

**COMPARISON OF THE ACCURACY OF ROOT ZX MINI AND
RAYPEX 6 IN DETECTING APICAL CONSTRICTION IN
HUMAN PERMANENT MAXILLARY ANTERIOR TEETH IN
THE PRESENCE OF VARIOUS IRRIGANTS USING
STEREOMICROSCOPE – AN IN VITRO STUDY.**

A dissertation submitted

in partial fulfillment of the requirements

for the degree of

MASTER OF DENTAL SURGERY

BRANCH – IV

CONSERVATIVE DENTISTRY AND ENDODONTICS



THE TAMILNADU DR. MGR MEDICAL UNIVERSITY

CHENNAI – 600 032

2012 – 2015

DECLARATION BY THE CANDIDATE



I hereby declare that this dissertation titled “**COMPARISON OF THE ACCURACY OF ROOT ZX MINI AND RAYPEX 6 IN DETECTING APICAL CONSTRICTION IN HUMAN PERMANENT MAXILLARY ANTERIOR TEETH IN THE PRESENCE OF VARIOUS IRRIGANTS USING STEREOMICROSCOPE -AN IN VITRO STUDY**” is a bonafide and genuine research work carried out by me under the guidance of **Dr.B.RAMAPRABHA, M.D.S, Professor**, Department Of Conservative Dentistry and Endodontics ,Tamilnadu Government Dental College and Hospital. Chennai -600003.

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ACKNOWLEDGEMENT

I wish to place on record my deep sense of gratitude to my mentor **Dr. M. KAVITHA, M.D.S.**, for the keen interest, inspiration, immense help and expert guidance throughout the course of this study as **Professor & HOD of the Dept. of Conservative Dentistry and Endodontics**, Tamilnadu Govt. Dental College and Hospital, Chennai.

It is my immense pleasure to utilize this opportunity to show my heartfelt Gratitude and sincere thanks to **Dr. B.RAMAPRABHA, M.D.S., Professor & Guide, Department of Conservative Dentistry and Endodontics**, Tamilnadu Govt. Dental College and Hospital, Chennai for her guidance, suggestions, source of inspiration and for the betterment of this dissertation.

I take this opportunity to convey my everlasting thanks and sincere gratitude to **Dr.S.PREMKUMAR, M.D.S., Principal(i/c), Tamilnadu Government Dental College and Hospital, Chennai** for permitting me to utilize the available facilities in this institution.

I sincerely thank **Dr.S.JAIKAILASH, M.D.S, DNB, Professor and Dr.K.AMUDHA LAKSHMI, M.D.S., Dr.D.ARUNA RAJ, M.D.S., Associate professors** for their guidance, constant support and encouragement throughout my postgraduate course.

I sincerely thank **Dr.G.VINODH, M.D.S., Dr.A.NANDHINI, M.D.S., Dr.P.SHAKUNTHALA, M.D.S., Dr.M.S.SHARMILA, M.D.S., Dr.SUDHARSANARANJANI, M.D.S., Dr.SMITHA, M.D.S., and Dr.JOTHI LATHA, M.D.S., Dr.VENKATESH, M.D.S., Assistant Professors** for their suggestions, encouragement and guidance throughout this study.

My sincere thanks to **Dr.A.Palanisammi, PhD, Professor and Head of the department, Dr.D. Reena, PhD, Assistant professor and Dr.Gopikrishnan, PhD scholar ,Department of Animal Biotechnology, Madras Veterinary College ,Chennai**, for their guidance in stereomicroscope examination.

I am extremely grateful to **Dr.M.Ramesh, M.D.S** for giving me the Root ZX Mini Apex locator used in this study and his suggestions, encouragement and guidance throughout this study.

I specially thank, **Dr.S.Ravanan, MBA, PhD, Data manager, Biostatistician** for all his statistical guidance and help.

I owe my sincere thanks to all my senior postgraduates, fellow post graduates and junior postgraduate students in the department for their constant encouragement and timely help.

I whole heartedly wish to thank my **Parents and my Brother T.Shanmuganathan, Dr.V.Harihara Subramanian MBBS, MPH** for their patience, constant support and encouragement in every step of my life.

Finally ‘Not that we are adequate in ourselves to consider anything as coming from ourselves, but our adequacy is from **God Almighty**’.

DECLARATION

TITLE OF DISSERTATION	COMPARISON OF THE ACCURACY OF ROOT ZX MINI AND RAYPEX 6 IN DETECTING APICAL CONSTRICTION IN HUMAN PERMANENT MAXILLARY ANTERIOR TEETH IN THE PRESENCE OF VARIOUS IRRIGANTS USING STEREOMICROSCOPE – AN IN VITRO STUDY.
PLACE OF STUDY	TAMILNADU GOVERNMENT DENTAL COLLEGE & HOSPITAL, CHENNAI – 3.
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Whereas the PG student as part of her curriculum undertakes to research on **“COMPARISON OF THE ACCURACY OF ROOT ZX MINI AND RAYPEX 6 IN DETECTING APICAL CONSTRICTION IN HUMAN PERMANENT MAXILLARY ANTERIOR TEETH IN THE PRESENCE OF VARIOUS IRRIGANTS USING STEREOMICROSCOPE – AN IN VITRO STUDY”** for which purpose the Principal Investigator shall act as principal investigator and the college shall provide the requisite infrastructure based on availability and also provide facility to the PG student as to the extent possible as a Co-investigator.

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1.

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ABSTRACT

AIM:

To compare the Accuracy of Root ZX mini (J.Morita Corp., Tokyo, Japan), and Raypex6(VDW, Munich, Germany) apex locators in detecting the apical constriction in human permanent maxillary anterior teeth in the presence of 0.9% saline; 5% sodium hypochlorite; 2% chlorhexidine digluconate, as various intracanal irrigants.

MATERIALS AND METHODS:

Sixty extracted, straight, single rooted permanent human maxillary anterior teeth were randomly divided into two main groups according to the apex locators tested such as Group1 (n=30,Root ZX mini) Group 2 (n=30,Raypex6). Then each group is further divided into 3 subgroups according to the irrigants used such as Group 1A(n=10,Root ZX mini,0.9% normal saline), Group 1B(n=10,Root ZX mini,5%NaOCl),Group 1C(n=10,Root ZX mini,2%chlorhexidine digluconate), Group2A(n=10,Raypex6,0.9% normal saline), Group2B(n=10,Raypex6, 5%sodium hypochlorite), Group2C (n=10,Raypex6, 2%chlorhexidine digluconate).The teeth were decoronated at the level of cementoenamel junction and the actual length (AL) of each specimen was determined by introducing a size 10 or 15 K file into the canal until its tip emerged through the major apical foramen at $\times 10$ magnification under a stereomicroscope. Each specimen was embedded in the gelatin model and the EALs were tested according to the manufacturer's instructions. The Electronically measured canal length was recorded by using size 10 or 15 K file(EL). Then the K-files were fixed at the WL determined electronically with GIC. The apical 4 mm of the root was longitudinally sectioned and examined under Stereomicroscope with 30x magnification.The distance from the file tip to the minor diameter is calculated from the Stereomicroscopic images. Independent sample t test and Pearson Chi-Square test was used to statistically analyse the significance of irrigants on the accuracy of apex locators and to compare the accuracy of both apex locators. Significance was set at $P < 0.05$.

RESULTS:

The overall accuracy of measurements within ± 0.5 mm of AL by Root ZX mini was 93.33% and Raypex 6 was 90% respectively.

CONCLUSION:

Within the limitations of this in vitro study the two electronic apex locators, the Root ZX mini and the Raypex6 were found to have similar accuracy and the use of 5% NaOCl, 0.9% normal saline, or 2% Chlorhexidine as irrigation solutions did not affect the accuracy of the two apex locators in detecting the apical constriction.

KEY WORDS:

Apical constriction, EAL, Root ZX mini , Raypex6, intracanal irrigant.

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INTRODUCTION

The success of endodontic treatment depends on the eradication of microbes (if present) from the root-canal system and prevention of reinfection. Correct working length(WL) determination and confining root filling materials only to the canal and not invading the periapical tissues results in better root canal treatment outcomes and reduces the odds of insufficient cleaning of the full extent of the canal⁶² . Working length is defined as ‘the distance from a coronal reference point to the point at which canal preparation and filling should terminate’ (American Association of Endodontists (AAE) 2003)² Instrumentation beyond the apical foramen (AF) should be avoided because it decreases the success rate. In the short term, accurate WL determination may prevent flare-ups, and in the long term it allows for successful treatment outcome by preventing periapical foreign body reactions⁵¹.

The apical constriction (AC) forms the minor foramen (or minor diameter) and the most apical opening of the root canal is designated as the AF or major foramen or greater diameter. The distance between AC and AF varies from 0.5 to 0.7 mm. Biomechanical preparation should end at the AC, where the contact between the root canal filling material and the apical tissue is minimal⁶¹.

The radiographic apex is defined as the anatomical end of the root as seen on radiographs, whilst the AF is the region where the canal leaves the root surface and the AC often coincides with the cemento–dentinal junction⁴². The AF deviates from the anatomic or radiographic apex in 60–94% of the cases. It is present 0.5–2.0 mm apical to the anatomic apex on the buccal, lingual or proximal surfaces. Studies show the distance between the AC and the anatomic apex on average 1 mm⁴².

Introduction

In clinical practice the AC cannot be detected radiographically. Moreover, a single distinct constriction that can be determined in a tactile approach is only present in 40–50% of cases⁹. Although Olson et al. (1991)⁵³ have reported that the location of the AF could be accurately determined radiographically, the distance from the AC cannot be measured. Despite the limited information provided by an intraoral radiograph, radiography remains an accepted and commonly used method for WL determination. Electronic apex locators (EAL) are useful adjuncts in locating the terminus of the canal during root canal treatment. However, they cannot replace radiographic techniques. The ability of EAL to accurately locate the apex is 55–93%. Studies^{63,61} also indicate that false readings are often obtained from EAL, indicating the need for radiographic films.

Custer(1918) was the first to determine WL Electronically later Suzuki's discovered the electrical resistances between the periodontal ligament and oral mucosa registered constant values of 6.5 kΩ, Sunada in 1962 developed the first electronic apex locator (EAL)⁶⁷. Since then, different generations of EALs have been developed. Recently developed electronic apex locators (EAL) are based on the measurement of alternating current impedance. For that, two or more different frequencies are used and processed using different mathematical algorithms. These EALs are now widely accepted by practitioners, especially because they can reduce the number of diagnostic radiographs required for working length determination. Current EALs have a high reliability, high accuracy and high reproducibility in locating the major apical foramen regardless of the electrolyte.

The Root ZX (J. Morita Corp., Tokyo, Japan) uses the 'ratio method' to locate the minor foramen (Kobayashi & Suda 1994)³⁶ by the simultaneous measurement of impedance using two frequencies. The Root ZX claims to work in the presence of

Introduction

electrolytes and nonelectrolytes and requires no calibration (Kobayashi 1995). Root ZX mini is a super compact design containing the same technology that made the Root ZX II. The Root ZX apex locator has been investigated extensively as regards its accuracy and its efficacy in the presence of various irrigants and is considered to be the gold standard against which newer EALs are evaluated.

The Raypex 6 (VDW, Munich, Germany) is the latest fifth generation apex locator based on multi frequency and is also claimed to be accurate in the presence of various intra canal conditions. It has Automatic calibration and the separate apical zoom shows the enlarged section between apical constriction and apical foramen⁴⁴.

Although modern EALs can locate the apical foramen and the apical constriction with high precision, it is unclear how accurate these devices are as they approach the apical region and how precise the meter readings correlate with the file position. A study by Higa et al. (2009)²⁹ demonstrated that there were differences between EALs depending on the distance of the measurement file to the apical foramen. The precision of measurement might also depend on the file size and the dimensions of root canal and foramen and fluid inside the canal.

To the best of our knowledge, few studies have evaluated the accuracy of the recently developed Raypex 6. Hence in this invitro study comparison of the accuracy of the Root ZXmini, and the Raypex 6 in detecting the apical constriction in the presence of various intracanal irrigants was done.

Aims and Objectives

AIMS AND OBJECTIVES

AIM

The aim of this study is to evaluate the accuracy of Root ZX mini and Raypex6 apex locators in detecting the apical constriction of human permanent maxillary anterior teeth.

OBJECTIVE

1. To compare the accuracy of Root ZX mini and Raypex6 apex locators in detecting the apical constriction of permanent maxillary anterior teeth in the presence of 0.9% saline, 5% sodium hypochlorite (NaOCl), 2% chlorhexidine digluconate as intracanal irrigants by using Stereomicroscope.
2. To determine the influence of various intracanal irrigants on the accuracy of Electronic apex locators in detecting the apical constriction.

REVIEW OF LITERATURE

The electronic apex locator (EAL) machine has attracted a great deal of attention because it operates on the basis of the electrical impedance rather than by a visual inspection. The EAL is one of the breakthroughs that brought electronic science into the traditionally empirical endodontic practice. EALs are particularly useful when the apical portion of the canal system is obscured by certain anatomic structures, such as impacted teeth, tori, the zygomatic arch, excessive bone density, overlapping roots, or shallow palatal vaults¹⁷. Indeed, EALs currently are being used to determine the working length as an important adjunct to radiography. EALs help to reduce the treatment time and the radiation dose, which may be higher with conventional radiographic measurements. In addition, EALs were reported to be an accurate and reproducible method as the newest third generation type and can acknowledge a root perforation. However, some questions still exist as to whether the accuracy of EAL can be affected by the different types of electrolytes, the types of electronic working mechanism, and the conditions of the root canal, such as pulp vitality or foramen size¹⁷. In this review we see about the factors affecting the accuracy of two newly introduced apex locators (Root ZX Mini and Raypex 6).

ROOT ZX SERIES APEX LOCATORS:

Joslyn A. Jenkins, et al (2001)³⁸ evaluated the accuracy of the Root ZX in vitro in the presence of a variety of endodontic irrigants. The following irrigants were tested: 2% lidocaine with 1:100,000 epinephrine, 5.25% sodium hypochlorite, RC Prep, liquid

Review of literature

EDTA, 3% hydrogen peroxide, and Peridex. A total of 30 extracted, single-rooted teeth were used. The experimental measurements in the presence of the various irrigants were compared with the actual canal lengths. The present data indicate that the Root ZX electronic apex locator reliably measured canal lengths to within 0.31 mm and that there was virtually no difference in the length determination as a function of the seven irrigants used. These results strongly support the concept that the Root ZX is a useful, versatile, and accurate device for the determination of canal lengths over a wide range of irrigants commonly used in the practice of endodontics

Fernando Goldberg, et al (2002)²² evaluated the accuracy of Root ZX apex locator to determine the working length in teeth with simulated apical root resorption. Fifty extracted, single-rooted, human teeth with mature apices were used in this study. An irregular cavity defect was drilled at the apex of each tooth simulating an apical root resorption. Three operators used the Root ZX to measure the working lengths, comparing the electronic readings with the direct visual measurements. The Root ZX was 62.7%, 94.0%, and 100.0% accurate to within 0.5 mm, 1 mm, and 1.5mm of the direct visual measurements, respectively. The results of this study conclude that the Root ZX may be used to determine the working length in teeth with apical root resorption.

