Original Article

Comparative evaluation of the accuracy of six different apex locators in working length determination of molars using intraoral periapical radiographs: An *in vivo* study

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Abstract

Context: One of the crucial steps in endodontic treatment is determining the working length (WL). There are various methods for performing this procedure, one of which is an electronic apex locator (EAL) measurement.

Aims: The aim of this study was to determine the accuracy of six EALs, i.e.. Root ZX, Root ZX Mini, Propex PiXi, Innvopex-1, Woodpex III, and Raypex 6 for WL estimation in the mandibular first molars.

Material and Method: The study included 180 root canals with symptomatic irreversible pulpitis, divided into six groups using different apex locators. WL determination was compared with intraoral periapical radiographs. Results were categorized as accurate, short, or long. The data were statistically analyzed.

Results: ROOT ZX had an accuracy of 96.7%, Root ZX Mini had an accuracy of 93.3%, PiXi had an accuracy of 90.0%, Innvopex-1 had an accuracy of 90.0%, Woodpex III had an accuracy of 86.7%, and Raypex 6 had an accuracy of 83.4%, respectively. There was a statistically nonsignificant difference between groups ($P < 0.05$).

Conclusion: Newly developed apex locators, such as the Innvopex-1, have shown accuracy comparable to well-established EALs like the Root ZX. This highlights the importance of conducting more extensive, large-scale research to confirm and validate their effectiveness.

Keywords: Apex locators; intraoral periapical radiographs; multirooted teeth; radiographic apex; working length

INTRODUCTION

Successful endodontic treatment is based on the knowledge of the root canal anatomy, thorough cleaning and shaping, and three-dimensional obturation of root canal space.[1-3] During cleaning, shaping, and subsequent obturation of root canals, instrumentation should terminate at the apical constriction (AC) (Kuttler 1955) to ensure optimal periapical healing. For this, precise working length (WL) determination is vital which may be achieved using tactile sense, radiographs, and electronic apex locators (EALs).[1]

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Date of submission : 08.04.2024
Review completed : 29.04.2024
Date of acceptance : 09.05.2024
Published : 08.07.2024

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_189_24

How to cite this article: Sayed A, Dighole S, Lobo WM, Sapkale K, Ramugade MM, Baker DC. Comparative evaluation of the accuracy of six different apex locators in working length determination of molars using intraoral periapical radiographs: An *in vivo* study. J Conserv Dent Endod 2024;27:695-700.

Among these, intraoral periapical (IOPA) radiographs are the most common method of WL determination. However, this procedure is associated with multiple limitations such as two-dimensional images, exposure of the patient to radiation, image distortion errors, superimposition of anatomical structures, and subjectivity.[4] This has led to the development of electronic root length measuring devices, i.e., apex locators.

The electrical resistance between the periodontal ligament and oral mucosa has a constant value that can be measured using two electrodes, which was demonstrated by Suzuki in 1942. This formed the basic principle on which Sunada, in 1962, developed the first apex locator.[5] Currently, there are various apex locators based on different principles, ranging from resistance and impedance to multiple and dual-frequency-based devices. There is a scarcity of clinical studies evaluating the accuracy of current apex locators in multirooted teeth. Therefore, this *in vivo* study was planned to compare and evaluate the accuracy of six different apex locators, namely, ROOT ZX, Root ZX Mini, Propex PiXi, Innvopex-1, Woodpex III, and Raypex 6, with IOPA radiograph in multirooted teeth.

MATERIALS AND METHODS

The study was conducted in the department of conservative dentistry and endodontics, and institutional ethical approval (4090/2023) was obtained for the study.

Methodology

One hundred and eighty root canals showing a configuration of 1–1 or 2–2 according to Vertucci's classification (maxillary and mandibular molars) diagnosed with symptomatic irreversible pulpitis were included in the study. Patients were chosen irrespective of gender in the age group of 17–30 years with noncontributing medical history. Preoperative IOPA radiographs were taken, and root curvature was measured. Patients were selected on the basis of following inclusion and exclusion criteria.

Inclusion criteria

Patients in the age group from 25 to 40 years irrespective of gender.

Teeth diagnosed with symptomatic irreversible pulpitis.

Teeth showing distinct one canal and not showing curvature more than 5°–10° according to the Schneider method were included in the study.

Patients willing to participate voluntarily in the study and who consented for the same.

Exclusion criteria

Patients reported with a configuration other than 1–1 or 2–2 according to Vertucci's classification radiographically or after access opening were excluded from the study.

Patients with any embodied electronic devices such as cardiac pacemakers.

Radiographic evidence of resorption (external or internal) or calcification.

Radiograph showing root curvature more than 10 degrees after selection of the patient.

