

Comparative Evaluation of Accuracy of Three Electronic Apex Locators in Different Simulated Clinical Conditions- An *invitro* Study

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Abstract

Background: The establishment of appropriate working length is one of the most critical steps in endodontic therapy. There is alteration in accuracy of apex locators in presence of irrigants, pulp/blood and open apices. Hence their accuracy in these conditions needs to be evaluated. **Aim:** The aim of this *in vitro* study was to determine the accuracy in measuring the working length by using CanalPro, Apex ID and Root ZX mini Apex locators in different simulated clinical conditions. **Materials and Methods:** 60 freshly extracted single-rooted teeth were equally assigned to three groups according to simulated clinical conditions: Group 1; Presence of irrigant, Group 2; open apex, Group 3; presence of blood & pulp. The working length was determined with all the apex locators and was then compared with actual working length of the tooth. The difference between the length measured by electronic apex locator (EAL) and actual length (AL) was tabulated and statistically analyzed using one way ANOVA and Post hoc Bonferroni test. **Results:** The accuracy in working length measurement by Root ZX mini was 100%, 60% and 80%; Apex ID was 100%, 80% and 90% and CanalPro was 100%, 90% and 90% in group 1, group 2 and group 3 respectively within ± 0.5 mm of AL. ANOVA revealed that comparison of the mean difference between length measured by all EAL's and AL was statistically insignificant in group I. In group II and III, CanalPro showed the least difference between AL and length measured by it though it was statistically insignificant as compared to Apex ID. Root ZX showed the maximum difference between actual length and length measured by it. **Conclusion:** CanalPro showed highest accuracy in all conditions with accepted accuracy percentage above 90%.

Keywords: Apex locators, Apical foramen, Apical widening, Open apex, Working length

Introduction

According to endodontic glossary working. Working length is defined as, "the distance from a coronal reference point to the point at which canal preparation and obturation should terminate". Apical constriction (AC) is recommended as the point upto which all instrumentation and obturation must terminate. Kuttler (1955) showed that the apical constriction (minor foramen) is 0.524 - 0.659 mm above the anatomic apex of the tooth (apical foramen, major foramen) [1].

Dummer et al. [2] affirmed that pinpointing the position of AC clinically is difficult, because of its discrepancy in position and topography. Radiographs, anatomical knowledge, anatomical averages, tactile sense and absorbent points have been used for determining root canal length. However, all the above mentioned methods have limitations [3]. Radiographs cannot accurately determine the AC since it gives a two-dimensional image of a three-dimensional object [4,5]. Also, they are associated with limitation of radiation exposure to patient and dental personnel. Tactile perception is inaccurate in some patients, due to open apex teeth and apical curvature [6].

Because of, advantages of EAL's, like elimination of radiographic obstacles and EAL's precision and ease, the application of EAL's has evolved [7,8].

Suzuki [9] recorded a constant value of 6.5k Ω as electrical resistance between the periodontal ligament and the oral mucosa. This led to the evolution of the first generation electronic apex locators (EALs) [10].

The Root ZX mini (J. Morita Corporation) is a fifth generation EAL that uses the 'ratio method' to calculate the root canal length [11]. The sixth generation EAL's: Apex ID (SybronEndo) and CanalPro (ColteneEndo) are based on dual frequencies that are sent from and returned to the unit after travelling along the electric circuit.

Until now, no study has been documented to compare the three apex locators in all three simulated conditions: with irrigant in canal, open apex, with blood and pulp tissue in canal. In this study, we have tried to throw light on this un-researched comparison.

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Hence, the rationale of this *in vitro* study was to compare and evaluate the accuracy of Root ZX mini, Apex ID and the CanalPro apex locators in determining the working length in 3 different simulated clinical conditions: with irrigant in canal, open apex, with blood and pulpal tissue in canal. The null hypothesis is that there is no difference in the accuracy of Root ZX mini, Apex ID and the CanalPro apex locators to determine the working length in different simulated clinical conditions.

