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The effect of different needle-insertion depths on the accuracy of the Root ZX II and Root ZX mini apex locators in the presence of various irrigants

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Original Article

Abstract

BACKGROUND AND AIM: The aim of the present study was to evaluate the effect of different needle-insertion depths on the accuracy of the Root ZX II and Root ZX mini apex locators in the presence of various irrigants.

METHODS: Ninety extracted single-canal human teeth were used in nine experimental groups. The coronal one-third of the canals was preflared, and the length to the major foramen was determined visually under a microscope. The teeth were embedded in an alginate model. NaOCl concentrations of 5.25%, 2.60%, and 2.00% chlorhexidine with three endodontic needles (21, 25, and 30 gauges) were delivered into the root canals of teeth in each group. Electronic length was determined with both devices using K-files of size 10. The results obtained with electronic apex locators were compared with the corresponding actual length. A multivariate linear regression model was used to determine the variables influencing the accuracy of the Root ZX II and Root ZX mini apex locators.

RESULTS: Irrigant solution concentrations had no effect on the accuracy of the measurements with these locators (P = 0.83). The statistical analysis of the results showed EAL accuracy to be 100% for both Root ZX and Root ZX mini, within a tolerance of ± 0.5 mm. Data were analyzed by ANOVA. Multivariate linear regression model demonstrated that needle-insertion depths influenced the electronic measurements (P = 0.05), while the concentrations of irrigants did not influence the results.

CONCLUSION: Under the conditions of this ex vivo study, needle-insertion depths influenced the electronic measurements.

KEYWORDS: Irrigation, Needle Gauge, Sodium Hypochloride, Chlorhexidine, Working Length, Apex Locator

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Working length determination is one of the most important steps in root canal therapy.[1] While the apical constriction is the recommended apical reference point for instrumentation and canal filling, radiographic interpretation alone is not adequate to localize this point.[2-4] Improvements in technology, such as electronic apex-locators, have facilitated the determination of working length

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measurements with increased accuracy. Chandler and Koshy reported that the use of electronic apex-locators in a dental student clinic resulted in a higher quality of obturation length control and an overall reduction in the number of radiographs taken.[5]

Electronic apex locators (EALs) are a valuable addition to the clinical endodontic armamentarium.[6] One of the most popular EALs used in root canal therapy is the Root ZX marketed by the J. Morita Corporation. This instrument uses the "ratio method" for measuring the root canal length. This method involves the measurement of impedance values at two frequencies (8 KHz and 0.4 KHz) simultaneously and calculates the quotient that denotes the position of the file tip in the canal.[7] Modified versions based on the electronics of the Root ZX have been developed including the Root ZX mini.[8]

Irrigation with antibacterial solution plays an important role during root canal treatment.[9] There has been increased use of various irrigating solutions such as sodium hypochlorite and chlorhexidine in different concentrations.[9,10] Conventional irrigation using syringes is still widely employed which allows the clinician to control the volume of irrigant flushed through the canal as well as the depth of needle penetration.[11] Different syringe needles have been designed by various manufacturers such as standard needles, with a beveled and an open end, and needles with a rounded tip and side port dispersal such as the Maxi-I-Probe (Dentsply, Tulsa Dental, Tulsa, OK, USA). Devi and Abbott concluded that both side-venting and standard needle designs were effective in filling the entire canal with irrigant.[12] The larger the gauge of the needle used for irrigation, the further it can be inserted into the canal.[13] The electro-conductivity of irrigation solutions may affect the results of the electronic working length measurements.[10] Therefore, the purpose of the study reported herein was to investigate the effect of different needle-insertion depths on the accuracy of the Root ZX II and Root ZX mini apex locators in the presence of various irrigants.

Methods

Ninety extracted, single-rooted human teeth containing a single canal were used in the study. Nine groups were established based on the different irrigants and irrigation needle gauges, with ten teeth in each group. The teeth were devoid of caries, restorations, and endodontic treatments. For disinfecting and gross debris removal purposes, samples were soaked in 2.5% sodium hypochlorite (NaOCl) (Golrang Co., Tehran, Iran) for two hours; the teeth were then stored in sterile 0.9% saline solution until used. The size of the root canal at the apical foramen was determined using the largest instrument that fit at this level without any instrumentation or force. Teeth with apical foramen corresponding to a size 15-25 file (Dentsply/Maillefer, Ballaigues, Switzerland) were chosen. The root surface of each tooth was examined for the absence of fractures and the presence of a mature apex using a dental operating microscope (Carl Zeiss, Jena, Germany) at x6 magnification. All teeth were radiographed in both buccolingual and mesiodistal directions to verify the presence of root resorption. The crown of each tooth was cut horizontally, 2 millimeters coronal to the CEJ, using a diamond bur with water cooling at right angles to the root axis.[14] This produced a level surface to serve as a fixed reference point for all of the measurements. The coronal flaring of each canal was accomplished by using Gates Glidden drills #4, #3, and #2 sequentially in a crown-down approach. Pulp tissue was partially removed by using a size 10 Hedstrom file (Dentsply/Maillefer, Ballaigues, Switzerland). Canals were cleaned of debris with at least 5 mL of normal saline.

