Research Article

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Accuracy of Electronic Apex Locator in Different Simulated Clinical Conditions

Dr. Ranjan Thapaliya,[1] Dr. Reetu Shrestha,[2] Dr. Reema Joshi,[3] Dr. Asha Thapa,[4] Dr. Shikha Bantawa[5]

[1-5]Conservative Dentistry and Endodontics Unit, Department of Dental Surgery, National Academy of Medical Sciences, Bir Hospital, Mahabouddha, Kathmandu, Nepal

Correspondence :
Dr. Ranjan Thapaliya. Email: thapaliyaji@gmail.com

ABSTRACT

Introduction: Root canal length determination is challenging as the accuracy of the electronic apex locators may vary in different clinical conditions. Hence, their accuracy in these conditions need to be evaluated.

Objective: This in vitro study had attempted to determine the accuracy of electronic apex locator (Propex Pixi) in different simulated clinical conditions of irrigant within the canal, open apex, bleeding within the canal, and horizontal root fracture.

Material and Method: After institutional ethical clearance from National Academy of Medical Sciences (NAMS), an analytical cross-sectional study was conducted at NAMS, Bir Hospital from 2020 April to 2021 February. Using convenience sampling method, 140 extracted intact human teeth with single root, single canal, and mature apex were used as the specimen for the study with 35 in each group of four simulated clinical conditions. The teeth with fractures, root resorption, perforation, caries, open apex, and canal anomalies were excluded from the study. Actual length of root was measured at 10X magnification. The teeth were mounted into alginate mould and measurements were obtained by Propex Pixi apex locator. Data were processed and analysed using R statistical software, (R version 4.0.2) and were compared with the actual length at 5% significance level.

Result: No significant statistical difference was found between the working length and the electronic working length in either of the different simulated clinical conditions.

Conclusion: Propex Pixi can accurately determine the root canal working length in different clinical conditions.

Keywords: Apex locator; apical foramen; propex pixi; working length.

INTRODUCTION

The success of endodontic treatment depends on complete removal of all root canal contents and is possible only with the accurate determination of working length of the root canal.[1] Various techniques like radiographic methods, apical

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periodontal sensitivity, paper points, digital tactile sensation and electronic apex locators have been used for determining root canal length. However, all these methods have some limitations.[2]

Modern electronic apex locators (EALs) determine working length by measuring impedance with multiple frequencies.[3] Among them, Propex Pixi (Dentsply, Maillefer) is a fifth generation EAL. It uses multiple frequencies, in addition to calculating root mean square (RMS) value of electric signals and is claimed to be less affected by electrical noises affecting other physical parameters, such as amplitude or phase of electrical signal.[4] Yet, its accuracy in other common clinical situation like presence of irrigants, blood, open apex, and root fracture is lacking. Hence, the main aim of this study was to determine accuracy of this fifth generation EAL device in various simulated clinical conditions of the tooth being treated. This will help clinicicans to know various clinical conditions where one can rely on this device for accurate working length measurement and predictable success of the endodontic treatment.

MATERIALS AND METHOD

This was an analytical cross-sectional study (in vitro) conducted in the Conservative Dentistry and Endodontics Unit, Department of Dental Surgery, National Academy of Medical Sciences (NAMS), Bir Hospital from 2020 April to 2021 February. The convenience sampling method was used for the study and the extracted intact human teeth with single root, single canal, and mature apex were used as the specimens for the study. Similarly, the teeth with fractures, root resorption, internal resorption, perforation, caries, open apex, and canal anomalies or canal calcifications were excluded from the study. Ethical clearance was obtained from Institutional Review board (IRB) of NAMS (Ref. 577).

Initially, 192 single rooted teeth scheduled for extraction due to periodontal, prosthetic, or orthodontic reasons were selected for the study. After the necessary informed consent from the patient and extraction of their teeth, the teeth were immersed in 5% sodium hypochlorite (NaOCl) solution (Pyrax Polymars) for two hours to remove the debris followed by cleaning with hand and ultrasonic scaler.

Subsequently, the teeth were examined to evaluate the presence of root fractures and completion of apex formation. The teeth were then radiographed from both buccolingual and mesio-distal directions to evaluate the root canal anatomy and root resorptions. Finally, 140 teeth were selected for the study after clinical and radiographical evaluation. The teeth were then kept in 0.9% saline solution (Axa Parenterals Ltd.) until the further in vitro study.

The teeth were decoronated at the cementoenamel junction with a diamond disc to simplify access to the root canal and to obtain a reliable occlusal reference point. A 3% NaOCl solution (Pyrax Polymars) was used for irrigation during the process and the patency of the apical foramen was maintained using size stainless steel (SS) 10K-file (Diadent Group International). The samples were randomly divided into four groups with 35 samples in each group and teeth were numbered with the permanent marker indicating the number (1 to 35) and the group they belonged to as A to D.

