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Effect of various irrigating solutions on working length determination by electronic apex locator: In vitro study

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Abstract:

The purpose of this study is to compare and evaluate the effect of various irrigating solutions on the working length determination by Electronic apex locator in an in vitro model. The accuracy of the apex locator was compared using single canal single rooted teeth (incisors and canine) that were to be extracted for periodontal or orthodontic reasons. A total of 90 extracted anterior teeth, preserved in 0.9% saline solution were used for the study. Teeth having single root canal were selected for the study. The study consisted of two parts: in the first part root canal access cavity preparation was done in all teeth followed by determination of actual working length. biomechanical preparation of teeth were done to three files size larger than the initially fitting file and then teeth were divided into 6 groups of 15 teeth each. Prior to assessment of working length by electronic apex locator an alginate model was developed to simulate the oral conditions, after embedding teeth in it readings were taken. Electronic measurement of working length was taken by electronic apex locator in dry conditions and various irrigating solutions. Each measurement was repeated till a stable reading came on the electronic apex locator. Results obtained were analyzed using paired sample t test and ANOVA. Chlorhexidine solution as an electroconductive medium was found to be most reliable.

Keywords: Electronic apex locator, Impedence, Working length.

Introduction:

Electronic apex locators (EAL) are widely used in endodontics to determine the root length during root canal treatment. Their functionality is based on the fact that the electrical conductivity of the tissues surrounding the apex of the root is greater than the conductivity inside the root canal system provided the canal is either dry or filled with a nonconductive fluid.[1] In 1918, Cluster first put the idea that the root canal length could be determined using electrical conductance. The development of EAL began in 1942, when it was reported by Suzuki that the electrical resistance between the periodontal ligament and the oral mucosa in vivo was a constant value of ~ 6.5kΩ. Later in 1962 Sunada introduced the principle of the ‘biological characteristics theory’ into clinical practice. It was reported that when the tip of an endodontic instrument had reached the periodontal membrane through ‘apical foramen’, the electrical resistance between the instrument and the oral mucous membrane was a constant value. Based on this fundamental principle, these resistance based devices should be able to detect the periodontal tissue at the ‘apical foramen’. [1,2]

The major disadvantage with the first and second generation devices despite considerable developments over the years was inaccurate and erroneous readings in root canal that contain moisture, vital pulp tissue, blood and other exudates or remnants of intracanal irrigants. [2-4]

The third generation of dual frequency EALs has attempted to overcome or minimize this problem; in fact these devices are also based on alternating current, but they operate on the principle that the impedance difference between electrodes depends on the signal frequencies used.[4]

In the present context there has been increased use of various irrigating solutions in various concentrations, and the electroconductivity of these solutions have been thought to affect the results of the electronic working length measurements. Some have suggested not using highly electroconductive solutions for measurement and some have come up with automatic compensation concept for electronic apex locators. The true effect of various solutions is still debatable.

The objective of the present study is to test in an *ex vivo* model the effect of various irrigating solutions on the accuracy and reliability of an Electronic Apex Locator (ProPex)©

Materials and Methods:

In total 90, human permanent, non-carious anterior teeth with single canals and mature apices were collected. The teeth scheduled for extractions due to periodontal disease or orthodontic reasons, were selected. The teeth were selected by direct clinical examination. Carious teeth, Fractured or broken down teeth, Restored teeth, Immature apices, Root resorption, Multiple canals were excluded from the study.

Before the test, the teeth were stored in formalin solution and placed in 0.5% sodium hypochlorite solution for 2 hours to remove the periodontal ligament.[2] All remaining organic residues were removed from external root surfaces with an ultrasonic scaler (Demetec, Korea©). After rinsing with tap water, teeth were transferred to 0.9% saline solution. All the teeth were treated by the same operator. Standard root canal access cavity preparation was prepared with a diamond bur (Pivo, Korea©) in a high-speed handpiece (NSK, Japan©) under water coolant. Gates glidden drills (Prime Dental,© India) were used to remove the shoulder around the orifice.

After the root canal orifice were identified the canals were cleansed of debris by irrigating with 5ml of 3% sodium hypochlorite after which canal patency was evaluated using a 10 or 15 K-Flexofile (Dentsply©, Germany) any teeth with canal obstructions were discarded. Pulp tissue was extirpated using barbed broaches (Medin©, Czech Republic) without any attempt to enlarge the canal with the root canal instruments. Root canals were irrigated with 5 ml of sodium hypochlorite in order to remove the organic contents of root canal space.