The actual length (AL) was measured under x6 magnification using the dental operating microscope by introducing a #15 K-file with double stoppers until the file tip was tangential to the major foramen,

representing the most coronal border of the major foramen. Double stoppers were used to decrease the possibility of stopper motion during measurements. After adjusting the silicone stoppers, the file was removed and the distance between the file tip and the stoppers measured using an endodontic millimeter ruler (Dentsply/Maillefer, Ballaigues, Switzerland) with a measurement accuracy of 0.5 mm. The final AL was established to be 0.5 mm coronal to the major foramen.[15] Files and stoppers were used for only five measurements and discarded. Two examiners obtained each AL and the interexaminer's agreement was verified. To achieve a consistent AL, new measurements were completed when there was a discrepancy among the examiners' results.

Once measurements were completed, a lip-clip of the Root ZX along with 10 of the study teeth (all of the teeth in one of the nine groups) were embedded up to the level of the CEJ in unset alginate (Alginoplast; HeraeusKulzer, Hanau, Holland) which had been prepared according to the manufacturer's instructions and poured into a plastic container. The alginate was then left to set.[14] Sodium hypochlorite (Golrang, Tehran, Iran) at concentrations of 5.25% and 2.65%, and 2% chlorhexidine (Consepsis V, Ultradent, USA) were injected into the teeth dynamically as described in table 1. 2.6% sodium hypochlorite was used within 24 hours of preparation. 21 (Soha, Tehran, Iran), 25 (ZafarTaghiz, Tehran, Iran), and 31 (Max-I-Probe, Dentsply, Rinn, Elgin, IL, USA) needle gauges were placed in the coronal, middle, and apical thirds of the canal, respectively (Figure 1).

The excess liquid at the surfaces was gently removed with a cotton pellet to eliminate the possibility of an error in measurement. The electronic measurements for tooth length were performed using the Root ZX and Root ZX mini according to the manufacturer's instructions. The 15 K-file connected to the electrode of the device was apically advanced in the canal until the display indicated the previously calibrated 0.5 mm sign, which was accepted as the

