

Distance From File Tip to Apical Constriction/Apical Foramen in Relation To Numeric Scale Reading on Display of Two Electronic Root Canal Length Determining Devices

Paras Mull Gehlot , Upendranatha Reddy, Sowmya Halasabalu Kalgeri , Annapoorna B M

Abstract: Modern Electronic root canal length determining devices (ERCLD) or Electronic apex locators (EALs), claim to determine accurately the tooth length based on the principle of measuring the impedance between the canal fluid and tip of the file with various frequencies. Many manufacturers claim the electronic apex locators (EALs) to exactly display the reading corresponding to the canal parameters. This invitro evaluation compared if the marks “0.5” and “0.0/APEX” on the display of two EALs Sybron endo Apex ID (SID) and Mini apex locator (MINI) were accurately representing the apical constriction or the apical foramen respectively. **Materials and Methods:** Sixty extracted, single rooted human teeth were used with alginate model. The electronic length was determined using 2 EALs, at the numeric scale/target “0.5” and “0.0/APEX” mark using K-file (electrode). After cementing the file coronally with type II glass ionomer cement, the apical 3–4 mm was trimmed until the file tip was visible under an operating microscope (X16). Images were captured under Dental operating microscope and the error between electronic length (EL) and actual length (AL) at target interval 0.5 (apical constriction) and 0.0 (major foramen) were analyzed by used Image J software. **RESULTS:** t-test revealed statistically significant differences between EL determination and AL for both EALs, at “0.0”/Apex, $p=0.001$, and at 0.5 (apical constriction) $p=0.007$. **CONCLUSION:** The numeric meter display of newer generation EALs like Apex ID, represent better correlation with the histologic landmarks and could become a useful guide for inexperienced clinicians, however they do not always indicate the position of the file in the canal.

Index Terms: Electronic Root Canal Length determining device, Electronic Apex locators, Numeric Meter Reading, Apical foramen, Apical Constriction

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Paras Mull Gehlot, Reader, Department of Conservative Dentistry and Endodontics. JSS Dental College and Hospital, JSS Academy of Higher Education & Research. Mysuru, Karnataka, India. . Email: dr.parasmullj@jssuni.edu.in

Upendranatha Reddy, Professor. Department of Conservative Dentistry and Endodontics. G Pulla Reddy Dental College and Hospital. Kurnool. Andhra Pradesh, India. Email: upendrareddy@hotmail.com

Sowmya Halasabalu Kalgeri, Senior Lecturer, Dept. of Conservative Dentistry and Endodontics. JSSAHER. Mysuru, Karnataka, India. Email: sowmyahk84@gmail.com

Annapoorna B M, Professor and Head. Department of Conservative Dentistry and Endodontics. JSS Dental College and Hospital. JSSAHER, Mysuru, Karnataka, India. Email: annapoornabm10@gmail.com

I. INTRODUCTION

Accurate estimation the Root canal length (working length-WL) is one of the key determinant in the success of endodontic therapy [1]. One of the common method of WL determination is the radiographic technique, but its disadvantage include the technique sensitivity during exposure and interpretation [2].

The use of Electronic Apex Locators (EAL) or Root canal length determining devices (ERCLD) for measuring length of root canal have obtained popularity and minimizes the problems encountered with conventional radiographic technique [3]. Suzuki discovered that the electrical resistances between the periodontal ligament and the mucosa of oral cavity registered constant values of 6.5 k Ω [4]. This principle formed the basis for the development of many EALs [3],[5].

EALs are widely used for locating the apical constriction or minor diameter (AC) [6]. Apical constriction has been considered ideal for terminating/establishing the working length during endodontic procedures [1],[7]. The new generation of EALs determine the position of AC by estimating the slight changes in the impedance values between the tip of file within the root canal generated by electrical impedances with different frequencies [5]. Regardless of the presence of electrolyte, canal conditions or the type of alloy of file, the stability and the precision of readings of newer EALs have increased in past few decades [2],[5],[8],[9].

According to Neekoofar, the narrowest portion of root canal is the apical constriction (minor apical diameter) and identification of this AC is unpredictable due to the presence of many morphological variations [5],[10].

The mark “0.5” on the display of many EAL device is claimed by manufacturers to indicate the position of file tip at the AC [11],[12]. As a result the “0.5” mm for apical constriction; and the mark between 0.5 to 1 mm have been used for electronic measurements by various studies [13],[14].

Literature study reveals a controversy if EALs can detect the apical constriction or apical diameter [6],[15],[16],[17].

