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Evaluation of Accuracy Of Different Electronic Apex Locators In Detecting Simulated Horizontal, Vertical Root Fractures And Root Perforations - An Invitro Study.

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Abstract

Aim - To evaluate the accuracy of Root ZX II, iRoot, EMS apex locators in detecting simulated horizontal, vertical root fractures and root perforations

Materials and methods - 40 freshly extracted single rooted maxillary central incisors were selected for study. Teeth were decoronated at CEJ and access cavities were performed and roots randomly divided into 4 groups. Group I (n-10) - The 6th mm from coronal flat surface of roots was cut with 0.2 mm thick disc simulating horizontal root fracture, Group II (n-10) - Incomplete vertical root fracture was simulated from 4th to 8th mm of roots, Group III (n-10) - The teeth with perforation in root, Group IV (n-10) – (Control group) teeth in which root lengths adjusted to 16 mm. All teeth were embedded in boxes containing alginate. Each single tooth in all groups was measured through Root ZX II, iRoot, and Endo Master System (EMS) apex locators. Analysis was done using SPSS version 21. Comparison of mean working length among three apex locators was compared with repeated measures ANOVA independently in each group.

Results – In Group I, III, IV all the three apex locators were accurate and there is no statistical significant difference (P>0.05). In Group II – Root ZX II and iRoot apex locators detected vertical root fractures more accurately than EMS apex locator and there was statistically significant difference (P<0.05).

Conclusion : Root ZX II, iRoot and EMS apex locator were accurate and acceptable clinical tools in detecting apical constriction, horizontal root fractures and root perforations. Root ZX II, iRoot apex locator were more accurate in detecting vertical root fractures than EMS apex locator.

Keywords - Apex locators, apical constriction, root fracture, perforation, root apex.

Introduction

The removal of pulp tissue, necrotic debris from the root canal is essential for endodontic success. This can only be achieved if the length of the root canal is determined with accuracy. The outcome of treatment of root canals with necrotic pulps and periapical lesions is influenced significantly by the apical level of the root filling.[1]

The point of termination for endodontic instrumentation and obturation has been determined by taking radiographs. The development of the electronic apex locator has helped make the assessment of working length more accurate and predictable.[2]

The accuracy of apex locators is higher when compared with that of the radiographic methods.[3,4,5] Apart from diagnosing perforations and root fractures,[6,7,8] a higher accuracy is achieved when Electronic Working Length (EWL) determination and radiographic evaluation are performed.[4,9,10] Only a few ex vivo studies have reported the inconsistent function of apex locators as a secondary finding.[11,12]

Incomplete root fractures are classified as vertical, horizontal or oblique, are among the most difficult cases to diagnose and treat in endodontic practice.[13] Electronic Apex Locator (EAL) devices are used to detect root fractures because of the physical principles on which they are based.[7,8] They should detect root fracture that reaches the pulpal chamber and should detect the fracture as an “apex” from the beginning of the periodontal connection at the fracture site.[13]

Root perforation is a serious dental complication that occurs in 3-10% of root canal treatments.[14,15] Early detection and immediate treatment of root perforations can significantly improve the prognosis.[16]

Diagnosis of root perforations requires a combination of symptomatic findings, clinical observation and diagnostic aids.[17] Among the diagnostic aids available EALs can assist in chair side diagnosis.[18,19] The limitation of radiographs to detect root perforations, especially in the buccal or lingual root surface has been demonstrated.[20]

All modern EALs are able to detect root perforations within a clinically acceptable limit.[21-23] This may aid in decision making and consideration of treatment options.[19,24] Any connection between the root canal and the periodontal membrane, such as root fractures, cracks and internal or external root resorption will be recognized by the EAL, which serves as an excellent diagnostic tool in these circumstances.[25]

Recent studies reveal that EALs are acceptable clinical tools in detecting root perforations in the middle third of root canal.[26] Devices have been introduced that integrate an EAL with an electric handpiece for canal preparation.[27] Some devices also allow the operator to select the apical position of choice and have a reverse motion to help to remove the file from the canal when the apex is reached or in case of canal blockage. One of such devices which has both apex locator and handpiece is EMS system.

In our study we used Root ZX II apex locator and compared it with iRoot and EMS apex locators.

Aim of the Study

To evaluate the accuracy of Root ZX II, iRoot, EMS apex locators in detecting simulated horizontal, vertical root fractures and root perforations.

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Fig 1.a –Teeth Samples.