A. Y. Kaufman et al (2002)⁴⁰ compared the accuracy of a Bingo 1020 electronic apex locator, with Root ZX, in an in vitro model using the radiographic method of tooth length determination. They concluded that the content of the root canal influenced the results of the measurements with both EALs, but the differences were not clinically significant and the Bingo 1020 proved to be as reliable as Root ZX and

Review of literature

was user friendly. Under the experimental conditions, electronic measurements were more reliable than radiographs in the process of root length determination.

W. Anthony Meares, et al (2002)⁷¹ Studied whether the presence of sodium hypochlorite influences the accuracy of the Root ZX electronic apex locator. Forty, extracted, human teeth were mounted in an experimental apparatus. After achieving ideal access, working length measurement were obtained using the Root ZX. The canals were flushed with 2.125% sodium hypochlorite and measurements were again made with the electronic apex locator. Before measuring a third time, 5.25% sodium hypochlorite was then administered to each canal. Finally, the tooth was removed from the apparatus and the actual canal length was determined by measuring a file brought to the apical constriction no significant differences were found between the experimental groups. Overall, Root ZX measurements were within 0.5 mm of the actual length 83% of the time. The results of this study indicate that the Root ZX is not adversely affected by the presence of sodium hypochlorite.

Aaron R. Welk, et al (2003)¹ compared the accuracy of a two-frequency (Root ZX) and a five frequency (Endo Analyzer Model 8005) electronic apex locator under clinical conditions. Thirty-two teeth planned for extraction were used. A K-type file was used to determine a separate working length in each canal using the electronic apex locators. The teeth were extracted and the apical 4 mm of each root canal was exposed along the long axis of the tooth. Photographic slides of each canal were projected and the file position in relation to the minor diameter was determined by two investigators. The ability to locate the minor diameter (\pm 0.5 mm) was 90.7% for the Root ZX and 34.4% for the Endo Analyzer Model 8005.

Review of literature

Lucena-Martín et al (2004)⁴⁵ evaluated the the accuracy of three electronic apex locators (EALs) (Justy II, Root ZX, and Neosono Ultima EZ) together with the concordance of the measurements obtained by two different operators. The results obtained with each EAL and by each operator were in turn compared with the corresponding control length. The statistical analysis of the results showed EAL reliability in detecting the apex to vary from 80% to 85% and 85% to 90% (depending on the operator) for the Justy II and Neosono systems, respectively, whereas reliability was found to be 85% for the Root ZX device and there is no significant differences between operators were observed , so they concluded if the apex locators are used according to the instructions of the manufacturer, no previous experience with these devices is essential in order to obtain correct measurements.

Fernando Goldberg, et al (2005)²³ evaluate the accuracy of three apex locators in determining the working length during the retreatment process. Twenty extracted single-rooted human teeth with mature apices were used in this study. The root canal length of each tooth was measured placing a #15 file until the tip was visible at the apical foramen. The direct visual measurement was reduced by 0.5 mm and recorded. The root canals were instrumented and filled to the direct visual measurement using lateral compaction technique. After 7 days the teeth were retreated using three apex locators: ProPex, NovApex, and Root ZX, for determining the retreatment working length. Afterward, comparison between the visual working length and the retreatment working length were made. ProPex, NovApex, and Root ZX were accurate within 0.5 mm 80, 85, and 95% of the time, and within 1 mm 95, 95, and 100%, respectively. No significant differences were detected between the three apex locators ($p \leq 0.05$).

Review of literature

Járcio V. Baldi, et al (2006)³⁵ compared the effectiveness of different embedding media for in vitro assessment of electronic apex locators. The tooth lengths of 30 extracted human mandibular central incisors were measured by introducing a size 15 K-file fitted with a silicone stop into the canal until its tip appeared through the apical foramen; the distance between the tip and stop was measured. The teeth were placed in cylindrical polyethylene tubes filled with different embedding media (1% agar, gelatin, alginate, saline, and flower sponge soaked in saline), and electronic reading was performed with the Root ZX device. According to their results they arrive a conclusion, despite the lack of statistically significant differences among the media, alginate provided the most coherent results with the actual working length. The flower sponge provided the worst results, including surpassing of the instrument.

Ricardo Affonso Bernardes, et al (2007)⁶⁰ performed a comparative analysis of precision of 3 apex locators such as Root ZX, Elements Diagnostic Unit and Apex Locator, and RomiAPEX D-30. Forty extracted single-rooted human teeth were selected. After endodontic access, measurement of the anatomical tooth length was visually performed by insertion of a K-file size 10 until its tip could be observed at the apical foramen with aid of a light microscope at 8x magnification. Following, the teeth were placed in a plastic box with alginate and electronically measured with the 3 apex locators at 1-mm short of the apical foramen. The results revealed a precision rate of 97.5% for Root ZX, 95% for Elements Diagnostic Unit and Apex Locator, and 92.5% for Romi APEX D-30, and the results confirm that all these electronic devices can accurately determine the root canal length within 1 mm from the apical constriction.

Fábio Luiz Cunha D'Assunção, et al (2007)²⁰ Compared the capacity of the Root ZX-II and Sybron endo Mini Apex Locator, to prevent overestimated working length.

Review of literature

Forty extracted human teeth were used for the study. The cervical portion of each canal was flared using Gates Glidden drills and the teeth were embedded in an alginate model. Canals were irrigated with 2.5% sodium hypochlorite. The actual length (AL) and electronic length (EL) measurements were made on each specimen separately with both devices with the aid of a k-type file. The results obtained with each EAL were compared with the corresponding actual length. The statistical analysis of the results showed EAL reliability to prevent overestimated working length to be 100% for the Sybron endo Mini Apex Locator and 97.44% for the Root ZX-II, within a tolerance of ± 0.5 mm into account. The results of this study indicate that the Root ZX-II and Mini Apex Locator are accurate devices to prevent overestimated working length.

Fernando Goldberg, et al (2008)²⁴ compared the accuracy of four electronic apex locators (EALs) to locate the apical limit in teeth with simulated horizontal oblique root fractures was investigated. A horizontal oblique incomplete root fracture was simulated on 20 freshly extracted maxillary anterior teeth by means of a notch made on the vestibular root plane 8 mm from the anatomic apex. The EALs investigated were the ProPex (Dentsply Maillefer, Ballaigues, Switzerland), the NovApex (Forum Technologies, Rishon Le-Zion, Israel), the Root ZX (J. Morita Corp, Kyoto, Japan), and the Elements Apex Locator (SybronEndo, Orange CA). The electronic measurements were compared with the real “working length.” The accuracy obtained was of 80% (n -16) and 95% (n -19) with the ProPex, 70% (n -14) and 95% (n-19) with the NovApex, 60% (n-12) and 90% (n-18) with the Root ZX, and 60% (n-12) and 85% (n-17) with the Elements Apex Locator when tolerances of 0.5-mm and 1.0-mm tolerance were, respectively, allowed. The analysis of variance ($p \leq 0.05$) and chi-

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square test (0.5 mm/p _ 0.47 and 1.0 mm/p _ 0.63 tolerances) showed no statistical significant differences between the EALs at either tolerance level.

Jung-A Kang,et al (2008)³⁹ evaluate the accuracies of 7 different frequency-dependent electronic apex locators (EALs) on using different irrigants in the root canal. Root canal lengths were measured with 7 different EALs in 40 extracted human teeth embedded in an alginate model after canal preparation and compared with the actual canal length measurements taken before embedding the teeth in alginate. The EALs used were Apex Finder 7005, Apit, Bingo-1020, e-Magic Finder, ProPex, Root ZX, and SmarPex. Measurements were taken with the canal dry, and saturated sequentially with 5.25% NaOCl, saline, 0.1% chlorhexidine, and 15% EDTA and Concluded most of the EALs tested can be considered reliable in the presence of various root canal irrigants and varying sizes of the apical foramen.

Euseong Kim et al (2008)¹⁶ compared the accuracy of working length determination using only the Root-ZX electronic apex locator versus adjusting Root-ZX measurements after obtaining a working length radiograph .This study recommended to use a Root ZX Electronic Apex Locator combined with radiographs for the determination of working length, although there was no statistical significance between those two groups.

Chris Siu,et al (2009)⁷ compared the accuracy of working length (WL) measurements by using the Root ZX II, Apex NRG XFR, and Mini Apex Locator with rotary nickel-titanium (NiTi) instruments. Twenty-eight teeth had their WLs determined with each electronic apex locator (EAL) by using 0.04 taper ProFiles sizes 40–20 in a crown-down technique until WL was reached. Four control teeth had their WL determined by using stainless steel hand files. The accuracy of the Root ZX II,

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Apex NRG XFR, and Mini Apex Locator in locating the minor diameter within ± 0.5 mm was 50%, 46.43%, and 39.29%, respectively. The determination of WL by using hand files in the control teeth was more accurate. The Root ZX II, Apex NRG XFR, and Mini Apex Locator used with rotary NiTi files were able to locate the apical constriction within ± 0.5 mm only 50% or less of the time.

Marco Aurélio Versiani, et al (2009)⁴⁹ compared the accuracy of Root ZX II to locate the apical constriction with the display meter set at “0.5” and “1” reading. Seventy single-rooted teeth were soaked in an alginate model and randomly distributed in 2 groups (n=35). Measurements were taken following canal irrigation with 1% NaOCl. The length was established using a #20 K-file attached to the holder when the display indicator reached the marks “0.5” (group I) or “1” (group II), after the meter read “Apex.” Then, the file was fixed in position and the teeth removed from the alginate. The apical portion of the root was shaved until the tip of the file could be seen, the distance to the apical constriction verified by means of a stereomicroscope and the measurements compared. The mean positions of the file tip relative to the apical constriction were $\pm 0.23 \pm 0.39$ mm and $\pm 0.42 \pm 0.45$ for groups I and II, respectively, with no statistical difference ($P \geq .05$). The accuracy was 90.5% and 83.78% for the Root ZX II “0.5” and “1” readings, respectively. It was concluded that the meter reading “1” of Root ZX II reduced the risk of working length overestimation.

E´ricson Janolio de Camargo, et al (2009)¹¹ compare the influence of preflaring on the accuracy of 4 electronic apex locators (EALs): Root ZX, Elements Diagnostic Unit and Apex Locator, Mini Apex Locator, and Apex DSP. Forty extracted teeth were preflared by using S1 and SX ProTaper instruments. The working length was established by reducing 1mm from the total length (TL). The ability of the EALs to

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detect precise (−1mm from TL) and acceptable (−1_0.5mm from TL) measurements in unflared and preflared canals was determined. The precise and acceptable (P/A) readings in unflared canals for Root ZX, Elements Diagnostic Unit and Apex Locator, Mini Apex ,and Apex DSP were 50%/97.5%, 47.5%/95%, 50%/97.5%, and 45%/67.5%, respectively. For preflared canals, the readings were 75%/97.5%, 55%/95%, 75%/97.5%, and 60%/ 87.5%, respectively. For precise criteria, the preflared procedure increased the percentage of accurate electronic readings for the Root ZX and the Mini Apex Locator ($P < .05$). For acceptable criteria, no differences were found among Root ZX, Elements Diagnostic Unit and Apex Locator, and Mini Apex Locator ($P > .05$). Fisher test indicated the lower accuracy for Apex DSP ($P < .05$) Conclude, the Root ZX and the Mini Apex Locator devices increased significantly the precision to determine the real working length after the preflaring procedure.

Bruno Carvalho de Vasconcelos, et al (2010)⁵ evaluate the precision of working length determination of 3 electronic apex locators (EALs): Root ZX, RomiApex D-30, and Ipex at 0.0 mm, at the apical foramen (AF), and at 1.0 mm short of the AF. Thirty-eight mandibular premolars had their real lengths previously determined. Electronic measurements were determined at 1.0 mm, followed by measurements at 0.0 mm, performed in triplicate. The results shows the precision of devices at 1.0 mm and 0.0 mm were: 94.7% and 97.4%, respectively (Root ZX); 78.9% and 97.4% (RomiApex D-30); and 76.3% and 97.4% (Ipex). Although no statistical differences were observed between the EALs at 0.0, at 1.0 mm Root ZX performed significantly better than the others. They concluded the EALs had acceptable precision when measuring the working length at the AF. However, when used at levels short of the AF, only Root ZX did not suffer a significant negative effect on precision.

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George M. Guise, et al (2010)⁴⁶ compare the accuracy of the Root ZX II Apex Locator (RZX), the Elements Apex Locator (ELE), and the Precision Apex Locator (PAL). Forty single-rooted extracted teeth were decoronated and the root canals coronally flared. Actual canal lengths were determined by inserting a #10 file until the tip was visualized just within the apical foramina. Teeth were mounted in gelatin conducting medium and randomly tested with each electronic apex locator (EAL) to determine the electronic canal length. Differences between the electronic and actual canal lengths were calculated. The mean differences were ± 0.02 mm, 0.13 mm, and 0.15 mm for the RZX, PAL, and ELE, respectively. The proportion of electronic canal length measurements falling within ± 0.5 mm of the actual canal lengths for the EALs was as follows: 97.5% for the RZX, 95% for the PAL, and 90% for the ELE. Conclude, the RZX was the most accurate at locating the apical foramen compared with the ELE and the PAL.

Luigi Cianconi, et al (2010)²⁰ compared the accuracy of three different electronic apex locators in detecting the apical foramen ex vivo under clinical conditions; the accuracy of digital radiography and EALs in determining the working length with visible control under a microscope; and the precision of #10, #15, and #20 K-files in electronic measurements. The length of 101 extracted human teeth was measured with three different EALs (Endex [Osada Electric Co, Tokyo, Japan], ProPex II [Dentsply-Maillefer, Ballaigues, Switzerland], and Root ZX [J. Morita Co, Tustin, CA], with radio videography (RVG) and compared with the actual length. They concluded that Endex and ProPex II were more accurate than Root ZX in determining the actual WL. Instrument sizes of hand files did not affect the accuracy of EALs. EALs showed to be more accurate in determining the WL than RVG.