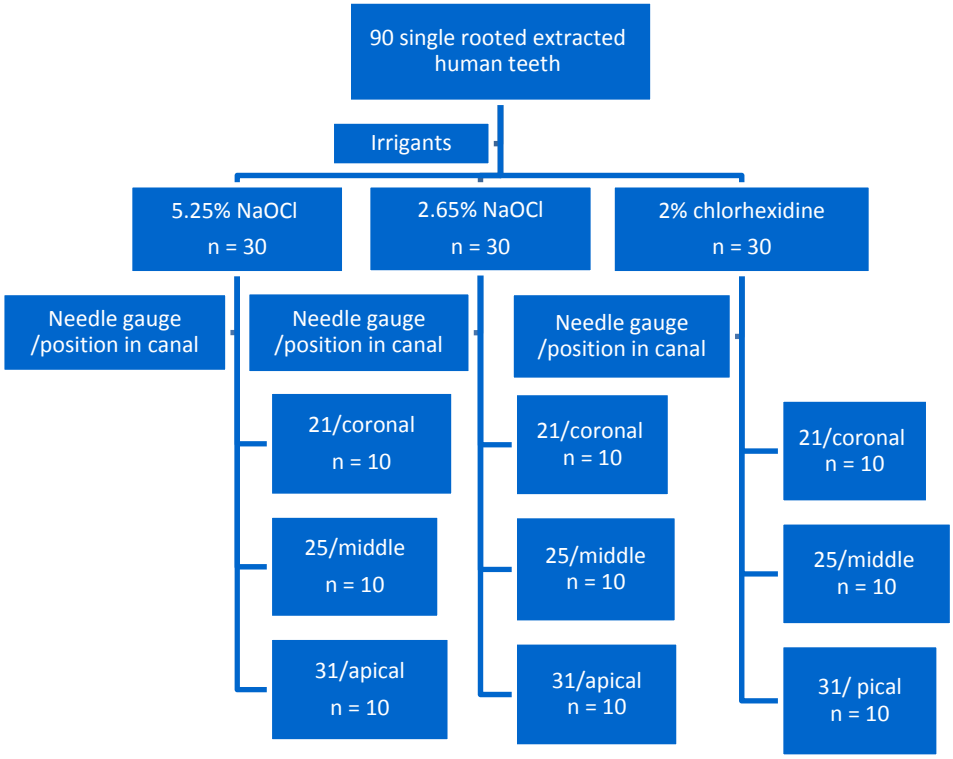

Figure 1. Distribution of samples among the study groups

apical constriction. After this determination with the device, the double stoppers were moved to a tangent to the reference point, and the file was removed from the root canal and measured with the aforementioned endodontic millimeter ruler. The length was registered as the electronic length (EL). Measurements were considered valid if they were stable for at least 5 seconds. Two examiners obtained each electronic working length.

EL measurements were classified into three different categories in accordance to the EL file tip position relative to the AL reference point; negative (measurements short of the apical constriction), positive (measurements exceeding the apical constriction), and correct (measurement coincides with the actual length) with an acceptable range of ± 0.5 mm.[6]

Analysis of variance (ANOVA) was used to statistically analyze the significance of the mean differences between EL and AL at the 95% confidence level.

Results

Kappa test results, with a significance set at 0.05, showed good interexaminer agreement with a value of 0.89.

The two electronic devices gave exactly the same reading every time and the correlation coefficient between the measurements was 1, indicating perfect positive correlation.

Although the highest distance values were obtained from the ninth group, there were no statistically significant differences among the groups (P = 0.83).

Despite the use of irrigant solution and the depth of needle penetration in the canal, the Root ZX and Root ZX mini were considerably accurate at locating the end-point for instrumentation and canal filling. Both devices were accurate 100% of the time in the range of ± 0.5 mm from the actual WL (Working length). In addition, in 90% of cases, the actual and electronic working lengths were exactly the same (Table 1).

Multivariate linear regression model demonstrated that needle-insertion depths influenced the electronic (P = 0.05) measurements.

Discussion

It has been shown that an error range of ± 0.5 mm in electronic apex locator measurements is clinically acceptable.[16] Within ± 0.5 mm of the actual WL, we found that the accuracy of Root ZX and Root ZX mini was 100% when the canals were irrigated with 2.50% and 5.25% sodium hypochlorite, and 2.00% chlorhexidine using three endodontic needle gauges (21, 25, and 30 gauge) and different needle-insertion depths. The results of several previous evaluations have supported such high accuracy for this device.[17-20] However, our finding is in contrast with results shown by Mancini et al. who reported that the mean accuracy of Root ZX in locating the apical

Table 1. Statistical evaluation of the positioning of the file-tip relative to final WL as determined by Root ZX and Root ZX mini

Group (irrigant , needle gauge)	Specimen (n)	Mean	SD	Minimum	Maximum	P
1 (5.25% NaOCL, 21)	10	0	0	0	0	
2 (5.25% NaOCL, 25)	10	0.05	0.158	0	0.50	
3 (5.25% NaOCL, 30)	10	-0.05	0.158	-0.50	0	
4 (2.60% NaOCL, 21)	10	0	0	0	0	
5 (2.60% NaOCL, 25)	10	0.05	0.158	0	0.50	0.83
6 (2.60% NaOCL, 30)	10	0	0	-0.50	0.50	
7 (2.00% chlorhexidine, 21)	10	0.05	0.158	0	0.50	
8 (2.00% chlorhexidine, 25)	10	0.05	0.158	0	0.50	
9 (2.00% chlorhexidine, 30)	10	0.10	0.211	0	0.50	

Negative value indicates file position coronal to the apical constriction

foramen within 0.5 mm was 65.30%.[21] This finding is most likely due to their inclusion criteria. In the mentioned study, all types of teeth such as anterior, bicuspids, and molars were included whereas our study selected only single-rooted human teeth with apical terminus size 15-25 file.

The manufacturer claims the Root ZX and Root ZX mini share the same technology.[22] In the current study, the results obtained from both instruments were identical, as we expected. Therefore, according to the results of this study, it is possible to use them interchangeably without compromising the working length.

