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Research Article

Accuracy of Two Different Electronic Apex Locators in Treatment and Re-Treatment Cases: An *Ex-Vivo* Study

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Abstract

Aim: The aim of this study was to compare the accuracy of two electronic apex locators (Root ZX II and Mini Apex Locator) at initial, preflaring, after instrumentation and retreatment stages of root canal therapy.

Methodology: Sixty canals in 47 extracted teeth were divided into two groups of 30 each. Teeth were accessed, and then the actual working length was measured visually and recorded as the actual canal length at the initial, at preflaring, after instrumentation and after retreatment stages. Teeth were embedded in alginate and the canal length was measured using the Electronic Apex Locator assigned for that group at each stage. Paired sample and the independent t-tests were used for statistical analysis (p = 0.05).

Results: At the initial and preflaring stages, the accuracy of Mini Apex Locator was significantly higher than the Root ZX II (P = 0.029 and P = 0.004). The corresponding percentage values of working length measurements as actual working length, within ± 0.5mm and within ± 1.0mm at each stage were ; for Root ZX II® (30% - 33.33% - 36.66%, 43.33% - 50% - 6.66%, 70% - 30% - 0% and 66.66% - 30% - 3.33%), respectively. For the Mini Apex Locator® (40% - 50% - 10%, 63.33% - 33.33% - 3.33%, 66.66% - 30% - 3.33% and 66.66 - 30% - 3.33%) respectively.

Conclusions: Both Root ZX II and Mini Apex Locator were accurate and reduced the risk of over instrumentation. The accuracy of Mini Apex Locator was more statistically significant at initial and preflaring stages.

Keywords: Electronic Apex Locator; Mini Apex; Root Canal; Root ZX II; Working Length

Introduction

A correct working length is a critical factor for endodontic success. Failure to determine the correct root canal working length during endodontic treatment may adversely affect the treatment outcome [1].

Working length is defined as the distance from the coronal reference point to the point at which canal preparation and obturation should terminate [2]. It has been recognized that working length should be established at the minor diameter (or apical constriction) of the root [3].

The apical constriction marks the transition between the pulpal and periodontal tissue [4]. This anatomic landmark might be located at 0.5-1mm from the major foramen, and it has been specified that it is an ideal point to end instrumentation and obturation of the root canal system [5].

Methods of determining working length include radiographs, tactile sensation, and electronic apex locators (EALs). Radiographic determination of working length has been used for many years. The radiographic apex is defined as the anatomical end of the root as seen on the radiograph, while the apical foramen is the region where the canal leaves the root surface next to the periodontal ligament [6].

Recently, electronic apex locators for root canal length determination have gained popularity. Studies have assessed the application of these devices as well as their measurements in the presence of electrolytes [7-10]. Among these devices Root ZX II (J Morita Corp., Tokyo, Japan) and Mini apex locator (Sybron Endo, Sybron Dent, Anaheim, CA, USA) [11].

Although apex locators play an important role in determining working length, it is believed that apex locators should not be

considered as a replacement of radiographs. It can be used as a good supplement to working radiographs that may improve length determination and could potentially reduce the number of diagnostic radiographs required for working length determination [12].

While electronic apex locators are very accurate in initial endodontic treatment situations, it has been shown that it is less accurate in retreatment situations. This clinical observation may be due to the file being covered with chloropercha (gutta-percha smear due to chloroform), which may affect its conductivity [13,14].

The aim of this study was to compare the accuracy of two electronic apex locators from two different generations (Root ZX II and Mini Apex Locator) at initial, preflaring, after instrumentation and retreatment stages of root canal therapy and to find out if they are reliable to be used during any stage of endodontic treatment.

Material and Methods

Sample size and selection of teeth

Forty-seven (47) extracted intact human teeth from adult patients were selected for this study with total sum of sixty canals (60). Only single rooted extracted teeth or teeth with two separate straight roots were used in this study; 11 upper and lower central and lateral incisors, 10 upper and lower canines, and 26 upper and lower premolars. No information was available regarding the reasons for their extraction. Teeth with open apices, fractured or badly carious were excluded. These criteria were confirmed by direct visualization. The sixty canals (60) were randomly divided into two groups, 30 canals in each; Group I: Root ZX II® apex locator was used to measure the working length at various stages (Initial, preflaring, after instrumentation and after endodontic retreatment) and Group II: Mini Apex Locator® was used to measure the working length at the same stages.