For the specimen preparation of Group A, barbed broaches (Dentsply, Maillefer) were used to extirpate the pulp followed by irrigation with 3% NaOCl. Then 1 ml of 3% NaOCl solution was injected to simulate the clinical condition of irrigant within the canal. The excess of the NaOCl solution was absorbed but no attempt was made to dry the canal.

For the specimen preparation of Group B, barbed broaches were used to extirpate the pulp followed by irrigation with 3% NaOCl. The apical 2-3 mm of the root tips were resected to simulate the clinical situation of open apex. Canal was instrumented with Peeso reamers #1 upto #3 (Mani). During instrumentation, each Peeso reamer was passed 1 mm beyond the apex. The canal of each tooth was packed with cotton up to the root apex so as to prevent any unwanted retrograde entry of alginate into the canal during mounting and taken out after the alginate had set.

For the specimen preparation of Group C, after the necessary aseptic universal precautions, 5 ml blood was drawn from the researcher and treated with 0.1% ethylenediaminetetraacetic acid (EDTA). This human blood mixed with EDTA as an anticoagulant was injected into the canal to simulate the clinical condition of bleeding within the canal. The excess of the blood was absorbed but no attempt was made to dry the canal.

For the specimen preparation of Group D, horizontal root fracture was simulated using a 0.2 mm thick diamond disc, until half of the canal was exposed circumferentially by another operator (the researcher was blinded about the fracture location to avoid biased reading and to ensure standardisation of the technique). After fracture simulation, the pulp was extirpated and irrigation was done with 3% NaOCl solution followed by irrigation with normal saline. Then, the canal was dried with absorbent paper points.

An adequate amount of alginate was condensed within the plastic tray that consisted of the boxes of the uniform dimensions. The marking of the box was done with the marker and upon setting, the corresponding root was embedded within the alginate, leaving approximately 2-3 mm of the coronal root surface exposed. The root was kept in that position until the alginate completely set. A 35-K stainless-steel endodontic file (Diadent Group International) was inserted into the alginate with 4-5 mm exposed outside to complete the circuit. All measurements were made within two hours, maintaining the alginate in sufficiently humid condition.

A snugly fitting file into the apex of the root was clipped to the apex locator and circuit was completed by attaching the lip clip with the stainless-steel endodontic file embedded into the alginate model. Electronic measurements were obtained by Propex Pixi (Dentsply, Maillefer). Values were acknowledged creditable if the reading remained stable for at least five seconds. The procedure was repeated three times for each tooth. If value remained same in all three attempts, that value was recorded. If the two values appeared same, then the repeated value was recorded. If all three values appeared different, then the mean value was calculated and recorded for each sample.

The actual length (AL) of root canal was measured by inserting a size 10 K-file into the root canal and viewed under 10X magnification using a magnifying glass. When the file tip was visible at the apical foramen, the silicone stop was placed at the reference point and the file was removed from the canal. The distance from the base of the silicone stop to the file tip was measured with a digital caliper (Ambica Tools & Hardware). Each measurement was repeated three times. If value remained same in all three attempts, that value was recorded. If the two values appeared same, then the repeated value was recorded. If all three values appeared different, then the mean value was calculated and recorded for each sample.

For the specimen simulating horizontal root fracture, they were removed from the alginate model and the length from the coronal reference

point to the fracture line was measured with the same digital caliper at the three aspects of the root and the average of the three measurements were taken to obtain the actual fracture length (AFL) measurement.

After completion of the procedure for each sample, the data were checked for the completeness and entered in Microsoft Excel Sheet 2013. Then, the data were analysed using R statistical software, (R version 4.0.2). The level of significance for each test was 0.05 and P <0.05 was considered significant. The summarised data were then presented in the form of tables and graphs. The mean actual length and electronic working length are presented in mean and standard deviation for each group.

RESULT

The difference in each group was calculated by subtracting electronic length from actual length. The distribution of difference in measurement by two methods were checked (Table 1, Figure 1). It was found that the difference in mean measurement

Table 1: Distribution of frequency of the actual length and the length determined by electronic apex locator (Propex Pixi).

Group	Above -1.0*	-1.0 to -0.51*	-0.5 to -0.01*	0.00	0.01 to 0.5	0.51 to 1.0	Above 1.0
A (Irrigant within the canal)			3		28	4	
B (Open apex)			3		30	2	
C (Bleeding within the canal)			1		30	4	
D (Horizontal root fracture)	1	3	6		18	7	

Note: Negative value indicates measurements more than actual length.