Hence the objective of the present investigation was to establish the association between the numeric reading (0.0 mark/0.5 mark) on the EALs display and the distance between the file tip to apical constriction/apical foramen in two different generation EALs Apex ID (SybronEndo, Glendora, CA) and MINI (SybronEndo Glendora, CA).

II. MATERIALS AND METHODS

A total of sixty freshly extracted human teeth, with straight and single-root configuration were used for the study. For disinfection 5% Sodium hypochlorite solution was used for a duration of 3 hours. The single canal configuration (type I) was confirmed radiographically in two planes (Buccolingual and Mesiodistal) by digital radiograph (Oralix Gendex, Dentsply, Italy). Exclusion criteria included root resorption, immature apex, calcified and curved canals. For providing a stable reference during length measurements, at the level of cement-enamel junction the crown and root were separated using a diamond disc. Coronal preflaring was done using the Gates glidden drills sizes 4-2, and 1% Sodium hypochlorite (Nice chemicals, India) was used for canal irrigation. A barbed broach (Spiro Colorinox, Dentsply Maillefer) was used to remove the pulp from the canal. Patency in the canal was confirmed with a #10 K-file.

To simulate the periodontium alginate model was used [18]. Apical two-third of the teeth were embedded in polystyrene specimen bottles (40 mL), containing alginate (Algitek, DPI, India). The lip electrode of the EAL was also placed in the alginate adjacent to the teeth to complete the circuit.

Teeth were randomly assigned to 2 groups of 30 each based on selected numeric meter reading on the EAL : Group I, apical extent for working length determination on the EALs was set at "0.0" (Apex ID) and "APEX" (Mini apex locator); and in Group II the apical extent on the EALs was set at "0.5" (Apex ID and Mini apex locator).

The EALs were used according to the manufacturers' instructions [11],[12]. Using a 23 gauge needle, root canals were irrigated with 1% sodium hypochlorite (Nice chemicals Pvt Ltd). A stainless steel hand K-file (size #15-#20) with the file holder was inserted into the canal progressing apically until the EAL displayed the "set" numeric reading ("0.0" or "0.5") for about 5 seconds on the respective EAL (Figure 1). After positioning the silicone stoppers (double) to the coronal reference, the file was removed and the distance between file tip and silicon stopper was determined using a digital caliper (CD-6" CSX, Japan).

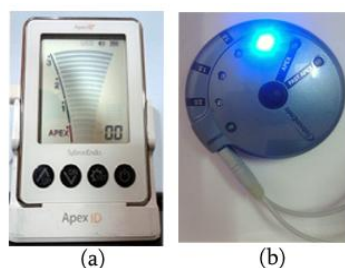


Fig 1 . (a) Apex ID- with LCD screen display and (b) Mini apex locator – with LED.

This was recorded as electronic length (EL). After determining the EL with both the devices, the apex locator that was used last was taken and the respective file adjusted to EL in the canal and cemented with light cured type-II Glass ionomer cement (GIC) (FUJI II, GC Corporation, Japan). The length was reconfirmed by the respective EAL to make sure that GIC placement did not disturb the measurement. To avoid bias, the EALs were used in an alternate manner on each tooth to allow for equal distribution of the file cementation in the canal. Each root

was sectioned apically about 4 mm in a longitudinal direction by using a fine diamond bur (Mani Japan) and fine soflex disk (3M ESPE, USA) to expose the file tip and the root canal.

A dental operating microscope (OPMI Pico, Germany) with magnification of X16, was used to observe the apical portion of the specimens by one investigator, blinded at which EAL was used. Images were captured to measure distance between file tip and histologic landmark (AC or Apical foramen). (Fig 2)

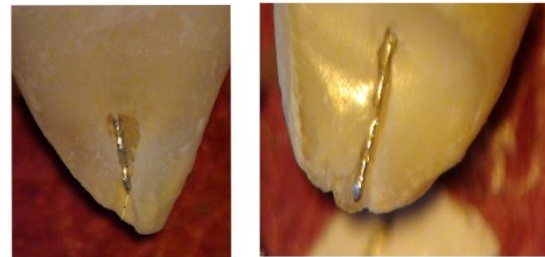


Fig 2. Apical 4 mm of root prepared to locate the position of file tip. Image J software was used to estimate the distance between the tip of file to the apical constriction/foramen.

In group I, the distance between the file tip and the apical foramen was estimated using Image J software, (National Institutes of Health, Bethesda), and the values were recorded. This distance was added or subtracted to the EL to obtain the Actual length (AL) which was used as control [19]. The mean error was calculated comparing the electronic length obtained by each device and actual length. Similar procedure was carried for group II, by measuring distance between the file tip to the apical constriction for both EALs.

