“Influence of Different Irrigants on the Accuracy of Two Electronic Apex Locators- An In-Vivo Study”

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BRANCH IV

CONSERVATIVE DENTISTRY & ENDODONTICS

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

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2017 - 2020

DECLARATION BY THE CANDIDIATE

I hereby declare that this dissertation titled **"Influence of Different Irrigants on the Accuracy of Two Electronic Apex Locators- An In-Vivo Study"**is a bonafide and genuine research work carried out by me under the guidance of **DR. P. HEMALATHA, M.D.S., Professor, Head of the Department,** Department of Conservative Dentistry and Endodontics, Best Dental Science College, Madurai - 625104.

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"Gratitude is the fairest blossom which springs from the soul."

– Henry Ward Beecher

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DURATION OF THE COURSE	**3 YEARS**
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And

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And

Dr. D.S.VENKATA RAMANAN, aged 25 years, studying as **postgraduate student** in the Department of Conservative Dentistry and Endodontics in Best dental Science College. Madurai-625104 (Herein after referred to as the PG/research student and co-investigator).

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LIST OF ABBREVATION USED
(In Alphabetical Order)

ABBREVATION	WORD EXPLANATION
ACL	Anatomic Canal Length
CBCT	Cone Bean Computed Tomography
CHX	Chlorhexidine
EAL	Electronic Apex Locator
EDTA	Ethylene Diamine Tetra Acetic Acid
ERCLMD	Electronic Root Canal Length Measurement Device
EWL	Electronic Working Length
IAF	Initial Apical File
KHz	Kilo Hertz
MAF	Master Apical File
RMS	Root Mean Square
WL	Working Length
µCT	Micro Computed Tomography

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INTRODUCTION

INTRODUCTION

Working length (WL) is defined as the distance from a coronal reference point to the point at which the canal preparation and obturation should terminate (American association of Endodontists 2003)[1]. As per the definition the endodontic therapy is mainly concerned with the WL within which all the procedures must terminate without any violation for a successful outcome.

Inaccurate working length determination may lead to short or over extended obturation. Initially before radiographic methods were introduced the determination of WL was approximated to where the patient experiences pain. The two crucial spots of apex while determining WL are minor apical constriction and major apical constriction. Apical constriction is located 0.5-0.75 mm coronal to the major foramen which is located 0.5 mm from the terminus. Blaney and Coolidge in 1920's stated that if obturation done slightly short of the apex will give best outcome. According to Kuttler on his microscopic study, the narrowest diameter does not determine the site of the exit of the canal and concluded that the average distance between the major and minor foramen is 0.524mm-0.659mm[2]. According to Ricucci and Langeland the constriction is of meagre blood supply and thereby even smallest wound site would result in best healing.

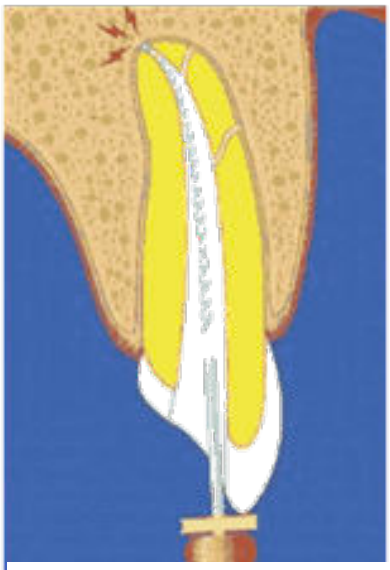

Figure 1 Determination of working length

According to American Association of endodontists (1984), The radiographic apex is defined as the anatomical end of the root as seen on the radiograph, while the apical foramen is the region where the canal leaves the root surface next to the periodontal ligament.

The success of the RCT is mainly dependent on proper cleaning and shaping of the canal space. To effectively clean and shape the root canal space the apical target i.e. apical constriction should be determined accurately[3]. Traditional methods for establishing working length have been (a) the use of anatomical averages and knowledge of anatomy, (b) tactile sensation, (c) moisture on a paper point and (d) radiography.

Tactile sensation, although useful in experienced hands, has many limitations. The anatomical variation in apical constriction location, size, tooth type and age make working length assessment unreliable. In some cases the canal is sclerosed or the constriction has been destroyed by inflammatory resorption (Stock 1994). Seidberg et al. (1975) found that, even among experienced clinicians, only 60% could locate the apical constriction by using tactile sense[4].

Leeb et al found that tactile acuity in probing for the apical constriction could be enhanced by enlargement of the coronal level of the canal space. When the orifice and coronal portions of the canal were initially instrumented, that is pre-flared, Stabholz et al. were able to probe to within 1.0 mm of the radiographic apex with a 75% accuracy rate, compared with an accuracy rate of 32% in unprepared canals. Thus, pre-flaring may offer the clinician an intuitive sense to go with either the electronic indication or radiographic data.

Traditionally, radiography has been the most used method in obtaining information on the anatomy of the root canal and its surrounding tissues. However, the working length measurement performed radiographically presents several limitations, namely radiation exposure, time expenditure and difficulty of interpretation because it is a 2-dimensional image that is often overlapped with anatomic structures and is subject to the interpretation of the observer[5]. When the apical foramen exits to the side of the root either in a buccal or lingual direction it becomes difficult to view on the radiograph. Dense bone and anatomical structures

can make the visualization of root canal files impossible by obscuring the apex. The superimposition of the zygomatic arch has been shown to interfere radiographically with 20% of maxillary first molar apices and 42% of second molar apices. The disadvantages of this method are lack of possibility to reflect the actual length of the root, difficulty with setting the proper projection, two-dimensional image, necessity for exposure to radiation and occurrence of interpretational differences. With concerns over radiation exposure and the increased use of electronically stored patient records, several types of digital radiography machines have been introduced. These use sensors instead of film and have several advantages over conventional radiographs such as reduced radiation exposure, speed of image acquisition and the possibility of enhancing or editing the image[6].

To overcome the hazard of radiation in radiographs and operator variability in tactile response, the electronic method of WL determination was invented called as Electronic Apex Locators (EAL) which is based on the electrical principles of resistance, capacitance and impedance depends upon the various generations of the EAL used. The root canal has dentin and enamel which are insulators to the electric current. Dentin along the tissue fluid inside the root canal forms a resistor which the values depends upon the dimensions and resistivity.

The endometric method assumes determining the working length of the root canal with the use of electric devices, the so-called endometers (electronic apex locators (EALs). Use of EAL's are not only can reduce the exposure to the X-ray but also reduce the time lapse for repetition of radiograph if necessary, leading to accurate measurement. Nevertheless, the electronic technique do not have an unquestionable reliability, because it may produce interference with metal restorations, submit wrong lengths and unstable readings, and is more expensive[7]. Despite the latter, the use of EAL has become increasingly popular, but an unequivocal consensus about the comparative accuracy between both methods is lacking and

therefore needed. Hilu et al (2006) reported that in all tested conditions the EAL with radiographic interpretation allow an improvement in the precision of working length.

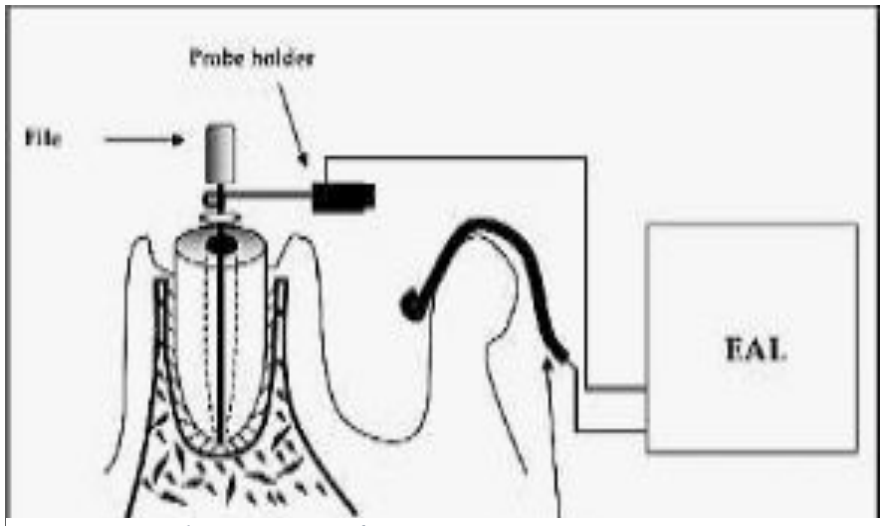

Figure 2 Working circuit of ERCLMD

EAL operate on direct current which is supplied by a unit where one electrode is in contact with the tooth which is a file and other contacts the soft tissue by a lip clip. When the tooth electrode is in contact with the periapical region the circuit completes and WL is determined. This is the basic working principle of an EAL. Found et al (2000) reported that using an EAL before radiograph would enhance the length control throughout the treatment thereby improving the length of the obturation from the apex and reduce the number of radiographs. Smadi et al (2006) reported that correct use of EAL could prevent further need for diagnostic radiographs.

A randomized clinical trial published by Ravanshadet et al(2007), evaluated the working length determination comparison between radiograph and apex locator on the adequacy of final working length. The observed differences were EAL's were of more reliable and number of required radiographs were lesser. Chakravarthy Pishipati et al have observed that EAL's are

more efficient in WL determination than radiographs and thereby reduce the possibility of over estimation.

Apex locators found to be reliable method next to CBCT although histological cross-sectional studies found to be gold standard based on Kuttler's study[8]. But severing a tooth is not a good decision to measure the working length. CBCT have high range of radiation exposure compared with digital radiography. As well as it is not a reliable method in terms of economy. Hence, EAL's can be considered best for in vivo evaluation of the working length. Despite this, the precision of electronic working length measurement depends on the device used, the type of irrigant and root canal anatomy variabilities. It has been reported that a large apical size can affect the variation in impedance values, especially seen in open apex cases, apical resorption as well as following over- instrumentation. It has also been

Direct current	**Original Ohmmeters used by Suzuki and Sunada (1942)**			
Alternating current	Resistance type	• Root canal meter/the endodontic meter (Onuki) • Sono explorer (Satəlec) • Neosono-D, MC • Ultima EZ (Amadent) • Apex finder (EIE-old version)		
	Impedance type	Endocator uses 400 kHz		
	Frequency type	Subtraction type	Endex/Apex (Osada) uses 1kHz and 5kHz Neosono Ultima EZ (Amadent)	
		Ratio type	2 frequencies	Root ZX (J Morita) uses 0.4 kHz & 8 kHz
			5 frequencies	The AFA apex finder (Sybron) Elements Diagnostic unit (Sybron)

Table 1 Classification of EAL's

demonstrated that capacity for electrical isolation of the root canal decreases in the apical third, as dentine tissue becomes less dense, possibly impacting on accuracy[4].

First generation apex locators: These apex locators use the resistance method for determining the WL. Basically these instruments measured the opposition to the flow of direct

current (resistance) and hence the name Resistance based apex locators. Initially an alternating current of 150 Hz Sine wave was used (Root canal meter, 1969) but the pain was felt by the patient due to high currents. Therefore modifications were made and new machines which used current less than 5 micro amperes were introduced (Endodontic Meter S II, Kobayashi, 1995). Since these machines were not found to be accurate, the research work continued to develop in this field.

Second generation apex locators: These apex locators use the Impedance method for determining the WL. Basically these instruments measure the opposition to the flow of alternating current (impedance) and hence the name Impedance based apex locators. These units utilize the current of a single frequency to perform the task. Formatron IV, Sono Explorer and Endocater are a few examples of this generation, almost all having the similar drawback of inaccurate readings especially in the presence of irritants in the canal.

Third generation apex locators: These apex locators use two frequencies instead of a single one to measure the impedance in order to determine the WL. With this scientific rationale these should be called “comparative impedance” type apex locators. However, the impedance of any given circuit is influenced by the frequency of the current flow, hence the name frequency based apex locators. The credit of being the first apex locator in this category goes to Endex. However it had the drawback of requiring calibration for each canal before use. Later came Root ZX, which did not require any calibration. It uses two different frequencies of 400 Hz and 8 kHz simultaneously to measure the impedance in the canal. Then it determines a quotient value by dividing 8 kHz impedance value by 400 Hz impedance value. The reading of minor diameter is revealed when the quotient value is 0.67. These apex locators had the upper hand over their predecessors in terms of accuracy and reliability. Other units falling into this category are AFA, Neosono Ultima EZ, Justy II, *etc*.