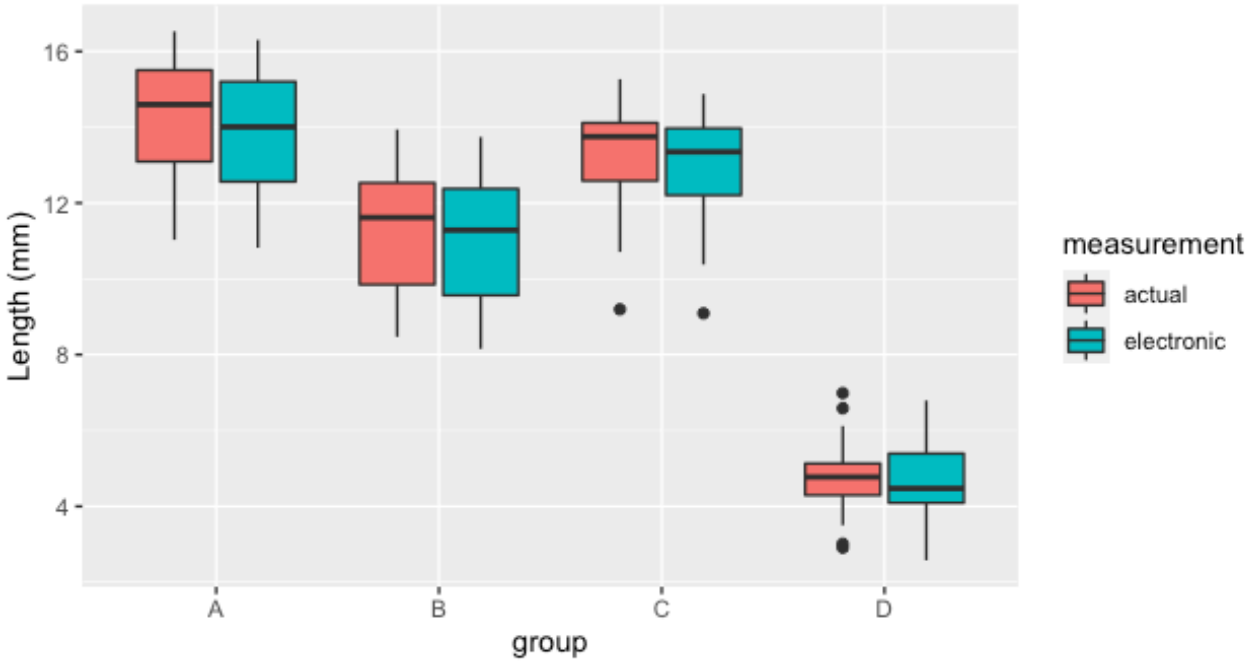

Figure 1: Box plot diagram showing no difference between two measurements in each group.

Table 2: Comparison of mean value between different simulated clinical conditions.

Group	Actual length(AL)	Electronic working length(EWL)	P Value
	Mean± SD	Mean± SD	
A (Irrigant within the canal)	14.14 ± 1.53	13.89 ± 1.52	0.48
B (Open Apex)	11.26 ± 1.57	11.08 ± 1.6	0.63
C (Bleeding within the canal)	13.21 ± 1.39	12.91 ± 1.4	0.36
D (Horizontal root fracture)	4.77 ± 0.89	4.64 ± 0.98	0.56

ranged from -1.27 mm to 1 mm. However, the majority were within the tolerance of ± 0.5 mm and the measurement accuracy was found to be 88.60%, 94. 20%, 88.60%, and 68.50% in Group A, B, C, and D respectively. If the difference within + 1.0 is considered, the measurement accuracy was found to be 100% in Group A, B, and C; and 97.10% in Group D respectively. Similarly, considering the apical constriction to be 0.5 mm short of apical foramen, the accuracy of the Propex Pixi apex locator in measuring the working length within tolerance of ± 0.5 mm was found to be 97.10% for Group A and B.

Independent t-test was applied to test the difference in measurement by two methods. No difference was observed between two measurements in each group (Table 2).

DISCUSSION

Determining working length is a critical factor in the prognosis of an endodontic treatment and it has become easier with the introduction of the latest generations of apex locators. However, the accuracy of these apex locators is a major concern amongst the clinicians. Root ZX is the most extensively researched apex locator and is considered the gold standard to which the newer apex locators are being compared. According to previous studies, its accuracy varies from 50% to 100%.[5,6] But, there are very few studies regarding Propex Pixi. Therefore, the purpose of this in vitro study was to evaluate the accuracy of Propex Pixi apex in determining the working length of the root canal in four different simulated clinical conditions.

In vitro studies can be performed with different experimental models to simulate the human periodontium. Alginate is a good medium to establish the necessary electric circuit for a correct working length measurement because it mimics the electric impedance of the human periodontium well.[7] Therefore, in the current study, alginate was selected as a medium to simulate the normal periodontium.