Preparation of the teeth

The pulp chamber of the teeth was accessed by using tapered fissure bur (Komet, Germany) rotating in a high-speed headpiece under abundant water spray. A flat reference point was prepared to allow a reproducible reference point for the canal length measurement. After identification of the canal orifice, pulp tissue was removed with a barbed broach (Endo Easy Efficient, ADW GMBH, Munich Germany). Canal patency was confirmed by using #10 K-file (MANI, Tochigi, Japan) before roots were stored in distilled water in test tubes.

Actual working length determination

The actual canal length was measured by inserting a size 10 or size 15 K-file (MANI, Tochigi, Japan) depending on the size of the canal. The file was inserted into the canal until the tip of the file became visible at the apical foramen. The tip of the file was visualized under magnification using the dental operating microscope at 6X magnification (Carl Zeiss, MicroImaging GmbH, Germany). The file's silicon stopper (MANI, Tochigi, Japan) was placed adjacent to the flat reference point and the length was measured using an endodontic ruler (Maillefer, Swisstzerland), 0.5mm was deducted from the length (the average of the apical constriction) and was recorded as the Actual Working Length (AWL). The teeth were then randomly divided into two groups (30 canals in each group).

Working length determination using the electronic apex locators

The model chosen for this research project was by using plastic containers in which alginate (Zhermack, Italy) was poured in to simulate the periodontal tissue. The alginate was mixed according to the manufacturer's instructions, and then poured into plastic containers. Each tooth was embedded in the alginate to the level of cement-enamel junction before it was set and the plastic containers were marked with a code to differentiate between the two groups. A small hole was made at the bottom of the plastic tube to facilitate the insertion of the lip-clip into the alginate to complete the circuit. The working length measurements were assessed immediately after the alginate was set (so the reading won't be interfered by the dryness of the alginate). All the canals were measured using the electronic apex locator which was assigned for. Both electronic apex locators (Group I: Root ZXII® and Group II: Mini Apex Locator®) were used according to the manufacturer's instructions. For Root ZX II®, the file holder was attached to K-file and advanced slowly into the canal until it reached the calibrate 0.5mm sign on the device, which was accepted as the apical constriction. On the other hand, for The Mini Apex Locator, the stop point which was considered as the apical constriction was when green light (apex) was lightened. The measurement was repeated several times until the operator was certain that the measurement is reproducible. Then, the silicon stopper on the file was carefully positioned on the flat tooth edge, and file was removed and its length was measured by the use of an endodontic ruler (Dentsply. Maillefer, Swisstzerl and) and the reading was recorded for every root canal.

Measuring of the working length after preflaring

Coronal pre-flaring of all the canals in both groups was made using rotary Pro Taper® system (Dentsply, Maillefer, Swisstzerland) size SX to facilitate the insertion of files and irrigation material. The working length was then measured again visually and recorded the same way as mentioned previously (AWL) and then the teeth were embedded in alginate to be measured by electronic apex locator assigned for each group.

Measuring of the working length after instrumentation

All canals were instrumented after removing them from the alginate with ProTaper® rotary system (Dentsply, Maillefer,

Swisstzerland) using rotary handpiece (NSK, Japan). The canals were instrumented according to the manufacturer's instructions up to size F3. Canals were irrigated with normal saline after each instrument. After that, the actual working length for each group was measured as mentioned previously and then embedded in alginate and the working length was measured with the electronic apex locator assigned for each group.

Measuring the working length after retreatment

All canals were obturated with Gutta Percha and AD seal® (Meta Dent, Korea) sealer using the cold lateral compaction technique. Temporary filling (Meta Dent, Korea) was placed on the access cavity and each tooth was kept in normal saline in a separate test tube. All the test tubes were stored in incubator with 100% humidity at 37°C for one week to let the sealer set.