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Manuele Mancini, et al (2011)⁴⁸ compared the accuracy of 3 different EALs (Endex, ProPex II, and Root ZX) with radiovideography in detecting the apical foramen in anterior teeth, bicuspid, and molars. Results showed that the 3 EALs and RVG were less accurate in anterior teeth and molars than in bicuspid. There is no statistically significant difference between mesiodistal plane and buccolingual plane digital radiography. This study concluded that the 3 EALs tested were more accurate in detecting the apical foramen in bicuspid than in both molars and anterior teeth. Radiographic measurements were not reliable for determining WL in all dental groups in both radiographic planes.

Eva K. Stöber, et al (2011)¹⁸ compared the accuracy of the Root ZX (J Morita Corp, Tokyo, Japan) and iPex (NSK, Tochigi, Japan) EALs. The working length (WL) was determined electronically for 40 root canals of human teeth with a K-file and one of the two 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. The samples were observed under a scanning electron microscope, and the distance from the file tip to the point 0.5 mm coronal to the major foramen (the actual WL) was measured. In determining the actual WL, the Root ZX was accurate 72% of the time to ± 0.5 mm and 100% of the time to ± 1 mm, whereas the iPex was accurate 57.8% of the time to ± 0.5 mm and 100% of the time to ± 1 mm.

Manuela Herrera, et al (2011)⁴⁷ evaluated the accuracy of the Root ZX apex locator (J. Morita Corp, Tokyo, Japan) in widened foramina. Ten single-root teeth were embedded in an alginate mold. The foramina were widened from 0.6 mm to 1.0 mm. The measurements were taken with all possible file sizes #10. The statistical accuracy of the Root ZX was calculated for the different diameters and for the influence of file

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size and the results were the accuracy of the Root ZX apex locator with a range of error of 0.5 mm was 87% in an apical foramen size of 0.6 mm and 84% using files size 45 or larger in an apical foramen size of 0.7 mm. With a tolerance of 1 mm, the accuracy was 99% in an apical foramen size of 0.6 mm, 98% using files size 45 or larger in an apical foramen size of 0.7 mm, and 95% using files size 70 or larger in an apical foramen size of 0.8 mm. They concluded that Root ZX apex locator was accurate for an apical size of 0.6 mm, independently of the file size; between 0.7 to 0.8 mm, we should adjust the files to the foramen, whereas above size 0.9 mm the locator is not accurate. The results show that the accuracy of this electronic apex locator is gradually lost as the foramen widens.

Solaiman Mohammed Al-Hadlaq (2011)⁷⁴ studied the accuracy of two compact electronic apex locators, the Root ZX mini and the Mini Apex Locator, in the presence of different endodontic solutions and to compare their performance to the Root ZX electronic apex locator. 5.25% Sodium Hypochlorite, 2.625% Sodium Hypochlorite, 1.0% Sodium Hypochlorite, 0.9% NaCl, 2% lidocaine with 1:80,000 Epinephrine, and 2% Chlorhexidine were used as irrigants. The difference between the electronic (EL) and actual length (AL) was calculated and measurements were classified into three categories: “correct” ($AL \pm 0.5$ mm), “long” (>0.5 mm from AL), “short” ($<_0.5$ mm from AL). This study concluded that the Root ZX mini and Mini Apex Locator have similar accuracy to the Root ZX and that the function of the three apex locators was not affected by the type of endodontic solution used.

Young Jung, et al (2011)⁷⁴ compared the reliability of the “0.5” and “APEX” mark measurements by using 2 impedance quotient-based electronic apex locators. One hundred four extracted human premolars were used in this study. After access

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preparation, the teeth were embedded in an alginate model. By using 2 EALs (Root ZX and i-Root), the tooth length was measured at the “0.5” and “APEX” marks with K-files. The file was then cemented, and the apical 3–4 mm was trimmed for the photograph under an operating microscope. The distance between the tip of the file and major foramen (MF) was measured. They Concluded that there was no significant difference in the reliability of the “0.5” and “APEX” marks for locating the MF in both devices.

Fernando Duran-Sindreu,et al (2012)²¹ compared the accuracy of the Root ZX electronic apex locator (J Morita Corp, Tokyo, Japan) between an in vivo and an in vitro model. . In determining the final WL, the Root ZX was accurate 78.3% of the time to ± 0.5 mm and 100% of the time to ± 1 mm in the in vivo group, whereas it was accurate 74% of the time to ± 0.5 mm and 100% of the time to ± 1 mm in the in vitro group and this study concluded that no statistically significant differences were observed between the in vivo group and the in vitro group.

J Paras Mull,et al (2012)³² compared the accuracy of Root ZX and Sybron Endo Mini, electronic apex locators (EALs), in the presence of various irrigants. In their study they used sixty extracted, single-rooted human teeth, they were decoronated and the root canals coronally flared. The actual length (AL) was assessed visually and teeth mounted in the gelatin model. The electronic length (EL) measurements were recorded with both EALs in the presence of 0.9% saline; 1% sodium hypochlorite (NaOCl); 2% chlorhexidine digluconate (CHX), and 17% EDTA solution, at “0.5” reading on display. The differences between the EL and AL were compared. Their Results shows the accuracy of EL measurement of Root ZX and Sybron Mini within ± 0.5 mm of AL was consistently high in the presence of NaOCl and found to be least with EDTA. They

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concluded that EL measurements were shorter with 1% NaOCl, whereas longer with 2% CHX for both the devices. Sybron Mini was more accurate with 1% NaOCl and 2% CHX than Root ZX.

RAYPEX SERIES APEX LOCATORS

K. T. Wrbas, et al (2007)⁷³ compared the accuracy of Root ZX and Raypex 5 apex locators (EALs) in the same teeth in vivo. The working lengths in 20 teeth with a single canal were determined with two different EALs before extraction then apex locators used to locate the minor foramen. The files were then fixed in removable and replaceable light curing composite patterns. The teeth were then extracted and the apical 4 mm of the root canals were exposed, the repositioned files in the canals were digitally photographed under a light microscope. On the images the minor diameter and the major foramen of each sample were marked and the respective distances of the file tips from these positions were measured with a computer program. The minor foramen was located within the limits of ± 0.5 mm in 75% of the cases with the Root ZX and in 80% of the cases with Raypex5.

Benjamín Briseño-Marroquín, et al (2008)⁴ made a study to determine the accuracy of 4 different electronic apex locators (EALs) with 3 different instrument sizes. For this study 146 roots were embedded in an agar solution. Electronic measurements were made to the physiologic foramen (apical constriction) with the Elements Apex Locator, Justy II, Raypex 5, and ProPex II and K-type files sizes 08, 10, and 15. Exact measurements to the physiologic foramen were made with the Elements Apex Locator, 36.99%, 39.04%, and 44.93%; Justy II, 38.62%, 32.41%, and 43.41%; Raypex 5, 42.76%, 39.31%, and 39.06%; and ProPex II, 38.62%, 43.45%, and 40.63% of the time with instrument sizes 08, 10, and 15, respectively. No significant differences

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were found between the actual working length and EALs/instrument size. A nonsignificant higher number of unstable measurements were observed in all EALs with instrument size 15.

Elizeu Álvaro Pascon, et al (2009)¹³ compared the accuracy of 3 different electronic apex locators (EALs) in establishing the working length in recently extracted teeth. Sixty teeth (100 canals) were soaked in an alginate model and electronically measured with 3 EALs (Dentaport ZX, Raypex 5, and Elements Diagnostic Unit and Apex Locator). The real working length was calculated as 1.0 mm short of the real length of the canal. The electronic measurements were taken following the manufacturers' orientations within ± 0.05 mm and ± 1.0 mm using a #15 K-file attached to the holder, after canal irrigation with 1% NaOCl. Within ± 0.5 mm and ± 1.0 mm, the accuracy was 39% and 90% (Dentaport ZX), 31% and 82% (Raypex 5), and 37% and 73% (Elements Diagnostic Unit and Apex Locator), respectively, with statistically significant differences between Elements Diagnostic Unit and Apex Locator and the other EALs. Conclude none of the EALs yielded an accuracy of 100%. Within the limitations of the present study. Elements Diagnostic Unit and Apex Locator proved to be less reliable than Dentaport ZX and Raypex 5 in the determination of the real working length.

Ashraf ElAyouti, et al (2009)³ studied the consistency of apex locators such as Root ZX [Morita, Tokyo, Japan] and Raypex5 [VDW, Munich, Germany]. Apex locator performance was considered "consistent" when the scale bars were stable and moved only in correspondence to the movement of file in the root canal. This study concluded that the function of apex locators was consistent in 85% and the inconsistent measurements were strongly associated with partially or totally obliterated root canal.

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Jiangfeng Ding, et al (2010)³⁷ investigate the ability of three electronic apex locators (EALs) to detect the minor foramen and morphological influencing factors relative to working length determination. Three hundred fifty-six extracted teeth were decoronated, and the coronal portion of the canal was flared. The distance between the major foramen and the file tips (DMFF) was determined by different EALs. The relationship between the DMFFs determined by the EAL and the morphological features of the root apex was analyzed by linear regression analysis. Results: The average DMFFs were 0.261mm, 0.376 mm, and 0.383 mm for the Root ZX (J.Morita, Kyoto, Japan), Raypex 5 (VDW, Munich, Germany), and Elements Apex Locator (SybronEndo, Anaheim, CA), respectively. The file tips determined by EALs were much closer to the major foramen in teeth with a “lateral major foramen” ($p < 0.001$). The area and diameters of the minor foramen were significantly related to the variation of the DMFFs determined by EALs. Conclude, When the “minor foramen” reading was given, the file tip connected to the Root ZX was much closer to the major foramen than the other two EALs. The minor foramen’s morphology and the major foramen’s location were both important influencing factors on the performance of EALs.

Eva Katia St€ober, et al (2011)¹⁹ compared the accuracy in vivo of 2 electronic apex locators (EALs), the Raypex 5 and the Mini Apex Locator. The working length (WL) was determined electronically for 40 human root canals by using a K-file and 1 of the 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. The samples were observed under a scanning electron microscope, and the distance from the file tip to the point 0.5 mm coronal to the major foramen (the final WL) was measured. In determining the final WL, the Raypex 5 was accurate 75% of the time to ± 0.5 mm and 100% of the time to

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_1 mm, whereas the Mini Apex Locator was accurate 77.8% of the time to _0.5 mm and 100% of the time to _1 mm.

Elice Chen, et al (2011)¹² aimed to develop a simple and inexpensive ex vivo model to teach students the use of electronic apex locators in a preclinical setting. Using 27 extracted human teeth, the Raypex 5 (VDW, Munich, Germany) and Dentaport ZX (J. Morita Co, Kyoto, Japan) were tested in three different media (ie, alginate, sugar-free gelatin, and 0.9% sodium chloride solution). Working lengths determined by these models were compared with those obtained by digital radiography and direct visualization using a linear mixed modeling statistical approach. Raypex 5 exhibited a higher percentage of measurements accurate to _0.5 mm and _1.0 mm of the control across all three media in all tooth types. In multirouted teeth, alginate showed the highest accuracy. Conclusions: The most accurate EAL/embedding medium combination was Raypex 5/alginate to both _0.5 mm and _1.0 mm of the control. The model tested in this study was accurate, easy to assemble, and cost-effective, making it suitable for teaching purposes.

Hale Cimilli et al (2012)²⁸ assess the accuracy of the minor apical diameter, as measured by the Root ZX II, Raypex 5, Propex, and ATR EndoPlus electronic apex locators (EALs). 40 extracted maxillary incisors were used to measure the distance from the coronal reference point to the file tip at the major diameter termed this as the reference canal length (RCL). Files were stabilized in this position with a flowable composite, then shaved 4 mm from the apical region and took photographs of the canal termination at 64% magnification to visualize the minor diameter. The minor diameter length (MDL) was then calculated. Results shows the measurements with Raypex 5 (15.22 _ 1.79 mm), Root ZX II (15.24 _ 1.73 mm), Propex (15.22 _ 1.76 mm) and ATR

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EndoPlus (15.27 \pm 1.78 mm) were significantly smaller than the MDL (15.43 \pm 1.75 mm) ($P < 0.05$). When measurements were evaluated to within ± 0.5 mm, the MDL determination was 82.5% acceptable for the Root ZX II and the ATR Endo- Plus, and was 85% acceptable for the Raypex 5 and the Propex.

Susana Gomes, et al (2012)⁶⁸ studied the performance of the Raypex 5 electronic apex locator in the presence of different irrigant solutions: 2.5% sodium hypochlorite (NaOCl), 2% CHX, and 17% EDTA. No significant differences were found among the experimental groups. The mean distance from the RWL to the file tip was -0.26 ± 1.14 mm when 17% EDTA was used, -0.03 ± 0.92 mm for 2% CHX, and 0.22 ± 0.93 mm for 2.5% NaOCl and concluded that the Raypex 5 performed equally well irrespective of the irrigant used.

Saddy Moscoso, et al (2013)⁵⁰ compared the accuracy of two EALs, the Dentaport ZX and the Raypex 6 to locate the major foramen. The study involved 36 straight single-rooted teeth. A 10-K file was advanced until the EAL detected the major foramen. The file was fixed in a replaceable pattern of light-cured composite. The apical part of each canal was trimmed to expose the file tip. The distances from the file tips to the major foramen were measured. Results shows no significant differences between the Dentaport ZX and Raypex 6 in terms of their abilities to detect the major foramen ($P = .52$) The Dentaport ZX was accurate 82.35% of the time to ± 0.5 mm and 97.05% of the time to ± 1 mm, whereas the Raypex 6 was accurate 88.22% of the time to ± 0.5 mm and 100% of the time to ± 1 mm

Lucena et al (2014)⁴⁴ compared the accuracy of working length (WL) determination using the Raypex 6 electronic apex locator and cone-beam computed tomography. A total of 150 extracted human teeth were decoronated and randomly assigned to five

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groups (n = 30). WL was measured with the Raypex 6 at both the ‘constriction’ and the ‘apex’ marks under dry conditions (group 1) or with 2.5% NaOCl, distilled water or Ultracain (groups 2–4). The radiological WL (group 5) was calculated from buccolingual and mesio-distal CBCT sections. Differences between electronic, CBCT measurements and actual length (AL) were calculated. Mean differences with respect to AL ranged from 0.26 to -0.36 mm and from 0.05 to 0.18 mm, respectively, for the electronic measurements at the ‘constriction’ mark and ‘apex’ mark. CBCT measurements were an average of 0.59 mm shorter than AL. Percentages of electronic measurements falling within ± 0.5 mm of the corresponding AL referred to the ‘apex’ mark were greater than at the ‘constriction’ mark, but the differences were only significant in group 4. Percentages of CBCT measurements falling within ± 0.5 mm of AL (46.7%) were significantly lower than electronic measurements, regardless of the condition of the root canal. In 30–38.5% of the measurements taken at the ‘apex’ mark and in 3.4–13.3% of those at the ‘constriction’ mark, the file tip extended beyond the foramen. This study concludes Electronic measurements were more reliable than CBCT scans for WL determination. The Raypex 6 was more accurate in locating the major foramen than the apical constriction under the experimental set-up.