Huang et al. (1987) showed that the moisture content of the root canal was one of the essential factors influencing the accuracy of electronic root canal measuring device.[8] Among the various irrigants, sodium hypochlorite is the most popular and the only irrigant of those in general use that dissolves necrotic and vital organic tissue. Thus, NaOCl solution is usually present in the canal during root canal treatment and working length determination. Hence, the accuracy of Propex Pixi in the presence of 3% NaOCl as irrigant in the canal was determined.

Many of the studies used an error range of ± 0.5 mm to assess the accuracy of EALs.[9] Measurements attained within this tolerance were considered highly accurate. However, many of the root canals do not always end with an apical constriction at 0.5 mm short of apical foramen, so tolerance upto

+1.0 mm to the foramen is considered clinically acceptable range of tolerance.[10]

In comparison to these standards, the accuracy of Propex Pixi within ± 0.5 mm and within + 1.0 mm to the major foramen, in the presence of 3% NaOCl was 88.5% and 100% respectively. Furthermore, considering the cementodentinal junction or minor diameter to be 0.5 mm short of the major foramen, the accuracy to detect the point within ± 0.5 mm and within ±1.0 mm range is 97.1 % and 100 % respectively. Similarly, an in vivo study by Pradhan et al. (2018) showed no statistical difference between the actual length of the canal and the length measured by Root ZX mini whereas, there was significant difference between actual length of the canal and the canal measured by Propex Pixi electronic apex locator similarly, 100% accuracy was seen with Root ZX mini within the range of 0.5 mm whereas 96.9% accuracy was seen with Propex Pixi apex locator.[11]

In the present study, the smaller sized SS K-files (8-110 K files) gave unstable results whereas snug-fitting SS K-file (120-K file) provided the most stable results. The findings are similar to the results of Shacham et al. (2020) who showed that both snug -fitting SS K-file and SAF file gave 100% of accurate results.[12] In this study, apical 3-4 mm of root was cut from the apical tip to simulate the defect with open apex so that apical constriction was not used as a landmark because it was impossible to determine the working length in these type of cases.[13] The accuracy of Propex Pixi was 94.3% within ± 0.5 mm whereas 100% accurate within +1.0 mm. In other previous study by Jain et al. (2020) in determination of the actual WL, within ± 0.5 mm, the accuracy of I-pex and Raypex-6 were 40% and 52% respectively whereas within +1.0 mm, accuracy of both were 60% whereas in 40% cases, file went 0.5 to 1 mm beyond the major foramen.[14] The reason behind the less accuracy of the instrument in comparison to our current study could be because of the use of small sized SS file (15 K file).

In this study, in the presence of blood, 97.1% fell into ± 0.5 mm tolerance to detect the apical constriction (considering apical constriction to be 0.5 mm short of the apical foramen). Whereas 100% accuracy was obtained within 1.0 mm clinically acceptable range of tolerance which is in accordance to a study by Bashar et al. (2008).[15]

In the present study, Propex Pixi detected the horizontal root fracture within ± 0.5 mm in 68.57% and within ± 1.0 mm in 97.10% samples. There was one measurement showing error of more than 1 mm. As all the simulated horizontal fractures were not perfectly parallel to the coronal reference point, the measurement in the oblique fracture line could have resulted in the actual length being short of the electronic working length. Because the Propex Pixi measurements were shorter than actual measurements in general, we are of the opinion that Propex Pixi is acceptable. Similarly, Ping et al. (2010) found that Root ZX apex locator could not detect the horizontal fracture in the case without separation or without ingress of impression material, whereas it detected with 100% accuracy within ± 0.5 mm if with separation was present.[16] This shows that soft tissue ingrowth may be needed for diagnostic value.

In this study, all fractures were simulated with a disk, producing an incomplete fissure of approximately 0.2 mm. The clinical situation may differ in that fracture or fissures are probably narrower and may be oblique. So, it is still unclear how accurate the EALs would be in horizontal or oblique narrow fissures or fractures, with minimum separation of fragments. Thus, the thickness of the fissure as detected by the EALs or the detection of the fractures under clinical conditions might be the subjects for further studies.

Similarly, further investigation using greater sample size along with in vivo study and histological

determination of apical constriction is required in order to determine the accuracy of electronic apex locators.

CONCLUSION

The present study showed that Electronic Apex Locator (Propex Pixi) can accurately measure the root canal working length in different simulated clinical conditions within clinically acceptable range of error. Furthermore, Propex Pixi could detect the apical constriction more accurately than the apical foramen. Though the results obtained in this in vitro study cannot be directly extrapolated to the clinical situation, it can provide an objective examination of a number of variables that are not practical to test clinically. At best, the EALs should be used as an adjunct, and not as the only method to determine the canal length in endodontic therapy.

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Conflict of interest: None.

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