The teeth were randomly divided into 6 groups consisting of 15 teeth each. All the teeth were prepared to three file size larger to the initially fitting K-file. The actual length was re-determined for each tooth. The solutions in to which the groups were assigned are as following 1. Dry group, 2. 0.9% Saline group, 3. 2% Chlorhexidine group, 4. 3% Sodium hypochlorite group, 5. 3% Hydrogen peroxide group, 6. 17% EDTA (Ethylenediaminetetraacetic acid)

The teeth were embedded into the freshly prepared alginate model. One group at a time was taken for study starting from number 1 group as assigned above. The root canal of each tooth was filled with the respective solution, the excess of solution was dried from the chamber and the external surface of the tooth to the pulp chamber of the tooth, was wiped dry with a cotton swab.

The readings were taken by advancing a 15 K-Flexofile till it read 0.0 on the electronic apex locator with a clear confirmatory sound beep. The root canal lengths in all the groups were recorded in the same way. All measurements were made within 2 hour of the model being prepared in order to ensure the alginate was kept sufficiently humid.

After recording all the readings, the Statistical analysis of the data was done by using Paired T test and ANOVA and the results compared.

Results: The study consisted of 90 extracted anterior teeth were used in the study. In all the teeth 15K file was visible at the end of the apex of the tooth. A range of ± 1 mm from the actual length was considered as the parameter for considering readings as accurate.

Stable measurement Readings were recorded by apex locator only when 0.0 mark appeared on the LCD screen of the apex locator with a confirming sound beep and it stayed stable at that position for few seconds. *Unstable measurement*s one unstable reading was recorded.

Accuracy was calculated only on stable measurements in all six groups. Sample size was 15 for each group. Out of 15 teeth in each group Dry group recorded readings in ± 1mm range in 6 teeth, 0.9% Saline in 10, 2%Chlorhexidine in 12, 3%Sodium Hypochlorite in 7, 3%Hydrogen peroxide in 7 and 17% EDTA in 10. The frequency table is presented in table below

Note:- Where

1 is -1 mm from the visualized apex
2 is -0.5 mm from the visualized apex
3 is 0.0 mm from the visualized apex
4 is 0.5 mm from the visualized apex
5 is 1.0 mm from the visualized apex

The ANOVA test (Table 2) showed that there is no significant difference between the working length values of different irrigating solutions and actual length (p>0.05).

Discussion:

The present study used a third generation Electronic apex locator ProPex©. ProPex© (Dentsply Maillefer©, Ballaigues, Switzerland) is a multi-frequency based apex locator which is based on the same principles of the other modern devices which use multiple frequencies to determine root canal length. One important characteristic of ProPex© is that the calculation is based on the energy of the signal whereas the other apex locators usually use the amplitude of signal. The manufacturer claims that energy measurement is more precise. The manufacturer does not specify any other technical characteristics and only some studies are present in current literature on the ex vivo or in vivo accuracy of this EAL.[2] It detects the canal terminus by determining a sudden change in the dominant characteristic (capacitive or resistive) of the impedance. It has been claimed to be unaffected by either dry or moist condition of canals. Based on these facts this device was considered suitable for the study.

