ORIGINAL RESEARCH

In Vitro Comparative Evaluation of the Accuracy of Three Electronic Apex Locators in Mandibular Molars Using Cone-beam Computed Tomography

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Abstract

Background: Accurate estimation of the working length (WL) from the coronal reference point to the minor diameter (apical constriction) is critical in endodontic therapy. Many electronic apex locators are available to precisely measure this apical limit.

Aim: To assess the precision of three current electronic apex locators—Root ZX Mini, CanalPro, and Apex ID in the mesial canals of mandibular molars. Cone-beam computed tomography (CBCT) was employed to verify their accuracy.

Materials and methods: Thirty mandibular first molars with curved mesial roots were selected. Cone-beam computed tomography (CBCT) was used to assess the length of the teeth. Samples were decoronated and mesiobuccal canal orifices were enlarged with Hyflex CM 25/08 and irrigated with 2 mL 3% sodium hypochlorite. Canals were prepared with size 10 K-file and the measurements were recorded with apex locators at marks "APEX 0/0" and "0.5 mark" as electronic tooth length and the electronic WL, respectively by visual means, and this was verified using CBCT. Statistical analysis was done using the repeated measures of ANOVA test.

Results: CanalPro, Root ZX Mini, and CBCT values were very similar. Apex ID values were longer than CBCT values.

Conclusion: CanalPro readings closely matched those of CBCT measurement followed by Root ZX mini. Apex ID showed longer readings.

Keywords: Cone-beam computed tomography, Electronic apex locator, Working length.

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Key Message

Proper WL determination is critical in endodontic therapy. Accuracy of recent generation apex locators needs validation. Cone-beam computed tomography (CBCT) has been shown to precisely locate the apical constriction. There are not many studies comparing the accuracy of recent generation apex locators with CBCT measurements.

Introduction

Precise estimation of WL is important for the success of endodontic treatment. Working beyond the apical constriction results in over instrumentation of the root canals leading to damage to the periapical tissues, whereas underestimation results in insufficient root canal preparation.[1,2] For WL determination two important apical landmarks are the apical foramen (AF) and apical constriction. Apical foramen (AF) is the location where a canal leaves the root surface. This may vary in its location. Sometimes it may be located laterally or maybe even up to 3 mm short of the anatomic root apex. Apical constriction (AC) corresponds to the narrowest portion of the canal in the apical region. It is usually situated 0.5–1 mm short of the AF.[2,3] It is the point where canal preparation and obturation should be completed.[4–6]

The apical limit of WL is usually taken as apical constriction based on Kuttler's observation as well as various other studies. Two popular methods of WL estimation are—radiographic techniques and electronic apex locators (EALs). The use of periapical radiographs for calculating the WL is demanding and not very accurate. Limitations of radiographs for WL determination include its two-dimensional nature, the possibility of image distortion or magnification, superimposition of anatomic structures, and its failure to accurately locate the apical constriction. Electronic apex locators (EALs) offer more precision and consistency in this regard.[7,8] These devices detect the location where the pulp tissue ends and periodontal tissue begins. Recent generation EALs have been reported to perform with improved accuracy as they have sophisticated software for accurate WL measurement.[9]

It is essential to use radiographs and EALs judiciously to estimate the WL accurately. While EALs locate the apical constriction accurately, visualization is possible only by means of radiographs.[10,11]

New imaging modalities like digital radiography, computed tomography, and CBCT have become popular. Cone-beam computed tomography (CBCT) is emerging as an advanced

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radiographic aid for diagnosis and treatment planning. Using CBCT multiplanar reconstruction, root canal morphology can be precisely analyzed. Limited CBCT scan makes WL calculation easier because of noise reduction, its high resolution, and its non-invasive nature. Compared to computed tomography, CBCT requires much less radiation dosage. It can precisely identify the location of the apical constriction and can therefore be able to verify the performance of EALs.[11]

The aim of this study was therefore to evaluate the performance of three recently introduced electronic apex locators: Root ZX Mini (J Morita, Tokyo, Japan), CanalPro (Coltene-Endo, Cuyahoga Falls, Ohio), and Apex ID (SybronEndo, Glendora, California) in mesiobuccal canals of mandibular first molars. Cone-beam computed tomography was employed for verification.