MATERIALS AND METHODS

The following armamentarium and materials are used in this in vitro study.

ARMAMENTARIUM

- Straight handpiece(NSK,NSK LTD,Japan)
- Diamond disc
- Contra angle micro motor handpiece (NSK,NSK LTD,Japan)
- Gates glidden drills (Mani Inc., Japan),
- K files (#10,15)(Mani Inc., Japan)
- Barbed broach(Spirocolorinox, Dentsply).
- Contra angle airtor(NSK,NSK LTD,Japan)
- Carbide bur 169L (Mani Inc., Japan),
- BP blade #15(Aditya Dispomed Products Pvt. Ltd)
- Plastic agate spatula
- Plastic instrument
- Stereomicroscope (WILD M2Z, Heerbrugg, Switzerland)

MATERIALS

- GIC (GC corporation, Tokyo,japan).
- Normal saline (Baxter Pvt Limited.India),

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- Chlorhexidine digluconate (Stedman Pharmaceuticals PVT LTD, India)
- 5% Sodium hypochlorite (Prime Dental Products Pvt. Ltd., India)
- Gelatin
- 10% formalin.

APEX LOCATORS TESTED IN THIS STUDY

- Root ZX mini apex locator (J. Morita Mfg Corp., Tokyo, Japan)
- Raypex 6 apex locator (VDW, Munich, Germany)

METHODOLOGY

Study design;

Two EALs tested in this experiment were: Root ZX Mini (fig 3) and Raypex 6 (fig4). Both EALs were used according to manufacturer's instructions.

The irrigants tested(fig 5) were: 0.9% saline, 5% sodium hypochlorite (NaOCl), 2% chlorhexidine digluconate (CHX).

Sixty extracted, straight, single-rooted permanent human maxillary anterior teeth with mature apices were selected for this study. Teeth were stored in a 10% formalin solution until use. Residual soft tissue on the root surface was removed by soaking the teeth in 5% NaOCl for 3h. Each tooth was Radiovisuographed (RVG) in buccolingual and mesiodistal projections to evaluate the shape of the root canal and to detect any obstruction. The root canal curvature was determined by Schneider's method. Teeth with resorption, curvature $>5^\circ$ angle, open apices, or radiographically invisible canals were excluded.

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Teeth were randomly divided into two main groups according to the apex locators tested such as

Group 1 (n=30, Root ZX mini apex locator)

Group 2 (n=30, Raypex6 apex locator).

Then each group is further divided into 3 subgroups according to the irrigants tested such as

Group 1A (n=10, Root ZX mini apex locator, 0.9% normal saline),

Group 1B (n=10, Root ZX mini apex locator, 5% sodium hypochlorite),

Group 1C (n=10, Root ZX mini apex locator, 2% chlorhexidine digluconate),

Group 2A (n=10, Raypex6 apex locator, 0.9% normal saline),

Group 2B (n=10, Raypex6 apex locator, 5% sodium hypochlorite),

Group 2C (n=10, Raypex6 apex locator, 2% chlorhexidine digluconate).

SAMPLE PREPARATION

The teeth were decoronated at the level of cemento-enamel junction with a diamond disc to allow access to the root canal and to provide a stable reference for all measurements. The coronal portion of each canal was preflared¹¹ using sequential Gates Glidden drills #2, #3, and #4, irrigated with saline and pulp extirpated with a barbed broach.

METHODOLOGY

The actual length (AL) was determined by introducing a size 10 or 15 Kfile into the canal until its tip emerged through the major apical foramen at 10x magnification under a stereomicroscope. The long axis of the tooth was placed perpendicular to the line of

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sight and the tip of the file was positioned tangential to the major apical foramen^{29,6}. After carefully adjusting the silicone stopper to the reference point, the file was withdrawn from the root canal, and the distance between the file tip and silicone stopper was measured with a caliper to the nearest 0.5 mm; 0.5 mm was subtracted from this length and recorded as AL.

To simulate the periodontium, this study used the in vitro model as designed by Donnelly⁸. A polystyrene specimen bottle (50 ml) was filled with warmed gelatin solution and refrigerated for 2 h to allow gelatin to set. The apical two-third of the root was embedded in gelatin, and the tooth was stabilized to the lid of a container with auto-polymerizing resin as described by Higa et al²⁹. The lip electrode was also placed in gelatin through another opening in the lid (fig1). The irrigants to be tested was introduced into the canal with a 23 guage needle.

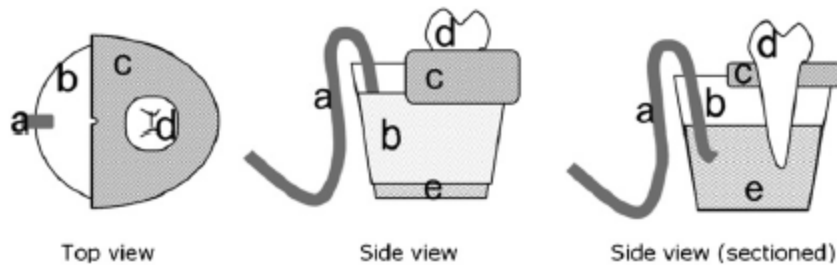


Figure 1. The model setup; a, lip clip; b, polystyrene specimen bottle; c, lid of the bottle; d, tooth; e, gelatin .

Depending on the size of the canal, #10 or #15 K-file was attached to the file holder and introduced into the canal. For Root ZX, the meter's 0.5 mm reading was set between the "APEX" and "1" (factory setting)³³ as indicated by a flashing bar and was used for electronic measurements. For each one of the devices, the file was gently inserted into the root canal until the "APEX" signal was displayed. The file was then

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gently retracted until the display showed a flashing image of the root canal and a flashing bar between APEX and 1 (0.5 reading) for Root ZX and the last yellow bar for Raypex6. Measurements were considered to be correct if the instrument remained stable for at least 5 seconds. Silicone stopper on the file was carefully adjusted to a reference point, and the file was withdrawn to measure the distance between the silicone stopper and the file tip to the nearest 0.5 mm. This was recorded as the electronically measured canal length (EL). Then the K-files were fixed at the WL determined electronically with GIC. The apical 4 mm of the root was shaved using a 169L carbide bur along the long axis of the tooth in a plane that was determined to show the best representation of the minor diameter in relation to the file. Shaving with the bur was performed until the file could be seen through a thin layer of dentin (fig2). The last layer was then carefully removed using a #15 scalpel blade⁵⁵.

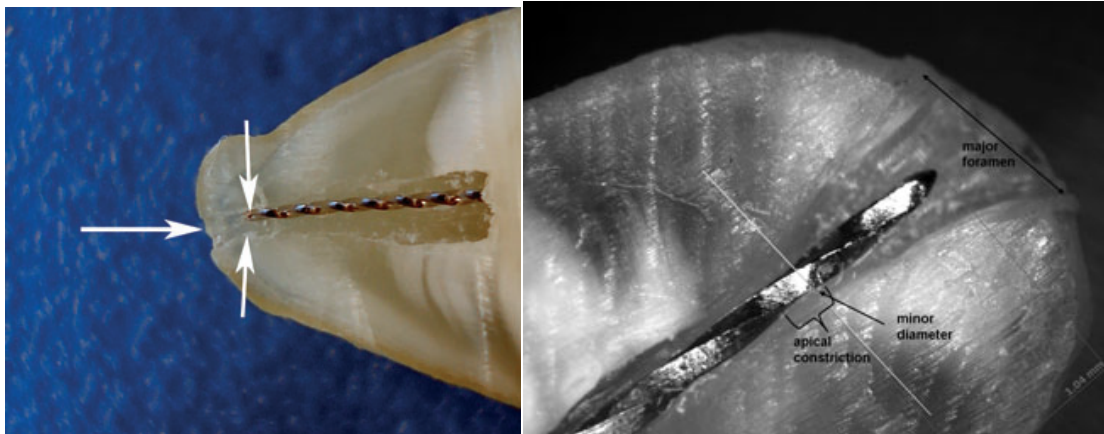


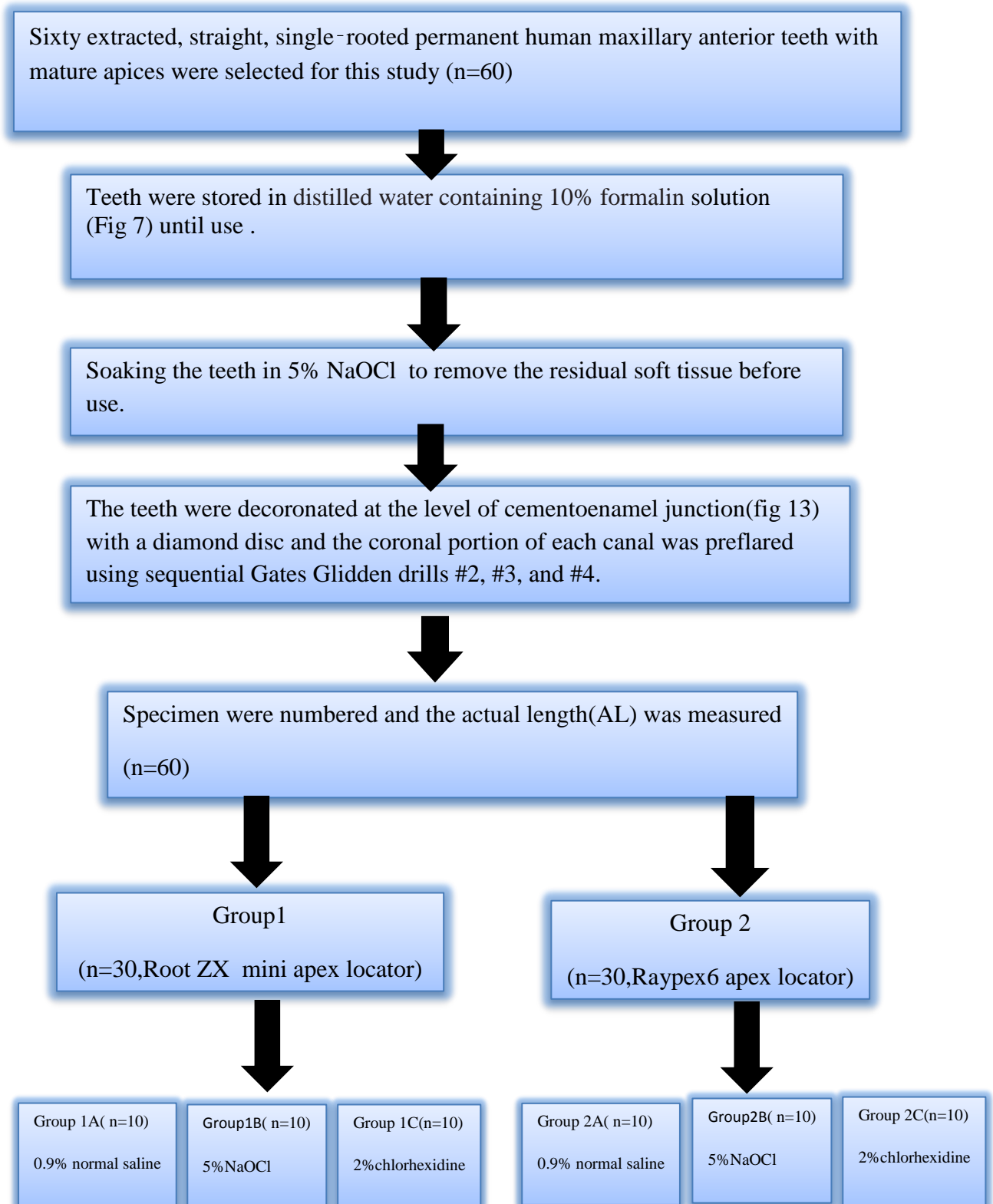
Figure 2; Preparation of apical 4 mm of root end and evaluation of the sectioned root apex with stereomicroscope (30x).

Each specimen was examined in a stereomicroscope with 30x magnification (fig2) and the image was captured. The distance from the file tip to the apical constriction is calculated. In this study, distances of -0.5mm to $+0.5\text{mm}$ from the apical constriction were considered¹⁷ acceptable.

Materials & Methods

To prevent cross contamination, fresh gelatin was used for the individual irrigant, the results obtained in millimeters were recorded. The difference between the electronically measured length (EL) and the AL were calculated for each tooth for all groups, and $AL \pm 0.5$ mm was used to evaluate the accuracy of the two EALs⁶⁴.

PROCEDURAL FLOW CHART



Materials & Methods

Each specimen was embedded in the gelatin model and the electronic apex locators were tested according to the manufacturer's instructions(fig 14&15).

Electronically measured canal length(EL) was recorded by using size 10 or 15 Kfile.

K files were fixed at the WL determined electronically with GIC(fig 16)

Apical 4mm of the root was longitudinally sectioned(fig 17) using 169Lcarbide bur and BP blade #15.

Examined under Stereomicroscope with 30x magnification and the images were taken.

Distance from the file tip to the minor diameter was calculated.

Apex locators used in this study



Fig 3-Root ZX mini apex locator



Fig 4- Raypex 6 apex locator



Fig 5- Irrigants tested in this study



Fig 6- Armamentarium used in this study



Fig 7- Teeth stored in 10% formalin



Fig 8- Group 1A



Fig 9- Group 1B



Fig 10- Group 1C



Fig 11- Group 2A



Fig 12a- Group 2B



Fig 12b - Group 2C

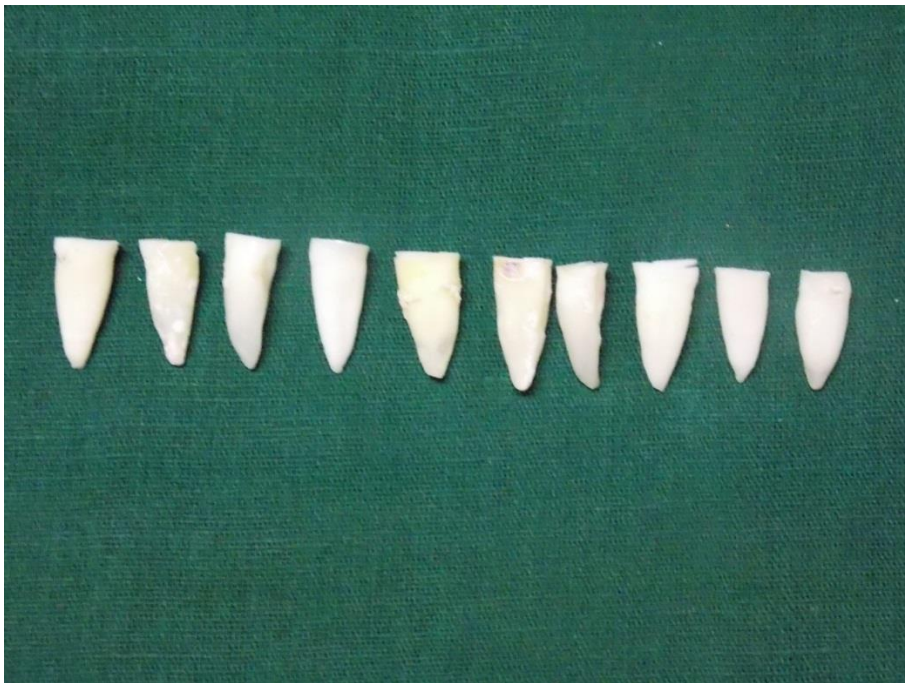


Fig 13- Decolorated samples at CEJ.