Table 1: Frequency Table

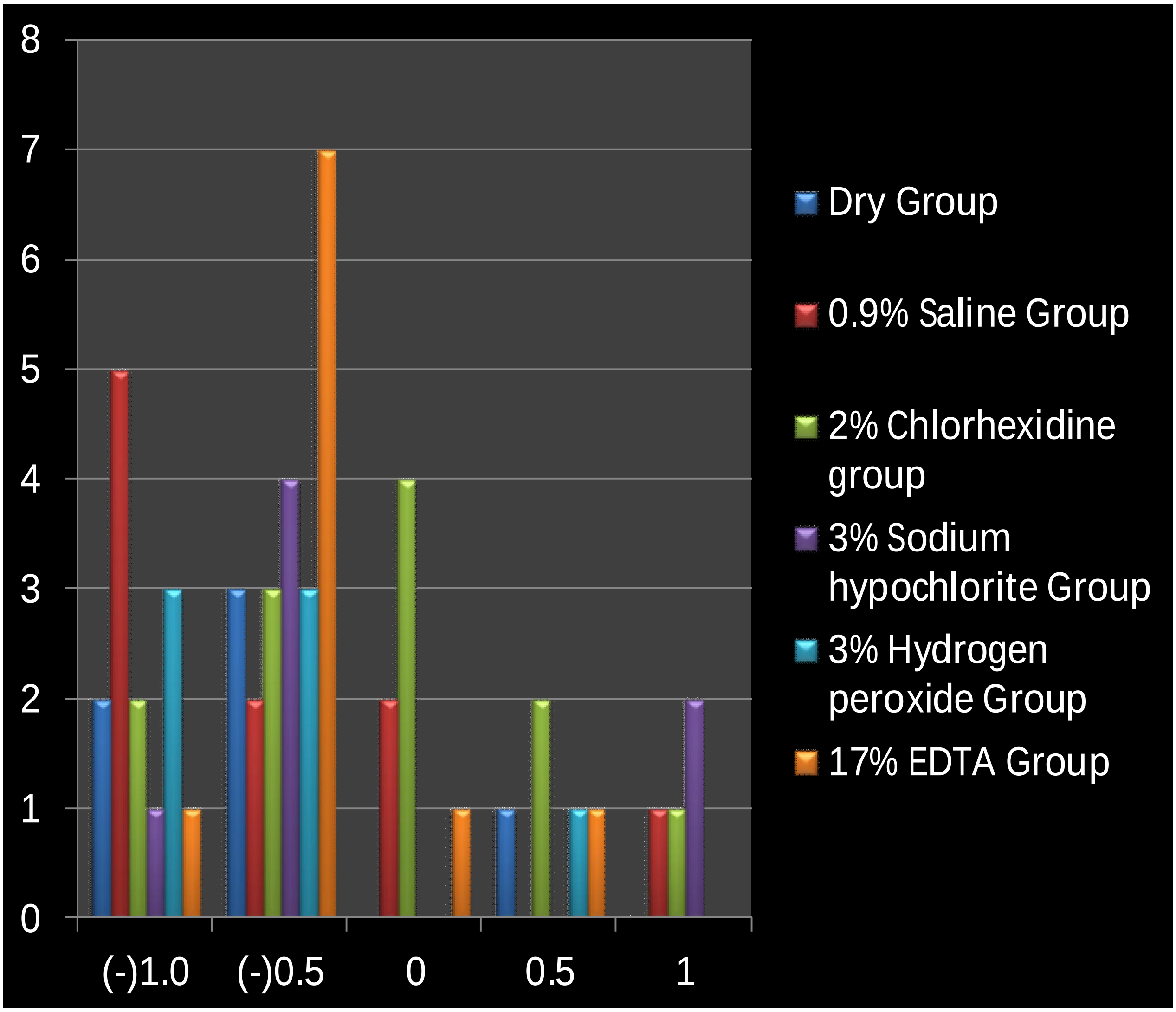
GROUPS						Total
RANGE	**1**	**2**	**3**	**4**	**5**	
Dry group	2	3		1		6
0.9% Saline group	5	2	2		1	10
2% Chlorhexidine group	2	3	4	2	1	12
3% Sodium hypochlorite group	1	4			2	7
3% Hydrogen peroxide group	3	3		1		7
17%EDTA group	1	7	1	1		10
Total	4	2	7	5	4	52

Table 2: Showing mean and standard Deviation

GROUPS	N	Mean	Std. Deviation	Std. Error
Dry group	14*	-0.536	1.447	0.387
0.9% Saline group	15	-0.633	1.187	0.307
2%Chlorhexidine group	15	-0.433	.842	0.217
3%Sodium hypochlorite group	15	-1.067	2.449	0.632
3%Hydrogen peroxide group	15	-0.867	1.420	0.367
17%EDTA	15	-0.567	1.280	0.330
Total	89	-0.685	1.493	0.158