Although some manufacturers and articles remark that different liquids have no effect on the accuracy of electronic apex locators, the possible modifications of any of these materials has not yet been taken into consideration.[14,23-25] The widespread use of different concentrations of NaOCl and chlorhexidine with different needle gauges led us to our study design. Using a multivariate linear regression model, we concluded that needle-insertion depths influenced the electronic measurements. However, irrigating solution concentrations had no effect on the accuracy of the measurements with the Root ZX. The larger the gauge of the needle used for irrigation, the further the irrigant may be inserted into the canal.[13] Our finding may be due to the fact that the electro-conductivity of irrigation solutions may affect the results of the electronic working length measurements. In this regard, Fan et al. concluded that, within ± 0.5 mm, the accuracy of Root ZX was 75.0% to 91.7% in dry tubes, but was 100% within ± 1.0 mm. It was also noted that in electrolyte filled tubes, the precision of the Root ZX declined as tubule diameter increased.[26] In the study by Jenkins et al., the greatest deviation from actual canal length when using the Root ZX apex locator was caused by the use of 5.25% hypochlorite sodium solution.[27]

Many in vitro and in vivo experiments have been performed that test various aspects associated with the use of EALs. Hor et al. demonstrated that apex locators and their displays should be calibrated on extracted teeth, in vitro, before being used clinically.[28] In the study by Duran-Sindreu et al. there was no difference between the results obtained using an in vivo model and those obtained by an in vitro model.[29] The present study used an in vitro model to obtain accuracy measurements. It should be noted that in vitro models have some advantages such as simplicity, are less costly, have less ethical considerations, ease of use, and the ability to control the experimental situation.

Our findings support the use of an in vitro model in the evaluation of EALs. This is in agreement with Huang's findings that lend support to the use of in vitro models for testing the accuracy of apex locators. He discovered that the results achieved by a non-conducting natural tube resemble those obtained with a tooth.[30] This shows that the phenomenon associated with the electronic measurement of the root canal does not depend on the resistance of biological tissues, but rather on the physical properties of the apical foramen.[30] However, a disadvantage of in vitro models is their inability to fully simulate in vivo conditions.[6]

Different conductive environments such as gelatin, alginate, agar, and saline have been proposed for in vitro studies on the evaluation of electronic apex locator accuracy.[16,29,31] Alginate models embedded with extracted human teeth is one of the most widely used and accepted models within the field of EALs accuracy assessment.[20] This model is simple, stable for hours, and covers the root apices.[32,33] The relatively firm consistency of the alginate prevents fluid intrusion into the canal that is responsible for the errors in electronic readings registered with previous models.[20] Furthermore, alginate has good electro-conductive properties and mimics the electric impedance

of the human periodontium.[34]

Different concentrations of chlorhexidine, ranging from 0.12% to 2.00%, have been investigated either in vivo or in vitro.[35,36] In the present study, we used the highest concentration in order to establish the maximum possible effect of this material on electronic apex locator readings.

According to Wrbas et al., a researcher can maximize precision using the same samples to compare the accuracy and differences of various types of EALs in the determination of the WL.[37] Considering this, we used the same samples for two apex locators.

The pre-flaring procedure of root canals before measurement with EALs can increase the percentage of accurate electronic readings.[38] Therefore, the canals were pre-flared in the current study before measurement.

Inconsistent measurements in the studies that evaluate EALs may be associated with procedural errors, which may be a result of inaccurate adjustment of the stopper to the reference point or by movement of the rubber stopper during the measurement procedure. Consequently, in the present study, new double stoppers were used to decrease the probability of stopper movement during measurements.

Electronic apex locators have been frequently studied using 15/0.02 stainless-steel hand K-files without considering the apical terminus size of the canals. In the present study, a size 15 K-file connected to the EAL was used in all cases. It has been suggested that the size of the canal at the apical terminus affects electronic working length determination.[39] Therefore, teeth with apical terminus size 15-25 files were chosen to control this parameter.

Goldberg et al. showed a decreased accuracy of 62.7%, at the parameter of ± 0.5 mm within the apical foramen, using the Root ZX device in teeth with simulated apical root resorption.[40] As a result, the resorbed teeth were excluded from this study.

As higher variations of measurements are expected in an in vivo study, the results of this in vitro assay should be verified under in vivo conditions.

Conclusion

Under the conditions of this ex vivo study, no statistically significant difference was observed for any of the groups measured using either the Root ZX or mini Root ZX. Multivariate linear regression model demonstrated that needle-insertion depths influenced the electronic measurements (P = 0.05), while the concentrations of irrigants did not influence the results.

Conflict of Interests

Authors have no conflict of interest.

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