Materials and Methods

Sixty freshly extracted single rooted caries free mandibular premolars freshly extracted for orthodontic treatment were chosen for the study. The teeth were examined under $\times 5$ magnification using a magnifying glass. Samples with root resorption, fractures or incomplete root development were excluded. For each sample, two radiographs using the Sopix radiovisiography system (Sopro, France) were taken in the buccolingual and mesiodistal projection to view the root canal anatomy and radiographic apex. Teeth with more than one canal were excluded.

Access opening and occlusal reduction of cusp tips of the samples was performed. The samples were randomly divided into three groups with 20 samples each.

In group I (n=20), the root canals were cleansed of debris by irrigating with 5 ml of 5% NaOCl. Canal patency was confirmed using a size 10 K-file (Mani Inc, Japan). Barbed broaches were used to extirpate the pulp. No root canal instruments were used to avoid canal enlargement. This was followed by irrigation with 5 ml, 5% NaOCl to remove the organic content. Then 2 ml of 5% NaOCl was injected to simulate the clinical condition of irrigant within the canal.

In group II (n=20), the root canals were irrigated with 5 ml of 5% NaOCl. The apical 3 mm of the root tips were resected to simulate the clinical situation of open apex. Canals were instrumented with Peeso reamers #1 upto #4. During instrumentation, each Peeso reamer was passed 1 mm beyond the apex.

In group III (n=20), no irrigation and no attempt to extirpate the pulp was made. Then blood samples were freshly collected from operator after taking his consent and were treated with 0.1% EDTA (EDH, New delhi, India). This human blood mixed with Ethylene Diamine Tetraacetic acid EDTA as an anticoagulant was injected into the canals to simulate the clinical condition of bleeding within the canal.

The samples were rooted up to the cementoenamel junction in a plastic container containing freshly mixed alginate. Readings were recorded within 2 hours. Adequate care was taken to keep the alginate models moist.

A size 15 K-file was clipped to the apex locator and circuit was completed by inserting the lip electrode into the alginate model. Electronic measurements were obtained by using all the three electronic apex locators- CanalPro, Apex ID and Root ZX mini. In group I, samples were replenished with fresh irrigant each time before using the new apex locator.

Values were acknowledged creditable if the reading remained stable for at least 5 seconds. The procedure was repeated 3 times

for each tooth. The mean value was calculated and recorded for each sample.

To determine the AL, AC of the sample was viewed directly. This was achieved by selective grinding of tooth. After using electronic method, sample was carefully sectioned in a longitudinal direction at a very low speed with a diamond disk. The grinding was continued till the canal was observable in the longitudinal direction. Then the file used to perform the measurements with EAL, was inserted into the canal. Samples were observed under stereomicroscope for the AL determination. The silicone stop was stabilized and distance between file tip, apical constriction, major foramen and the anatomical apex was measured under $\times 4.5$ magnifications with a millimeter ruler to the nearest 0.25 mm.

In all open apex samples, the actual length was determined with a size 15 K-type stainless steel file by inserting it into the canal until the file tip was just visible through the apical foramen. This was performed with a magnifying glass (X5). A digital caliper (Insize, India) with the accuracy of 0.01 mm was used to measure the file length. 0.5 mm was subtracted from the file length and recorded as the AL.

The recorded AL was compared with the values obtained with the EALs and their difference was tabulated and subjected to statistical analysis.

Statistical Analysis

The tabulated data was subjected to One way analysis of variance (ANOVA) followed by post hoc bonferroni using statistical package for social sciences (SPSS Inc., Chicago, IL, USA) version 16 for windows. $p < 0.5$ was considered statistically significant.

Results

The results of this study showed that the accuracy in working length measurement by Root ZX mini was 100%, 60% and 80%; Apex ID was 100%, 80% and 90% and CanalPro was 100%, 90% and 90% in group 1, group 2 and group 3 respectively within ± 0.5 mm of AL [Figure 1].