* one unstable reading was recorded

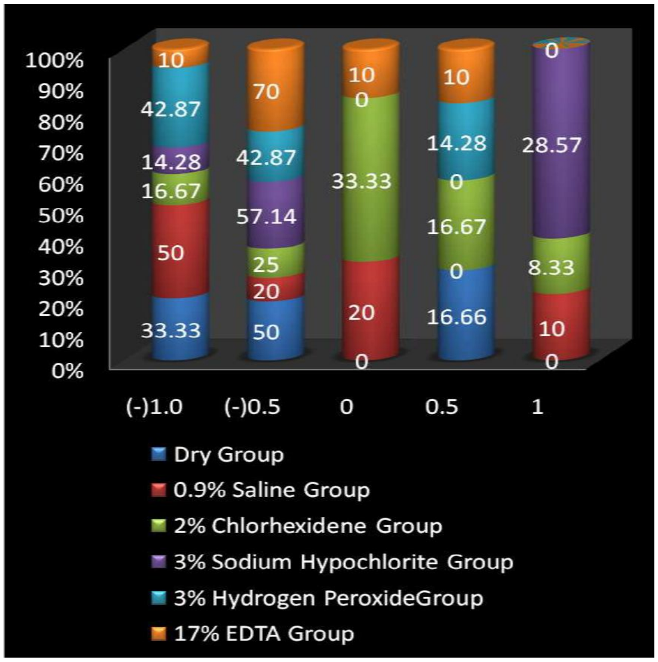
Graph.1 Readings of various irrigating solutions in relations to various ranges corresponding to actual length



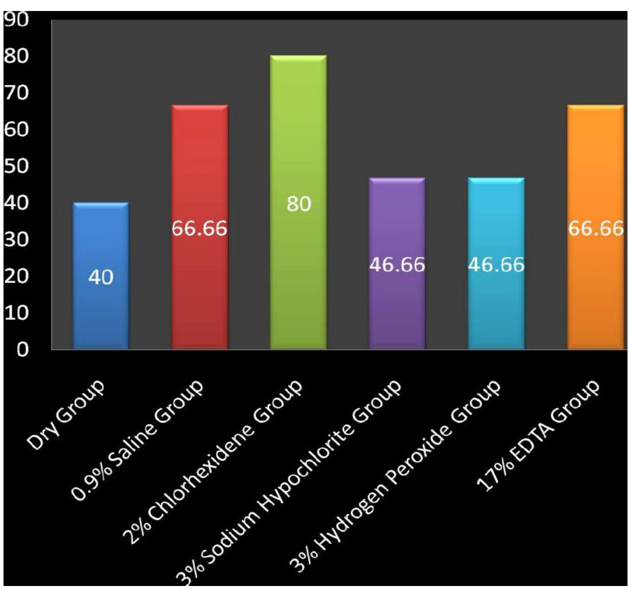
In vitro studies on the accuracy of Electronic apex locators are problematic, as the human periodontium is excluded. To minimize drawbacks, a number of experimental models have been proposed. The materials most often used are alginate, agar, saline, and gelatin. Alginate provided the most coherent results with the actual working length.[5] Kaufman et al (1997) developed the alginate model, which was used in other studies. Alginate is a good medium to establish the necessary electric circuit for a correct Electronic apex locator measurement, because it mimics well the electric impedance of the human periodontium.[6]

It has been concluded from various reviews of literature and studies that the minor constriction lies around 0.5 to 0.7 mm short of the anatomical apex. [7-9] But in cases where teeth are affected by periapical lesion with apical resorption the minor constriction can be pathologically altered so the detection of correct termination of root end becomes even more challenging.[10] So this study used a parameter of recording the readings in a range of ±1mm so as to determine readings which were clinically acceptable in the range of -0.5 to -1.0 mm and also to determine the readings on longer side.[3]

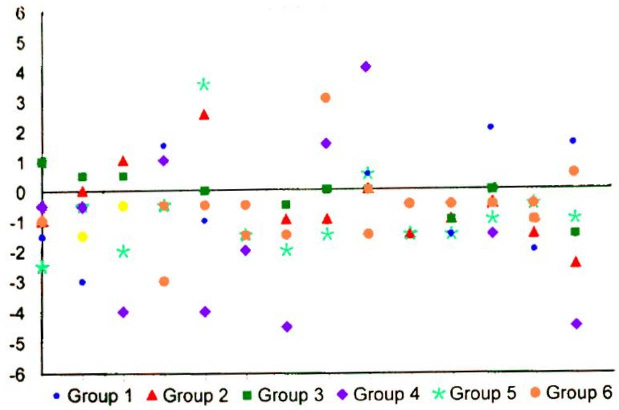
Graph 2: Percentage readings of various irrigating solutions in relation to various ranges corresponding to actual length



Graph 3: Accuracy graph of various irrigating solutions



Graph 4: Frequency distribution of various groups



The extracted teeth were stored in saline solution, because this solution is neutral and kept the teeth hydrated.[1]

In this study 2% Chlorhexidine gave maximum number of readings in the range of ±1mm range while 17% EDTA gave more no. of readings closer to actual length. Normal saline fared equally well in overall readings while 3% sodium hypochlorite, 3% hydrogen peroxide and dry canals did not fare satisfactorily.

In clinical conditions complete drying of moisture is not likely to be achieved because some degree of moisture is bound to be present in the canals due to the hydration of dentin from the surrounding periodontium but in very dry canals the signal can drop suddenly nearing the apex or be little unstable, this happens mostly because when the file tip is at extremely dried point, there is little or no electric contact, even at higher frequencies. As soon as it meets with the apical tissue, sudden circuit breaks out, this brings the signal to the APEX mark. [11]

An instrument that retains its accuracy in the presence of moisture in the canal is more useful than others without this property, since the relatively dry conditions achieved prior to our first set of measurements would be difficult to consistently obtain clinically. This is especially true in narrow uninstrumented canals or with continual fluid seepage from periapical tissues.

Conductivity of Hydrogen peroxide and sodium hypochlorite is lower and higher respectively according to Kim et al (2000)[12] and Pilot and Pitts (1997)[13]. The solutions from most to least conductive are as following 5.25% NaOCl solution, 14.45% EDTA solution, normal saline and finally RC-prep and 70% isopropyl alcohol, with the last two being essentially nonconductive. When the electrical resistance of the most frequently used irrigants was measured, NaOCl was much higher (10 times), whereas H_2O_2 was much lower (50 times), than saline. It was speculated the change in electroconductivity shifts the quotient curve of the frequency. The changes in electrical characteristics when the foramen is approached and passed are minimal when conductive solutions are inside the canal. This condition would complicate electrical determination of the foramen. In fact it has been reported by Meredith and Gulabiwala that there was a clear increase in series resistance with increasing distance from the radiographic apex for dry canals (22.19–92.07 kΩ) and these figures were markedly higher than for those containing deionized water (9.32–12.10 kΩ) and sodium hypochlorite (7.46–8.92 kΩ). Measurement of changes in resistance was therefore easier in dry root canals and it is likely that this is why some commercial EALs perform better in dry canals. Kim et al[12] in their study have shown that during actual determination of the working length, the file would go deeper in a higher electroconductive condition such as NaOCl, whereas it would go less deep in a lower electroconductive condition such as H_2O_2.

A study done by Erdemir et al (2007) determined difference in sensitivity of readings regarding two apex locators Root ZX and Tri Auto ZX this was attributed to difference in test condition and difference in devices. The measured canal length can also be influenced by different size of the file and different diameter of the apical foramen[14]. Nguyen et al (1996)[15] and Ebrahim et al (2006)[16] also concluded that in enlarged canal, a file matching the canal diameter and a consistently smaller file yielded comparable measurements. Also in an in vitro study done by Fan et al (2006)[3] electrolytes in tubules decreased the accuracy of Propex© when the tubule diameter was large.

As in many other studies, in this study 2 % Chlorhexidine, 17% EDTA and 0.9% Saline were found to be more reliable solutions for carrying out electronic canal measurements than with the more commonly used solutions like 3% Sodium hypochlorite, 3% Hydrogen peroxide and Dry canal. As with the earlier solutions not much clinical data prevails on their effects on working length determination by electronic apex locator as most of the studies are on effects of sodium hypochlorite on electronic measurement of working length as it is the most commonly used root canal irrigant, but with whatever data present it indicates towards relative electroconductivity of various irrigating solutions in accordance with the electronic apex locator and its principle of functioning for obtaining correct readings in various root canal conditions.

Conclusion:

1. 2% Chlorhexidine is the most reliable irrigating solution to be used in root canal for working length determination by electronic apex locator followed by 17% EDTA, while dry canal was highly unreliable.
2. The results show that electronic apex locator device is adjunct to endodontic practice and with the correct working conditions, accurate results can be obtained consistently

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