Fourth generation apex locators:These apex locators use multiple frequencies (2-5 frequencies) to measure the impedance in order to determine the WL. Multi-frequency measurement system is used to calculate the distance from the tip of the file to the foramen by measuring changes in impedance between two electrodes. Unlike the third generation, these ones do not use the impedance value as a mathematical algorithm only to assess the WL but instead utilize the resistance and capacitance measurements and thereafter compare them with a database to measure the distance of the file to the apex of the canal. This technology presumably leads to less sampling error and more consistent readings. Canal pro apex locator (Coltene) belongs to this category. The measurements in Canal Pro apex locator was performed using AC signals at two frequencies. The frequencies are alternated rather than mixed, as it is done in other apex locators, thus canceling the need for signal filtering and eliminating the noise caused by non-ideal filters. The RMS (Root Mean Square) level of the signal is measured, rather than its amplitude or phase. The RMS value is much more immune to various kinds of noises than other parameters of the measured signal. The two-field display with file tracking over the whole canal length and enlarged apical zoom makes this apex locator uniquely different from the existing third generation ones. The apex locators of this generation, so far, are the best in their category owing to their high accuracy and reliability. For a clinician, looking for high accuracy and reliability in their WL determination, the fourth generation apex locators would be the most ideal, for they can be trusted upon the most.

Although many generations of EAL are available but third generation ROOT ZX Mini made a benchmark when compared with the other apex locators regarding the accuracy calibrated to $\pm$ 0.5mm. So this study involves the comparison of Root ZX mini with Propex II which belongs to 3rd and 4th gen. EAL respectively. Root ZX uses two different frequencies (8 KHz and 400 Hz) simultaneously to measure the impedances in the canal. The device then determines a quotient value by dividing the 8 KHz impedance value by 400 Hz impedance

value. The minor diameter is located when a quotient equals 0.67. Root ZX can be used in canals filled with all types of fluids because the quotient (0.67) is always the same. Propex II is a 4th generation apex locator that uses two separate frequencies (400Hz and 800Hz). It is claimed that the combination of using only one frequency at a time and basing the measurements on the root mean square values of the signal frequency increases the measurement accuracy and the reliability of the device. Viera et al(2011) compared the accuracy of Root ZX Mini with four EAL and the radiographical method of WL determination which revealed the accuracy percentage as follows-Anterior teeth:89.1%; Premolars:75%; Molars:69%: but there was no significant difference. Also the short measures of Root ZX mini (1mm) was 0 % in all type of teeth except molars which was 1.3%; the long measure (0.5mm) was anterior: 10.9%; premolar:25% and molars: 29.7%, revealing significant difference between the apex locator and radiograph but no difference between the EAL's.

Wet contaminants in the canal were recognized as factors adverse to reliable performance. Consequently, one manufacturer placed plastic insulation over the electronic probe to prevent electrical conductance through moist canal contents[9]. However, the thickness of the insulating material prevented entry of the probe into tight and tortuous canals, especially at mid root and the apical level. Root ZX states that it can perform with high accuracy in the presence of sodium hypochlorite solution, blood, water, local anesthetic and pulpal tissues without the need to precalibrate the circuitry before locating the apical foramen.

Hence this In-vivo study is designed to evaluate the efficacy of EAL in both dry and wet conditions. Moreover 3rd and 4th generations EAL working principle is a proven fact that works in the presence of fluid inside the canal. For a basic current to pass in a solution there must be electron for the exchange of the charges thereby producing the flow of the current. Such electrons will be present in the electrolytic solutions. So the irrigants used in endodontics may have an influence over the accuracy of WL by EAL's.

Irrigation solutions used in endodontics usually helps in flushing the debris namely vital and necrotic tissues away from the canal as well as removing the smear layer helps in dentinal tubule penetration of the sealers. The ideal properties of a root canal irrigant are: it should be systemically nontoxic, should not harm the periodontal tissues, should not cause anaphylaxis, possess a broad antimicrobial spectrum, should be capable of dissolving necrotic pulp tissue, inactivating endotoxins and either preventing the formation of a smear layer or dissolving it once it has formed[10].

QMiX is a novel endodontic irrigant for smear layer removal with added antimicrobial agents. It contains EDTA, CHX and a detergent. QMiX is a clear solution, ready to use with no chair-side mixing. Mixing EDTA and CHX is known to produce a white precipitate. In QMiX, this is avoided because of its chemical design. Another recent concern in endodontic irrigation is a potentially carcinogenic precipitate between sodium hypochlorite and CHX. Despite the CHX content, mixing QMiX with sodium hypochlorite does not produce any precipitate and the solution does not turn brown/orange[11].

Influence of irrigation solution on EWL measurement:

- Electrolytes present in the irrigant may alter the accuracy
- Change in ionic activity during irrigation has influence over the accuracy of EAL's.

The irrigation solutions used in this study are Saline, Sodium hypochlorite and QMix which all contains electrolytes which may interfere with the electric current in EAL's. Saline is a hypotonic solution that just flushes the debris but do not dissolve any tissue contents. The safe use of saline is an advantage that it is biocompatible with the tissue fluids. Sodium Hypochlorite 5.25% solution has a greater tissue dissolving property with effective disinfection of the root canal at 20°C[12].

According to Anthony et al in the presence of sodium hypochlorite, Root ZX Mini and Propex II were found to have accuracy of 83% and 86.6% resp., explains the electrical conductivity of irrigant solution may interfere with the accuracy. The precision of electronic working length measurement depends on the device used, the type of irrigant and root canal anatomy variabilities. It has been reported a large apical size can affect the variation in impedance values, especially seen in open apex cases, apical resorption as well as following over- instrumentation. It has also been demonstrated that capacity for electrical isolation of the root canal decreases in the apical third, as dentine tissue becomes less dense, possibly impacting on accuracy[13].

AIMS AND OBJECTIVES

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The aim of the study was to evaluate the accuracy of two electronic apex locators in wet and dry conditions. Dry canal was considered as control and the presence of irrigation solution was considered as experimental groups.

APEX LOCATORS-

1.Root ZX Mini

2.Propex II

IRRIGATION SOLUTIONS:

1. Dry canal (Control);

2. 0.9% Saline;

3. 5.25% Sodium hypochlorite solution;

4. QMix solution

REVIEW OF LITERATURE

REVIEW OF LITERATURE

KoÇak MM et al (2016) compared the accuracy of four different electronic apex locator namely Root ZX, Raypex, iPex II and Propex II in the dry canal and in the presence of NaOCl2 and QMix. 90 extracted mandibular incisors were mounted in alginate models and pursued for electronic working length which is compared with radiographic working length. WL were measured using Digital caliper for standardization. They concluded that within the limitations of the study in ± 1 mm range all the EAL were reliable and did not alter the accuracy[14].

Wrbas KT et al (2006) compared the accuracy of two EAL Root ZX and Raypex 5 in the same teeth. 20 single rooted teeth which is going to be extracted for periodontal reason were collected. EWL were initially measured with two EAL and the files are stabilized with composite resin pattern for standardization and extracted. The actual working length measured at minor foramen and photograpghs taken which is then compared with the EWL. The conclusion was the use of EAL were reliable method for measuring the WL but the differences were not statistically significant[15].

Aanchal Ashok Rana et al (2017) compared the efficacy of two EAL Root ZX Mini and Propex pixie with sixty five extracted human permanent single rooted teeth. The samples were subjected to access cavity preparation and biomechnical preparation. The EAL were measured pre and post BMP in the presence of green tea, turmeric and tulsi. The results were not significant in the presence of herbal irrigating solutions[16].

J.P.Vieyra et al (2010) et al evaluated the accuracy of Root ZX and Elements Diagnostic apex locator when compared with radiographs for locating the canal terminus at minor foramen. 482 canals of maxillary and mandibular teeth were considered for measuring the EWL In Vivo and

compared with radiographs. Root ZX was 68% correctly measured anterior teeth and 58% in posterior teeth. Elements Diagnostic apex locator was 58% in anteriors and 49% in posteriors. The radiographic accuracy was 20% correct in anteriors and 11% correct in posteriors. They concluded that measuring the minor constriction was more accurate using EAL compared with radiographs[17].

Shabahang et al(1996) evaluated the accuracy of Root ZX in 26 permanent teeth which was to be extracted.Two clinicians participated who measured the initial measurement with EAL (Root ZX) which was denoted by an audible signal.The apex of each tooth was inspected under stereomicroscope under moist canal environment.The Root ZX device was able to locate the apical foramen precisely in 17 specimens. The endodontic tip file protruded in 8 specimens and did not reach the foramen in 1 root. The mean distance of overextension of the file tip was observed to be 0.269mm[18]

Jenkins et al (2001) evaluated the accuracy of the Root ZX in vitro in the presence of a variety of endodontic irrigants. Thirty single rooted extracted teeth were subjected to standard access preparations and the occlusal edges flattened for reproducible reference points. Apical instrumentation was completed to #20 ISO Flex-R file. Canals were initially irrigated with 20 ml distilled water. All the procedure were performed in Jell O Sugar free model where the tooth and electrode were mounted. The canals were dried with paper points . Liquid irrigants such as saline, H2O2, Peridex, EDTA, 5.25% NaOCl, 2% Xylocaine, RC prep were placed into the canal and measurement was taken three times per tooth and recorded. It was concluded that there is a strong and equivalent relationship between the actual length and the measured canal length using EAL independent of the irrigant[19].

Cicek et al (2015) compared the accuracy of different electronic apex loactors in the presence of irrigants.180 single rooted canals with mature apices were evaluated for EWL and AWL in the presence of 5.25% NaOCl2, 2% CHX, MTAD, ozonated water and SBT with 3 EAL Root ZX Mini, Propex II and Raypex 5. The percentages of accuracy of Root ZX mini, Propex II and Raypex 5 were found to be 90.5%, 89.4% and 82.6%. It was concluded that the reliability of the apex locators were more accurately reliable when the 2% CHX irrigant were used, in comparison to other irrigants[20].

Prasad et al (2016) compared the accuracy of Root ZX and i-Root apex locator for determining working length in the presence of different irrigating solution.80 single-root extracted teeth were used. Actual length was measured using #10 size file with EAL i-Root and Root ZX apex locator in the presence of irrigating solution namely 0.9% saline, 3% NaOCl, 2% CHX and 17% EDTA. It was concluded that Root ZX and i-Root can be used safely to determine working length in the presence of various irrigants[21].

Janeczek et al (2016) conducted with the use of a Septodont kit consisting of a small chamber filled with the examined solution in which a healthy second incisor was placed. The step back method was applied for the root canal preparation and master apical file of 30 was used. The working length was 22 mm. The examination was conducted with the use of steel as well as nickel titanium hand instruments. Different irrigation solutions and two types of apex locators were used. Measurements of the working length of the root canal showed dependence on the size of the instrument. Examinations carried out in various environments showed that analogical measurements were obtained only for sodium hypochlorite solutions. In other environments the measured sections were shortened. Comparative examinations with the use of steel instruments demonstrated insignificant measurement differences. Compared to these

results, the measurements in nickel titanium group were characterized by more considerable deviations[4].

El Hachem et al (2018) evaluated the accuracy of the Root ZX (J. Morita, Tokyo, Japan) electronic apex locator in determining the working length when palatal maxillary molar roots are in a relationship with the sinus. Seventeen human maxillary molars with vital pulp were scheduled for an extraction and implant placement as part of a periodontal treatment plan. The access cavity was prepared, and a #10 K file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the palatal root using the Root ZX apex locator in order to determine the electronic working length (EWL); then, the teeth were extracted. To determine the real working length (RWL), a #10 K file was introduced into the root canal until its tip touched a glass plate. EWL and RWL were compared. Images reconstructed with CBCT revealed that eight palatal roots were related to the maxillary sinus, whereas nine were not. The results showed a significant difference between the EWL and the RWL of the palatal roots related to the sinus ($p < 0.001$). No significant difference was observed in measurements of roots not in contact with the sinus ($p > 0.05$). Within the study limitations, the reliability of Root ZX was influenced by the relationship of the roots with the maxillary sinus[6].