The accuracy was measured by calculating the percentage of readings measured by that particular EAL that fell within ± 0.5 mm of the AL.

On applying ANOVA and intergroup comparison with

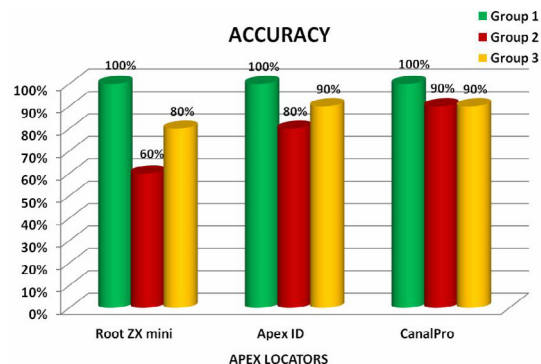


Figure 1: Bar diagram showing accuracy of Root ZX, Apex ID and CanalPro for all three groups.

Bonferroni it was found that the difference between actual length and length measured with different apex locators was statistically insignificant in group I. In group II and III difference was least in case of canal pro followed by Apex ID though it was statistically insignificant. Root ZX showed the maximum difference [Tables 1 and 2].

Discussion

An accurate assessment of working length is a critical factor in determining the prognosis of an endodontic treatment [12-14]. With the introduction of the latest generation of apex locators, determination of the WL has become extensive. However, the accuracy of these apex locators is a major concern amongst the clinicians [15-19]. Therefore, the purpose of this *in vitro* study was to compare and evaluate the accuracy of Root ZX mini, Apex ID and the CanalPro apex locators in determining the working length in 3 different simulated clinical conditions:

- With irrigant
- In Open Apex
- With blood and pulpal tissue

Root ZX is the most extensively researched upon apex locator. It is considered as the gold standard to which the newer apex locators are being compared. According to previous studies, its accuracy varies from 50% to 100% [20-22]. The manufacturers claim that Root ZX mini is accurate, even in the presence of electrolytes, such as sodium hypochlorite, saline, tap water or hydrogen peroxide [20-22].

In the present study, sixty single-rooted premolar teeth were selected. Flattening of the cusp was done to obtain a reproducible reference point for file length measurement. The current *in vitro* study consisted of mature teeth instrumented with peeso reamers (group 2) to mimic divergent open apex of immature roots [11].

To electronically measure and simulate the clinical conditions, the extracted teeth were embedded in alginate because it mimics the electrical impedance of the human periodontium [23,24].

To establish the AL with regard to cementodentinal junction, histological method has been recommended [25,26]. In our study,

samples were sectioned for histological viewpoint in order to compare with the AL. Martínez-Lozano et al. [25] and Muthu et al. [26] confirmed that the best approach for recording actual working length, is by removing cementum and dentin.

In group I (with NaOCl), all apex locators showed 100% accuracy *In vitro* studies have demonstrated the accuracy of Root ZX mini to be varying from 82.3% to 96.2% within ± 0.5 mm when used with NaOCl [27,28].

The result of present study for Root ZX mini with NaOCl (100% accuracy) is in concurrence with an earlier *in vitro* study by Friedman et al. [24] but was paradoxical to findings of Remeikis et al. [28] This may be because Remeikis et al. compared the canal length determined by an apex locator to the apical constriction in both vital and necrotic canals, *in vivo*.

For Root ZX, the presence of electrolytes inside the canal reduces its resistance and increases its capacitance. This favors its circuit as it depends on differentiating the modulation in electrical capacitance near the AF.

The accuracy of Sybron's Apex ID was 100% and similar to an earlier study of 97.5% accuracy using NaOCl as an irrigant by De Camargo et al. [29]. The accuracy of Sybron ApexID using NaOCl is believed to be because of its multifrequency mechanism and shorter transmission line.