Fig. b : Armamentarium

Materials & Methods

An invitro study was undertaken in the Department of Conservative Dentistry and Endodontics to evaluate the efficacy of apex locators.

Preparation of Samples

40 extracted intact straight, single-rooted anterior teeth with mature apices and patent single canals without any crack or perforations were selected (Fig 1). The teeth were soaked in 3% NaOCl for 24 hours to dissolve tissue debris. Calculus deposits were removed from root surface with an ultrasonic scaler (EMS Piezon Master 400, CH-1260 Nyon, Switzerland).

Infection control protocol for the teeth collected in this study

Collection, storage, sterilization and handling of extracted teeth were followed according to the occupational safety and health administration (OSHA) and center for disease control and prevention (CDC) recommendations and guidelines.

Teeth were decoronated at CEJ to provide flat horizontal surface and root lengths were adjusted to 16 mm (Fig 2 a). Teeth were cleaned and access cavities were performed.

Roots were randomly divided into 4 groups of 10 each.

Group I -The 6th mm from coronal flat surface of roots was cut with 0.2 mm thick disc (Dentsply Raintree Essix manufacturers, Sarasota, Florida) until canal was exposed in horizontal plane thus simulating incomplete horizontal fracture at the 6th mm of the 10 roots (Fig 2 b).

Group II - An incomplete vertical root fracture was simulated by preparing vertical straight incision from 4th to 8th mm of roots with 0.2 mm thick disc until canal was exposed in longitudinal plane (Fig 3 a).

Group III - With K- file No 20 held in the root canal, teeth were perforated with a bur (Kave Co., Tehran, Iran) fixed in a high-speed hand piece under water coolant with 45 degrees angulation to the tooth long axis until the file was seen through the perforation surface. The perforation site was located at middle third of root (Fig 3 b).

Group IV – (Control group) teeth in which root lengths were adjusted to 16 mm, without any fractures or perforations were selected.

Fig 2 : a. Decoronation at CEJ

Fig 2 : b. Horizontal root fracture simulation

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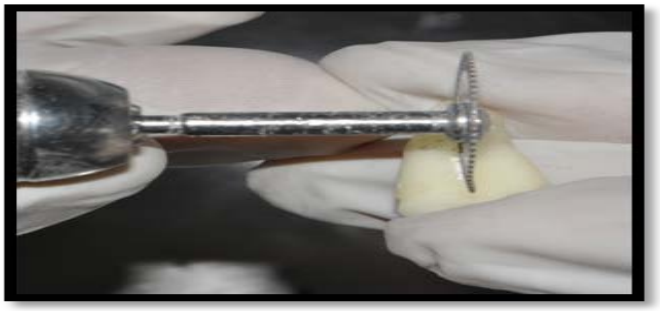

Fig 3 – a. Vertical root fracture simulation

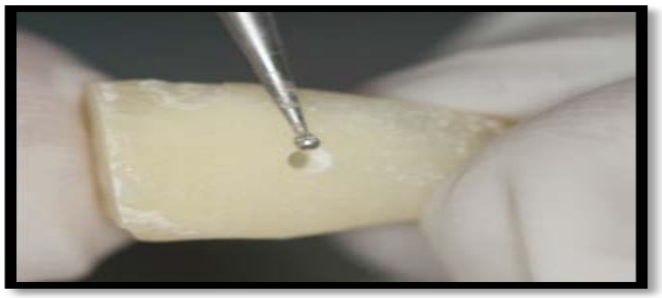

Fig 3 b : Root perforation simulation

After fracture and perforation simulation, access cavities were dried with cotton pellets and all root canals with paper points. Sterile saline (2 ml) was then injected in each root canal and was examined visually with the help of cotton pellets to verify canal exposure.

Working Model for the study

Three plastic rectangular boxes 16 x 4 x 5 cm were used for preparing this model. Alginate was poured into box and all teeth were embedded in rectangular boxes containing alginate. To complete the circuit the labial clip was fixed to the edge of plastic box and immersed in alginate. Measurements were made within 2 hours of pouring the models.