Er et al (2013) evaluated ex vivo, the effects of three solvents on the accuracy of a contemporary electronic root canal length measurement device (ERCLMD), the Mini Root ZX. The actual working length (AWL) of 56 extracted maxillary incisor teeth were measured with an ERCLMD. All root canals were prepared with the ProTaper system to AWL. Of them, 20 were filled with gutta-percha and a resin-based sealer (Group A), 20 with gutta-percha and a zinc oxide/eugenol-based sealer (Group B), and 16 roots were used as the control group (Group C). Removal of the root filling and repreparation processes were performed using the ProTaper

system. Guttasolv and Resosolv were used as the solvents in Group A and Guttasolv and Endosolv E in Group B. After the removal of the root fillings had been achieved, the same ERCLMD was used to measure the working length (WL). Differences between AWL and WL measurements were analysed by paired t-test, and the accuracy of ERCLMD was assessed using chi-squared tests. There were significant differences between AWL and WL measurements in subgroups A2 (Resosolv group) and B2 (Endosolv E group). In these subgroups, WL was shorter than AWL ($P<0.05$). Also, the accuracy of the Resosolv group was significantly lower than the others ($P<0.05$) at a 0.5mm margin of error. Removing root fillings may require use of a solvent. In these cases, ERCLMDs may exhibit a lower accuracy, thus operators must exercise additional care when measuring the working length using ERCLMDs[22].

Froughreyhani et al (2018) evaluated the effect of high-frequency alternating currents (AC) applied by an electronic apex locator (EAL) on the antibacterial properties of chlorhexidine (CHX) on E. faecalis biofilm. The root canals of 120 extracted human single-rooted teeth were prepared using Gates Glidden drills and hand K-files. After contaminating the root canals with E. faecalis, they were incubated for 60 days. Then, the teeth were randomly divided into six experimental groups (n=20). Group 1, 2% CHX; group 2, normal saline (NS) with direct current (DC); group 3, normal saline (NS) with high-frequency alternating current (AC); group 4, 2% CHX with DC; group 5, 2% CHX with AC; group 6, control (normal saline). The samples were collected from the root canal walls of 16 teeth in each group and 1:10 serial dilutions were prepared and added to Muller-Hinton agar (MHA) plates and incubated at 37°C for 48 h. The longitudinal sections of the other 4 teeth used to observe under a scanning electron microscope (SEM). A classic colony counting technique was used for counting the vital E. faecalis bacteria in MHA. The electric current significantly changed the colony-forming units

(CFU) values (P<0.001). The highest bioelectric effect occurred with the use of high-frequency alternating electric current in the form of an apex locator with CHX as a canal irrigant[23].

Pishipati et al (2013) compared the accuracy of radiography in assessing working length to Propex II apex locator. Thirty single canal extracted human teeth with patent apical foramen were selected. Access cavities were prepared. Anatomic length (AL) was determined by inserting a K-file into the root canal until the file tip was just visible at the most coronal aspect of the apical foramen; subsequently 0.5 mm was deducted from this measured length. Working length by radiographic method (RL) was determined using Ingle's method. Propex II apex locator was used to determine the electronic working length (EL). The percentage accuracy of RL and Propex II apex locator was 76.6% and 86.6%, respectively. Paired t-test revealed significant difference between the RL and Propex II apex locator. Under these in vitro conditions, Propex II apex locator has determined working length more accurately than radiographic method[24].

Ashwini et al (2016) compared the accuracy of Root ZX and i-Root apex locator for determining working length in the presence of different irrigating solution. Eighty extracted single rooted human teeth were used. The teeth were sectioned at Cemento Enamel Junction (CEJ) and actual canal length determined. Then, working length measurements were obtained using Root ZX and i-Root apex locator in the presence of irrigating solutions namely 0.9% saline, 3% of sodium hypochlorite (NaOCl), 2% chlorhexidine digluconate(CHX) and 17% Ethylene Diamine Tetra Acetic acid (EDTA). The measurements obtained with Root ZX and i-Root apex locator were compared with actual canal length and subjected to statistical analysis .This study revealed that both the tested Electronic apex locators (EAL) were able to measure the canal length in the presence of tested irrigating solutions. The presence of irrigating

solutions of saline, NaOCl, chlorhexidine and EDTA in the root canal marginally influenced the accuracy of the Root ZX or i-Root ($P < 0.36$), but with no clinical significance. Root ZX and i-Root can be used safely to determine working length in the presence of various irrigants. The content of the root canal did not influence the accuracy while measuring working length using Electronic apex locators (EAL)[21].

KoÇak et al (2013) evaluated the clinical accuracy of two electronic apex locators (EALs). 120 patients with 283 roots were randomized into three groups including, traditional radiographic method, EAL (Root ZX mini), and apex locating endodontic motor (VDW Gold) for working length (WL) determination. Root canals were instrumented to a size ProTaper F3 nickel titanium file. The obturation quality of matched tapered master cone (ProTaper F3) was determined for the accuracy of WL. $P < 0.05$ was considered statistically significant for all tests. There was no statistically significant difference between the three tested groups ($P = 0.894$). The success of both apex locators was similar to the radiographic WL determination technique[14].

Duran-Sindreu et al (2013) evaluated in vivo performance of the iPex and Root ZX electronic apex locators (EALs) in the presence of several irrigant solutions: 2.5% sodium hypochlorite (NaOCl) and 2% chlorhexidine (CHX). Thirty-two single-rooted human teeth that were scheduled for extraction were selected. Teeth with metallic restorations, fractures, root resorption, pulp necrosis or open apices were not included The working length (WL) was determined electronically for the root canals with the iPex and Root ZX EALs in the presence of two different irrigant solutions, 2.5% NaOCl and 2% CHX. After the teeth had been extracted, a size 10 K-file was used to determine the reference working length (RWL), which was established at 0.5 mm short of the major foramen. In each case, the RWL was subtracted

from the electronic measurements. Positive values indicated electronic measurements that exceeded the RWL (long measurements), whereas negative values indicated measurements that were short of the RWL. Significance was set at $P < 0.0$. The accuracy of the iPex nor Root ZX EAL was not affected by 2.5% NaOCl or 2% CHX ($P > 0.05$). However, significant differences were observed between the readings of the iPex and Root ZX, irrespective of whether 2.5% NaOCl or 2% CHX was used as the irrigant ($P < 0.05$). The iPex was less accurate than the Root ZX in determining the RWL. The accuracy of neither the iPex nor Root ZX EAL was affected by the irrigant used. However, the iPex was less accurate than the Root ZX in determining the RWL both for 2.5% NaOCl and for 2% CHX[25].

Saraswathi et al (2016) compared the accuracy of two generations of apex locators in teeth with simulated apical root resorption. Forty maxillary central incisors were selected and after access preparation, were embedded in an alginate mold. On achieving partial set, teeth were removed, and a 45° oblique cut was made at the apex. The teeth were replanted and stabilized in the mold, and WL was determined using two generations of apex locators (Raypex 5 and Apex NRG XFR). Actual length of teeth (control) was determined by visual method. Raypex 5 and Apex NRG was accurate for only 33.75% and 23.75% of samples, respectively. However, with ±0.5 mm acceptance limit, they showed an average accuracy of 56.2% and 57.5%, respectively. There was no significant difference in the accuracy between the two apex locators. Neither of the two apex locators were 100% accurate in determining the WL[26].

Cimilli et al (2012) evaluated the accuracy of the Dentaport ZX apex locator for working length determination during root canal retreatment of mandibular molars. Fifteen extracted mandibular first molars with separate mesial canals and apical foraminae and one distal canal were selected. The mesiobuccal and distal canals were investigated; the length with the file tip

at the major diameter was defined as the tooth length (TL). The canals were prepared with ProTaper files to 1 mm short of this and filled with gutta-percha and AH Plus sealer. One week later, the root fillings were removed using ProTaper retreatment files. Tooth length was remeasured and recorded as the retreatment tooth length (RTL). Then electronic measurements were taken at the major (electronic apex locator (EAL) major) and minor (EAL minor) foraminae as suggested by the instrument display. These lengths were compared with RTL and measurements 0.5 and 1 mm short of this distance. For both canals, no significant difference was found between RTL and EAL major, and 0.5 mm short of RTL and EAL minor ($P > 0.05$). There were significant differences found between all other readings. The Dentaport ZX could not detect the minor foramen accurately but was able to indicate the major foramen in molars undergoing a root canal retreatment procedure[27].

Chaudary et al (2018) compared the accuracy of Propex II and iPex II electronic apex locator (EAL) in determining the WL under clinical conditions, to that of radiographic working length (RWL) using stainless steel (SS) and nickel–titanium (NiTi) hand files. Thirty-seven patients, with 60 anterior teeth (60 canals) scheduled for endodontic treatment participated in this study after ethical approval. Electronic working length (EWL) was determined by the Propex II and iPex II according to manufacturer's instructions using SS Hand K-files and NiTi Hand files. RWL was determined after EWL determination. The results obtained with each EAL with SS and NiTi files were compared with RWL. Data was analyzed statistically at a significance level of $p < 0.05$. Interclass correlation coefficient was calculated. Statistical analysis revealed no significant difference between the EALsNo significant difference was found between the EWL and RWL and between SS and NiTi files for WL determination ($p > 0.05$) as well. Under the in vivo clinical conditions of this study, both Propex II and iPex II were similar to the RWL

determination technique showing high correlation to RWL. Both are clinically acceptable EAL for WL determination[28].

Bolbolian et al (2018) evaluated of the accuracy of the Root zx electronic apex locator in the presence of NaOCl 2.5% and chlorhexidine 0.2%. Thirty extracted human premolars with complete root formation were enrolled. The actual length (AL) was assessed visually (under stereo microscope) and teeth mounted in the saline model. The electronic length (EL) measurements were recorded in the presence of NaOCl 2.5% and chlorhexidine 0.2% and the differences between the EL and AL were compared. By accepting the error of 0.5 and 1 mm, the accuracy of Root zx was 76.7% and 96.7% in the presence of chlorhexidine 0.2% and 90% and 100% in the presence of NaOCl 2.5%, respectively. No statistical differences was found between the measured groups (P=0.223). Conclusions Our results confirmed that Root zx can accurately determine the apical constriction in presence of both NaOCl 2.5% and chlorhexidine 0.2%[29].

Uzunoglu et al (2015) compared the ability of several techniques to remove calcium hydroxide (CH) from the root canal and determined the influence of CH residues on the accuracy of the electronic apex locator. Root canals of 90 human maxillary lateral incisors with confirmed true working length (TWL) were prepared and filled with CH. The teeth were randomly assigned to one of the experimental groups according to the CH removal technique (n = 14): 0.9% saline; 0.9% saline + master apical file (MAF); 17% ethylenediamine tetra acetic acid (EDTA); 17% EDTA + MAF; 5.25% sodium hypochlorite; 5.25% NaOCl + MAF. Six teeth were used as negative control. After CH removal, the electronic working length was measured using Root-ZX (Morita Corp.) and compared with TWL to evaluate Root-ZX accuracy. All specimens were sectioned longitudinally, and the area of remaining CH (CH) and total canal area were

measured using imaging software. The EDTA + MAF and NaOCl + MAF groups showed better CH removal than other groups ($p < 0.05$). Root-ZX reliability to prevent overestimated working length to be > 85% within a tolerance of ± 1.0 mm ($p < 0.05$). There was strong negative correlation between amount of CH residues and EAL accuracy ($r = -0.800$ for ± 0.5 mm; $r = -0.940$ for ± 1.0 mm. The mechanical instrumentation improves the CH removal of irrigation solutions although none of the techniques removed the dressing completely. Residues of CH medication in root canals affected the accuracy of Root-ZX adversely[30].