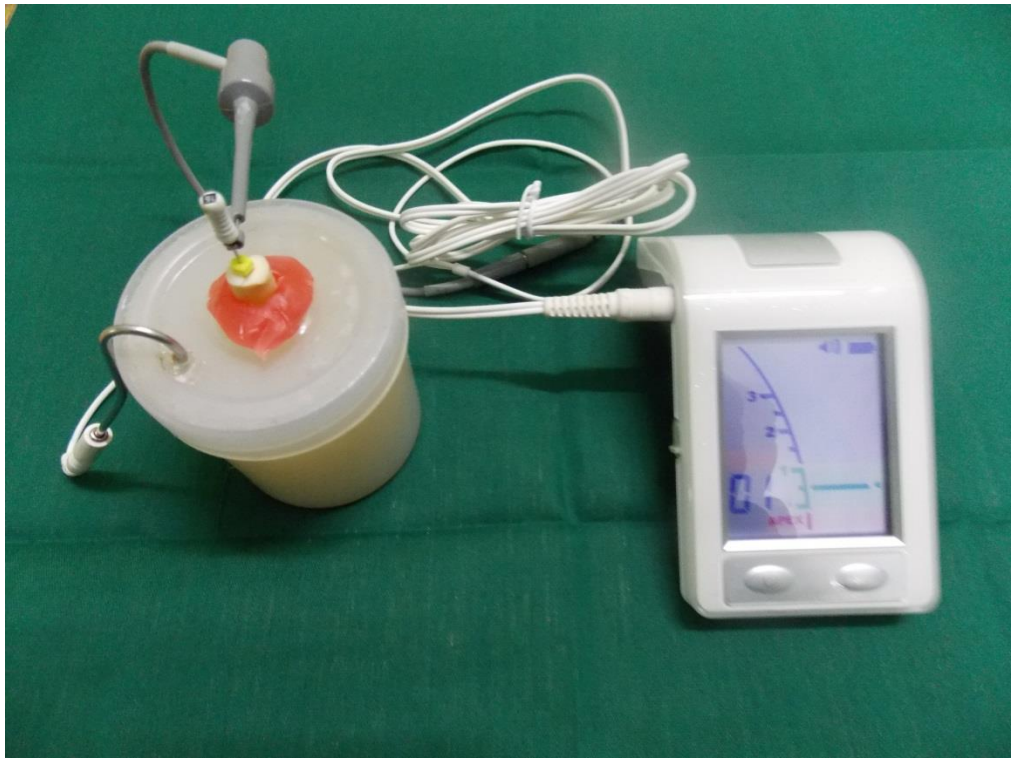


Fig 14- EL measurement with Root ZX Mini



Fig 15- EL measurement with Raypex 6



Fig 16- K files fixed at EL using GIC in all samples

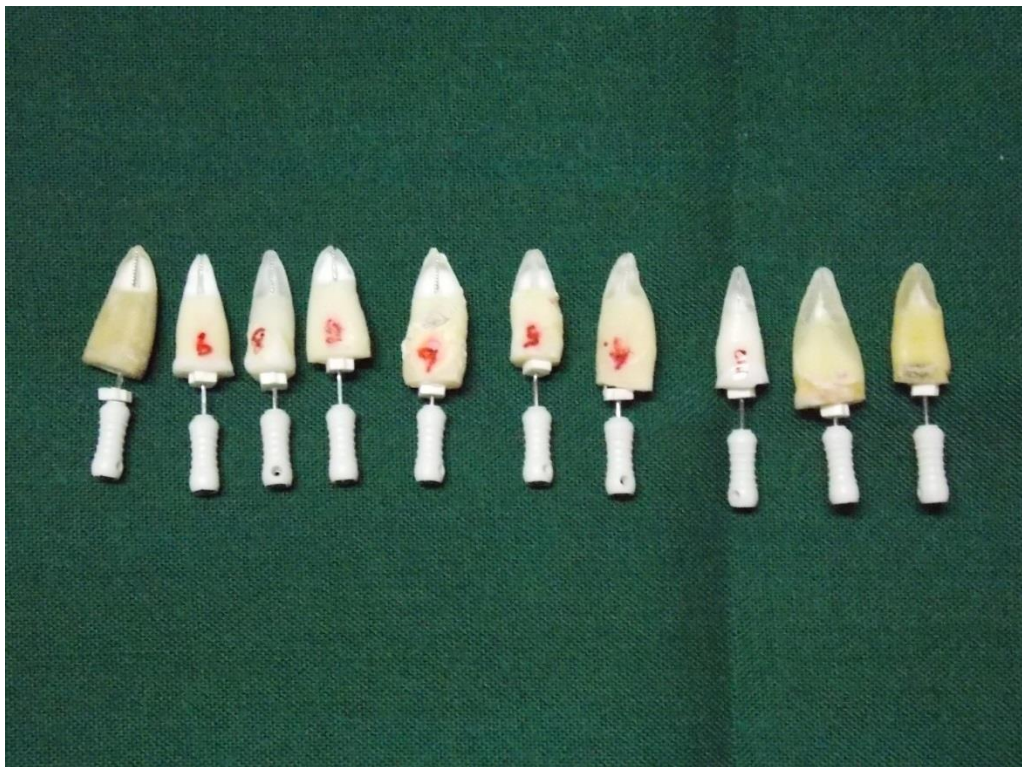


Fig 17- Apical 4 mm longitudinally sectioned for stereomicroscope examination

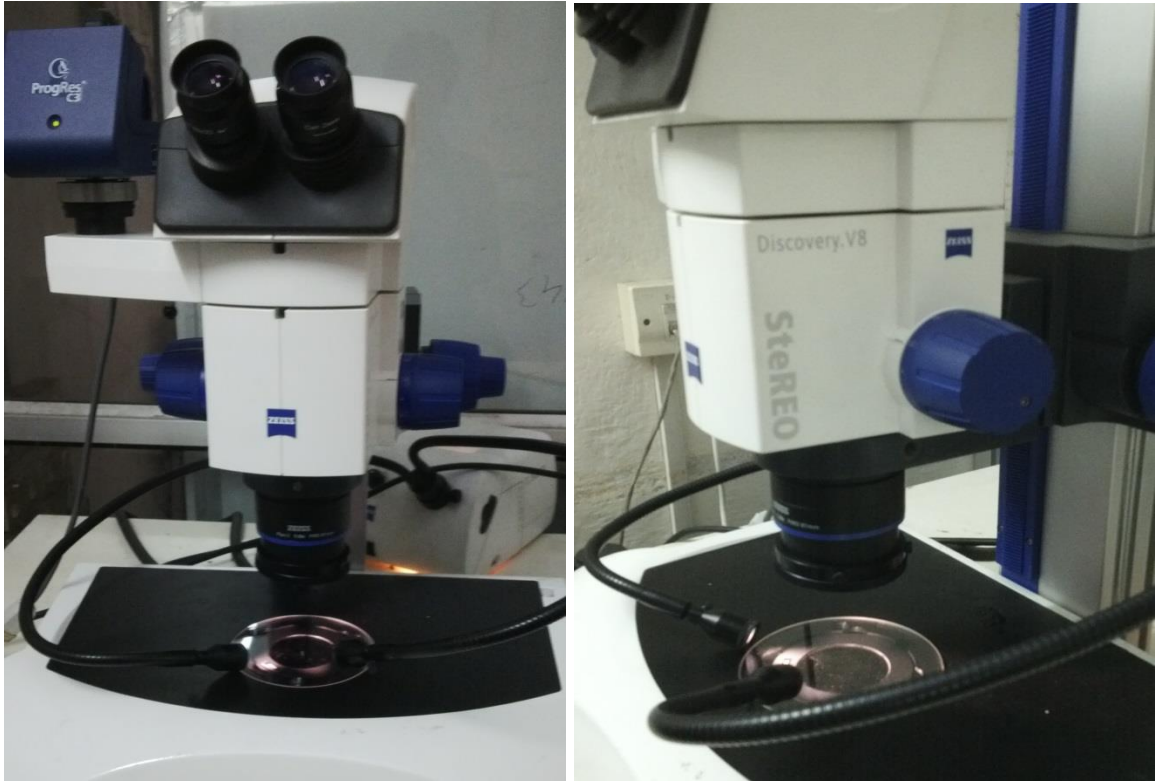


Fig 18-stereomicroscope

Results

RESULTS

Individual values of AL and EL and their differences were tabulated in table 1 to 6 and stereomicroscope image values were tabulated in table 9 to 11. Independent sample t test was employed to statistically analyse the significance of mean difference between EL and AL and Pearson Chi-Square test was used to statistically analyse the significance of irrigants on the accuracy of apex locators and to compare the accuracy of both apex locators. Significance was set at $P < 0.05$. The analysis was performed with SPSS 20.0, (SPSS Inc, Chicago, IL) software.

Table 1;

GROUP 1A (n=10, Root zx mini apex locator, 0.9% normal saline),

Sample no	AL	EL	AL-EL
1	19	19.5	+0.5
2	17.5	18	+0.5
3	15	15.5	+0.5
4	17	17.5	+0.5
5	15	15	0
6	18	18	0
7	16.5	16	-0.5
8	14.5	14.5	0
9	15.5	16	0
10	15	15.5	+0.5

Results

Table 2;

GROUP1B (n=10,Root ZX mini apex locator,5%sodium hypochlorite)

Sample no	AL	EL	AL-EL
1	15.5	15.5	0
2	18	17.5	-0.5
3	15.5	15.5	0
4	15	15	0
5	15.5	15.5	0
6	18	18.5	+0.5
7	16.5	16.5	0
8	20	20.5	+0.5
9	16.5	16	-0.5
10	14	13	-1

Table3

GROUP 1C(n=10,Root zx mini apex locator,2%chlorhexidine digluconate)

Sample no	AL	EL	AL-EL
1	18.5	19	+0.5
2	13	13	0
3	15.5	16	+0.5
4	17	17.5	+0.5
5	17	16.5	-0.5
6	17	18	+1
7	17.5	18	+0.5
8	17	17.5	+0.5
9	17	17.5	+0.5
10	16	16	0

Results

Table 4

GROUP 2A (n=10,Raypex6 apex locator,0.9% normal saline)

Sample no	AL	EL	AL-EL
1	15.5	15.5	0
2	14	14.5	+0.5
3	17	17.5	+0.5
4	15.5	16	+0.5
5	17.5	17.5	0
6	15.5	16.5	+1
7	16.5	16	-0.5
8	15	15	0
9	15	14.5	-0.5
10	15	15	0

Table 5-**GROUP 2B (n=10,Raypex6 apex locator, 5%sodium hypochlorite)**

Sample no	AL	EL	AL-EL
1	16.5	16	-0.5
2	14.5	14	-0.5
3	16.5	16	-0.5
4	15.5	14	-1.5
5	15.5	15.5	0
6	17	17.5	+0.5
7	16.5	16	-0.5
8	17	16.5	-0.5
9	16	15.5	-0.5
10	15.5	15	-0.5

Results

Table 6

GROUP 2C (n=10, Raypex6 apex locator, 2% chlorhexidine digluconate)

Sample no	AL	EL	AL-EL
1	14.5	15.5	+1
2	17	16.5	-0.5
3	14	14	0
4	16	16.5	+0.5
5	16.5	16	-0.5
6	15	15.5	+0.5
7	14	14	0
8	13.5	14	+0.5
9	16.5	16.5	0
10	13	13.5	+0.5

AL=Actual length (mm)

EL=Electronic apex locator measured canal length (mm)

Negative value indicates measurements short of the actual length.

Positive value indicates measurements beyond the actual length.

Results

Table 7 - Comparison of AL vs EL using Independent sample t-test for Root ZX Mini.

GROUP	Sample	N	Mean	Std. Deviation	Std. Error Mean	P
GROUP 1 (OVER ALL)	AL	30	16.433	1.5466	.2824	.697
	EL	30	16.600	1.7440	.3184	
GROUP 1A	AL	10	16.300	1.5312	.4842	.726
	EL	10	16.550	1.6064	.5080	
GROUP 1B	AL	10	16.450	1.7709	.5600	.909
	EL	10	16.350	2.0690	.6543	
GROUP 1C	AL	10	16.550	1.4804	.4682	.625
	EL	10	16.900	1.6633	.5260	

Table 8- Comparison of AL vs EL using Independent sample t-test for Raypex 6.

GROUP	Sample	N	Mean	Std. Deviation	Std. Error Mean	P
GROUP 2 (OVER ALL)	AL	30	15.567	1.1651	.2127	.910
	EL	30	15.533	1.1214	.2047	
GROUP 2A	AL	10	15.650	1.0554	.3337	.760
	EL	10	15.800	1.1106	.3512	
GROUP 2B	AL	10	16.050	.7976	.2522	.302
	EL	10	15.600	1.0750	.3399	
GROUP 2C	AL	10	15.000	1.4142	.4472	.738
	EL	10	15.200	1.2065	.3815	

Results

The mean and standard deviation of actual length (AL) and electronic length (EL) measurements obtained by Root ZX Mini and Raypex 6 in the presence of various irrigants are shown in Table 7 and 8. There is no statistical significant difference between the mean value and **p** value of AL and EL of both apex locators in presence of various irrigants. The mean differences between the EL and the AL were 0.15 mm and -0.05 mm for Root ZX Mini and Raypex6, respectively.