According to the null hypothesis, there would be no variations in the readings of the three apex locators and CBCT measurements.

Materials and Methods

Thirty extracted permanent mandibular molars with curvatures in the mesial roots having two separate canals were selected for the study. Teeth were placed in thymol solution for 1 week. Atraumatically extracted intact healthy molars with fully formed apex, caries-free teeth, and teeth without any defects were included. Exclusion criteria included teeth with fractures, caries, resorptions, immature apices, and calcified canals. They were imaged using CBCT to assess their internal morphology. Teeth presenting with apical curvature between 5 and 20° were included. All the teeth were then decoronated using the diamond disc with water spray. They were positioned in a sectional tray loaded with alginate, which is an electroconductive medium to simulate the periodontium. The pulp space was accessed, and coronal flaring of the mesiobuccal root canals was achieved using Hyflex CM orifice shaper 25.08% (Coltene Whaledent, Allstetten, Switzerland) and 3% sodium hypochlorite was used as irrigating solution. A manual size 10 K-file (Mani, Japan) was used to check whether the canal was patent till the apical region. The file was then inserted into the mesiobuccal root canal, and the readings with each apex locator: Root ZX Mini (J Morita, Tokyo, Japan), CanalPro (Coltene-Endo, Cuyahoga Falls, Ohio), Apex ID (SybronEndo, Glendora, CA) were obtained by positioning the lip clip in alginate and the file clip on the 10 k-file. The file was moved ahead until the reading APEX or 0.0 mark stayed stable for 5 seconds and readings were recorded. The file was then withdrawn until it reached the "0.5 mark" on the device to identify the electronic working length (EWL). The reference point was standardized for all three tested apex locators and the WL measurements were recorded.

Statistical Analysis

Statistical package for social sciences (SPSS) for Windows, Version 22.0. Released in 2013. Armonk, New York: IBM Corp., was used to perform statistical analyses.

Descriptive Statistics

The descriptive analysis includes expression of the root canal and WL in terms of mean and standard deviation (SD), whereas the tolerance level for the difference in measurement in terms of frequency and percentage.

Inferential Statistics

Repeated measures of the ANOVA test followed by Bonferroni's *Post hoc* test were used to compare the mean root canal length and WL (in mm) between actual and three different apex locators.

Chi-square test was used to compare the difference in the tolerance level of measurement difference for root canal length and WL between three apex locators.

The level of significance (p-value) was set at $p < 0.05$.

Results

Comparing the readings of the three apex locators with CBCT measurements showed that CanalPro gave highly accurate readings. Root ZX Mini readings were closer to CBCT values while Apex ID gave longer readings (Tables 1 and 2 and Figs 1 and 2).

Discussion

Cone-beam computed tomography (CBCT) is a contemporary radiographic imaging system that produces undistorted images which can be displayed in axial, sagittal, or coronal planes providing

Table 1: Comparison of mean root canal length (in mm) between actual and three different apex locators using repeated measures of ANOVA test

Methods	*N*	*Mean*	*SD*	*Min*	*Max*	*p value*
CBCT actual	30	10.62	1.38	7.8	12.5	<0.001*
JM	30	10.77	1.42	8.0	13.0	
CP	30	10.66	1.40	8.0	12.5	
AI	30	10.98	1.42	8.0	13.6	

*Statistically significant. JM, J-Morita apex locator; CP, canalpro; AI, apex ID

Table 2: Comparison of mean working length (in mm) between actual and three different apex locators using repeated measures of ANOVA test

Methods	*N*	*Mean*	*SD*	*Min*	*Max*	*p value*
CBCT actual	30	10.11	1.39	7.3	12.0	<0.001*
JM	30	10.36	1.39	7.5	12.0	
CP	30	10.18	1.37	7.5	12.0	
AI	30	10.46	1.46	7.5	12.5	