Akisue et al (2014) assessed the influence of foramen widening on the accuracy of 5 different electronic foramen locators (EFLs) and compared the accuracy of EFLs in different foramen sizes. The following EFLs were used: MiniApex, Root ZXII, iPex, Propex II, and Elements Apex Locator. Each EFL was used in 3 groups (n = 20) of extracted teeth, with foramen diameters of 0.27 mm (G27), 0.47 mm (G47), and 0.72 mm (G72). Working length was measured according to manufacturer's instructions and compared with visual measurements (control method). Results were classified as accurate (equal or differences ≤ 0.05 mm) or inaccurate (differences > 0.5 mm). In G27, all EFLs yielded accurate findings (intragroup reliability; Fisher exact test, $P < .05$), compared with only MiniApex, Root ZXII, and Elements Apex Locator in G47 and G72. MiniApex, Root ZXII, and Elements Apex Locator were similarly accurate regardless of foramen size. iPex and Propex II were the least accurate among the devices tested, and foramen diameter influenced their accuracy, with greater diameters yielding poorer EFL performance. Foramen diameter did not influence the accuracy of MiniApex, Root ZXII, and Elements Apex Locator EFLs. iPex and Propex II showed decreased accuracy as foramen size increased[13].

Saxena et al (2017) comparatively evaluated the accuracy of iRoot, iPex II, and Propex pixi apex locator using histological sections as the gold standard. Thirty patients indicated for extraction of single-rooted permanent teeth with single canal system were selected. Working lengths (WLs) of teeth were determined using iRoot, iPex II, and Propex pixi. Teeth were then extracted, and the files were reintroduced to the anatomic apex to measure anatomic canal length (ACL) and fixed at the ACL using flowable composite. The apical 4 mm of the roots were longitudinally shaved away to visualize the canal under a stereomicroscope at ×24 magnification. Digital photographs were evaluated to measure the distance between the major diameter and minor diameter. Thus, the WL, that is, the minor diameter length (MDL) was ascertained. Measurements of mean WLs within ±0.5 mm of minor diameter were 90% acceptable for iRoot, 86.66% for iPex II, and 80% for Propex pixi when compared with mean MDL as obtained from the histological sections. All apex locators have been shown to produce acceptable level of accuracy which clearly indicates their reliability in determining the WL[28].

Dinapadu et al (2013) evaluated the accuracy of Root ZX-II (J Morita Corp) apex locator in enlarged root canals with different root canal irrigants. 48 freshly extracted single rooted mandibular premolar teeth were used. The apical enlargement was done up to #45 K-file as the master apical file (MAF). The teeth were randomly divided into 4 groups and mounted in an experimental apparatus. The following irrigants were used during electronic canal measurements: group 1: saline; group 2: 3% NaOCl; group 3: 2% chlorhexidine; group 4: 17% EDTA. The canal measurement was done with Root ZX-II apex locator using #10 and #45 K-file. Root ZX-II was accurate in the presence of 3% NaOCl and 17% EDTA when measured with smaller and larger files. However, it was accurate in the presence of saline and 2% CHX when larger files were used[31].

Vascancelos et al (2016) evaluated the variations in root canal length (RCL) occurring during endodontic treatment stages (initial, preflared, and concluded) and correlated them with the accuracy of Root ZX II (RZX). After access cavity preparation, 26 mandibular molars had the apical foramen of the 52 mesial canals were standardized (250 μm) and their respective initial RCL was recorded (RCL1 = initial) by using a clinical microscope (×16) and manual K-file instruments. By using the alginate model, sequential electronic measurements were taken with the RZX. After the initial measurement (EM1), WaveOne Primary instruments were used to prepare the cervical and middle thirds of the root canals, and then the second RCL and EM measurements (RCL2/EM2 = preflared) were obtained. Finally, mechanical preparation was concluded, and the measurement procedures were repeated to obtain the final RCL and EM measurements (RCL3/EM3 = concluded). Results Statistically significant differences were observed in all comparisons in the RCL ($P < .05$). The RCL1 – RCL3 showed the highest variation (0.6 mm), with the extent of specimens reduced by up to 1.75 mm. No statistically significant differences were found in the accuracy of the RZX ($P > .05$); 100% precision (± 0.5 mm) was found in all stages[11].

Orosco et al (2017) evaluated the impact of different file sizes on the accuracy of two electronic apex locators (EALs). Thirty extracted human single-rooted permanent mandibular incisors were used. A #10 K-file was inserted in the root canal until its end could be observed (using a light microscope) through the apical foramen. One millimetre was subtracted to establish working length (WL). Electronic readings were performed using MiniApex Locator and Root ZX II, from #10 K-file to #130 K-file. From #60 to #130 K-file, observed differences were noted between the values obtained with both EALs and WL. The Mini Apex Locator showed increased means when measurements were made with #50 to #70 and with #120. File sizes influenced the accuracy of EALs - the greater the instrumentation size, the higher mean

differences compared to WL. Electronic readings performed with the MiniApex Locator and the Root ZX II are influenced by different size files as the greater the instrumentation size, the higher mean differences compared to actual working length[7].

Baruah et al (2018) compared the accuracy of Root ZX Mini and Propex II in the presence of 0.1% octinidine dohydrochloride (OCT), 2% chlorhexidine gluconate (CHX), and 5% sodium hypochlorite (NaOCl) heated and nonheated before and after preparation.Eighty extracted single-rooted teeth were selected for the study and decoronated. Teeth were mounted in an alginate model. Actual working length (AL) was measured using a stereomicroscope under ×4 magnification. Electronic working length measurements were recorded using Root ZX Mini and Propex II apex locators in the presence of 0.1% OCT, 2% CHX, and 5% NaOCl (nonheated and heated to 60°C) before and after preparation. Mean and standard deviation differences before and after preparation were calculated and statistically analyzed using analysis of variance and paired t-test.The accuracy of Root ZX Mini before and after preparation within ±0.5 mm of AL was consistently high in the presence of irrigants than Propex II. 5% NaOCl (heated and nonheated) showed more variation than the other irrigants, in the working length determination in both the apex locators. Electronic length measurements were shorter with heated and nonheated 5% NaOCl and longer with 0.1% OCT and 2% CHX for both the electronic apex locators[32].

Tampelini et al (2017) assessed the accuracy of 2 third-generation electronic apex locators, Propex II (Dentsply Maillefer) and Root ZX II (J. Morita), and radiographic technique for locating the major foramen (MF). Thirty-two premolars with single canals that required extraction were included. Following anesthesia, access, and initial canal preparation with size 10 and 15 K-flex files and SX and S1 rotary ProTaper files, the canals were irrigated with 2.5%

sodium hypochlorite. The length of the root canal was verified 3 times for each tooth using the 2 apex locators and once using the radiographic technique. Teeth were extracted and the actual WL was determined using size 15 K-files under a x 25 magnification. The measurements obtained using the visual method exhibited the strongest correlation with Root ZX II, followed by Propex II and Ingle's technique. Both EALs presented similar accuracy that was higher than that of the radiographic measurements obtained with Ingle's technique[33].

Oliveira et al (2017) evaluated the accuracy of 5 electronic apex locators: Root ZX II (RZX; J Morita, Tokyo, Japan), Raypex 6 (RAY; VDW GmbH, Munich, Germany), Apex ID (AID; SybronEndo, Orange, CA), Propex II (PRO; Dentsply Maillefer, Ballaigues, Switzerland), and Propex Pixi (PIXI, Dentsply Maillefer) when used in the following protocols: (1) −1.0, insertion up to 1.0 mm below the apical foramen (AF); (2) 0.0/−1.0, insertion until the AF and withdrawn 1.0 mm short of the AF; (3) 0.0, insertion until the AF; and (4) over/0.0, insertion until "over" and withdrawal to AF. Thirty human lower premolars had coronary accesses and cervical and middle thirds preparations performed, allowing AF standardization (200 μm). Using an alginate experimental model, root canal length (RCL) measurements were performed sequentially with EALs following each of the protocols. Comparing the results obtained in 0.0 with those found in −1.0 and 0.0/−1.0, significant differences were observed for most EALs ($P < .05$). For the comparison between EALs, significant differences were observed only in protocols −1.0 and over/0.0 ($P < .05$). Conclusions Under the conditions of the study, it was concluded that, regardless of the mechanism of the device, the best results were found when electronic RCL measurement was performed at the AF; furthermore, the electronic withdrawal did not offer any additional advantage over the reach of the AF[34].

Vasconcelos et al (2015) evaluate the accuracy of electronic foramen locators , Root ZX II (RZX; J. Morita, Tokyo, Japan), Propex II (Dentsply Maillefer, Ballaigues, Switzerland), and Apex ID (AID; SybronEndo, Glendora, CA), in root canals with an obstructed apical foramen (OAF) and to compare them with those 1.0 mm short of the apical foramen (AF; -1.0) and at the AF (0.0). Thirty human mandibular molars had their coronal and cervical preparations accessed. Then, the AFs were standardized (250 μm). Electronic root canal measurements were performed for the -1.0 and 0.0 working lengths, and the canals were obstructed with dentinal debris. The distance to the AF displayed by the EFLs was then recorded. The last instrument used was fixed with a cyanoacrylate-based adhesive; the apical portions of the roots were scraped, allowing for the determination of the distance between the tips of the instruments and the AFs. Results The precision rates at 0.0, -1.0, and the OAF were 94.7%, 43.9%, and 1.8% (RZX); 93.0%, 54.4%, and 54.4% (Propex II); and 93.0%, 68.5%, and 75.4% (AID), respectively (±0.5 mm). No significant differences were found between the devices at 0.0; however, for the measurements at -1.0 and the OAF, the AID offered significantly better results than RZX ($P < .05$). The absence of foraminal patency caused by dentin debris obstruction affects the accuracy of the EFLs differently, suggesting distinctive interactions with their operating mechanisms[34].

Vasconcelos et al (2015) compared in vivo, the accuracy of two electronic foramen locators (EFLs) based on different operation systems - Root ZX and Propex II. Ten healthy adult patients needing premolar extractions due to orthodontic reasons participated in the study, providing a sample of 17 noncarious, non-restored, vital teeth (n= 24 canals). After coronal access preparation and cervical preflaring and prior to tooth extraction, the root canal length was measured alternating the two EFLs. All measurements were performed with K-files well fitted to the canal diameter at the level that each EFL indicated the apical foramen in their

display (APEX or 0.0). The last K-file were fixed in place with cyanoacrylate, the tooth was extracted, and the apical 4 mm of each root were resected to measure the distance between the file tip and the apical foramen. The mean errors based on the absolute values of discrepancies were 0.30 ± 0.29 mm (Root ZX) and 0.32 ± 0.27 mm (Propex II). The apical foramen was accurately located in 75% (Root ZX) and 66.7% (Propex II) of the cases, considering a ±0.5 mm error margin, with no statistically significant difference. Despite having different measurement mechanisms, both EFLs were capable of locating the apical foramen with high accuracy in vivo. Under the tested clinical conditions, Root ZX and Propex II displayed similar results[35].

Jain et al(2015) compare the efficacy of electronic apex locators after cleansing and shaping of the root canals and whether there was any alteration in accuracy when used in the presence of irrigants. Seventy extracted human permanent molars with mature apices were selected. Equal number of maxillary and mandibular permanent molars (35 each) were sectioned at the cemento-enamel junction. Access opening was done and only the mesiobuccal root canal was studied for the purpose of standardization. Electronic working length measurements were taken before and after preparation of the mesiobuccal canal with Root ZX and ProPex II using various irrigants. Within the limitations of this study Root ZX can be considered to be an accurate electronic apex locator and CHX as irrigant matched more precisely with the actual canal length measurements[36].

Altenburger et al (2012) compared the in vivo measurement of three different electronic root canal length devices: Dentaport ZX, Raypex 5 and ProPex II. Thirty single-rooted permanent teeth scheduled for extraction because of periodontal disease were selected from 10 adult patients (ranging from 45 to 67 years) and divided into three groups of 10 teeth. Before the

extraction, an access cavity was prepared and the crown was adjusted to establish a stable reference point for all measurements. The working length in Group 1 was determined using the Dentaport ZX apex locator. A K-file with the largest diameter that could reach the last green bar on the screen was stabilized in the canal using a dual-curable flow resin composite. The same procedure was used for the Raypex 5 (the file reached the last yellow bar) and Propex II (0.0 orange bar) apex locators. The teeth were then extracted and cleared. The distance between the tip of the file and the major foramen was then calculated for each tooth using digital photography according to Axiovision AC software (Carl Zeiss). Positive values were assigned when the file tip passed beyond the major foramen, negative values when the tip was short of the foramen and zero value when the file tip and the foramen coincided. Statistical analysis was performed using the chi-squared test or Fisher's exact test ($P \leq 0.05$).Dentaport ZX, Raypex 5 and ProPex II produced, respectively, 6, 2 and 4 out of 10 correct measurements, 0, 6 and 5 long measurements and 4, 2, and 1 short measurements. The differences between the three electronic root canal length measurement devices were not significant ($P = 0.507$).Under the in vivo conditions of this study, the three electronic root canal length measurement devices were not significantly different in terms of locating the major foramen[37].