Electronic measurement of Horizontal, Vertical root fractures and Root perforations

Detection of fractures and perforations were carried with K - files (Mani Co., Japan) attached to file clips of apex locators. Each single tooth in all the groups were measured through Root ZX II, iRoot and Endo Master (EMS) apex locators (Fig 4 a,b,c) and detection was established when the meter value reached apex on each apex locator (Fig 5). The file stopper was placed adjacent to the flat coronal surface and fixed with a flowable light curing resin (Prime – Dent Light Cure Flowable Composite, Chicago, IL, USA). The file was removed, and the distance between the stopper and file tip was measured with a digital vernier caliper (TCM, Tchibo GmbH, Hamburg, Germany) to 0.01-mm accuracy and recorded (Fig 6). Similarly in control group working length was measured with all the three apex locators. All measurements were performed by two examiners who were not informed of the perforation site. Each tooth was measured two times with apex locators and mean value was calculated.

Fig 4

a. Root ZX II apex locator b. iRoot apex locator c. EMS apex locator

Fig 5- Detection of horizontal, vertical root fractures, root perforations and apical constriction by Root ZX II, iRoot and EMS apex locators.

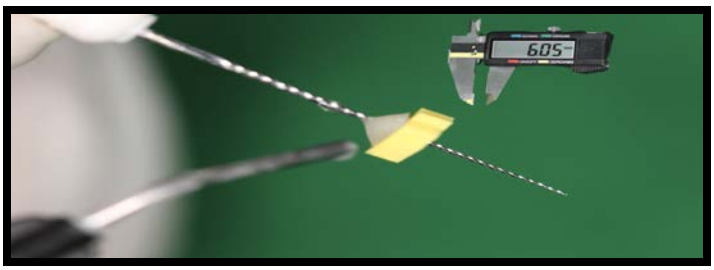

Fig 6 – K-file stopper fixed with flowable composite, (Insight) picture showing measurement made by vernier calipers

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Statistical Analysis

All the analysis was done using SPSS version 21 (SPSS Inc, Chicago,IL). A p-value of <0.05 was considered statistically significant. Comparison of mean working length among the three apex locators was compared with repeated measures ANOVA independently in each group.

Results

The mean values of measurements obtained using different apex locators are summarized in Table 1

Group	RootZX mini [a]		I-ROOTApex [b]		EMS [c]		p-value	Post-hoc test
	Mean	SD	Mean	SD	Mean	SD		
I	5.95	.06	5.91	.09	5.88	.03	0.06	-
II	3.68	.24	3.67	.21	3.24	.21	0.001	1,2>3
III	7.67	.27	7.61	.38	7.36	.49	0.155	-
IV	15.62	.19	15.62	.23	15.61	.28	0.984	-

Table 1 - Descriptive statistics of mean and standard deviations for all experimental groups

Repeated measures ANOVA

The values of above table state that P>0.05 for Groups I,III,IV and there was no statistically significant difference. P<0.05 in Group II (Vertical root fracture) with statistically difference.

Discussion

The main purpose of this in vitro study was to evaluate the accuracy of different EALs in detecting simulated horizontal, vertical root fractures and root perforations. Root fractures and perforations exhibit inadequate signs and symptoms and are often difficult to diagnose clinically and radiographically.[28,29] Accurate radiographic diagnosis is difficult as it depends on tooth inclination, position, angulation of X ray beam and superimposition of anatomic structures. Clinical experience demonstrated that there are some conditions in which EALs indicate apical constriction when just entering the root canal.[7,8] However, in the absence of disease a fracture or root perforation might be present.[8]

In the present study, horizontal fractures were simulated at the 6th mm of the roots, and vertical fractures extended from the 4th– 8th mm of roots. The simulated fractures were made by sectioning the roots with a 0.2-mm disk so the fragment separation distance was equal for both horizontal and vertical fractures. Clinically it is important to diagnose exact location of fracture as it can influence the treatment options and prognosis of the teeth.[30] In the recent years electrical devices have been developed for determining the location of fractures and perforations along with the length of the tooth. This is one of the break through that brought electrical science into endodontic practice. Most modern EALs are able to provide an accurate measurement in the presence of exudates and blood e.g. fractures and perforations.

The Root ZX II (J. Morita Corp., Tokyo, Japan), a 3rd Generation EALs that uses dual-frequency and comparative impedance principles, was described by Kobayashi & Suda in 1994.[31] The electronic method employed was the “ratio method.” The Root ZX simultaneously measures two impedances at two frequencies (0.4kHz and 8) inside the canal (Fig 4 a). The change in electrical capacitance at the area of communication with periodontal ligament is the mode of operation and its reported accuracy. Root ZX II is one of the most evaluated EAL with many studied reporting 95 - 100 % accuracy and is often used as the gold standard to which other EALs are compared. [32-34]

i-Root(E – Magic Finder)(S-Denti, Seoul, South Korea) is a 5 th generation EAL using multiple frequencies to enable accurate detection of apical constriction. It is developed & upgraded based on the technology of E-Magic Finder (EMF-100Series) apex locator. It measures the capacitance and resistance of the circuit separately. It

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is supplied by diagnostic table that includes the statistics of the values at different positions to diagnose the position of the file. Its unique patient management software helps to measure the working length on the computer screen and printing it (Fig 4 b).

