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Comparison of Accuracy in Determining the Root Canal Working Length by Using Two Generations of Apex Locators – An In Vitro Study

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Abstract

AIM: The present in-vitro study aims to compare the accuracy of root canal working length determination between the third generation and fourth generation electronic apex locators.

MATERIAL AND METHODS: Fifty extracted single-rooted single canal teeth were selected for the study, and a definite coronal plane was prepared. Actual working length (AL) was measured using a stereomicroscope under 8X magnification. Electronic working length measurements were recorded using Root ZX (EL1) and Elements Diagnostic Unit (EL2) apex locators. One-way ANOVA test was carried out to analyse the data among the experimental groups.

RESULTS: The results of the one-way ANOVA test showed that difference in the working length determined by either apex locators (EL1 and EL2) and actual length determined under a stereomicroscope (AL) was statistically not significant. The independent 't' test comparing between groups EL1 and AL; and EL2 and AL showed that working length determined by either of the apex locators (EL1 and EL2) and actual length determined under a stereomicroscope (AL) was statistically not significant.

CONCLUSION: In this in vitro study, the Root ZX and Elements Diagnostic Unit apex locators are equally accurate for determination of working length when compared to actual working length.

Introduction

The prerequisites for successful endodontics are a proper access opening, complete debridement and biomechanical preparation of the root canal to an accurate predetermined length and three-dimensional obturation of the prepared root canal space. Out of these three prerequisites, the latter two cannot be accomplished accurately unless the working length is determined precisely [1].

The working length is defined as "the distance from a coronal reference point to the point at which canal preparation and obturation should terminate". Accurate working length determination is a crucial part of successful endodontic treatment. Determining the working length accurately decides the apical end-point for the instrumentation and obturation [3].

Grove [4] in 1930 stated that, 'the proper point to which root canal should be filled is the junction of the dentin and the cementum and that the pulp should be severed at the point of its union with the periodontal membrane'. The cement-dentinal junction (CDJ) is a landmark where the periodontal ligament begins, and the pulp ends [5]. The cement-dentinal junction is a histological landmark that cannot be located clinically or radiographically. The cement-dentinal junction does not always coincide with the apical constriction. Hence, the apical constriction is regarded as an ideal apical end-point for instrumentation and obturation in root canal therapy [6].

The most common methods for working length determination are radiographic methods and electronic methods. Other methods like digital tactile sense, apical periodontal sensitivity, and paper point measurements have also been used, but are unreliable and subjected to marked intra-subject differences [8].

The idea of electronic determination of working length is not new and has a history, long back when Custer [9] in 1918 first reported that the root canal length could be determined by using the electrical conductance. Authors have performed a series of experiments on patients and reported that the electrical resistance between the mucous membrane and the periodontium was consistent regardless of the age of the patients or the shape and type of the teeth [8], [10]. Since then, many electronic apex locators under various generations were developed, with every new unit being somewhat superior and overcoming the drawbacks of earlier ones.

The third-generation apex locators measure the impedances of 8 kHz and 400 Hz at the same time, calculates the quotient of the impedances and expresses this quotient in terms of the position of the file inside the canal. This quotient is barely affected by the electrical conditions inside the canal. Also, it is not necessary to calibrate this device each time because the microprocessor automatically controls the calculated quotient. This device has been exhaustively tested and reported to be quite accurate in various conditions [8], [11].

The fourth-generation device breaks impedance down into its primary components (resistance and capacitance) and measures them independently during use. This eliminates erroneous readings because different combinations of these properties provide the same impedance reading. This prevents apex locator from being jumpy and erratic. Multiple frequencies are still used to compensate for canal conditions. The Elements Diagnostic Unit apex locator (Sybron Endo, Sybron Dental, Orange, California, USA) does not make calculations internally as third-generation units do. Instead, all combinations of capacitance and resistance relating to a location within the canal have been loaded into a matrix database within the unit. This decreases processing time, making the displayed information much more stable [12].

The aim of the present *in vitro* study is to compare the accuracy of working length determination between two generations of electronic apex locators; between third generation and fourth generation apex locators.

Material and Methods

Fifty extracted, single-rooted, single canal teeth, with mature apices, were used in this study (Figure 1). The criteria for tooth selection included intact enamel without caries, restorations or surface anomalies. Teeth were kept in 5% sodium hypochlorite (Septodont health care India Pvt. Ltd) for 2 hours to remove the periodontal remnants and then stored in sterile 0.9% saline solution (Baxter India Pvt. Ltd) until use. A definite coronal plane prepared with carborundum disc (Dentorium, New York, USA) fixed on slow speed straight handpiece (Marathon, Korea) provided a fixed, stable surface for the adaptation of rubber stopper. This helped to avoid measuring errors resulting from different interpretation of the coronal reference point.

Figure 1: Fifty single-rooted teeth with definite coronal plane

The access cavity was prepared using No. 2 round bur (Mani, Japan), patency of the canal established using No.10 k-file (Dentsply, Maillefer, USA). Gates Glidden drills no. 5 and 6 (Dentsply, Maillefer, USA) were used to flare the coronal one-third of each canal. The canals were cleansed of debris by irrigating with 5% sodium hypochlorite (Septodont health care India Pvt. Ltd) after which canal patency was evaluated using a size 10 K file (Dentsply, Maillefer, USA).

Working length determination

Group AL-Actual length determination under the stereomicroscope **(**Magnus**)**.

Group EL1-Electronic working length

determination by third-generation electronic apex locator (Root ZX, J. Morita Co., Kyoto, Japan). Group EL2-Electronic was working length determination by fourth-generation electronic apex locator (Elements Diagnostic Unit Apex locator).

Actual length determination

The actual length (AL) was measured with the aid of a stereomicroscope (Magnus Opto Systems India Pvt. Ltd) under 8 X magnification by introducing a no. 15 K-file until it emerged at the apical foramen. The file was then withdrawn until its tip was tangential to the apical foramen (Figure 2). After adjusting the silicone stopper to the flattened reference point, the file was removed, and the distance between the file tip and the stopper was measured with digital callipers. To record the actual root canal length (AL), 0.5 mm was subtracted from it. This determined length served as the control group.

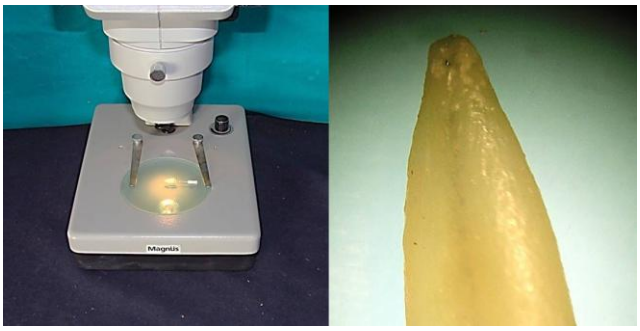

Figure 2: Actual working length determination under the stereomicroscope

Working length determination using third-generation apex locator

The file was advanced within the root canal to just beyond the foramen, as indicated by the flashing APEX bar and the solid tone. The file was then withdrawn to a flashing bar halfway between APEX and 1, and that measurement was recorded.

Working length determination using fourth-generation apex locator

The file was advanced into the canal to just beyond the foramen, as indicated by the '0.0' mm mark on the LCD. The file was then withdrawn until the reading showed a consistent '0.5' mm mark with the corresponding symbol and audible signal, and the measurement was recorded

In order to reproduce clinical conditions involved in the electronic measurement of the root canal length and to complete the circuit apical third of each tooth is immersed in 0.9% saline bath in a glass beaker with a rubber lid and the lip clip is attached to the lid is in contact with the saline (Figure 3).

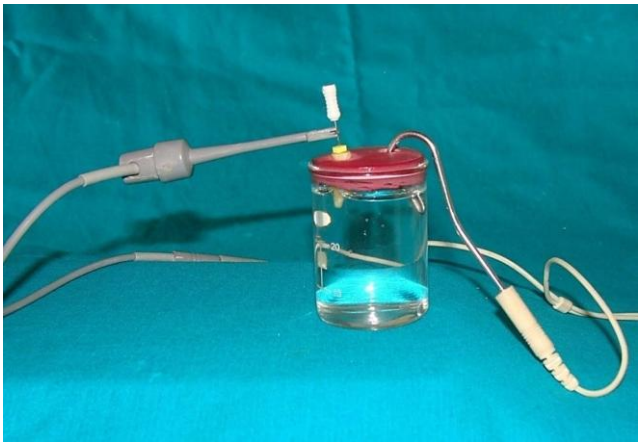

Figure 3 Apparatus for working length determination using apex locators

The statistical analysis was performed using a commercially available software program SPSS version 12. One-way ANOVA test was carried out for comparing the three groups, whether significant differences existed among the tested groups.

Results

The mean working length obtained from third-generation apex locators, Root ZX (Group EL1) at 14.72 mm and from fourth-generation apex locator, Elements diagnostic unit apex locator (Group EL2) at 14.66 mm were comparable to the actual length determined under a stereomicroscope (Group AL) at 14.76 mm (Table. 1).

Table 1: Mean ± SD values of actual length and length determined by apex locators

GROUP	N	Mean ± SD (mm)	Minimum (mm)	Maximum (mm)
Group AL	50	14.76 ± 1.84	11.64	20.74
Group EL1**	50	14.72 ± 1.85	11.51	20.72
Group EL2 ***	50	14.66 ± 1.84	11.62	20.70

*AL = Actual length determination under stereomicroscope; **EL1=Electronic working length determination by third-generation electronic apex locator; ***EL2=Electronic working length determination by fourth-generation electronic apex locator.

The results of the one-way ANOVA test showed that difference in the working length determined by either apex locators (EL1 and EL2) and actual length determined under a stereomicroscope (AL) was statistically not significant. (Table. 2)

Table 2: Results of One-way ANOVA test comparing the three groups

GROUP	N	Mean ± SD	F	p-value
Group AL*	50	14.76 + 1.84	0.0370	p = 0.963
Group EL1 **	50	14.72 + 1.85		
Group EL2***	50	14.66 + 1.85		

[c]Statistically significant difference p ≤ 0.05; *AL = Actual length determination under stereomicroscope; **EL1=Electronic working length determination by third-generation electronic apex locator; ***EL2=Electronic working length determination by fourth-generation electronic apex locator.

The independent '*t*' test comparing between groups EL1 and AL; and EL2 and AL showed that test statistic p-value was, 0.9214 and 0.7882 respectively. This showed that working length determined by either of the apex locators (EL1 and EL2) and actual length determined under a stereomicroscope (AL) was statistically not significant, (Table 3).

Table 3: Results of Independent 't' test comparing the individual groups

Comparing groups	*t'*	p-value
Group EL1 and Group AL	0.0989	p = 0.9214
Group EL2 and Group AL	0.269	p = 0.7882
Group EL1 and Group EL2	0.170	p = 0.8656

[c]Statistically significant difference p < 0.05; *AL = Actual length determination under stereomicroscope; **EL1=Electronic working length determination by third generation electronic apex locator; ***EL2=Electronic working length determination by fourth generation electronic apex locator.

The test statistic p-value obtained for independent 't' test between groups EL1 and EL2 was 0.8656 (more than 0.05), this showed that working length determined by third-generation electronic apex locator, Root ZX (Group EL1) and by fourth-generation electronic apex locator, Elements diagnostic unit apex locator (Group EL2) was statistically not significant.

Discussion

An accurate working length determination is one of the critical steps for successful endodontic treatment [2]. The radiographic method has disadvantages like more radiation exposure, time-consuming, and in most cases, the cement-dentinal junction does not coincide with the point 0.5 mm short from the radiographic apex because of cementum deposition. Also, it is only able to give a two-dimensional image and provides reliable information on the location of the radiographic apex [15].

In recent years, electrical devices have been developed for determining the length of the tooth without resorting to radiography. Here, the working length is determined by comparing the electrical resistance of the periodontal ligament with that of the gingiva surrounding the tooth, both of which should be similar by measuring the depth of insertion of the file one may determine the exact working length of a root canal [12].

Third generation apex locators have set a landmark inaccurate location of tooth apex and are now considered an essential tool in the endodontic armamentarium [16]. The new fourth-generation apex locators claim to be even more accurate regarding accuracy in apex location.

Root ZX (J. Morita Co., Kyoto, Japan) is a third-generation multi-frequency apex locator which uses two waveforms, 8 kHz and 400 Hz. Studies have shown it to be accurate in the range of 64% to 100% [16]. If 1.0 mm difference is deemed acceptable, the accuracy reported at 100% [18]. Lesser deviations from the apical constriction are reproducible [11], [13]. Elements diagnostic unit apex locator, (Sybron Endo, Sybron Dental, Orange, California, USA) is a fourth-generation apex locator which breaks impedance down into its primary components (resistance and capacitance) and measures them independently during use. This eliminates erroneous readings because different combinations of these properties provide the same impedance readings, and also prevents the apex locators from being "jumpy" and erratic [14]. Since this generation of apex locator guarantees better accuracy than the third generation, this apex locator has been used in the present study.

To reproduce clinical conditions involved in the electronic measurement of root canal length and to complete the circuit various laboratory models have been suggested: immersion in agar solutions or gels [22], or embedding in alginate [23], or a sponge soaked with saline solution [24]. In the present study, a 0.9% solution of NaCl was used according to a study conducted by Kobayashi and Suda [21] to obtain good contact with the K-file. The electrode-electrolyte interface impedance when the electrolyte is a biological tissue is similar to 0.9% NaCl, and this solution has become a benchmark since its ionic content is equivalent to that of blood plasma [25]. The disadvantage of this model is that it is not able to completely simulate the in vivo conditions [16].

Comparison between third-generation apex locator and actual length showed statistic p-value as 0.9214, and that between fourth-generation apex locator and actual length showed statistic p-value as 0.7882. Thus, statistically, both third generation and fourth generation apex locators are equally accurate for determination of working length.

The results of the study are in agreement with the study done by Plotino G *et al*., [8], where the accuracy of three electronic apex locators was tested and was found that the accuracy of the Elements diagnostic unit apex locator was not significantly different from the accuracy of Root ZX. The accuracy in determining the working length for both the apex locators are comparable with the previous studies by Baruah Q *et al.,* [16] and Pagavino G *et al.,* [18].

In conclusion, inaccurate measurement of working length leads to inappropriate biomechanical preparation and obturation of the root canal, which in turn fails treatment. Electronic root canal length measuring devices were developed to improve the accuracy of the root canal length measurement, reduce the number of radiographs during the treatment, and to save time.

In the present study, we compared the accuracy of working length determination of two generations of apex locators and found that there is no statistically significantly difference in working length measurement between the two apex locators,

Root ZX and Elements diagnostic unit apex locator. Statistically both third generation and fourth generation apex locators are equally accurate for determination of working length when compared to actual working length.

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