Piasceki et al (2018) evaluated the accuracy of 3 electronic apex locators (EALs) Canal Pro , Apex ID and Root ZX Mini in curved mesial canals of extracted mandibular molars using micro–computed tomographic (micro-CT) scanning. The root canal length and the actual working length of 58 canals were measured using the visual method and 3-dimensional micro-CT reconstructions. The measurements of the EALs at marks “APEX/0.0” and “0.5 mark” were recorded as the electronic root canal length and the electronic working length, respectively. The absolute mean values and the percentages of distribution of the electronic measurements were compared with the actual lengths of the canals. All electronic measurements showed high

agreement with their respective gold standard, except the electronic root canal length of the Apex ID ($P < .05$). No difference in the percentage of precise measurements (within the 0.5 mm) was found. Of the anatomic parameters evaluated, the presence of a lateral foramen negatively affected the 0.0 mark of the Apex ID (Wilcoxon test, $P < .05$). Conclusions: The Root ZX Mini and CanalPro were precise for both root canal length and working length determination in mesial curved canals of mandibular molars, whereas the Apex ID was accurate for the working length when using the 0.5 mark[38].

Zand et al (2017) evaluated the accuracy of the Root ZX electronic apex locator (EAL) (J. Morita, Tokyo, Japan) and the NovApex in determining the working length (WL) during endodontic treatment. Forty extracted single-rooted human teeth were selected for this study. The actual WL was measured with visual technique by a size #15 k-file under magnification. Then, the canal lengths were measured electronically with both Root-ZX and NovApex apex locators within ±0.5 and ±1 mm. Mean percentage of data was analyzed between groups using paired t-test, with a statistically significant level of $p < 0.05$. The accuracy of NovApex apex locator was 85% within ±0.5 mm and 92.5% within ±1 mm. The accuracy of Root-ZX apex locator was 70% within ±0.5 mm and 97.5% within ±1 mm. There was no significant difference between the accuracy of the two EALs.Both the NovApex and Root-ZX EALs are useful for measuring the WL with high accuracy.Given the importance of accurate WL determination in the success of endodontic treatments, the accuracy of different apex locators should be evaluated.

Tian AL et al(2012) investigate the effect of canal curvatures on the accuracy of 3 electronic apex locators (EAL) in vitro. Alginate and 123 canals were used to mimic the situation in vitro. Three kinds of electronic apex locators including Raypex5(®), Propex(®)

and Rider(®) were applied to determine the length of the canals divided into 3 groups including straight (<5°), middle (>10°,<20°) and severe (>20 °) according to the root canal curvatures. Experimental measurements and the distances (IF value) between experimental and ideal actual measurements under the same measurement environment were recorded. Paired sample t test was applied to analyse the results by using SPSS11.5 software package.The results showed that with the allowance of ±0.5 mm, the accuracy ratios of straight canal, moderate and severe curvature canal were 84.6%, 81.6%, 87.5% for Raypex5 76.9%,89.8%, 91.7% for Propex, and 92.3%, 89.8%, 87.5% for Rider, respectively. There was no significant difference in the accuracy between the EALs regarding three degrees of root canal curvatures. The curvatures of the root canals have no influence on the accuracy of the EALs, though the difference exists in the accuracy rate among the EALs[39].

Khandewal et al (2015) evaluated the accuracy of the Raypex 5 and Apex NRG XFR electronic apex locators (EALs) in determining the working length when compared with radiographs. Twenty-five human single-rooted teeth were selected, and the access cavity was prepared. The working length (WL) was determined radiographically and electronically by using 2 EALs. The files were fixed at the WL, and the teeth were extracted. The apical 4 mm of each canal was trimmed to expose the file tip, and the samples were observed under a stereomicroscope. The distance from the file tip to the point 0.5 mm coronal to the anatomic apex was measured. The data were analysed by using 1-way analysis of variance and the Tukey Honestly Significant Difference test. There was no significant difference between the Raypex 5 and the Apex NRG XFR devices with respect to their accuracy in determining the final WL. When compared with radiography, both the EALs had no significant difference. When comparing EALs and radiographic measurements with control measurements, accuracy results were found to be 20%, 36%, and 52% for the Raypex 5, Apex NRG XFR, and

radiography, respectively. Overestimations of WL determination by the Raypex 5, Apex NRG XFR, and radiography were 4%, 0%, and 40%, respectively. Underestimations of WL determination by the Raypex 5, Apex NRG XFR, and radiography were 76%, 64%, and 8%, respectively. Both the EALs had the same accuracy in determining the WL when compared with radiography[26].

Saatchi et al (2014) determine whether tooth length influenced the accuracy of the Root ZX device. Materials and methods. Forty extracted maxillary canine teeth with a length range of 27–29 mm were selected. Access cavities were prepared and coronal flaring of canals performed. The teeth were mounted in self-polymerizing acrylic resin to facilitate horizontal sectioning except for the apical 3–4-mm portion of the root and embedded in alginate as the electronic medium. Electronic measurements were taken at the major foramen, 'zero' reading using the Root ZX and compared with the actual root canal length. The teeth were sectioned 3 mm from the coronal reference point to create a second group with shorter length; these reductions in the length continued six times in all to create seven groups of 40 specimens each. The actual and electronic lengths of specimens in each group were measured. Data were analysed by Pearson's correlation coefficient. Identical measurements between the actual and electronic root canal length from the longest to the shortest groups were 12.5%, 10.0%, 20.0%, 27.5%, 37.5%, 35.0% and 45.0%, respectively. There was a mild negative correlation between the precise measurements of the Root ZX and root canal lengths in the seven groups. Under the conditions of the study, the Root ZX device was more accurate in shorter teeth compared to longer ones[40].

Mandik J et al (2013) compare the ability of digital tactile, digital radiographic and electronic methods to determine reliability in locating the apical constriction. Informed consent was

obtained from patients scheduled for orthodontic extraction. The teeth were anesthetized, isolated and accessed. The canals were negotiated, pulp chamber and canals were irrigated and pulp was extirpated. The working length was then evaluated for each canal by digital tactile sensation, an electronic apex locator and digital radiography. The readings were then compared with post-extraction working length measurement. The percentage accuracy indicated that EAL method (Root ZX) shows maximum accuracy, i.e. 99.85% and digital tactile and digital radiographic method (DDR) showed 98.20 and 97.90% accuracy respectively. Hence, it can be concluded that the EAL method (Root ZX) produced most reliable results for determining the accurate working length.

Topaloglu et al (2015) evaluate the accuracy of root canal length measurements of primary teeth using an electronic apex locator (EAL) and digital radiography in comparison to stereomicroscopic measurement as gold standard. After preparation of access cavities of twenty extracted primary molars, the teeth were embedded in alginate blocks. Endodontic files were inserted in the root canals and the length was measured using ProPex II. When the reading was stable for 5s a silicone stop was used for reference. The true lengths of the files were then measured using a micrometer. The gold standard was determined by observing the tip of the file at the apical foramen under a stereomicroscope. For radiographic measurements standard images were obtained at 30 cm source-to-object distance, and zero degrees vertical and horizontal angulations. Radiographic images of each experimental tooth were obtained with the Digora Storage Phosphor Plates (SPP) with the x-ray unit operating at 65 kVp and 10 mA for 0.16 seconds. The radiographic root lengths were measured with the measurement tool of the Digora for Windows software. The mean measurements obtained with the EAL (14.06±1.89 mm) were significantly lower than measurements done with SPP images (14.24±1.98 mm) ($p<0.05$). However, when both root canal length measurement techniques

were compared to stereomicroscopic measurements (gold standard), no statistically significant difference was found. The EAL might be safer than digital radiography for the measurement of root canal length in primary teeth[41].

Yolagiden M et al (2018) compared the accuracy of four different electronic apex locators (EALs) in detecting a position 0.5 mm short of the major foramen. The actual working length of thirty-five extracted human teeth was determined visually as 0.5 mm short of the apical foramen. After actual working length measurements, electronic working length was measured with four different EALs -Apex Pointer+, Raypex 5, Apex ID, and Raypex 6. Measurements were repeated three times by different operators. The data were analyzed using the intraclass correlation coefficient (ICC), the repeated measure analysis of variance (rANOVA) and Bonferroni post hoc tests. The significance level was set at $p < 0.05$.The mean differences between electronic and actual working length were-0.305 mm, 0.098 mm, 0.037, and 0.144 mm for the Apex Pointer+, the Raypex 5, the Apex ID, and the Raypex 6, respectively. Multiple paired comparisons (Bonferroni test) also showed the Apex Pointer+ is significantly different from the Raypex 5, Apex ID and Raypex 6 ($p = 0.000$, $p = 0.001$, and $p = 0.001$ respectively).All EALs showed an acceptable determination of the working length between the ranges of ± 0.5mm except for the Apex Pointer+ device, which had the lowest accuracy. Further studies may be beneficial especially to better evaluate the accuracy of the Apex Pointer. This article shows that Apex ID, which has only recently been introduced into the market, showed an acceptable determination of the working length. Its accuracy was similar to that of Raypex 5 and 6[42].

Vanitha S (2019) assessed the clinical accuracy APEX and 0.5 marks of three different apex locators - iPex II, Root ZX, and Apex ID - before and after canal preparation in

the mandibular first molar.Sixty patients between the ages of 13-60 years participated in the study. After access gaining and canal preparation stages files were inserted with the apex locator clip attached until the electronic apex locators (EALs) shows readings of APEX and 0.5 marks and same is confirmed with periapical radiographs. Eighteen apex locator readings were recorded from each tooth, and 1080 readings were obtained from the 60 patients. Differences among readings from apex locators and radiographic readings were assessed using paired t test. Only in two patients (1 male and 1 female) were the APEX mark readings different from the radiograph estimation. When the 0.5 mark readings of three different EALs were compared with each other, we could observe that the readings from Root ZX differed significantly ($P < 0.05$). In the present study, we observed the negligible differences in readings between the EAL at the APEX mark readings, coinciding with the radiographic observation. Clinically, we recommend the apical foramen be located with the apex locators' APEX mark readings prior to identifying the apical constriction position[43].

Jadhav GR et al (2018) evaluated the accuracy of three EALs [RootZX (third generation), iPex (fourth generation) and Raypex 6 (modification of a fifth generation)] in determining the WL of teeth with simulated apical root resorption in permanent teeth. Forty freshly extracted maxillary anterior teeth were collected and a 45° oblique cut was made at the root apex with a disc to simulate apical root resorption. Actual working length (AWL) was determined by direct visual method and was used as a control. Electronic working length (EWL) values were measured by three different apex locators that are RootZX (Group I), iPex (Group II) and Raypex 6 (Group III) at apex, 0.5 mm and 1 mm from apex. All values obtained were tabulated and statistical evaluation was carried out. At apex, EWL obtained using iPex ($p=0.05$) showed a statistically significant difference from AWL. At 0.5 mm and 1.0 mm tolerance, iPex showed

non-acceptability for WL measurement in 67.5% and 17.5% of samples compared to Root ZX (12.5% and 2.5%) and Raypex (7.5% and none) respectively. Within the limitation of this study, it can be concluded that Raypex 6 and RootZX show statistically significant accuracy in WL measurement compared with iPex in teeth with apical root resorption[44].