The data obtained were tabulated and statistically analyzed using paired sample *t*-test to evaluate the accuracy of two EALs in determining the end points (0.0 or 0.5). The *p* value < 0.05 was selected as significant. SPSS software (ver.21, SPSS Inc., USA) was used for statistical analysis. To illustrate the distribution of distances between file tip and apical foramen or apical constriction the Bland-Altman plot used with upper and lower limits of agreement (Figure 3).

III. RESULTS

Mean length and the mean difference between the AL and EL for both EALs in group I (0.0 mark) and group II (0.5 mark) were determined and are presented in Tabular format (Table 1 and 2). Statistically significant differences were found between EL determination and AL for both EALs, at "0.0"/Apex, $p=0.001$, and at 0.5 (apical constriction) $p=0.007$.

In group I, 76.6% of file tips electronically measured by APEX ID were found ± 0.5 mm of apical foramen ("0.0") and for MINI this was 40%. For APEX ID, the maximum distance between the tip of file and the apical foramen was - 1.24 mm, and in MINI, the maximum distance between file tip and apical foramen was 1.43 mm. Majority of the readings were short of the apical foramen. (Negative value indicates, distance short of apical foramen)

In group II, the probability of reaching ± 0.5 mm of the target apical constriction was 43.4% for APEX ID, and 36.7 % for MINI apex locator.

For APEX ID, the maximum distance between file tip and the target interval (AC) was -1.6 mm, and for MINI, this was -2.01 mm. Box plot were used to analyze the distribution of the measurements with outliers.

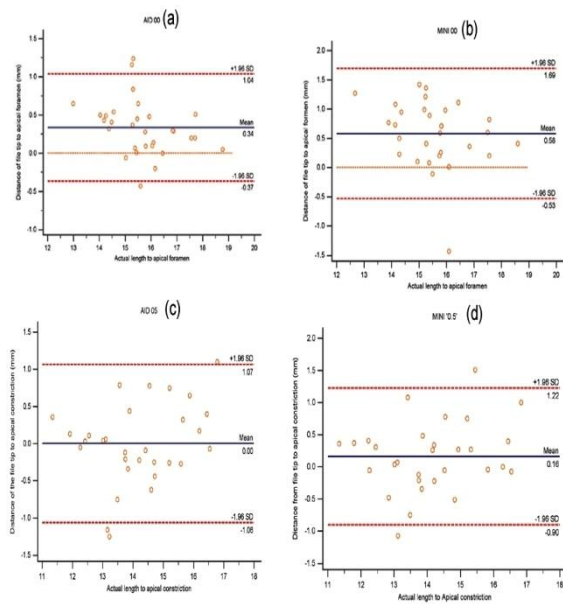


Figure 3. The Bland-Altman plot illustrates the distribution of distances between the file tip to the apical foramen (00) and apical constriction (0.5) with the upper and lower limits of agreement for both Apex ID and MINI. (a,b for Group I and c, d for Group II)

IV. DISCUSSION

This study evaluated the accuracy of two EALs namely the Apex ID and Mini apex locator, which operate differently with regard to their frequency at two apical scale points (0.5 and 0.0). Apex ID is a dual frequency (0.5 and 5.0 kHz) device with microprocessor that detects the change in micro signals of the circuit and converts the difference into a distance value, which is projected on the LCD. According to manufacturer the firmware of Apex ID is upgraded than other devices. Depending on the distance between the file end and the canal end, the impedance of the electric circuit may be vary, which results in a change in the micro signals that are sent back to unit. Accordingly, the zero point can be customized at “0.0” (apical foramen) or “0.5” (at or near apical constriction) [11].

Mini Apex Locator (SybronEndo, Glendora, USA), is an older model from the same manufacturer; it is a compact device with multifrequency digital system and according to the manufacturer it accurately measures the location of the apical terminus [12].

Most of the studies agree that the position of apical constriction (AC) is approximately 0.5-1 mm short of apex [5]. Classic studies by Kuttler have discovered the apical constriction to be at average distance 0.5-0.75 mm from the apical foramen, and there was an increase in this distance due to deposition of cementum. [7]. Studies on precision of EALs have concluded that there are controversies if these electronic devices detected apical contraction or apical foramen [15]. However, many of evaluations have used the electronic readings for the apical constriction between the 0.5 mm and 1 mm mark of the device display[13],[14].

Studies using modern EALs claim that these device are highly precise in location of both apical constriction and apical foramen. However, some studies have questioned the

accuracy of these devices as the file approaches the apical region and the correlation between file position in the canal and the meter readings [21]. The type of display may also effect the accuracy of EALs [17] so does the distance of the file to the apical foramen [18],[21],[22].