The literature review unfolded no studies evaluating the accuracy of CanalPro in the presence of irrigants.

In group 2 (Open apex), snugly fitting files were used for electronic measurements as reported by Herrera et al. [30]. The order of accuracy in group 2 was CanalPro(90%) > Apex ID (80%) > Root ZX mini (60%) with statistically insignificant difference between CanalPro and ApexID. The results were in corroboration with findings of Herrera et al. [31] and Akisue et al. [32].

Readings of Root ZX mini in group 2 are in agreement with findings of Ebrahim et al. [33] which reported that beyond size 80, Root ZX is less accurate and the apical size used in present study was peeso #4 which corresponds to 130 mm). Abalos et al. [31] reported that there is no effect on accuracy of apex

Table 1: Mean (SD) values of Actual length and length determined by apex locators

Working length determination method	Group I (NaOCl as irrigant) Mean (S.D.)	Group II (Open Apex) Mean (S.D.)	Group III (In presence of pulp tissue and blood) Mean (S.D.)
Actual Length	18.375 (1.5801)	15.275 (0.8188)	18.750 (1.3621)
Root ZX	18.075 (1.6958)	13.350 (0.7626)	16.625 (1.3848)
Apex ID	18.150 (1.5985)	14.525 (1.0696)	18.625 (1.3066)
Canal Pro	18.375 (1.5801)	15.050 (0.8569)	18.600 (1.4382)

Table 2: Mean difference between actual length and length obtained by Apex Locator

	Group I (with irrigant) Mean difference (S.D.)	Group II (open apex) Mean difference (S.D.)	Group III (with pulp and blood) Mean difference (S.D.)
Root ZX mini	0.30 (0.42) ^a	1.90 (0.32)	2.10 (0.39)
Apex ID	0.15 (0.24) ^a	0.75 (0.54) ^a	0.10 (0.21) ^a
Canal Pro	0.0 ^a	0.25 (0.26) ^a	0.10 (0.21) ^a

*Same superscripts indicate insignificant difference between apex locators across the column

locators above 4th generation in cases of open apex with absence of blood, serum and pus. This could be attributed to the accuracy of Apex ID in group 2.

The highest accuracy of CanalPro Apex Locator in group 2 could be due to its mechanism of measuring two frequencies that are alternated and not mixed, thus canceling the need for signal filtering and eliminating the noise caused by non-ideal filters which makes the measurement much more immune to various kinds of electromagnetic noises.

The order of accuracy in group 3 (root canal with blood and pulp) was CanalPro (90%) > Apex ID (90%) > Root ZX mini (80%) with statistically significant difference between CanalPro and Root ZX. Also, there was statistically significant difference between Apex ID and Root ZX. However, statistically insignificant difference between CanalPro and Apex ID was observed. These findings are in agreement with Ebrahim et al.^[33] who stated that blood in canal adversely affects the readings of Root ZX mini and Apex ID. On the contrary, Herrera^[28] demonstrated that presence of blood does not influence the accuracy of apex locators when the foramen was sufficiently small.

The better accuracy of CanalPro in group 3 could be attributed to its mechanism as discussed earlier. However, no studies have been reported to corroborate or contradict the findings of CanalPro in group 3.

Attempt to simulate the 3 different clinical conditions has been made as precisely as possible, however there may be some variations. In group 3, ideal clinical scenario doesn't involve having root canal measurement without instrumentation. But, to prevent variation due to remaining pulp tissue in group 3, no attempt was made to extirpate the pulp.

Conclusion

Within the limitations of this study, null hypothesis for Group 1 was acceptable and was rejected for Groups 2 & 3.

All apex locators were 100% accurate when used with irrigant but were less accurate when used in open apex and with blood & pulp tissue within the canal. CanalPro showed highest accuracy and a very strong correlation when compared to actual length in all conditions with accepted accuracy percentage above 90%. Further research is required to evaluate the accuracy of these apex locators in different clinical conditions.

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