MATERIALS AND METHODOLOGY

MATERIALS

S.NO	MATERIALS USED	BRAND NAME/ MANUFACTURER DETAIL
1	Human permanent anterior teeth	N=60
2	Root ZX Mini Apex locator	J Morita Corp. USA
3	Propex II apex locator	Dentsply Maillefer, Germany
4	Electronic Digital Caliper	Hi-tech Scientifics, Bangalore, India
5	K- files	Mani Inc, Japan
6	Normal saline 0.9%	Euro life healthcare pvt Ltd, Chennai, India
7	Sodium Hypochlorite 5.25%	CERKAMED, Poland
8	QMix 2in1 Irrigating solution	Dentsply Tulsa Dental Specialties, Tennessee
10	High speed dental turbine handpiece	Sicher holding Ltd, United Kingdom
11	Rubber dam kit	GDC India Ltd, India
12	Paper points	Sure endo, Korea

13	Lignox 2%	Indoco remedies, Mumbai, India
14	Light cure GIC	GC Fuji, Tokyo, Japan
15	5ml syringe with 27G needle	Dispovan, India
16	Sopix 2 RVG	Acteon, France

SELECTION OF SAMPLES

The tooth must be class III or Class IV caries with mature apices and coronally available reference point for the root canal length measurement that is planned for root canal treatment. The tooth must be free of cracks, mobility, root fracture, periapical lesion and weeping canal.

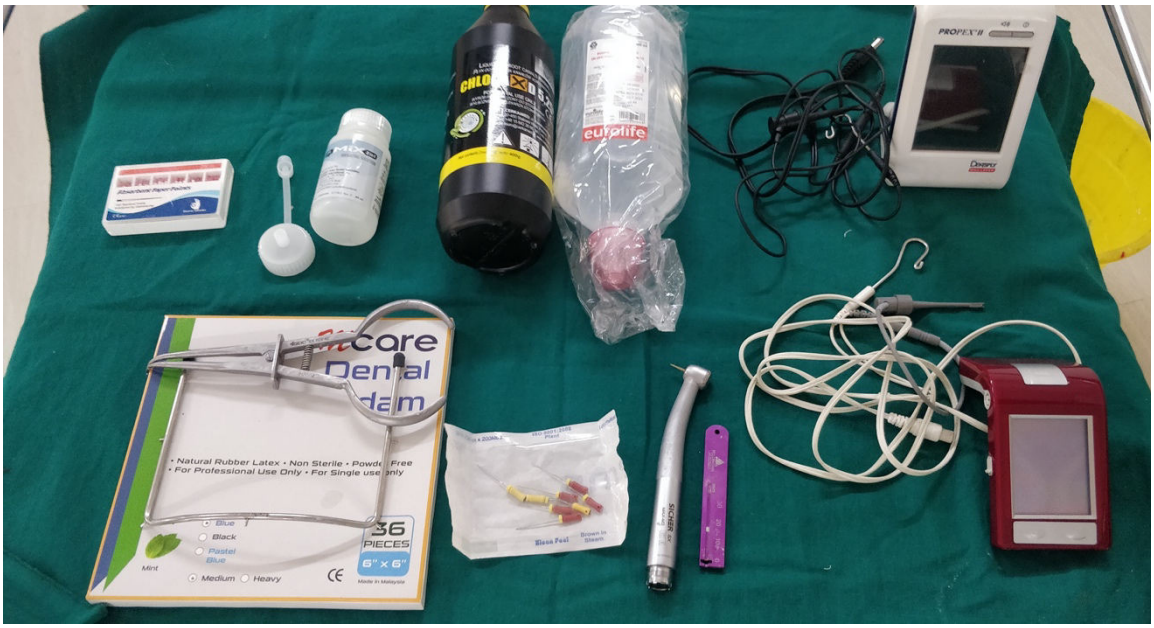
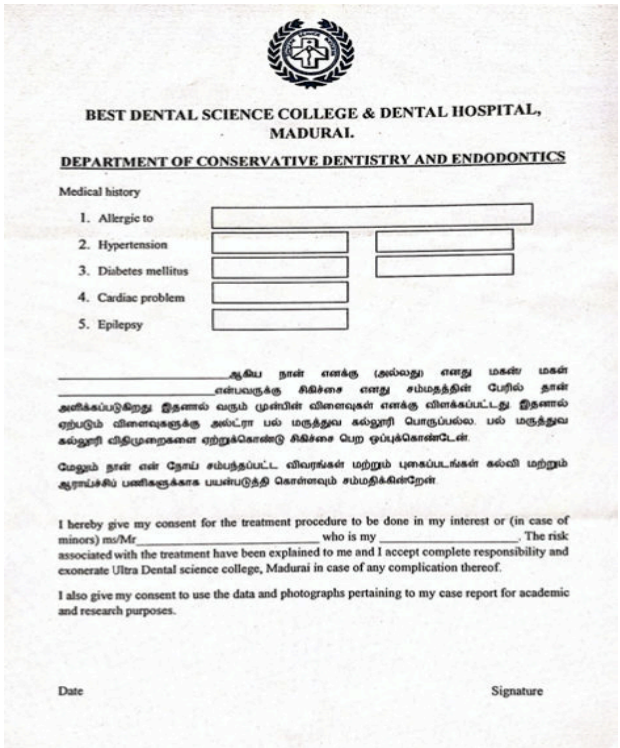


Figure 3 Materials used for this In Vivo study



BEST DENTAL SCIENCE COLLEGE & DENTAL HOSPITAL, MADURAI.

DEPARTMENT OF CONSERVATIVE DENTISTRY AND ENDODONTICS

Medical history

1. Allergic to
2. Hypertension
3. Diabetes mellitus
4. Cardiac problem
5. Epilepsy

_____ஆகிய நான் எனக்கு (அல்லது) எனது மகன்/ மகள் _____என்பவருக்கு சிகிச்சை எனது சம்மதத்தின் பேரில் தான் அளிக்கப்படுகிறது இதனால் வரும் முன்னின் விளைவுகள் எனக்கு விளக்கப்பட்டது இதனால் ஏற்படும் விளைவுகளுக்கு அல்ட்ரா பல் மருத்துவ கல்லூரி பொருப்பல்ல. பல் மருத்துவ கல்லூரி விதிமுறைகளை ஏற்றுக்கொண்டு சிகிச்சை பெற ஒப்புக்கொண்டேன்.

மேலும் நான் என் நோய் சம்பந்தப்பட்ட விவரங்கள் மற்றும் புகைப்படங்கள் கல்வி மற்றும் ஆராய்ச்சி பணிகளுக்காக பயன்படுத்தி கொள்ளவும் சம்மதிக்கின்றேன்.

I hereby give my consent for the treatment procedure to be done in my interest or (in case of minors) ms/Mr._____ who is my _____. The risk associated with the treatment have been explained to me and I accept complete responsibility and exonerate Ultra Dental science college, Madurai in case of any complication thereof.

I also give my consent to use the data and photographs pertaining to my case report for academic and research purposes.

Date Signature

Figure 4 Consent form

INCLUSION CRITERIA

1. Single rooted tooth
2. Presence of single canal
3. Non- carious tooth
4. Teeth with closed apex

EXCLUSION CRITERIA

1. Extensively carious tooth
2. Periodontally compromised tooth
3. Morphologically defective teeth
4. Open apex
5. Young patients with cardiac pacemakers

METHODS

This In-Vivo study was approved by Ethical committee/ Institutional review board (2018-STU-BrIV-SVR-07) of Best Dental Science College, Madurai. Single rooted maxillary and mandibular anterior teeth were considered for this study to eliminate the variation between the samples. The samples have its own inclusion and exclusion criteria.

INITIAL ISOLATION AND ACCESS

Initial pre-operative intra oral periapical radiographs were taken using RVG for the evaluation of periapical status of the sample tooth. Under local anesthesia and rubber dam isolation access cavity preparation done using ½ bur with high speed dental turbine handpiece in the prescribed shape. Pulp extirpation done using desired broaches. Pulp extirpation was done using broach and Initial apical file that snugly fits at the apex was selected.

Figure 5 Rubber dam isolation

Figure 6 Initial access cavity preparation

ELECTRONIC WORKING LENGTH MEASUREMENT (EWL)

The electronic working length was measured using two Electronic apex locators in dry canal and in the presence of various solutions. The apex locators were calibrated to ±1.0 mm which is the default configuration. Once the apex is reached with the stainless steel initial apical K-file the Apex locator beeps. The stopper is adjusted to the coronal reference point till the beep is stable for 3 seconds. “Apex mark” appeared. The silicone stop was then cemented to the file with light-cured glass ionomer cement (GC Fuji® Automix LC, GC Corp., Tokyo, Japan), and the distance between the stop and the file tip was measured with a digital caliper. The consecutive readings were recorded in the desired EWL in desired conditions i.e. in the presence of irrigation solutions.

Figure 7 EWL measurement using ROOT ZX Mini & Propex II

Figure 8 File measurement

EXPERIMENTAL GROUPS

The 60 samples were evaluated for EWL under two groups and four subgroups:

GROUP I - Root ZX Mini

GROUP II - PROPEX II

The subgroups are

SUBGROUP A- DRY CANAL (Control)

SUBGROUP B- NORMAL SALINE 0.9%

SUBGROUP C- SODIUM HYPOCHLORITE 5.25%

SUBGROUP D- QMix SOLUTION

The EWL was measured in the dry canal and in the presence of Normal Saline 0.9%, Sodium Hypochlorite 5.25% and QMix. The stoppers was stabilized using Light cure GIC. The file with stabilized stopper was measured using electronic digital caliper and were recorded. The recorded readings were subjected to statistical analysis.

RESULTS

RESULT

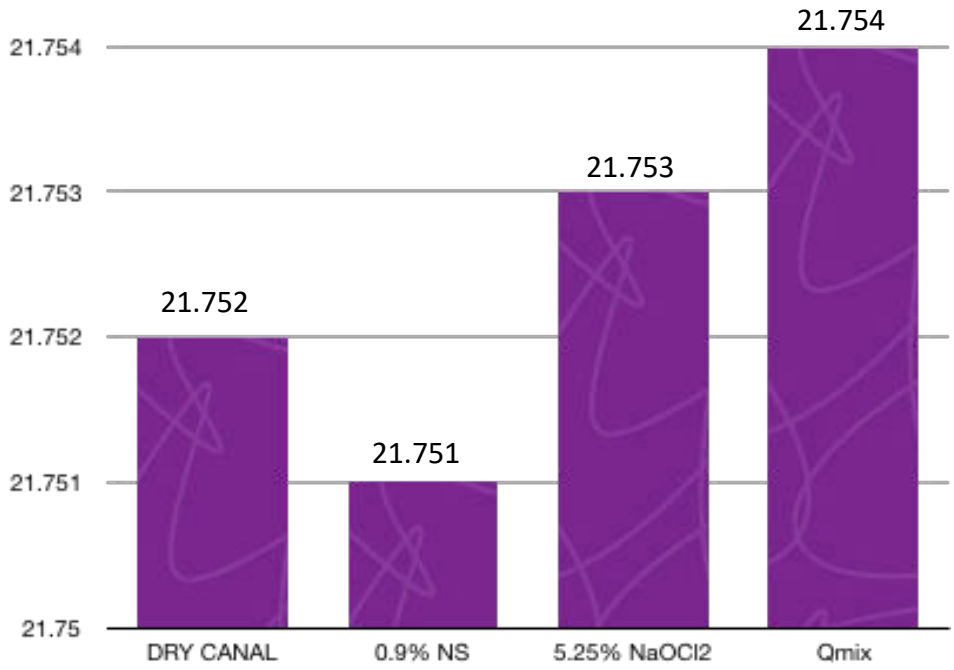
The data collected were compiled using MS Office Excel and loaded in SPSS IBM Software for statistical analysis. For mean group comparison descriptive statistics was used. For inter group and intragroup comparison Independent sample test and Bonferroni Post Hoc test was used respectively. There were no statistically significant values found in intergroup and intergroup comparison.