A study by de Vasconcelos *et al* compared the accuracy of Root ZX II, Propex II, and Apex ID at different apical positions (obstructed apical foramen, 1.0 mm short of the apical foramen and at the AF). The accuracy rates (± 0.5 mm) at OAF, -1.0, and the at AF were 75.4%, 68.5%, and 93% for AID, respectively [23]. In the present study, the accuracy of AID at “0.0” was 76.6% and at 0.5, was 43.4%, which is less compared to previous studies. Oliveira *et al*, evaluated accuracy of six EALs and using various protocols and the found the lowest mean error values were observed at “0.0” ie., 0.10 mm for Root ZX and 0.16 mm for Apex ID. They concluded apical foramen could be located by EALs and the mechanism of operation of device has little effect on the accuracy. The study also highlighted the step of electronic withdrawal did not significantly help in accurately determining the position of AF [24]. In the present study, lowest mean error for apex ID at “0.0” was 0.43 mm; and at “0.5” was 0.75mm.

Piasecki *et al*, evaluated the accuracy of Apex ID and Root ZX by using micro-CT, visual and electronic methods. The study found at “0.5” mark, Apex ID was 60.6% (± 0.5 mm) accurate and Root ZX was 63.6 % accurate. However, when 0.5 mm was subtracted from Apex/0.0 mark, the accuracy for Apex ID was 48.5 % (± 0.5 mm) and 57.6% for Root ZX. The authors concluded that working length could be determined at “0.5” mark for both Electronic apex locators and it was not necessary to subtract 0.5 mm from the reading while using “APEX/0.0” mark [25].

The above statement is in contrast to some authors who suggested that the EALs accuracy to detect the apical constriction may be increased by slightly advancing the instrument deeper in canal and then retracting until display shows the desired landmark [26]. But there is a risk of pushing the infected debris beyond the apical foramen and also the apical foramen may be damaged [17].

Studies have found inaccuracy in EALs whenever the instruments are advanced or withdrawn in the canal. This was due to the fact that, when advancing the instrument into the canal and retracting from the canal, it will no longer be adapted closely to the walls, and this could cause impairment in the interpretation of the capacitance factor of

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Table 1: Mean (SD) of AL and EL measurements, and mean differences between AL and EL determined at “0.0/APEX” and “0.5” numeric mark of display on AID and MINI

		0.0			0.5			
	Actual length (SD)	Electronic Length (EL)			Actual length (SD)	Electronic Length (EL)		
n=30		AID (SD)	MINI (SD)	p		AID (SD)	MINI (SD)	p
Length (mm)	15.83 (1.20)	15.50 (1.31)	15.25 (1.35)		14.70 (1.53)	14.19 (1.39)	14.03 (1.41)	
Mean difference (mm)		- 0.3360 (.36)	-0.5803 (.56)	.001		-0.5010 (.54)	-0.6640(.54)	0.007

Negative value indicates measurements short of the actual length. AL: Actual length, EL: Electronically measured canal length

the impedance determined by the electronic apex locators [5],[23],[24].

Hor *et al.*, questioned whether the probability to hit the target interval (major foramen – minor foramen) could vary for different apex locators in a given canal; and does the canal length estimation depend on the scale point on the display of device or particular frequency used in the measuring circuit [17].

Table 2: Incidence (%) of Measurements Equal to and Different from the AL at the “0.0” and “0.5”

0.0			0.5		
Interval	APEX ID	MINI	Interval	APEX ID	MINI
-2 to -1.51	-	1 (3.3%)	-1.5 to -1.01	2 (6.7%)	1(3.3%)
-0.5 to 0.01	3 (10%)	1 (3.3%)	-0.5 to 0.01	2 (6.7%)	2(6.7%)
-0 to 0	1 (3.3%)	0 (0%)	-0 to 0	0 (0%)	-
0.01 to 0.5	19 (63.3%)	11(36.7%)	0.01 to 0.5	11 (36.7%)	9 (30%)
0.51 to 1.0	5 (16.7)	11 (36.7%)	0.51 to 1.0	10(33.3%)	13 (43.3%)
>1.5	2 (6.7%)	6 (20%)	>1.5	5(16.7%)	5(16.7%)

Based on the impedance quotient measurements, modern EALs, by measuring the impedance between file tip and canal fluid with different frequency, can determine an area between the apical constriction and apical foramen by measuring the impedance between the file tip and the canal fluid with different frequencies [2],[16],[17],[27]. Accordingly, accurate determination of apical constriction position with an apex locators is not possible, however, the measuring error for electronic measurements can be limited apically to the apical/major foramen [16],[17]; and the position of the tip of the file is limited coronally to a position apical to the canal constriction [27]. Hence, as suggested by Hoer *et al.*, extensive correction of EALs readings can be achieved by empiric calibration of different scales and devices in extracted human root canals [17],[27]. Venturi concluded that the readings were most accurate at apical foramen, than the file located coronally [22]. Studies by Voß and siebenkees have shown that based on the resistance of the dentin, a point between the apical constriction and apical foramen could be determined by the EALs [28].