*Statistically significant. JM, J-Morita apex locator; CP, canalpro; AI, apex ID

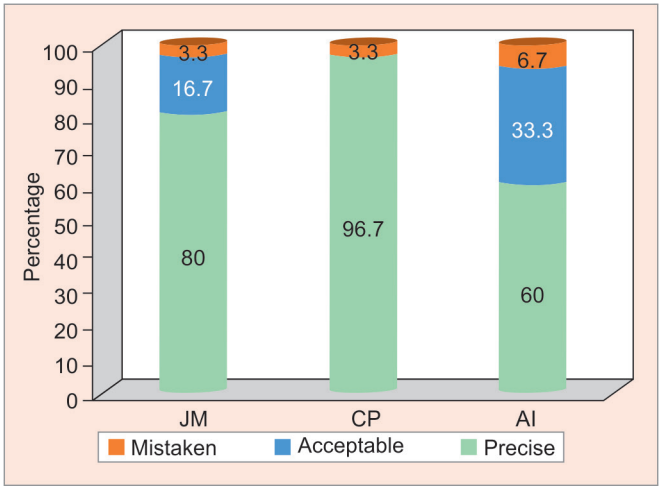

Fig. 1: Distribution of the tolerance level of measurement difference for root canal length between three apex locators

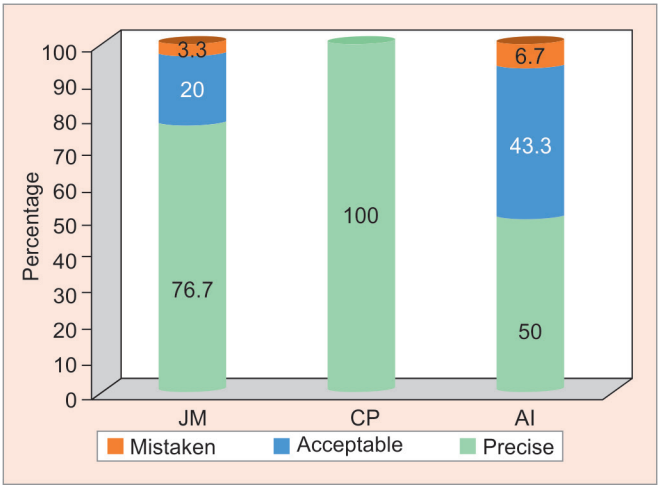

Fig. 2: Distribution of the tolerance level of measurement difference for WL between three apex locators

a three-dimensional view. There is increasing use of CBCT in recent times for diagnosing root canal anatomy, root fracture, periapical pathology, and root resorption. Compared to CT, CBCT has several advantages such as lower cost, ease of use in dentistry, the smaller size of scanner, and low radiation dose.[2,12]

WL is commonly determined using radiographs and electronic apex locators. Recent studies have evaluated the use of CBCT for WL determination and found it to be highly accurate.[13] A prospective *in vivo* study by Jeger et al. stated that high accuracy is seen with CBCT showing a mean difference of 0.51 mm between CBCT and electronic apex locator measurements. Thus, CBCT measurements are helpful in calculating WL.[7,8] A pilot study by Janner et al. investigated the utilization of pre-existing CBCT scans for accurate WL measurement. They reported a close match between EAL readings and CBCT measurements of WL. The mean difference was 0.4 mm (range 0.03–1.6 mm).[8] Hence, in the present study CBCT was used for WL calculation and verify the accuracy of three newly introduced apex locators.

Electronic apex locators are presently most popular for accurate estimation of WL. The principle of these devices is based on the electrical conductivity of the apical periodontal tissues being higher than the conductivity inside the root canal in the absence or presence of irrigating solutions.[9] Root ZX Mini (J Morita, Tokyo, Japan) is a smaller replica of Root ZX and its working principle and accuracy have been reported to be similar. Apex ID (SybronEndo, Glendora, California) is also based on the impedance principle but operates at two different frequencies of 0.5 and 5.0 kHz. CanalPro (Coltene-Endo, Cuyahoga Falls, Ohio) is another newly introduced EAL that ascertains the mean square root values for two alternating frequencies. The manufacturers claim that this device exhibits superior accuracy as the readings for each frequency are measured independently.