(mm)	**DRY VS NS**	**DRY VS NAOCL2**	**DRY VS QMIX**	**DRY VS NS**	**DRY VS NAOCL2**	**DRY VS QMIX**
SAME	1	1	5	5	3	7
0.1TO 0.5	40	31	29	37	33	33
0.5 TO 1	4	9	9	8	8	8
>1	5	9	7	0	6	2

Table 2 Difference in range of values

GROUP		**Mean**	**Std. Deviation**
ROOT ZX MINI	DRY CANAL	21.752	2.4500
	0.9% NS	21.751	2.3463
	5.25% NaOCl2	21.753	2.3680
	QMix	21.754	2.4327
PROPEX II	DRY CANAL	21.796	2.4553
	0.9% NS	22.032	2.3932
	5.25% NaOCl2	21.222	2.5469
	QMix	22.353	2.4784

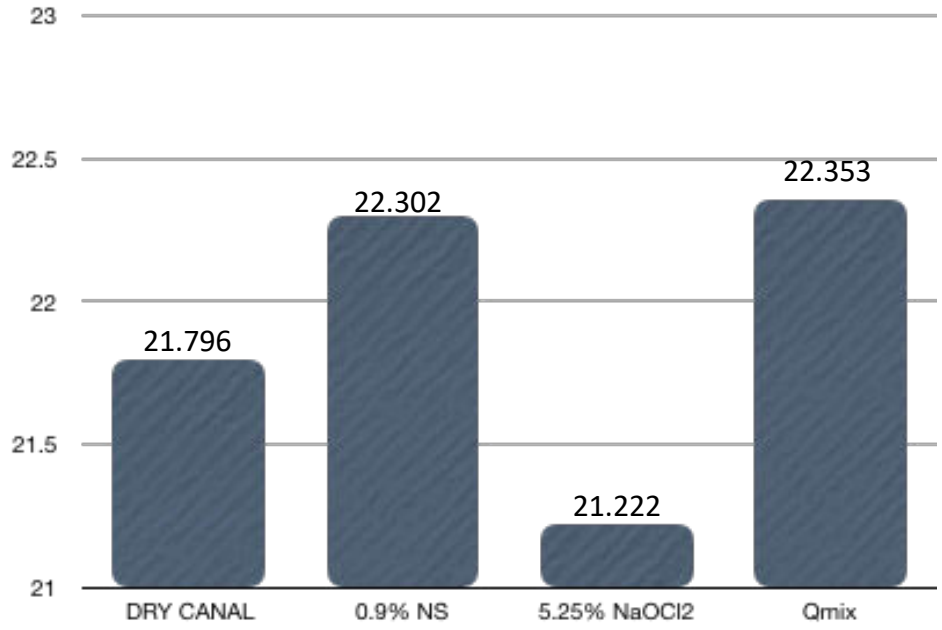
Table 3 Mean group comparison using descriptive statistics



GROUP I

ROOT ZX MINI

Graph I: Bar graph distinguishing the correlation between subgroups of Root ZX Mini



GROUP II

PROPEX II

Graph II: Bar graph distinguishing the correlation between subgroups of Propex II

OP NUMBER	PATIENT NAME	AGE/ SEX	TOOTH NO	ROOT ZX MINI (mm) GROUP I				PROPEX II(mm) GROUP II			
				DRY CANAL SUBGROUP I	0.9% NS SUBGROUP II	5.25% NaOCl2 SUBGROUP III	Qmix SUBGROUP IV	DRY CANAL SUBGROUP I	0.9% NS SUBGROUP II	5.25% NaOCl2 SUBGROUP III	Qmix SUBGROUP IV
448122	HARISH ARAVINDHAN	13/M	11	21.5	20.5	20	19	21	20.5	20	20.5
448122	HARISH ARAVINDHAN	13/M	21	20.5	20.5	20.8	20.5	21	21	20.6	20.5
426111	MEENAKSHI	47/F	11	20	21	21	21	21	21	20.5	21
427578	RATHISH KUMAR	24/M	21	20.6	21.1	20.4	21.6	21.7	21.6	21.7	21.6
452654	MANIKANDAN	18/M	11	21.6	21.4	21.9	22.2	21.5	21.9	21.5	22
452654	MANIKANDAN	18/M	12	22	21.6	22	22.8	22.4	22.7	23	22.4
451370	MOHAMMED DHARIK	20/M	12	20.6	19.5	20.5	19.3	20.3	20.6	20.8	20.5
451370	MOHAMMED DHARIK	20/M	11	18.1	18.5	19	19.1	18	18.8	19	18.6
451370	MOHAMMED DHARIK	20/M	21	22.5	22	21.3	22	22	21.5	21	20.8
449230	SUMATHI	42/F	23	21.7	21.3	22	21.2	21.6	21.6	21.2	21.7
434346	SUNDAR	24/M	12	20.3	20.9	21.2	20.3	20.4	21	20.5	20.8
450300	KUMAR	21/M	11	24.2	23.8	23.5	24	23.9	23.4	23	24
459391	PALANI KUMAR	31/M	11	21.4	21.5	20.2	21.3	21.2	20.8	21.2	22
459391	PALANI KUMAR	31/M	22	21.5	20.8	20.9	21.5	20.9	21.4	21	21.5
460618	SATHIYA	32/F	12	18.8	19	18	19	18.9	18.5	18.3	19.3
456445	MANOJ PRABHAKARAN	28/M	11	17.5	18	17.3	17.8	18.2	18.5	18.6	17.8
456445	MANOJ PRABHAKARAN	28/M	12	12.9	12.5	13	12.2	12.5	12.8	12.2	12.5
452161	VINOTH	25/M	11	20	19.5	20.5	20.3	19.8	19.7	20.1	19.9
452161	VINOTH	25/M	21	19	19.3	19.5	19.3	19.8	19.4	19	19.5
465322	SHANTHI	32/F	21	24	23.3	23	23.7	24	23.6	23.5	23
465322	SHANTHI	32/F	11	23.5	23	23.3	23.9	23.5	23.8	23.7	24
438565	VIGNESH KUMAR	22/M	11	22	21.8	21.5	21.9	22	21.3	21	21.3
444757	AZHAGU SUNDARAM	62/M	22	17	16.5	17.3	16.5	17	17.1	17.5	17.3
465742	VINOTH	17/M	21	25.3	24.8	25.6	24	25.4	24.9	25.5	25.3
466231	JASMINE	30/F	21	19.5	20	19.8	19.5	19.5	19.9	19.6	19.3
466231	JASMINE	30/F	11	21	21.3	21.6	21.1	21	21.2	21.3	21.5
425693	ANISHA FATHIMA	35/F	11	25.8	23	25.3	25.6	25.8	25.4	26	25.9
469381	MANIMALA	32/F	13	24.6	24.3	24.5	24.8	24.6	24.7	25	24.9
469166	MADHIRAJA	30/M	11	24.5	24	23.5	23.9	24.3	24.3	25	24.9
469166	MADHIRAJA	30/M	21	24.5	24	23.9	23.4	24.5	23.6	24	24.8
469166	MADHIRAJA	30/M	22	21	20.5	22	21.5	21	20.9	20.8	20.6
460624	RAMESH	32/M	23	26	26.3	25.8	25.4	26.2	26.2	26.3	25.9
469568	PUSHPASHRI	18/F	11	19.5	20.1	18.5	18.9	19.5	18.9	19.1	18.7
470224	TAMIZHARASI	29/F	12	21.9	21.4	22	22.6	21.8	22.2	21.5	21.4
470224	TAMIZHARASI	29/F	13	25.1	25	24.6	25	25.8	25.9	26	25.8
470224	TAMIZHARASI	29/F	43	22.8	22.9	23.2	22.9	23	23.5	23.1	23
470786	LATHA	35/F	13	22.3	22.5	21.8	22.4	22.1	22.2	22.5	22.9
443216	MURUGANANTHAM	26/M	41	21.3	21.5	21.8	21.2	21.3	21.4	21.5	21.7

465742	VINOTH	17/M	21	25.3	24.8	25.6	24	25.4	24.9	25.5	25.3
466231	JASMINE	30/F	21	19.5	20	19.8	19.5	19.5	19.9	19.6	19.3
466231	JASMINE	30/F	11	21	21.3	21.6	21.1	21	21.2	21.3	21.5
425693	ANISHA FATHIMA	35/F	11	25.8	23	25.3	25.6	25.8	25.4	26	25.9
469381	MANIMALA	32/F	13	24.6	24.3	24.5	24.8	24.6	24.7	25	24.9
469166	MADHIRAJA	30/M	11	24.5	24	23.5	23.9	24.3	24.3	25	24.9
469166	MADHIRAJA	30/M	21	24.5	24	23.9	23.4	24.5	23.6	24	24.8
469166	MADHIRAJA	30/M	22	21	20.5	22	21.5	21	20.9	20.8	20.6
460624	RAMESH	32/M	23	26	26.3	25.8	25.4	26.2	26.2	26.3	25.9
469568	PUSHPASHRI	18/F	11	19.5	20.1	18.5	18.9	19.5	18.9	19.1	18.7
470224	TAMIZHARASI	29/F	12	21.9	21.4	22	22.6	21.8	22.2	21.5	21.4
470224	TAMIZHARASI	29/F	13	25.1	25	24.6	25	25.8	25.9	26	25.8
470224	TAMIZHARASI	29/F	43	22.8	22.9	23.2	22.9	23	23.5	23.1	23
470786	LATHA	35/F	13	22.3	22.5	21.8	22.4	22.1	22.2	22.5	22.9
443216	MURUGANANTHAM	26/M	41	21.3	21.5	21.8	21.2	21.3	21.4	21.5	21.7
443216	MURUGANANTHAM	26/M	31	21.4	21.3	22	21.8	21.4	21.3	21.7	21.4
443216	MURUGANANTHAM	26/M	32	22	22.5	22.4	22.3	22.1	22.5	22.8	22
443767	SOUNDARARAJAN	33/M	21	24	24.3	23.6	24	24	24.3	23.6	24.1
456371	RAJAGURU	35/M	21	23.5	23.8	23.3	23.6	23.5	23.8	24	23.2
471371	SAMRITHA	18/F	21	21.5	21.6	22	21.7	21.5	21.8	22.1	21.6
471371	SAMRITHA	18/F	11	21.8	21.4	22	22.3	21.8	21.7	21.9	21.6
474342	KAMEELA BANU	40/F	13	22.5	22.6	23	23.2	22.5	23.2	23	22.9
473436	NAJATHA BANU	34/F	21	23.7	24	24.1	23.9	23.7	23	24	23.7
464321	RENGARAJAN	42/M	23	24.5	24	24.6	23.8	24.5	24.3	25.2	24.8
464321	RENGARAJAN	42/M	22	22	21	21.5	22.4	22	22.1	22.4	22.4
473376	RADHA	38/F	12	21	21.4	22	21.2	21	21.4	22.3	21.7
473376	RADHA	38/F	13	23.4	23.6	24.2	23.2	23.4	24.1	24.5	22.9

Table 4 Working length data collected for analysis

According to Table 3 the difference in range of values of working length in both the groups which has same values on comparison with dry canal is more in the Group II. Thereby on consideration with the dry canal as control group the irrigants did not alter the EWL. The EWL measured in the range of 0.1 to 0.5 was mostly recorded which concludes even if there is a change in EWL it is only between range of 0.5 mm. The comparison between dry and QMix in both the groups was recorded high rather than other sub group comparison. Graph I and Graph II exhibits the variation in third decimal for Group I whereas Graph II exhibits variation in second decimal which concludes the irrigants does not have any effect over the EWL measurement.

DISCUSSION

DISCUSSION

The primary concern of endodontic treatment is to determine the root canal length and limiting all the steps within the determined root canal length which is known as working length. Successful endodontic treatment depends on the accurate location of the apical foramen (i.e.) correct determination of the working length. Determination of working length have been explained by various methods by various authors but it is made still easier by the use of Electronic apex locators. The best method to determine the accuracy of EAL readings is to compare them with the gold standard represented by actual root canal readings. In the endodontic literature, devices used to measure root canal length are mostly termed electronic apex locators and are classified as resistance, impedance, frequency, or ratio-based devices. However, Nekoofar et al reported that the devices did not assess the position of the root apex, that the name 'electronic apex locator' was not appropriate, and that 'electronic root canal length measurement device' (ERCLMD) as a generic name would be more appropriate[45].