Combination of electronic apex locators and handpieces is used in recent times and is able to achieve excellent results with same accuracy as individual units.[35] By stopping the rotation of Ni Ti files at the point estimated at the end of the root canal these devices eliminate the need to maintain working length with multiple files and the need for reference point on the tooth. One of such devices is the Endo Master System.

Endo Master System (EMS) (EMS, Nyon, Switzerland) is a fifth generation apex locator with integrated endomotor used for detection of apical constriction and chemo mechanical preparation. It is an autonomous apex locator which is fully automatic and operates in all conditions (Sodium hypochlorite , sodium chloride, water, saliva, blood). To make it more comfortable, it has a large display featuring color LEDs indicating the file progression in the canal, towards the apex. It has 3 different modes (Auto, Run, Apex over) for adaptation to various clinical situations (Fig 4 c).

Several in vitro studies used electro conductive materials like alginate, gelatin, agar to simulate the clinical situations.[36] We used an alginate model described by Kaufman et al.[37] Alginate is one of the ideal embedding media and because of its relative firm consistency prevents intrusion of material into apical foramen and resists force exerted during file movement, mimics the electric impedance of human periodontium and can be used for in vitro assessments of EALs.[38] This model can also be used with any irrigation solution.[39,40] In the present study, it was important that alginate was inserted in the simulated vertical or horizontal fracture to mimic the periodontal communication of the fracture site. To achieve this, alginate was prepared as more flowable. All the measurements are made within 2 hours of model preparation. The alginate model used in the study was easy for manipulation and cost effective.[41]

When using EALs some authors have suggested that taking the instruments slightly beyond the apex and then retracting them may increase the accuracy of readings of EALs.[42,43] Thus to confirm the measurement the file was advanced and then retracted to obtain consistent 0.5 mm reading. In our study all the three apex locators detected horizontal root fracture accurately and there is no statistical significant difference among three groups.

Although there were many studies of comparison of Root ZX II apex locator with other apex locators in detecting root fractures and perforations there are limited studies in comparison with i-Root and EMS apex locators for detection of root fractures and perforations. The results were similar to study conducted by Ebrahim[7] et al who found out Root ZX accurate in diagnosing horizontal root fractures. The results were also similar to study conducted by Sakkir N [44] et al whose results showed Root ZX II, i-Root, Endo Master apex locators accurate in determining the working length with high precision and greater predictability.

In our study Root ZX II and iRoot apex locators detected vertical root fractures more accurately than EMS apex locator and there was statistically significant difference. These results were similar to study conducted by Topuz [13] et al who found out Tri Auto ZX which has inbuilt apex locator of Root ZX accurate in diagnosing vertical root fractures. The results were contrary to studies conducted by Ebrahim[7] et al and Azabal[8] et al who found out Root ZX unreliable in detecting vertical root fractures. The results were also similar to study conducted

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by Saxena D [45] et al which showed i-Root apex locator more accurate in detecting the minor diameter in comparision with iPex II and Propex pixi. Barthelemy[27] et al conducted a study of comparing the manual and the motor-driven modes of the Endomaster device for which there was small difference between 2 operating modes. This might be one of the reason for less accuracy of EMS apex locator in detecting vertical root fractures.

The measurements obtained revealed that the EALs were able to measure the root canal length with a precision compared with the actual length. If the estimated working length, i.e., actual length ± 0.5 mm is considered to be clinically acceptable, then the measurements made with the Root ZX II, iRoot, EMS apex locators were acceptable in virtually all cases.

Conclusion

Within the limitations of the present study of the present study all the three apex locators (Root ZX II, i-Root and EMS) were able to determine working length, horizontal root fractures and root perforations with high precision and greater predictability. This clearly revealed reliability of these apex locators in detecting root fractures, perforations and apical constriction. However EMS apex locator was less accurate in determining vertical root fractures. Further studies however need to be conducted to corroborate findings of the present study.

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