Modern EALs determine the electronic length of root canal by impedance between the canal fluid and the file using different frequency (Multifrequency). The impedance of electrode is measured by calculating the quotient of these

measurements; higher value is recorded at the foramen and least at the constriction [2],[16],[27].

According to Gulabivala and Stock, since the impedance characteristics for the canal coronal to apical foramen cannot be calibrated accurately, highest accuracy of EALs can be achieved at “apex/0.0” mark [29]. As the tip of the file approaches the foramen the accuracy of apex locators increases [22]. In the present study, each apex locator was set at two different apical landmarks, i.e., at “00/AF” and “0.5/AC” and majority of positive results were found with 00/AF readings. Mayeda *et al.*, suggested the vitality of pulp could have an effect on accuracy of EALs. Accordingly, the vital pulp may have a different impedance value compared to necrotic [20]. Contrarily, a study found there was no influence of pulp vitality and the foramen location on the working mechanism of the EALs [30]. The impedance measurements are also affected by the diameter of the canal in the apical third. A study reported that in a small diameter apical foramen (approximately 0.2mm) the resistance of the canal from the file tip to the apical foramen is decreased and a part of the current might flow through the dentin. The authors also highlighted the multifrequency methods advantage in accurate determination of canal length by calculating the ratio between impedances measured (or simulated) at two (or more) frequencies [31]. The current conduction in the canal varied between different positions of the file. Accordingly, current flows predominately via the dentin if the file tip is far from the apical foramen, while the current flow via the dentin decreases and increases through the apical foramen if the file tip is close to or in contact of the apical foramen [32]. The microprocessor of Apex ID could be the reason for consistent results of device, which calculates the change in microsignals to convert the difference into a distance value, which will be displayed on the LCD display. The output of Mini apex locator is digital LED signal and is separated linearly. This is a laboratory study which a major limitation.

V. CONCLUSIONS

To summarize, the numeric meter reading on display of newer generation electronic root canal length determining device represent better correlation with the histologic landmarks and could become a useful guide for inexperienced clinicians, however they do not always indicate the position of the file in the canal.

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AUTHORS PROFILE



Dr. Paras Mull Gehlot is working as a faculty, Department of Conservative Dentistry and Endodontics, JSSDCH and former member of UG board of studies in JSS Academy of Higher Education & Research, Mysore. He is an active member of Indian Endodontic Society and Indian Association of Conservative Dentists and Endodontists. He has been as Under-graduate and Post-graduate examiner. He is NAAC co-ordinator at department level. He has authored publication in national and international journals. Has presented scientific papers at national level conferences. He has received research fund as a co-investigator on research on nanohardness of restorative dental materials from government agencies viz. ICMR. His area of interest include regenerative endodontics, electronic apex locators, endodontic irrigants and endodontic traumatology.



Dr. Upendranatha Natha Reddy is professor working in the Department of Conservative Dentistry and Endodontics, at G Pulla reddy Dental college, Kurnool. He is an active member of Indian Dental Association and Indian Association of Conservative Dentists and Endodontists. He has been as examiner for various universities for under-graduate and post-graduate studies. Author to several publications, his area of interest include 3D printing in endodontics, Endodontic imaging using Cone beam CT and regenerative endodontics.



Dr. Sowmya H K is faculty in the Department of Conservative Dentistry and Endodontics, JSSDCH. She is an active member of Indian Association of Conservative Dentists and Endodontists. She is member in Anti-ragging flying squad and student counselor. She has several national publications and has represented herself in various national conferences. Her area of interest include rotary endodontics, internal anatomy of tooth and imaging in endodontics.



Dr. Annapoorna B M is professor and Head of Department of Conservative Dentistry and Endodontics, JSS Dental college and Hospital. She is member of PG board of studies; and a PG and PhD guide in JSS Academy of Higher Education & Research, Mysore. She is a life member of Indian Association of Conservative Dentists and Endodontists. Dr Annapoorna has been as examiner for interstate under-graduate and post-graduate students. She has authored several publication and also presented scientific papers in numerous national and international conferences. Her area of interest include management of root caries, herbal etchants, micro-shear bond strength studies and dental traumatology. She has guided research projects funded by government agencies like ICMR.