In the present study, WL was assessed for the mesiobuccal canals of mandibular first molars as these usually exhibit multiplanar curvatures making WL estimation difficult. The position of the apical constriction does not coincide with the root apex.[14]

The methodology of our study is similar to the one employed by Piasecki et al. which closely mimics the clinical situation.[14] In the present study, the samples were decoronated and a flat reproducible reference point was created for accurate measurements. Following this, the coronal third was preflared. To mimic the clinical situation, the teeth were mounted in alginate impression material, which is an adequate electroconductive medium. For EAL calculations, both apex mark 0.0 and 0.5 marks were used as a reference for WL. This is in accordance with previous studies.[3,12]

The results of the present study showed CBCT values were very similar to the readings of CanalPro. Readings with Root ZX Mini (J Morita) were slightly higher, whereas Apex ID showed much longer readings than the other two EALs. A previous study comparing CanalPro and CBCT for WL estimation in primary teeth reported similar accuracy for both.[15]

An *in vivo* study compared the accuracy of CanalPro, Apex ID, and Root ZX Mini apex locators in different simulated clinical conditions. CanalPro showed the highest accuracy and a very strong correlation when compared to actual length in all conditions with an acceptable accuracy percentage above 90%.[16] Manufacturers' instructions of using 0.0 mark were followed for CanalPro measurements (Fig. 3). The present results support the use of the 0.0 mark of this device to locate the AF, which yielded precise measurements (0.5 mm) in 91.4% of the cases. Similar to the other EALs, the 0.5 mark of the CanalPro may be used to indicate the position of the AC (Fig. 4).

Fig. 3: Working length (WL) recorded at 0.0 mm or at the apex by CanalPro

Fig. 4: Working length (WL) recorded at 0.5 mm short of the apex by CanalPro

Although the readings with Root ZX Mini were slightly higher than those of CanalPro, this difference was not of any statistical significance. Overall, our findings indicated that both CanalPro and Root ZX mini were similar in their accuracy. A recent *in vivo* study compared the radiographic WL values with that obtained by three electronic devices: Root ZX, iPex, and Apex ID. The authors concluded that Root ZX readings closely matched with radiographic WL, followed by Apex ID and iPex which were less accurate.[17]

Apex ID (Sybron Endo, USA) is another new apex locator that guarantees high levels of precision. The device also works on the principle of dual-frequency comparative impedance. The microprocessor in the device analyzes the change in micro signals and converts the difference into a distance value. This is displayed clearly on the Apex ID liquid crystal display (LCD). In the present study, Apex ID readings regarding the actual tooth length and WL were significantly longer than Root ZX. This is also in accordance with the findings of a previous study.[17]

For routine endodontic treatment, EALs should be used in conjunction with radiographs for the accurate establishment of WL. In order to minimize radiation during treatment, EALs should be used first in precisely locating the apical constriction followed by a confirmatory radiograph. In the case of patients with pre-existing CBCT scans, the additional information about the third dimension provided by these scans may be valuable in correct WL estimation. Thus CBCT can be considered as an alternative means to aid in the calculation of WL.[7] Cone-beam computed tomography (CBCT) can be a valid tool to assess the accuracy of recent generation EALs.

Further clinical studies are necessary to compare CBCT and EALs for WL determination in different types of teeth, that is, incisors, canines, premolars, and molars.

Conclusion

Cone-beam computed tomography (CBCT) offers a new imaging modality to verify the accuracy of EALs. In the present study, CanalPro readings closely matched those of CBCT measurements. Root ZX mini readings were slightly less accurate than CanalPro. Apex ID showed longer readings. More *in vitro* and *in vivo* studies are needed to confirm the accuracy of new EALs.

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