After one week the samples were removed from the incubator. The main two groups were subdivided into two groups (15 canals in each group). In the first fifteen canals from each main group, gutta percha was removed with the use of Pro Taper® Universal retreatment kit. The canals were enlarged to the size of D3 (Dentsaply, Maillefer, Swisstzerland). In the other 15 canals from each main group Gutta Percha was removed using Pro Taper® Universal retreatment kit with chemical solvent (chloroform). Once the retreatment was completed, the teeth were again embedded into the alginate (Zhermack, Italy) and divided back into their original groups. The canals were checked for any remnant of Gutta Percha by using H files (Dentsply. Maillefer, Swisstzerland) and paper points (Dentsply. Maillefer, Swisstzerland). Working length was measured again with the use of the electronic apex locators assigned for each group.

Statistical analysis

The accuracy of each electronic apex locator compared with the visual working length was determined by using paired sample T-test. The independent T-test was used for the comparison between the two electronic apex locators. For the retreatment part, sample T-test was conducted to find out if chloroform had an effect on the accuracy of both electronic apex locators. All tests had a 0.05 level of statistical significance IBM SPSS version 19 software was used for the data analysis.

Results

In the initial and preflaring stages, the Root ZX II showed statistically significant difference from the actual working length ($P < 0.001$) with a mean measurement shorter from working length by (0.55mm and 0.32mm), respectively. However, after instrumentation and after retreatment stages, there was no statistically significant difference between Root ZX II measurement and actual working length ($P = 0.096$ and $P = 0.103$), respectively, table 1.

Stage	Actual (M ± SD)	Root ZX II (M ± SD)	Difference (M ± SD)	P Value
Initial	21.55 ± 1.85	21.00 ± 1.83	0.55 ± 0.44	0.000
Pre flaring	20.97 ± 1.84	20.65 ± 1.92	0.32 ± 0.31	0.000
Instrumentation	20.70 ± 1.87	20.62 ± 1.87	0.08 ± 0.27	0.096
Retreatment	20.70 ± 1.85	20.63 ± 1.88	0.07 ± 0.22	0.103

Table 1: The Actual and Root ZX II root canal length measurements.

At the initial, after instrumentation and after retreatment stages the mean difference between the Mini Apex Locator and the actual working length was (0.32mm, 0.17mm and 0.16mm) which was statistically significant ($P < 0.000$ and $P = 0.016$), respectively. While, at the preflaring stage, the mean difference was (0.07mm) and was not statistically significant ($P = 0.293$), table 2.

Stage	Visual (M ± SD)	Mini (M ± SD)	Difference (M ± SD)	P value
Initial	21.32 ± 1.91	21.00 ± 1.97	0.32 ± 0.36	0.000
Pre flaring	20.80 ± 1.83	20.73 ± 1.86	0.07 ± 0.34	0.293
Instrumentation	20.49 ± 1.81	20.32 ± 1.91	0.17 ± 0.36	0.016
Retreatment	20.48 ± 1.81	20.32 ± 1.91	0.16 ± 0.36	0.016

Table 2: The actual and Mini Apex Locator root canal length measurements.

Comparison between the mean differences of root canal length measurements by each apex locator and the actual working length was calculated at each stage. At the initial and preflaring stages, the accuracy of Mini Apex Locator was significantly higher compared to the Root ZX II ($P = 0.029$ and $P = 0.004$), respectively. On the other hand, there was no statistically significant difference between both apex locators after instrumentation and after retreatment stages ($P = 0.308$ and $P = 0.195$), respectively, table 3.

Stage	Root ZX II (M ± SD)	Mini (M ± SD)	Difference (M ± SD)	P value
Initial	0.55 ± 0.44	0.32 ± 0.36	0.23 ± 0.10	0.029
Pre flaring	0.32 ± 0.31	0.07 ± 0.34	0.25 ± 0.08	0.004
Instrumentation	0.08 ± 0.27	0.17 ± 0.36	0.09 ± 0.08	0.308
Retreatment	0.07 ± 0.22	0.17 ± 0.36	0.10 ± 0.08	0.195

Table 3: The mean differences between root canal length measurements by (Root ZX II and Mini Apex Locator) and the actual working length at the different stages.

The ability of the EALs to detect the canal length as the actual length (0.0 mm) and within ± 0.5mm and ± 1.0mm of the actual length was measured in each stage (initial, preflaring, after instrumentation and after endodontic retreatment) and the corresponding percentage values of working length measurements

were as the following. For Root ZX II® (30% - 33.33% - 36.66%, 43.33% - 50% - 6.66%, 70% - 30% - 0% and 66.66% - 30% - 3.33%) respectively. For the Mini Apex Locator® it was as follow; (40% - 50% - 10%, 63.33% - 33.33% - 3.33%, 66.66% - 30% - 3.33% and 66.66 - 30% - 3.33%), respectively as shown in figure 1.