Pregnant patients

Sample size Calculation

The sample size was calculated on the basis of the mean between these groups with the help of the formula given by Rosner.[6]

$$n1 = \frac{(Z_\alpha + Z_\beta)^2 \ .2. \ P_1(1-P_2)}{(d)^2}$$

where,

P1 = Proportion for group #1 = 93.3% =0.933

*P*2 = Mean for group #2 = 62.2% =0.622

α = Probability of type I error = 0.05, Confidence interval = 95% =0.95

β = Probability of type II error = 0.2, Power = 80% =0.8

Z^α = Critical *Z* value for a given α =1.96

$Z_{1-}{}^{\beta}$ = Critical *Z* value for a given α =0.84

d = Difference = 0.20

k = Ratio of sample size for group = 1

The minimum sample size per group is 27.

A 10% attrition rate is added, so the final sample size is 30 patent single-root canals per group.

The procedure was explained to the patient, and written consent was obtained [Annexure 1]. The patients were allotted into six different groups based on the lottery method of randomization. All procedures were performed by a single operator independently.

Local anesthesia (2% lignocaine with 1:100,000 adrenaline) was administered, and access cavity preparation was done under rubber dam isolation. The canal was explored, and patency was established using size #10 K-file.

Following this, a 15 K-file was used in a watch-winding motion to the same point. Coronal flaring was achieved with SX Rotary ProTaper Gold.[7] A K-file, the size dependent on the canal width, was introduced into the canal, and the

rubber stopper was adjusted on a reference point. Readings were taken twice as per manufacturer instructions using the respective EALs, and the average value was calculated as WL. Three radiographs were taken using the bisecting angle technique, in straight, mesial, as well as distal angulations, and the average of these was calculated for each canal. These readings were then compared with EAL readings, and the data were statistically analyzed.

The samples were categorized using the scoring criteria,[8] wherein Acceptable was considered 0–1 mm short of the radiographic apex, Short was >1 mm short of the radiographic apex, and Long/Beyond was considered beyond the radiographic apex.

Table 1 and Graph 1 give an overview of the comparison of accuracies among the six different apex locators.

RESULTS

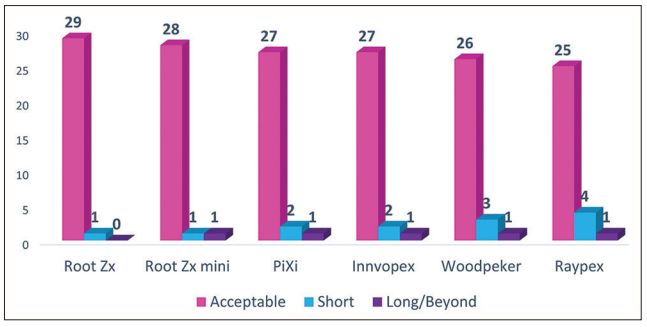
The data were transformed from a precoded survey form to the computer. The job of data entry, validity checks, and formation of desired results (as per the analysis plan) were done using the SPSS version 22.0 (IBM Corporation, Statistical Package for the Social Sciences. N.Y., USA). The comparison of the accuracy of different apex locators was compared by using the Chi-square test. The level of statistical significance was set at $P \leq 0.05$.

A total of 180 canals (30 canals per group) were evaluated in this study, and it was observed that WL estimations were acceptable in 162 canals short in 13 canals and beyond in five canals.

The Root ZX had the highest accuracy at 96.7%, followed by the Root ZX Mini, Propex PiXi, Innvopex-1, Woodpex II, and Raypex 6 with accuracies of 93.33%, 90.0%, 90.0%, 86.7%, and 83.4%, respectively.

Table 1: Comparison of the accuracy of six different apex locators

Group	Canals	Acceptable (%)	Short (%)	Long/ beyond (%)	Test
Root ZX	30	29 (96.7)	1 (3.3)	0	χ^2=4.52, P=0.921
Root ZX mini	30	28 (93.3)	1 (3.3)	1 (3.3)	
PiXi	30	27 (90.0)	2 (6.7)	1 (3.3)	
Innvopex-1	30	27 (90.0)	2 (6.7)	1 (3.3)	
Woodpex III	30	26 (86.7)	3 (10.0)	1 (3.3)	
Raypex 6	30	25 (83.4)	4 (13.3)	1 (3.3)	
Total	180	162 (90.0)	13 (7.2)	5 (2.8)	



Graph 1: Comparison of the accuracy of six different apex locators

DISCUSSION

Successful endodontic therapy is largely dependent on a triad of access cavity, canal preparation, and three-dimensional sealed obturation of the canals. Cleaning, shaping, and obturation cannot be accomplished accurately unless the WL is determined precisely.[1]

According to the Glossary of Endodontic Terms, WL is defined as "The distance from a coronal reference point to the point at which canal preparation and obturation should terminate."[9] Grove stated that the optimum point to which root canals should end is the junction of the dentin and the cementum, i.e., CDJ. The CDJ is the anatomical and histological landmark where the pulp ends and the periodontal ligament begins.[10] Clinical detection of the CDJ is unpredictable. Therefore, the AC, identified as the narrowest part of the root apex morphology, is considered the optimum point to complete the root canal procedure. When endodontic treatment is confined to AC, it provides minimum contact between the filling material and apical tissue, thus reducing inflammatory responses and foreign body reactions.[8]