STEREOMICROSCOPE IMAGE ANALYSIS

For evaluation of the effects irrigants on the accuracy of apex locators were tabulated in table 9&10

Table 9

Group1- ROOT ZX MINI

Distance of file tip from apical constriction	0.9% Saline (group1A) n=10	5% Sodium hypochloride (group1B) n=10	2% Chlorhexidine digluconate. (group1C) n=10
$\leq \pm 0.5\text{mm}$	7	4	7
0 mm	3	5	2
$> \pm 0.5\text{mm}$	0	1	1

Results

Table 10

Group 2- RAYPEX 6

Distance of file tip from apical constriction	0.9% Saline (group1A) n=10	5% Sodium hypochlorite (group1B) n=10	2% Chlorhexidine digluconate. (group1C) n=10
$\leq \pm 0.5\text{mm}$	5	8	6
0 mm	4	1	3
$> \pm 0.5\text{mm}$	1	1	1

For comparison of two apex locators

Table 11

Distance of file tip from apical constriction	Root ZX Mini (n=30) Group 1	Raypex 6(n=30) Group 2
$\leq \pm 0.5\text{mm}$	18	19
0 mm	10	8
$> \pm 0.5\text{mm}$	2	3

Results

Distance of file tip from apical constriction was considered into following for statistical analysis.

Code1 - $\leq \pm 0.5\text{mm}$ (Acceptable)

Code2 - 0 mm (correct)

Code3 - $> \pm 0.5\text{mm}$ (not acceptable)

Both code 1 and code 2 were considered as accurate to determine the apical constriction.

Table 12

Chi-square test for comparison of 2 apex locators -irrigant used was saline

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.476 ^a	2	.478
Likelihood Ratio	1.865	2	.394
Linear-by-Linear Association	1.230	1	.267
N of Valid Cases	20		

The measurements of Root ZX Mini and Raypex 6 in presence saline shows no statistical difference between them ($p=0.478$, table 12). Root ZX mini 100% accurately locate the minor constriction and Raypex 6 90% accurately locate the apical constriction in presence of saline as intracanal irrigant.

Results

Table 13

Chi-square test for comparison of 2 apex locators- irrigant used was Sodium hypochlorite

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.000 ^a	2	.135
Likelihood Ratio	4.270	2	.118
Linear-by-Linear Association	1.689	1	.194
N of Valid Cases	20		

The measurements of Root ZX Mini and Raypex 6 in presence of 5% sodium hypochlorite shows no statistical difference between them ($p=0.135$, table 13). Both Root ZX mini and Raypex 6 were 90% accurately locate the apical constriction in presence of 5% sodium hypochlorite as intracanal irrigant.

Table 14

Chi-square test for comparison of 2 apex locators -irrigant used was Chlorhexidine digluconate

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.277 ^a	2	.871
Likelihood Ratio	.278	2	.870
Linear-by-Linear Association	.106	1	.745
N of Valid Cases	20		

The measurements of Root ZX Mini and Raypex 6 in presence of 2% Chlorhexidine digluconate shows no statistical difference between them ($p=0.871$, table 14). Both

Results

Root ZX mini and Raypex 6 were 90% accurately locate the apical constriction in presence of 2% chlorhexidine digluconate as intracanal irrigant.

Table 15

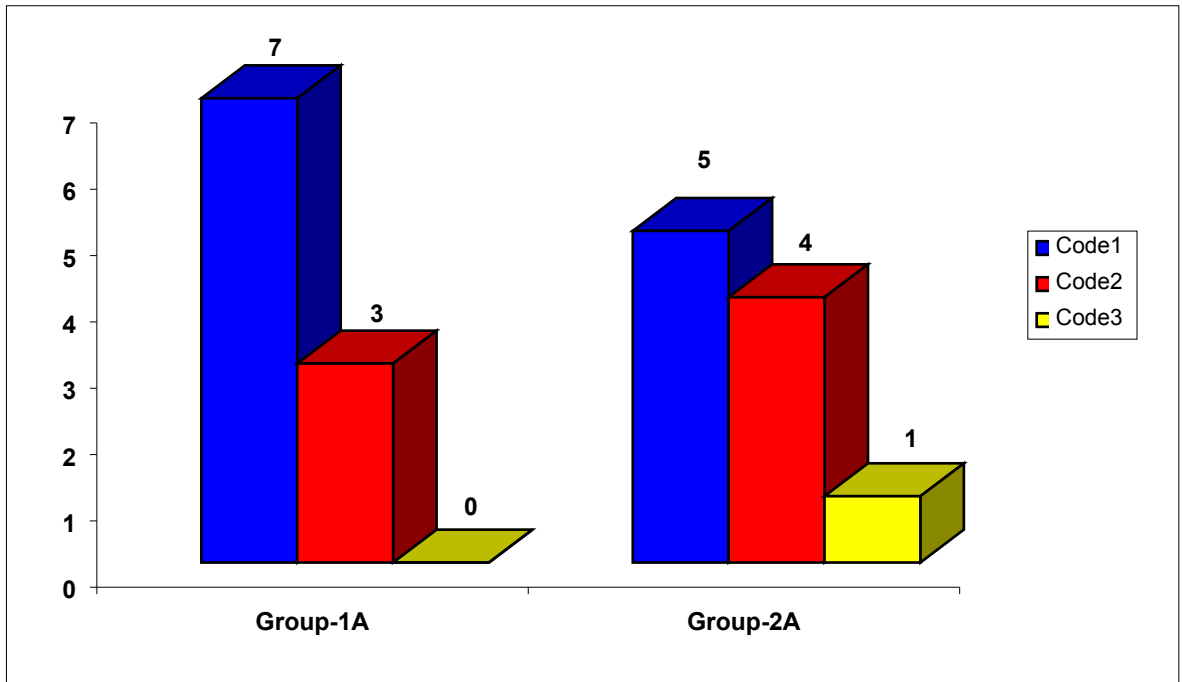
Chi-Square Test for Comparison of the accuracy of both apex locators

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.449 ^a	2	.799
Likelihood Ratio	.451	2	.798
Linear-by-Linear Association	.000	1	1.000
N of Valid Cases	60		

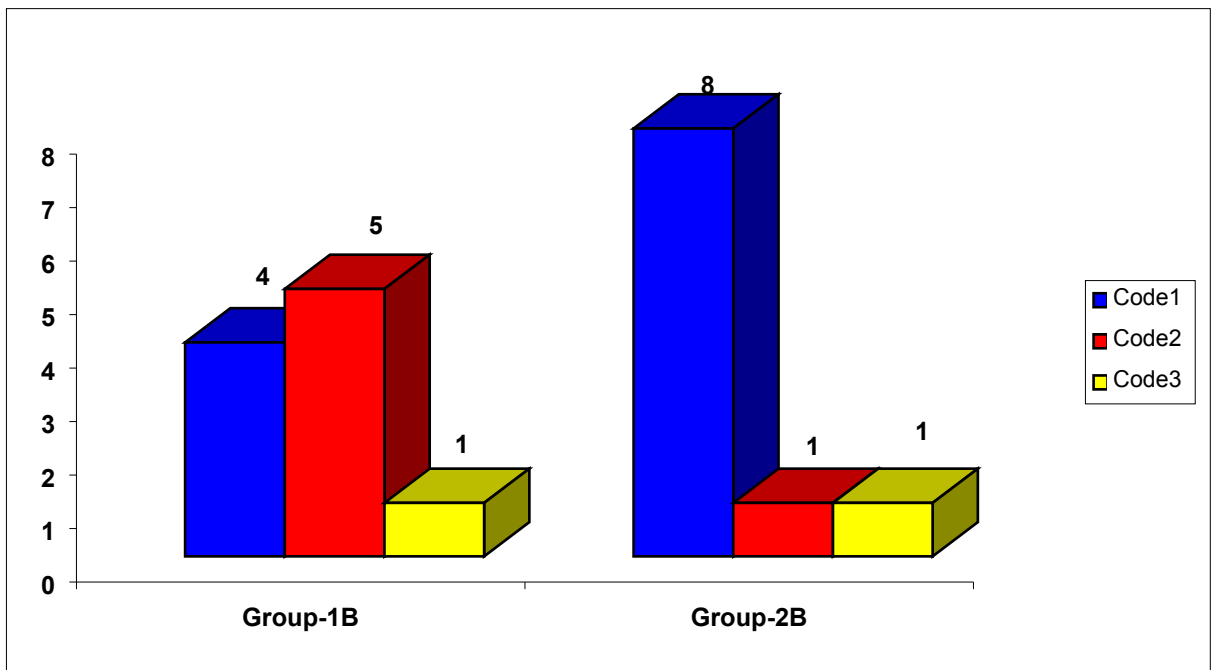
Collectively the measurements of Root ZX Mini and Raypex 6 in presence of various irrigants to locate the apical constriction shows no statistical difference between them ($p=0.799$, table 15) and the majority of the readings were within the acceptable range of ± 0.5 mm for both EALs. The overall accuracy of measurements within ± 0.5 mm of AL by Root ZX mini was 93.33% and Raypex 6 was 90% respectively.

Within the limitations of this study the irrigants play no significant role in the accuracy of apex locators and both the apex locators have no significant difference between their accuracy.

Results

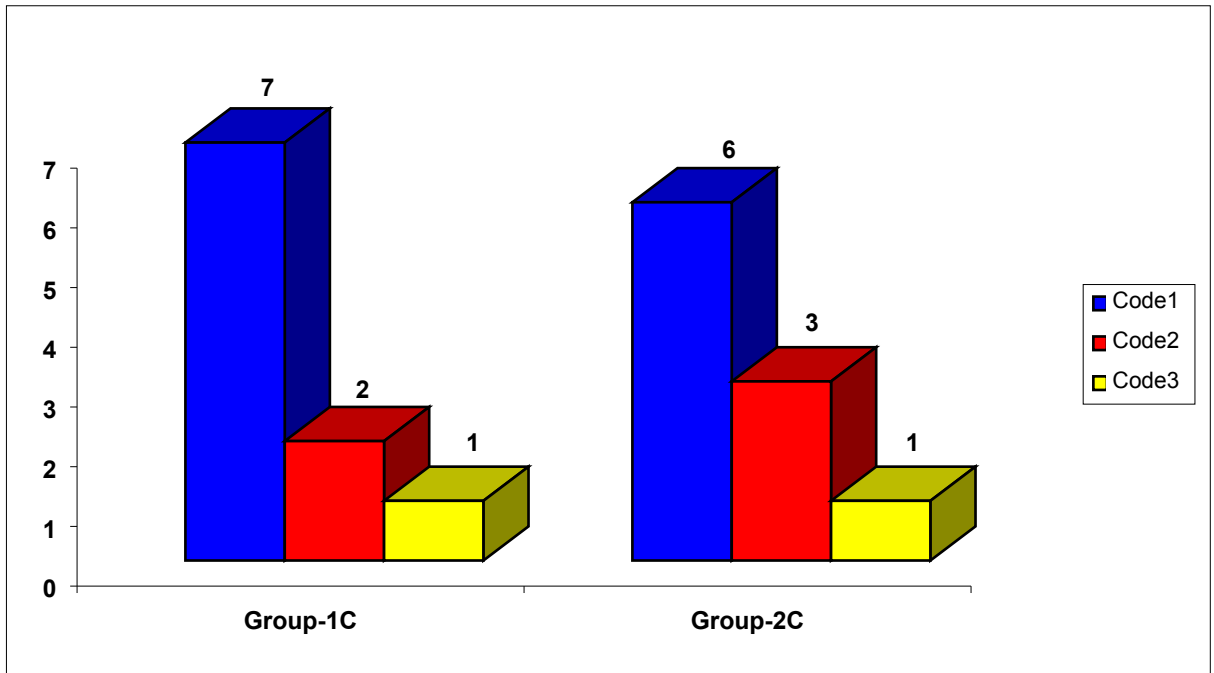


Graph 1- Comparison of accuracy in presence of saline.

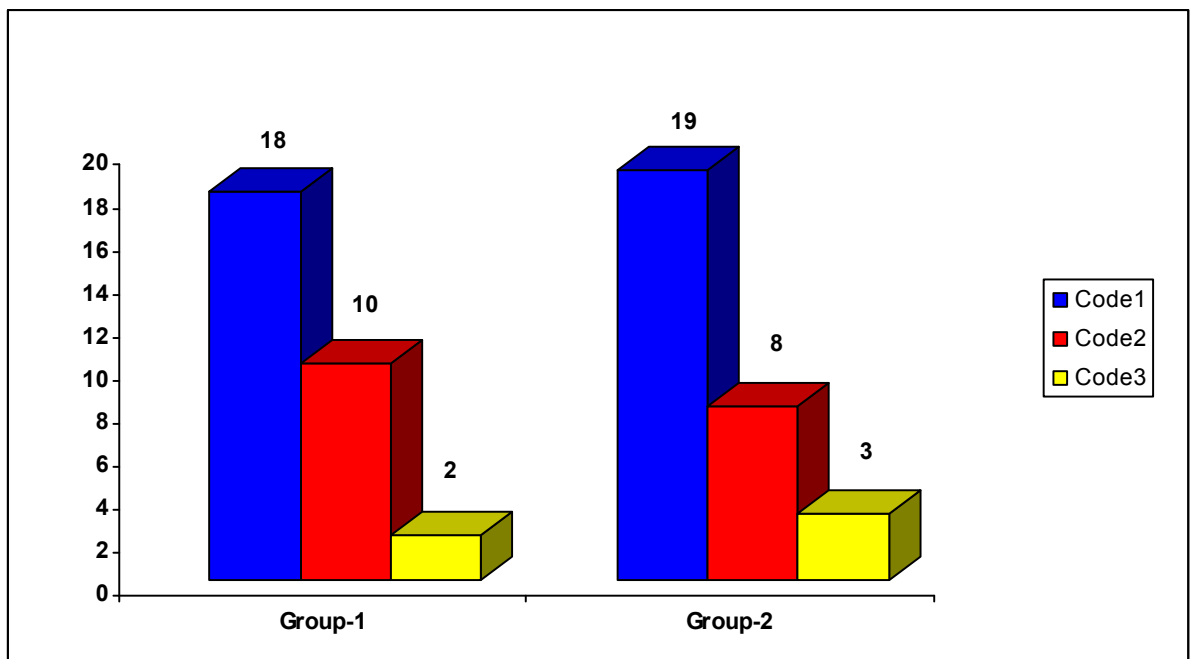


Graph 2- Comparison of accuracy in presence of 5% NaOCl.

Results



Graph3-Comparison of accuracy in presence of 2% Chlorhexidine digluconate.



Graph 4 - Comparison of overall accuracy of Root ZX Mini and Raypex 6.

STEREOMICROSCOPIC IMAGE AT 30 X MAGNIFICATION



Fig 19- Group 1A sample

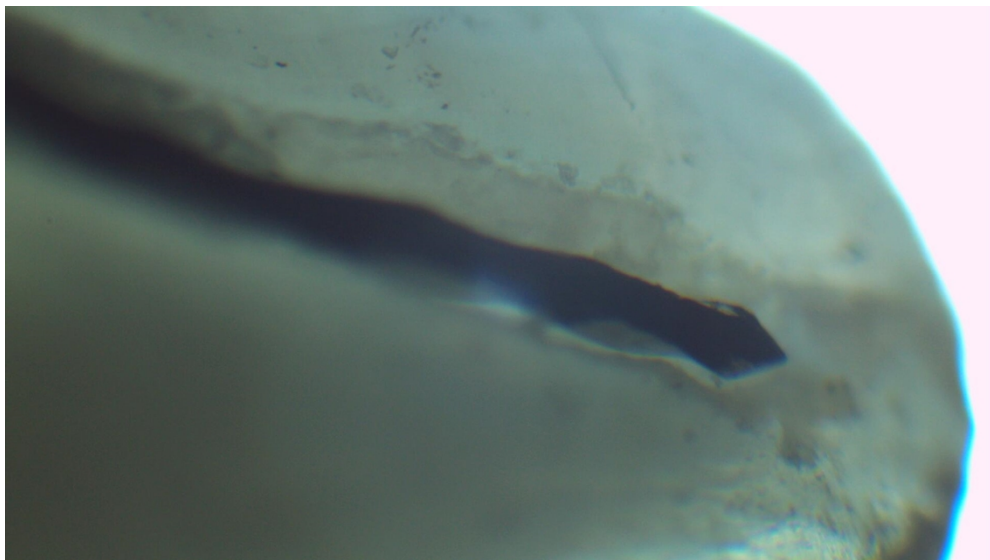


Fig 20- Group 1B sample

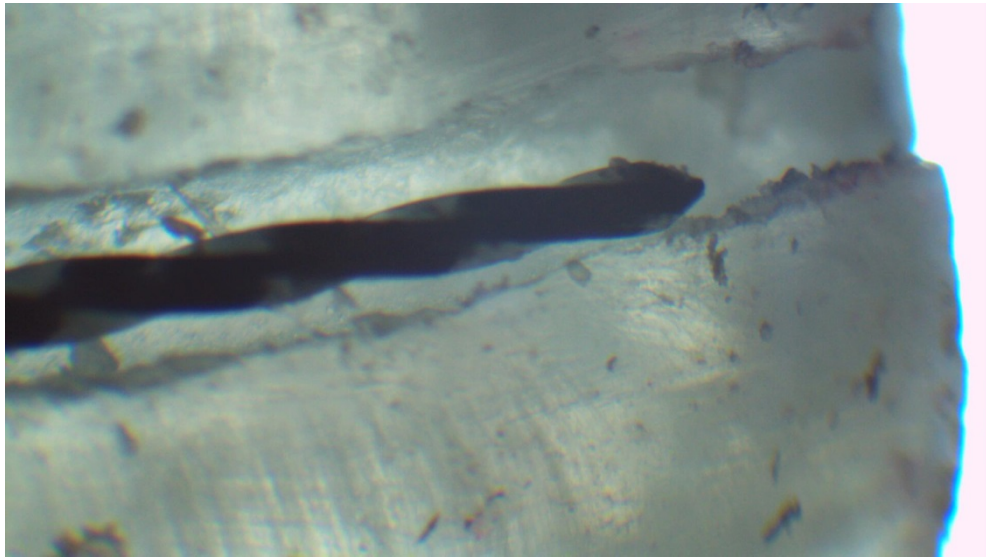


Fig 21- Group 1C sample

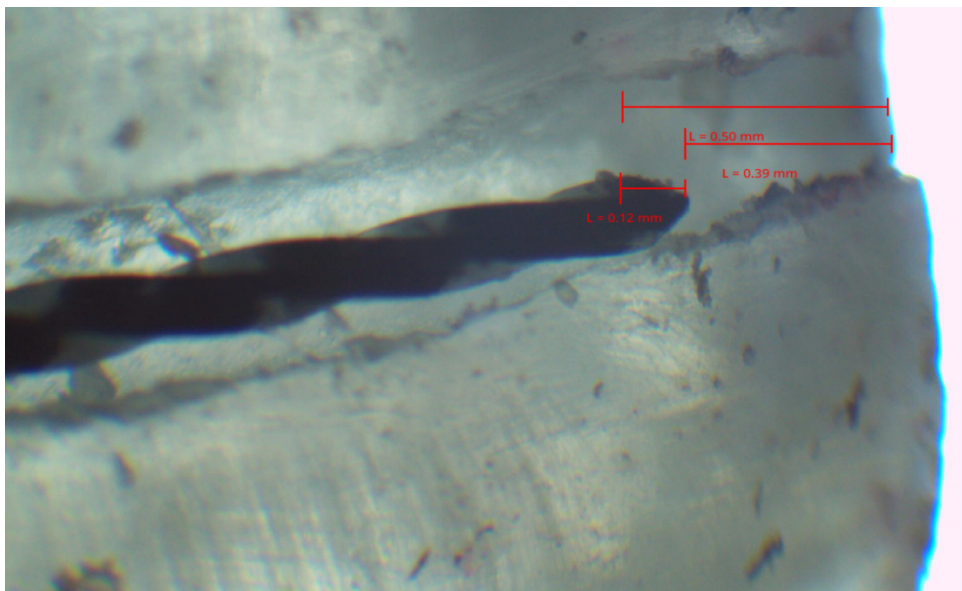


Fig 22- Group 2A sample

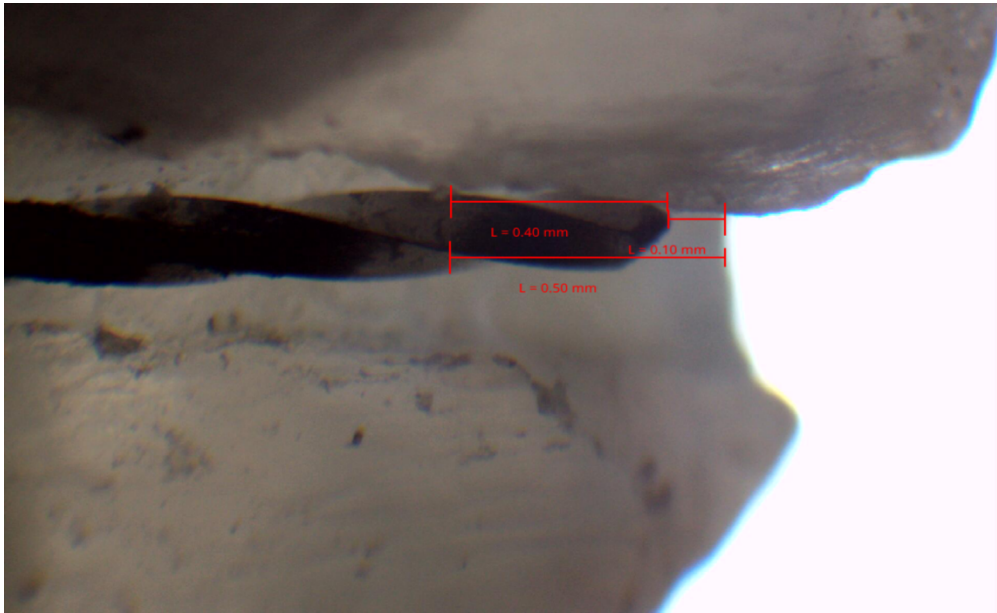


Fig 23- of Group 2B sample

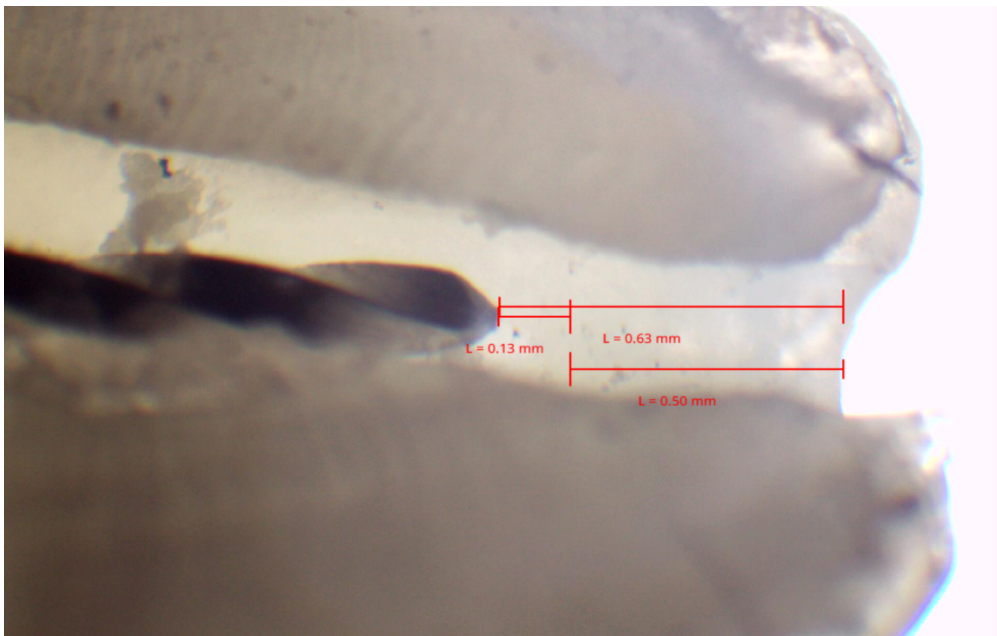


Fig 24- Group 2C sample

DISCUSSION

Accurate determination of working length during root canal treatment is a challenge and a critical step. Establishing the working length at the apical constriction is considered ideal for endodontic treatment⁴². The apical constriction (minor apical diameter) is the narrowest apical portion of the root canal with a variety of morphological variations that make its identification unpredictable⁵².

Working length (WL) is the distance from a coronal reference point to the point at which canal preparation and filling should terminate². Correct WL determination and confining root filling materials only to the canal and not invading the periapical tissues results in better root canal treatment outcomes and reduces the odds of insufficient cleaning of the full extent of the canal. Instrumentation beyond the apical foramen (AF) should be avoided because it decreases the success rate⁵¹. In the short term, accurate WL determination may prevent flare-ups, and in the long term it allows for successful treatment outcome by preventing periapical foreign body reactions, sealing of root canal apices and microbial control.

The apical constriction (AC) forms the minor foramen (or minor diameter) and the most apical opening of the root canal is designated as the Apical foramen(AF) or major foramen or greater diameter. The distance between AC and AF varies from 0.5 to 0.7 mm⁶¹. Biomechanical preparation should end at the AC, where the contact between the root canal filling material and the apical tissue is minimal. The best prognosis for the root canal treatment is ensured when instrumentation terminates at the AC. Instrumentation beyond the AC or short of it should be avoided because it reduces the success rate⁵¹.

Discussion

The radiographic apex is defined as the anatomical end of the root as seen on radiographs, whilst the AF is the region where the canal leaves the root surface and the AC often coincides with the cemento–dentinal junction⁴². The AF deviates from the anatomic or radiographic apex in 60–94% of the cases. It is present 0.5–2.0 mm apical to the anatomic apex on the buccal, lingual or proximal surfaces. Studies show the distance between the AC and the anatomic apex on average 1 mm⁴².

In clinical practice the AC cannot be detected radiographically. Moreover, a single distinct constriction that can be determined in a tactile approach is only present in 40–50% of cases. Although Olson et al. (1991)⁵³ have reported that the location of the AF could be accurately determined radiographically, the distance from the AC cannot be measured. Despite the limited information provided by an intraoral radiograph, radiography remains an accepted and commonly used method for WL determination⁶³.

Limitations of conventional radiography include the sensitivity of the technique, subjectivity and errors due to image magnification, distortions or the superimpositioning of anatomical structures⁵⁹. Moreover, because the AC cannot be detected radiographically, the radiographic WL is actually an estimation based on the average distance between the constriction and the major foramen. Thus, WL is often measured 0.5–1 mm short of the radiographic apex. Nevertheless, the major foramen does not always coincide with the anatomical apex, but may be located laterally and at a distance of up to 3 mm from the anatomical apex⁴². The above reasons could explain the common overestimation of radiographic WL.

Electronic apex locators (EAL) are useful adjuncts in locating the terminus of the canal during root canal treatment. Electronic devices for assessing the root canal

Discussion

length have gained popularity and eliminate many of the problems associated with radiographic measurements¹⁷. Sunada in 1962 developed the first electronic apex locator (EAL) based on Suzuki's discovery that electrical resistances between the periodontal ligament and oral mucosa registered constant values of 6.5 k Ω . Since then, different generations of EALs⁶⁷ have been developed. Whilst the simplest devices measure resistance, other devices measure impedance using either high frequency, two frequencies, or multiple frequencies. In addition, some systems use low frequency oscillation and/or a voltage gradient method to detect the canal terminus⁵².

The first generation EALs were resistance based and the second generation EALs were impedance based apex locators. The main shortcomings of these EALs included poor accuracy in the presence of fluids and pulp tissue, and the need for calibration¹⁷. The frequency based third generation EALs have more powerful microprocessors and are able to process mathematical quotient and algorithm calculations required to give accurate readings.

Root ZX Mini (J. Morita Mfg Corp., Kyoto, Japan)³³ is a third generation EAL that uses dual frequency and comparative impedance principle and 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 Mini requires no calibration, and can be used when the canal is filled with a strong electrolyte. The Root ZX apex locator has been investigated^{7,21,36,49} extensively as regards its accuracy and its efficacy in the presence of various irrigants and is considered to be the gold standard against which newer EALs are evaluated.

Discussion

Multi frequency based EALs have been developed to further increase the accuracy of EALs. The fourth-generation apex locators do not process the impedance information as a mathematical algorithm, but instead they take the resistance and capacitance measurements separately and compare them with a database to determine the distance to the apex of the root canal²⁷. The Raypex 6 (VDW, Munich, Germany) is the latest fifth generation apex locator based on multi frequency and is also claimed to be accurate in the presence of various intra canal conditions. It has automatic calibration and the separate apical zoom shows the enlarged section between apical constriction and apical foramen⁴⁴.

Modern electronic apex locators are believed to be able to perform well in the presence of various irrigation solutions⁶⁵; however, some reports suggest that accuracy of electronic apex locators is dependent on the type of irrigation solution used^{39,40,69}. Hence, there is still a concern as to whether high electro conductive irrigants such as saline, anesthetic solution, and sodium hypochlorite can affect the performance of these new-generation EALs. Sodium hypochlorite, chlorhexidine and normal saline are the most commonly used irrigants. According to Shabahang et al (1996)⁶⁴ the presence of sodium hypochlorite adversely affected the Root ZX accuracy, while other reports indicate that it had not adversely affected the Root ZX performance^{3,10}. The use of 0.9% normal saline as an irrigation solution has been reported to lower the accuracy of some electronic apex locators, while other reports indicate that it had no effect on the accuracy of electronic apex locators.