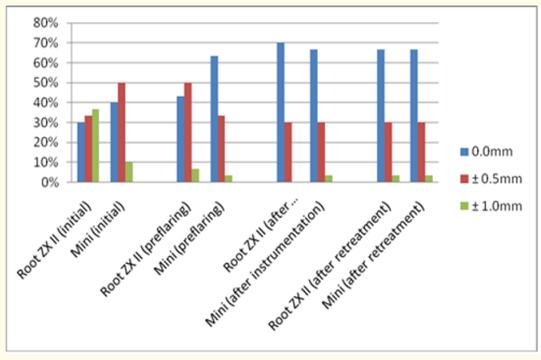

Figure 1: The corresponding percentage values of working length measurements for both apex locators in each stage within 0.0mm, 0.5mm and 1.0mm of the actual length.

Discussion

Patient's acceptance of root canal treatment is increasingly arising. Their expectations and treatment cost are arising as well. This faces us with the issue that endodontic treatment needs to be performed with great consistency in order to ensure a high predictable results. In addition, obtaining a correct working length is critical to the success of endodontic treatment [15].

The electronic apex locators were designed and marketed as a useful tool for finding the apical foramen with great accuracy [16]. These deceives, when attached to a file, are able to detect the point at which the file leaves the root canal and enters the periodontal ligament [17]. Electronic apex locators, especially the most recent generations, hopefully will increase the overall standard of endodontic treatment.

Undoubtedly, instrumentation beyond the apical foramen should be avoided, because it reduces the success rate and the prognosis becomes poor with obturation beyond the apex [18]. Methods of working length determination include the use of radiographs, EALs and tactile sense. However these methods are questionable when they are used isolated. Thus, EALs are a valuable addition to the clinical endodontic armamentarium.

In the present study, the precision of the Mini Apex locator was higher than that of Root ZX II at the initial stage when compared to the actual working length. However, there are very few information in the literature about the accuracy of the Mini Apex Locator in determining the correct electronic working length [1]. There were no statistically significant differences between the two devices except at the initial and the preflaring stages where the Mini Apex Locator had higher accuracy then Root ZX II.

At the initial stage, the accuracy of Root ZX II was 30% as accurate as the actual working length, 33.33% was within ± 0.5mm and 36.66% within ± 1.0mm. This gave the accuracy of 63.33% within 0.5mm. On the other hand the accuracy of the Mini Apex Locator was 40% as accurate as the actual working length, 50% was within ± 0.5mm and 10% within ± 1.0mm. In this case the accuracy of the Mini Apex Locator was 90% within 0.5mm.

El Ayouti., et al. (2009) compared the working length accuracy of Root ZX and RayPex5 with radiograph [19]. Also, Vieryra., et al. (2010) compared Root ZX and Elements Diagnostic Unit and Apex Locator with radiograph [20]. Both studies found out that EALs were more accurate than radiographs. The Root ZX showed an accuracy of 68% within 0.5mm of the apical foramen, which is in agreement to the present study. De Camargo., *et al.* (2009) conducted a study were he compared four EALs; Root ZX, Element Diagnostic Unit and Apex Locator, Mini Apex Locator and Apex DSP. They concluded that the Root ZX and Mini Apex Locator were equally accurate and 50% of the electrical measurements were precise as the visual working length [21], which is also comparable to the results of this study.

On the other hand, some studies showed that Root ZX had higher accuracy compared to other EALs [6,10,22-24]. This may be attributed to the differences in the definition of the apical end of the canal. In this study the apical constriction was used as the apical limit. But other studies have determined the location of the measurement file with respect to the apical foramen [25-28], the apical constriction [22,29-31] or the radiographic apex [32,33]. Another explanation may be differences in methodology and experimental protocol or using different irrigation material in the canals.