Radiographic method is the most common technique of working length determination. Ingle's method is considered as most acceptable radiographic method. Radiographs were taken using individual template for each tooth in combination with paralleling technique. This assists in the reproducibility of the radiograph technique and reduces the potential interpretation errors. Even when a paralleling technique was used elongation of images has been found to approximately 5%. Chakravarthy pishipati et al indicates that the acceptable measurements of radiographic and Propex II apex locator were 76.66% and 86.6%, respectively. Martvnez-Lozano et al showed accuracy of 61.4% by digital radiological method (RVG system) as compared to apex locator, which showed accuracy of 67.8%. According to Vasconcelos et al the absence of statistically significant differences between Propex II and Root ZX measurements suggests that the operating mechanism of the novel EFL, which is based on evaluating the energy of the current signal by calculating the mean square root of impedances

in two frequencies, seems to be reliable. This device was capable of exceeding interferences in the resistance/capacitance system, since its mean error was close to the apical foramen and similar to the gold standard device. According to André Luiz Gomide de Morais et al the determination of the working length of root canal using CBCT images was precise when compared to radiographic method and electronic apex locator. Dunlap et al (1998) stated that pulp vitality does not significantly affect the accuracy of ERCLMD's[22].

The first-generation ERCLMD's were resistance-based and the second-generation ERCLMD's were impedance-based apex locators. The main shortcomings of these ERCLMD's included poor accuracy in the presence of fluids and pulp tissue, and the need for calibration. The frequency-based third-generation ERCLMD's have more powerful microprocessors and are able to process mathematical quotient and algorithm calculations required to give accurate readings[46].

Root ZX (J. Morita, Japan) is a third-generation ERCLMD that uses dual frequency and comparative impedance principle is based on the "ratio method" for measuring canal length. This method simultaneously measures the impedance values at two frequencies (8 and 0.4 kHz) and calculates a quotient of impedances. This quotient is expressed as a position of the file in the canal. Root ZX requires no calibration, and can be used when the canal is filled with a strong electrolyte. Fan et al encountered, in dry tubes that the accuracy of Root ZX was 75 to 91.7% within ± 0.5 mm and 100% within ± 1.0 mm, whereas in tubes filled with electrolyte, the accuracy of the Root ZX decreased as tubule diameter increased[27].

Propex technology was considered reliable in the presence of various root canal irrigant. Similarly, Propex II was found to be an accurate device in determining the actual working length. Additionally, Propex II was reported to be more accurate than the digital radiographic method. Propex II is a fourth-generation electronic apex locator that uses multiple frequencies (up to five frequencies) to measure the impedance in order to determine the EWL[47].

Multiple frequency measurement is used to calculate the distance from the tip of the file to the foramen by measuring changes in impedance between two electrodes. Unlike third generation these do not use the impedance values as a mathematical algorithm only to assess the WL but instead utilize the resistance and capacitance measurement and thereafter compare them with a database to measure the distance of file to the apex of the canal[40]. The width of the foramen and the size of the file plays important role in EWL measurement. Most of the ERCLMD's are capable of measuring the RCL at the point where the PDL fibers start[13].

An in vivo study presents a great challenge for evaluation; however, it simulates an actual clinical situation more closely. Another important factor in In-Vivo study is the standardization of specimen. The tooth must be fully developed to obtain accurate readings using electronic apex locators. If the root is immature the readings may oscillate resulting in false readings.

The use of irrigating solutions is an important aspect of endodontic treatment[48]. Several studies using advanced techniques such as micro-computed tomography (CT) scanning have demonstrated that proportionally large areas of the main root-canal wall remain untouched by the instruments. Sodium hypochlorite (NaOCl) is the most popular irrigating solution. NaOCl ionizes in water into Na and the hypochlorite ion, establishing an equilibrium with hypochlorous acid (HOCl). At acidic and neutral pH, chlorine exists predominantly as HOCl, whereas at high pH of 9 and above, OCl predominates. Hypochlorous acid is responsible for the antibacterial activity. NaOCl is commonly used in concentrations between 0.5% and 6%. It is a potent antimicrobial agent, killing most bacteria instantly on direct contact. It also effectively dissolves pulpal remnants and collagen, the main organic components of dentin. Hypochlorite is the only root-canal irrigant of those in general use that dissolves necrotic and vital organic tissue. It is difficult to imagine successful irrigation of the root canal without hypochlorite. Various electroconductive materials such as sodium hypochlorite were used

along with these devices to check its accuracy. Because of its electroconductivity it is believed that it interferes with the electronic circuit completed by ERCLMD, the resultant readings may be inaccurate[9]. But with various advancements in the technology and microprocessors incorporated in the device would overcome such situations. First two generations of ERCLMD do not work under wet conditions but further generations are devised in manner to work on both dry and wet conditions. Our results shown that the irrigants evaluated did not by and large have an effect on the accuracy of the Root ZX. Ultimately, using either untransformed or absolute value data, these studies demonstrate that the Root ZX was able to consistently determine the location of the apical foramen (within approximately 0.4 mm) in the presence of any of the tested irrigants. It is as yet unclear why the greatest deviation from actual canal length was obtained with NaOCl. Given the widespread utility of NaOCl as an intracanal irrigant, the existence, if not the source, of the increased variance observed in the presence of this irrigant should be considered. Nonetheless, collectively, these results support the statements made by the manufacturers of the Root ZX, namely that the Root ZX is an accurate EAL across a variety of irrigants commonly used in the practice of endodontics. Further investigations with different irrigants in vivo seem warranted[49].

In this In-Vivo study the use of Normal Saline, Sodium hypochlorite and QMix along with the ERCLMD does not have any impact over the accuracy. In correlation with the difference in ranges of values in the both the groups in comparison with the dry canal and QMix has more of same values i.e EWL. Henceforth the QMix irrigation solution can be considered as it does not have any electroconductivity[1]. The range between 0.1 to 0.5 mm difference was found in most in of the samples taken, hence the irrigation solutions does not have any impact over EWL measurement. It was observed that during the EWL measurement in the presence of sodium hypochlorite the readings were oscillating and the accurate reading was difficult to conclude. So, the oscillation in reading caused due to the high

electroconductivity of the solutions. The recordings with normal saline and QMix were close to the actual WL in dry canal rather than the recordings with Sodium Hypochlorite[50].

SUMMARY

SUMMARY:

Working length (WL) is defined as the distance from a coronal reference point to the point at which the canal preparation and obturation should terminate (American association of Endodontists 2003). As per the definition the endodontic therapy is mainly concerned with the WL within which all the procedures must terminate without any violation for a successful outcome.

According to American Association of endodontists (1984), The radiographic apex is defined as the anatomical end of the root as seen on the radiograph, while the apical foramen is the region where the canal leaves the root surface next to the periodontal ligament.

The success of the RCT is mainly dependent on proper cleaning and shaping of the canal space. To effectively clean and shape the root canal space the apical target i.e. apical constriction should be determined accuratel[3]. Traditional methods for establishing working length have been (a) the use of anatomical averages and knowledge of anatomy, (b) tactile sensation, (c) moisture on a paper point and (d) radiography.

The aim of the study was to evaluate the accuracy of two electronic apex locators in wet and dry conditions. Dry canal was considered as control and the presence of irrigation solution was considered as experimental groups.

APEX LOCATORS:1.Root ZX Mini2.Propex II IRRIGATION SOLUTIONS:1. Dry canal (Control); 2. 0.9% Saline; 3. 5.25% Sodium hypochlorite solution; 4. QMix solution . 33 patients with 60 maxillary anterior teeth (60 canals) scheduled for endodontic treatment participated in this In vivo study. Previous approval was obtained from the Institutional Review Board/ Ethical committee (2018-STU-BrIV-SVR-07) for this study. Informed consent was obtained from the patient. Inclusion criteria were teeth that are planned for non-surgical endodontic treatment and Exclusion criteria were Teeth with cracks, undefinable coronal

reference points, periapical lesions, immature apices, root canal obliteration, perforation, internal resorption, curved canals and periodontally compromised teeth. A standardized preoperative diagnostic periapical radiograph was taken for each tooth. Under Local anesthesia and rubber dam isolation initial access cavity preparation was done using ½ round diamond bur and highspeed dental handpiece. Pulp extirpation done and initial apical file was selected according to the snug fit that is evident at the apex. EWL measurements were recorded accordingly with the two apex locators - Root ZX Mini and Propex II, in dry canal(control) and in the presence of three irrigant solutions – Normal saline 0.9%; Sodium Hypochlorite 5.25% and QMix. In between change of irrigation solution, the canal is flushed with saline and dried with paper points to eliminate any reaction between the solutions. The measurement taken in dry canal was co-related with those measurement taken with the three different irrigants. The data collected were compiled using MS-Office Excel and was subjected to Statistical analysis using IBM corp. SPSS (Statistical package for social sciences) Statistics for windows, version 20.0 (Armonk, NY) Statistical significance was set at $P < 0.05$. Descriptive and inferential statistics were used to analyse the data. Normality of the data was assessed. Independent t-test was done to assess the statistical difference between Group A and Group B.ANOVA with bonferroni posthoc was done for within group comparison

Propex II was found to have maximum coordinated EWL values in dry and with the presence of various irrigants like Normal saline, Sodium hypochlorite and QMix. On comparison of mean of EWL measured, Root ZX Mini was found to be more consistent with the difference in the values only in the third decimal in both dry and with presence of various irrigants like Normal saline, Sodium Hypochlorite and QMix. More than 50% of the samples falls in range of 0.1 to 0.4 which is well in the limits of location of minor apical constriction. To conclude with that the presence of various irrigation solution does not alter the accuracy of ERCLMD's.

CONCLUSION

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BEST DENTAL SCIENCE COLLEGE & DENTAL HOSPITAL, MADURAI.

DEPARTMENT OF CONSERVATIVE DENTISTRY AND ENDODONTICS

Medical history

1. Allergic to
2. Hypertension
3. Diabetes mellitus
4. Cardiac problem
5. Epilepsy

_____ஆகிய நான் எனக்கு (அல்லது) எனது மகன்/ மகள் _____என்பவருக்கு சிகிச்சை எனது சம்மதத்தின் பேரில் தான் அளிக்கப்படுகிறது இதனால் வரும் முன்பின் விளைவுகள் எனக்கு விளக்கப்பட்டது இதனால் ஏற்படும் விளைவுகளுக்கு அல்ட்ரா பல் மருத்துவ கல்லூரி பொருப்பல்ல. பல் மருத்துவ கல்லூரி விதிமுறைகளை ஏற்றுக்கொண்டு சிகிச்சை பெற ஒப்புக்கொள்கிறேன்.

மேலும் நான் என் நோய் சம்பந்தப்பட்ட விவரங்கள் மற்றும் புகைப்படங்கள் கல்வி மற்றும் ஆராய்ச்சி பணிகளுக்காக பயன்படுத்தி கொள்ளவும் சம்மதிக்கின்றேன்.

I hereby give my consent for the treatment procedure to be done in my interest or (in case of minors) ms/Mr_____ who is my _____. The risk associated with the treatment have been explained to me and I accept complete responsibility and exonerate Ultra Dental science college, Madurai in case of any complication thereof.

I also give my consent to use the data and photographs pertaining to my case report for academic and research purposes.

Date

Signature

INSTITUTIONAL ETHICAL COMMITTEE

Best Dental Science College and Hospital

Ultra Nagar, Madurai - 625 104.

RECOGNIZED BY DENTAL COUNCIL OF INDIA, NEW DELHI
AFFLIATED TO THE TAMILNADU Dr. M.G.R MEDICAL UNIVERSITY, CHENNAI)

IRB/IEC Reference No: 2018-STU-BrIV-SVR-07

Project title: Influence of Different Irrigants on the Accuracy of Two Electronic Apex Locators- An In-vivo Study

Principal Investigator: Dr. D.S. Venkata Ramanan,

PG student

Review: New/Revised/Expedited

Date of Review: 23/02/2018

Date of previous review, if revised application:

Decision of the IEC/IRB:

- Approval to conduct the study is being given

Signature of the Principal

PRINCIPAL
BEST DENTAL SCIENCE COLLEGE
MADURAI-625104

NB:

Inform IRB/IEC immediately in case of any issue(s)/adverse events

Inform IRB/IEC in case of any change of study procedure, site and investigator

This permission is only for the period mentioned above

Annual report to be submitted to IEC/IRB

Members of IEC/IRB have right to monitor the trail with prior intimation

URKUND

Urkund Analysis Result

Analysed Document: plagarism new.docx (D62889685)
Submitted: 1/23/2020 5:14:00 PM
Submitted By: ${Xml.Encode(Model.Document.Submitter.Email)}
Significance: 10 %

Sources included in the report:

PLAGARISM.docx (D62324554)

Instances where selected sources appear:

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