Hence in this in vitro study we compared the accuracy of the newly introduced Raypex 6 apex locator with the gold standard Root ZX mini in the presence of 5%

Discussion

sodium hypochlorite, 2%chlorhexidine, 9%saline as intra canal irrigants in detecting the apical constriction.

Studies evaluating the accuracy of electronic apex locators use a wide range of experimental procedures to conduct the study, and to record and report findings. These experiments could be either in vivo or ex vivo. Most of them demonstrate a high-degree accuracy in measurement of the working length. Usually extracted teeth are placed in a conductive environment made of agar-agar, alginate, gelatin, or saline for laboratory studies⁶⁵. The use of a saline solution has shown to produce reliable measurement data. The gelatin model was used in this in vitro study to simulate the periodontium⁸, and has the advantage of simplicity, ease of the use and the ability to have a strict control over the experimental conditions tested.

In some studies^{64,26,41}, a general accuracy with tolerance of ± 1.0 mm to apical constriction is regarded as clinically acceptable, especially concerning primary teeth or teeth without a well-defined apical constriction. The measurements of the present study were attained in a target interval of ± 0.5 mm to the minor diameter of the apical constriction. This clinical tolerance of ± 0.5 mm is considered to be the strictest acceptable¹⁷. Measurements within this minimal tolerance are highly accurate.

The findings of this study have shown that the apical constriction is not consistent with the major foramen. This result is in accordance with the studies of Pineda & Kuttler (1972)⁵⁷ and Dummer et al. (1984)⁹. In previous studies testing the accuracy of frequency-dependent EALs, the major foramen at a tolerance of ± 0.5 mm or ± 1.0 mm was used as a reference. The results of the present study demonstrate that the tip of the file was beyond the major foramen in two cases for the Root ZX Mini

Discussion

and in three cases for the Raypex6. This was inspite of the fact that the EALs were used according to the manufacturers' instructions to determine the apical constriction.

The actual working length can be determined by visually observing the tip of a file inserted into the canal at the apical foramen⁵⁶, or to determine the location of the tip of the file that was used for the electronic working length measurement relative to the apical constriction by cementing it in the canal and then exposing the apical 4 mm of the root canal³⁰. In addition, the apical reference point for recording the electronic length can be set at the "apex" indicator on the device electronic dial, the "0.5 mm" mark, or the "1.0 mm" mark²⁵. Furthermore, the findings have been reported as percentage of readings that are exactly at or fall within a certain tolerance level that ranges from ± 0.5 mm to ± 1.0 mm with regard to a predetermined reference point that could be the apical foramen⁴⁵, the actual apical constriction⁷⁰ or estimated apical constriction⁵⁸ (apical foramen – 0.5 mm), or 1 mm short of the apical foramen⁴⁹.

In this study the actual length (AL) was determined by introducing a size 10 or 15 Kfile into the canal until its tip emerged through the major apical foramen at $\times 10$ magnification under a stereomicroscope. The location of the tip of the file that was used for the electronic working length measurement relative to the apical constriction was determined by cementing it in the canal and then exposing the apical 4 mm of the root canal³⁰ and was examined in a stereomicroscope with 30x magnification.

Preflaring of root canals before measurement with EALs can increase the precision of working length determination¹¹. Thus, the canals were preflared by using sequential Gates Glidden drills #2, #3, and #4 in the current study before measurement.

Discussion

Usually the major foramen²⁵ or the apical constriction³¹ is used as an apical reference point for laboratory studies. As the aim of this study was to compare the accuracy of Root ZX mini and Raypex6 apex locators in detecting the apical constriction we use the apical constriction as a reference point. Locating the apical constriction visually after exposing the apical part of the root canal can be challenging since less than 50% of the teeth have a definitive constriction point⁴³. The findings of our study were reported as percentage of reading within a predetermined range; where the zone between the apical foramen and 1.0 mm coronal to that (estimated apical constriction \pm 0.5 mm) was considered “correct”(acceptable), readings beyond the apical foramen were considered “long’(not acceptable)’, and readings more than 0.5 mm short of the estimated apical constriction were considered “short”(not acceptable). This was adopted with modification from Hoer and Attin (2004)³⁰ who considered the area between the apical foramen and the apical constriction to be the “target’ interval.

Inconsistent measurements in laboratory studies that evaluate EALs may be explained by procedural errors, by bias that results from the inaccurate adjustment of the stopper to the reference point, or by movement of the stopper during the measurement procedure⁷¹. As a consequence, in the present study, the file was cemented in position with glass ionomer cement. In addition, the distance between the instrument and the final WL was measured under a stereomicroscope after performing transversal wear of the apical portion of the root^{30,73}. We performed transversal wear of the apical portion of the root in this study because it reduced the number of variables involved and allowed a more precise measurement of the distance³⁴; it is only possible to determine the position of the file tip or the actual length of the root

Discussion

canal exactly if the teeth are examined histologically³⁰. According to Wrbas et al.⁷³ it is important to use the same teeth in order to obtain a precise comparison of the accuracy and differences of types of EALs in the determination of the WL. However, we did not use the same teeth because upon removal of the file from the tooth and again repositioning during stereomicroscope examination there is a possibility of repositioning it incorrectly.

To evaluate the accuracy of EALs, the ± 0.5 mm range from AL was chosen in this study, which is considered clinically acceptable and highly accurate. **Root ZX mini was 100%** accurately locate the apical constriction and **Raypex 6 was 90%** accurately locate the apical constriction in presence of **saline as intracanal irrigant**, Both Root ZX mini and Raypex 6 were **90%** accurately locate the apical constriction in presence of **5% sodium hypochloride as intracanal irrigant** and Both Root ZX mini and Raypex 6 were **90%** accurately locate the apical constriction in presence of **2% chlorhexidine digluconate as intracanal irrigant**. This study concluded that the Root ZX mini and Raypex 6 Apex Locator have similar accuracy and the function of the two apex locators was not affected by the type of endodontic irrigants used.

This is similar to the results of previous study by Solaiman Mohammed Al-Hadlaq (2012)⁶⁵ in which he evaluated the accuracy of Root ZX mini and Sybron endo mini apex locator in the presence of 5.25% Sodium Hypochlorite, 2.625% Sodium Hypochlorite, 1.0% Sodium Hypochlorite, 0.9%NaCl, 2% lidocaine with 1:80,000 Epinephrine, and 2% Chlorhexidine. He concluded that the Root ZX mini and Mini Apex Locator have similar accuracy and the function of the two apex locators were not affected by the type of endodontic solution used.

Discussion

Jung-A Kang, et al in 2008³⁹ evaluated the accuracies of Apex Finder 7005, Apit, Bingo-1020, e-Magic Finder, ProPex, Root ZX, and SmarPex in presence of 5.25% NaOCl, saline, 0.1% chlorhexidine, and 15% EDTA as different irrigants in the root canal. He concluded that most of the EALs tested can be considered reliable in the presence of various root canal irrigants.

The measurements of Root ZX Mini and Raypex 6 in presence of various irrigants to locate the minor constriction shows no statistical difference between them and the majority of the readings were within the acceptable range of ± 0.5 mm for both EALs. In this study the overall accuracy of measurements within ± 0.5 mm of AL by Root ZX mini was 93.33% and Raypex 6 was 90% respectively. In vivo studies^{17,48} have shown the accuracy of Root ZX mini to be varying from 82.3% to 96.2% within ± 0.5 mm. The accuracy of the Root ZX mini reported in our study (93.33%) is similar to the 94% accuracy reported by Stoll et al (2010)⁶⁶ in his in vitro study. The overall accuracy of Raypex 6 in this study with various irrigants was 90%; it was comparable to a previous study by Saddy Moscoso, et al (2013)⁵⁰ where it was 88.22% accuracy with NaOCl as irrigant.

In the presence of saline, the accuracy of Root ZX Mini and Raypex 6 within ± 0.5 mm was 100%, and 90%, respectively. The use of 0.9% normal saline as an irrigation solution has been reported to lower the accuracy of some electronic apex locators (Erdemir et al., 2007; Ozsezer et al., 2007)^{15,54} while other reports indicate that it had no effect on the accuracy of electronic apex locators (Kaufman et al., 2002; Kang and Kim, 2008)^{39,40}. The present study found no adverse effect of using 0.9% normal saline as an irrigation solution on the accuracy of the two apex locators tested.

Discussion

The use of 2% Chlorhexidine as an irrigation solution has been advocated to take advantage of its good antimicrobial properties and its residual effect in the root canal¹⁴. The effect of lower Chlorhexidine concentrations (0.1%, 0.2%, and 0.8%) on the accuracy of electronic apex locators has been previously investigated (Kaufman et al., 2002; Kang and Kim, 2008)^{39,40}; and very few studies are reported in the literature regarding the effects of 2% Chlorhexidine on the accuracy of electronic apex locators. In our study both Root ZX mini and Raypex 6 were 90% accurate in locating the apical constriction in the presence of 2% chlorhexidine digluconate as intracanal irrigant this was similar to the study conducted by Solaiman Mohammed Al-Hadlaq (2012)⁶⁵ who stated that the presence of 2% Chlorhexidine in the root canal did not affect the accuracy of the electronic apex locators.

Sodium hypochlorite is the most commonly used endodontic irrigant and various concentrations of sodium hypochlorite are used for this purpose, in our study we have used 5% NaOCl. The results of our study using 5% NaOCl as intracanal irrigant with Root ZX Mini and Raypex6 within ± 0.5 mm were 90% which is similar to the study by Weiger et al(1999)⁷² who in his *in vitro* study had found this to be 95.7% within ± 1 mm. However Wrbas *et al*(2007)⁷³ in his *in vivo* study with 1% NaOCl found that the accuracy of Root ZX within ± 0.5 mm to be only 75%. Saddy Moscoso et al(2013)⁵⁰ found the accuracy of Raypex6 with 4% NaOCl to be 88.22% (± 0.5 mm) 100% (± 1 mm). The presence of sodium hypochlorite as an irrigant did not affect the accuracy of both apex locators tested in this study which is similar to the study conducted by Solaiman Mohammed Al-Hadlaq (2012)⁶⁵ in that various concentration of NaOCl have no significant effect on the accuracy of the EAL.

Discussion

The results obtained in this in vitro study cannot be applied to the clinical situation, but can provide an objective assessment of a number of variables that are not practical to test clinically. At best the EALs should be used as an adjunct, and not as the only method to determine the canal length in endodontic therapy. Clinicians should exercise caution when interpreting the canal measurements using EALs with different irrigants.

SUMMARY

This study was undertaken to compare the accuracy of Root ZX mini and Raypex6 apex locators in detecting the apical constriction and the influence of various intra canal irrigants on the accuracy of Electronic apex locators in detecting the apical constriction.

Sixty extracted, straight single rooted permanent human maxillary anterior teeth with mature apices were selected for this study. The teeth were stored in distilled water containing 10% formalin solution until use and the teeth were soaked in 5% NaOCl to remove the residual soft tissue before use. Teeth were randomly divided into two main groups according to the apex locators tested such as

Group1 (n=30,Root ZX mini apex locator)

Group 2 (n=30,Raypex6 apex locator).

Then each group is further divided into 3 subgroups according to the irrigants used such as

Group 1A (n=10,Root ZX mini apex locator,0.9% normal saline),

Group 1B (n=10,Root ZX mini apex locator,5%sodium hypochlorite),

Group 1C (n=10,Root ZX mini apex locator,2%chlorhexidine digluconate),

Group 2A (n=10,Raypex6 apex locator,0.9% normal saline),

Group 2B (n=10,Raypex6 apex locator, 5%sodium hypochlorite),

Group 2C (n=10,Raypex6 apex locator, 2%chlorhexidine digluconate).

Summary

The teeth were decoronated at the level of cementoenamel junction with a diamond disc and the coronal portion of each canal was preflared using sequential Gates Glidden drills #2, #3, and #4.

The actual length (AL) of each specimen was determined by introducing a size 10 or 15 K file into the canal until its tip emerged through the major apical foramen at 10x magnification under a stereomicroscope. After carefully adjusting the silicone stopper to the reference point, the file was withdrawn from the root canal, and the distance between the file tip and silicone stopper was measured with a caliper to the nearest 0.5 mm; 0.5 mm was subtracted from this length.

Each specimen was embedded in the gelatin model and the electronic apex locators were tested according to the manufacturer's instructions. The electronically measured canal length (EL) was recorded by using size 10 or 15 Kfile. Then the K-files were fixed at the WL determined electronically with GIC. The apical 4 mm of the root was longitudinally sectioned using 169Lcarbide bur and BP blade #15 along the long axis of the tooth in a plane that was determined to show the best representation of the apical constriction in relation to the file and examined under Stereomicroscope with 30x magnification.

The distance from the file tip to the apical constriction is calculated from the Stereomicroscopic images. Distance of file tip from apical constriction was considered into following for statistical analysis.

Code1 - $\leq \pm 0.5\text{mm}$ (Acceptable)

Code2 - 0 mm (correct)

Summary

Code3 - $> \pm 0.5\text{mm}$ (not acceptable)

Both code 1 and code 2 were considered as accurate to determine the apical constriction in this study.

Independent sample t test was employed to statistically analyze the significance of mean difference between EL and AL and Pearson Chi-Square test was used to statistically analyse the significance of irrigants on the accuracy of apex locators and to compare the accuracy of both apex locators. Significance was set at $P<0.05$. The analysis was performed with SPSS 20.0, (SPSS Inc, Chicago, IL) software.

The results of the measurements of Root ZX Mini and Raypex 6 in presence of various irrigants to locate the minor constriction showed no statistical difference between them ($p=0.799$) and the majority of the readings were within the acceptable range of $\pm 0.5\text{ mm}$ for both EALs. The overall accuracy of measurements within $\pm 0.5\text{ mm}$ of AL by Root ZX mini was 93.33% and Raypex 6 was 90% respectively.

CONCLUSION

Within the limitations of this in vitro study the following conclusions could be drawn:

- The two electronic apex locators, the Root ZX mini and the Raypex6 were found to have similar accuracy in detecting the apical constriction in human permanent maxillary anterior teeth.
- The use of 5% NaOCl, 0.9% normal saline, or 2% Chlorhexidine as irrigation solutions did not affect the accuracy of the two apex locators in detecting the apical constriction.
- Further in vivo studies are required to confirm the accuracy of Root ZX mini and Raypex 6 apex locators.

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