Preflaring of the root canal during endodontic treatment is important to remove cervical dentin interferences. Consequently, it allows the file to easily reach the apical constriction and avoid changes in the working length. Ibarrola., *et al*. (1999) stated that this procedure increases the accuracy of the Root ZX for electronic measurements of the working lengt [34]. In the present study, after the coronal and cervical parts of the canal were prepared, the accuracy of the two EALs increased and gave more precise results. The Root ZX II accuracy was 93.33% within 0.5mm, while the Mini Apex Locator accuracy was 96.66% within 0.5mm.

D'Assunção., *et al*. (2007) conducted a study to measure the accuracy of both Root ZX II and the Mini Apex Locator compared with the visual working length after preflaring. They found that 97.44% of Root ZX II measurements were accurate, while for the Mini Apex Locator it was 100% [1]. De Camargo., *et al*. (2009) found

that the accuracy of all the four EALs tested increased significantly after preflaring, but the two most accurate EALs were the Root ZX II and the Mini Apex Locator. Goldberg., et al. (2005) found that electronic measurements obtained with ProPex®, NovApex® and Root ZX® showed an accuracy of 80%, 85% and 95% respectively within 0.5mm of the apical foramen [35].

The accuracy of the EALs was examined after instrumentation, when the canals were fully prepared and the size of the apical foramen diameter was changed. About 80% of the root canals working length measurements were changed and the change ranged between 0.5mm-1.0mm. Interestingly, after instrumentation both EALs showed improvement in the accuracy of determining the working length which may be related to the straightening of the canals after instrumentation. The Root ZX II had an accuracy of 100% within 0.5mm, while the Mini Apex Locator had an accuracy of 96.66% within 0.5mm. Although Root ZX II accuracy was higher, the results were not statistically significant and both EALs were highly accurate.

There are no studies on the accuracy of the EALs after the root canals are fully prepared, but some studies were published in regard of the apical foramen diameter changes with the accuracy of the EALs. Herrera., *et al.* (2007) suggested that when the apical foramen diameter is larger than 1.02 mm, and file #30 or higher was used, the precision of the Root ZX was variable [36]. Ebrahim., *et al*. (2006) conducted a study comparing four different electronic apex locators with different canal diameters and different file sizes. They concluded that both Root ZX and Foramatron D10 were more reliable than Apex NRG and Apit7 after enlarging the apical foramen diameter [12]. They concluded in a different study that with larger apical foramen diameter in the presence of NaOCl, the Root ZX was highly accurate even with the use of smaller files. They found out that using small and large files were reliable, but when CHX or RcPrep was present in the root canal, using larger files was more accurate [12].

During endodontic retreatment it is almost impossible to remove all traces of gutta-percha/sealer from canal walls [37,38]. It is important to note also that the root canal in a routine preparation includes debris, dentin chips, organic remnants and irrigation solution, but in retreatment procedures, gutta-percha pieces, sealer and gutta-percha solvents might also be found [39].

While other studies were in agreement with the present study that the accuracy of the EALs are not affected with the endodontic retreatment procedure and the use of chloroform has no effect on the accuracy of the EAL. The results of the present study revealed that both Root ZX II and Mini Apex Locator accuracy were 96.66% within 0.5mm and the differences were not statistically significant. Yet, the results of this study need to be verified in an *in vivo* study.

One of the limitations of this study was the incubation period after obturation with gutta-percha/sealer, which may considered not enough to allow complete setting of the sealer. This might had an effect on the difficulty of removing the obturation materials.

It would have been better to have more EALs to be compared, specially these days the number and use of EALs has increased. Some amount of measurement errors is likely to have been present in this study. However, this is expected to be present in many electronic apex locator studies. These errors might be due to the adjustment of stopper or reading the length of the measuring file. Moreover, the conclusions obtained from this study were based on strict interpretation of the statistical analysis and increasing the sample size may have affected the results and therefore the conclusions

Similar studies need to be carried out with resilon being the obturation material and using different sealers to find out whether these variables have different effect on the EAL's measurements. Additionally, the accuracy of EALs in molar teeth and curved canals should be investigated in future research.

Conclusion

Under the conditions of this study it can be concluded that both Root ZX II and Mini Apex Locators are accurate and can be reliable to be used at any stage of endodontic treatment and in retreatment cases and reduced the risk of over instrumentation. Preflaring is a very important procedure and need to be done before working length is determined.

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