± 0.30
*p**	0.775	0.634

(-) Value: WL shorter than the actual length of the root canal.

** Student's t-test*

The Mean WL and deviation from the actual length of the root canal measured by the Apex ID EAL with K-files size 30 made of steel and NiTi showed no statistically significant difference (p*>0.05).

3.5. Accuracy of the Apex ID apex locator under different WL measurement conditions

Table 5. Accuracy of the Apex ID apex locator under different measurement conditions

Factors	Value	Accuracy (%)
Concentration of irrigation solutions	NaOCl 2% solution	100
	NaOCl 5.25% solution	100
Type of irrigation solutions	NaOCl 2% solution	100
	NaCl 0.9% solution	100
	EDTA 17% solution	30
	CHX 2% solution	50
File sizes	K-file size 08	0
	K-file size 10	30
	K-file size 15	80
	K-file size 20	100
	K-file size 25	100
	K-file size 30	100

File materials	Steel K-file size 30	60
	Niti K-file size 30	80

For two different concentrations of NaOCl solution (2% and 5.25%), the Apex ID apex locator measured WL with 100% accuracy. WL measured in 0.9% NaCl solution also showed 100% accuracy. However, CHX 2% and EDTA 17% irrigation solutions reduced the accuracy of the Apex ID apex locator to 50% and 30%, respectively.

For K-files sizes 08-10-15 used to measure WL, smaller files showed lower accuracy. Using K-files sizes 20, 25, and 30 to measure WL resulted in 100% accuracy. When comparing the accuracy of the Apex ID apex locator using size 30 K-files made of two different materials, NiTi K-files (80%) showed higher accuracy than steel K-files (60%).

4. DISCUSSION

In this *in vitro* study, 40 mandibular premolars were identified with working lengths by the Apex ID apex locator under different irrigation solutions and file types. WL and deviation of WL from the actual length of the root canal (ΔWL) were evaluated, with accuracy equivalent to values of ±0.5mm commonly proposed and accepted by many authors [8, 9]. This study showed no statistically significant difference in WL and ΔWL values between different measurement conditions. However, the accuracy of the Apex ID varied among different irrigation solutions, file sizes, and file materials.

NaOCl is a commonly used irrigation solution in endodontic treatment with concentrations of 2% and 5.25% [10]. The results of this study showed that the accuracy of the Apex ID was not different between these two concentrations, with 100% accuracy. Similar results have been reported with different NaOCl concentrations measured by different EALs [5, 11]. However, a study by Cimpean et al. (2023) reported a decrease in the accuracy of the Apex ID from 80% to 75% when increasing the concentration from 2% to 5.25% [12]. NaOCl is known for its high electrical conductivity and ability to penetrate dentinal tubules, reducing the resistance in the root canal wall and improving electrical contact with periapical tissues [13]. In this study, NaOCl was found to be a suitable irrigation solution for accurate WL determination regardless of concentration.

In addition to NaOCl, other irrigation solutions such as NaCl 0.9%, CHX 2%, and EDTA 17% are used to enhance cleaning, remove debris, and disinfect the root canal. WL measurements by the Apex ID showed that, compared to the actual length of the root canal, NaCl 0.9% had accuracy equivalent to NaOCl 2% (100%), while EDTA 17% and CHX 2% had accuracies of 30% and 50%, respectively.

Changes in WL between different irrigation solutions depend on the nature of the solution, particularly its conductivity. The study by Pilot et al. (1997) showed a decreasing trend in conductivity: NaOCl 5.25% > EDTA 14.45% > NaCl 0.9% [13]. This explains the results of our study, where solutions with low conductivity showed less variation in WL measurement compared to solutions with no conductivity or poor conductivity. This is consistent with the study by Kang et al., which found the least accurate results with EDTA present in the root canal [14]. In the study by Prasad et al. (2016), the largest deviation was observed in the CHX 2% group [15].

During endodontic treatment, initial WL is determined using the Apex ID apex locator with small diameter files to reach the apex. After completing root canal preparation, WL needs to be reconfirmed with larger files appropriate for the size of the prepared apex. Our study showed that with file sizes 08, 10, and 15, the accuracy was 0%, 30%, and 80%, respectively, while for sizes 20, 25, and 30, the accuracy was 100%. Studies by Ebrahim et al. (2006) and Janeczek et al. (2016) also found that WL measured with smaller diameter files after preparation with larger ones was shorter than the actual length of the root canal [5, 6]. Using files with diameters equivalent to the canal size results in more accuracy even in the presence of irrigation solutions [5].

The Apex ID EAL operates based on the resistance principle between the oral mucosa and the periodontal ligament. Therefore, the material composition of the file can also affect the accuracy in determining WL. Instruments used in endodontic treatment are usually made from various materials, including stainless steel, carbon steel, chromium alloy, nickel, and nickel-titanium [5]. The accuracy of the Apex ID with steel and NiTi size 30 K-files was 60% and 80%, respectively, but the difference was not statistically significant ($p>0.05$). Our results are similar to the study of Sadeghi S. et al (2010) using the Rapex 5 apex locator, recording the accuracy of steel files and NiTi files as 70% and 75%, respectively [16]. The resistance varies from 80-100 ohm/cm for NiTi alloy to 73-78 ohm/cm for steel alloy, which may

affect the accuracy of the Apex ID [17].

The study was conducted with a small sample size and a simple evaluation method, so there may be limitations in assessing the accuracy of the Apex ID apex locator. However, the results of the study also provide recommendations for clinical practice when using the Apex ID, suggesting that using NaOCl solution with file sizes appropriate for the canal size will help to assess WL more accurately.

5. CONCLUSION

The accuracy of the Apex ID apex locator varies under different conditions of measuring the working length with different irrigation solutions, file sizes, and file materials. Using the Apex ID apex locator with NaOCl solution and selecting file sizes close to the size of the root canal is recommended to achieve high accuracy.

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