Different methods have been used to locate the AC and to measure the WL of root canals. These include tactile sensation, paper points, conventional periapical radiographs, and EALs. Among these, the most common method of WL measurement is conventional periapical radiographs. However, there are known limitations in this method, including two-dimensional images, image magnification, distortion errors, radiation exposure, and superimposition of anatomical structures.[4]

To overcome these shortcomings, apex locators were developed leading to a less invasive method of EWL determination.[11] According to the Glossary of Endodontic terms, "An EAL is an electronic device used in endodontics to determine the position of the AC and thus determine the length of the root canal space. "Apex locators have many advantages over conventional radiographic methods of WL determination such as it is easier, faster, and can be repeated without exposure to radiation. Besides measuring WL correctly, it is also used to detect over-instrumentation and perforations (iatrogenic and natural). Studies have shown that apex locators have higher accuracy than conventional intraoral radiographs.[12]

Apex locators measure EWL precisely by locating the AC, which is an optimal endpoint for root canal preparation and obturation. Nevertheless, it has been shown that a higher accuracy can be reached when both radiographic and EWL determination are performed. A WL radiograph after EWL determination can reduce over-instrumentation and provide a mapping of the AC. In certain clinical situations, such as cases with an immature apex, calcified canals, root resorption, and perforation, radiographic verification of the electronic WL is warranted, as apex locators may provide false readings.[13]

Among the array of EALs introduced to the market over time, all claiming advancements in accuracy, Root ZX and Root ZX Mini, have emerged as the gold standard, backed by the findings of numerous studies. Our study was conducted to estimate the accuracy of six different EALs, namely, ROOT ZX, Root ZX Mini, Propex PiXi, Innvopex-1, Woodpex III, and Raypex 6 with IOPA radiograph in multirooted teeth. The mandibular first molars were chosen for the study as these teeth are the most common candidates for endodontic treatment. Considering the complexity of their anatomical features and root patterns, they are the more challenging teeth class for WL determination.[14] Teeth diagnosed with symptomatic irreversible pulpitis were selected for the study as it is the most prevalent pulpal pathology indicative of endodontic therapy.[15,16]

In the present study, the bisecting angle technique was used to avoid errors in positioning which may be caused due to the presence of a rubber dam, rubber dam clamp, and root canal instruments. According to Kuttler, in 1950, AC may vary but is usually 0.5–1 mm short of the apical foramen. In the present study, 0–1 mm short of the radiographic apex was considered as the acceptable range as given by Weine's modification of Ingle's technique of radiographic method of WL determination.[17]

Similar to other studies conducted in the past, Root ZX and Root ZX Mini displayed the highest accuracy compared to the other four EALs. Propex Pixi demonstrated an accuracy of 90%. This is in comparison to a study conducted by Serna Peña *et al*., wherein the accuracy of Root ZX Mini and Propex Pixi was compared revealing rates of 100% and 89.99%, respectively. wherein the accuracy of Root ZX Mini and Propex Pixi was compared revealing rates of 100% and 89.99%, respectively.[14,18]

In our study, Woodpex III demonstrated an accuracy of 86.7%, which is similar to a study conducted by Ramezani *et al*., wherein it was found to be 87.93%.[19] The accuracy of Raypex 6 was comparatively lower (83.2%), which is in agreement with the study by Aydin *et al*., where it was found to be 88.29%.[20]

Innvopex-1, a newly introduced EAL, lacks extensive research evaluating its accuracy. Recognizing this gap, we conducted this study to address the limited existing research on its precision and effectiveness. We observed that the accuracy of Innvopex-1 and PiXi was comparable, both achieving a remarkable 90.0%. Importantly, there was no statistically significant difference when compared to the performance of the Root ZX, considered the "gold standard" in EALs. Keeping in mind the limitations of our study due to the *in vivo* settings, it can be concluded that recently developed apex locators, such as Innvopex-1, can exhibit accuracy levels on par with established EALs like Root ZX. This highlights the necessity for further research on a larger scale to substantiate and validate their efficiency.

CONCLUSION

WL determination is an important aspect of root canal treatment. No single method for the determination of WL is 100% meticulous. It was noted among all the six EALs, Root ZX had the highest accuracy, followed by Root ZX Mini, Innvopex-1, PiXi, Woodpex III, and Raypex 6, the differences in accuracy being statistically nonsignificant. Although apex locators determine the WL accurately in the majority of cases, the role of radiographs as an adjunct must always be considered.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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ANNEXURE I

INFORMED CONSENT FORM

TITLE OF STUDY-

COMPARATIVE EVALUATION OF THE ACCURACY OF SIX DIFFERENT APEX LOCATORS IN WORKING LENGTH DETERMINATION OF MOLARS USING INTRAORAL PERIAPICAL RADIOGRAPHS - AN *IN VIVO* STUDY

I, Mr./Ms.…….. hereby give consent to……. to perform the root canal treatment using the instrument provided to me by ……. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.

I also consent to use my case for research purposes and to publish the data obtained from my case in the research journal, provided, my personal details will be kept confidential.

Date: / /

Place:

Name of Researcher/Student: