Original Article

# A Comparative Clinical Study On The Correlation Of Working Length Determined Using Three Different Electronic Apex Locators With Radiographic Working Length: An In Vivo Study

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## Abstract

**Aim:** This in vivo study was done to correlate the values of three different electronic apex locators: Root ZX II, iPex II, and Raypex 6, with the radiographic working length (WL).

**Materials and Methods:** Nineteen maxillary incisors with completely formed root apices indicated for endodontic treatment were chosen. After access preparation, coronal flaring and pulp extirpation, electronic measurement of WL was done with a No: 15 K-file using the three devices on each tooth. A WL radiograph was then taken with the file placed within the canal and the length determined by following Ingle's method. The data were then analyzed using the correlation coefficient and Z-test.

**Results:** Root ZX II showed the maximum correlation ($r = 0.9881$) with radiographic WL followed by Raypex 6 ($R = 0.9731$) and iPex II ($R = 0.9508$). Root ZX II had a statistically significant higher correlation with radiographic WL in comparison with iPex II ($P < 0.05$).

**Conclusion:** Maximum correlation of readings with the radiographic length was shown by Root ZX II followed by Raypex 6 and then by iPex II.

**Key words:** Electronic apex locators; endodontic treatment; working length.

## Introduction

The apical constriction where the pulp is linked to the apical periodontal tissue referred to as the minor diameter is recommended by many as the appropriate landmark where root canal preparation and obturation should terminate.**[1]** The traditional method used to determine working length (WL) is based on the radiographic visualization of an instrument placed in the canal.**[2]** However this presents several limitations. Radiographic image being a two dimensional one, may often be overlapped with anatomic structures and thus can cause difficulty in interpretation. There can also be technical errors in projection and also the danger of radiation exposure.**[3]**

The development and production of electronic devices for locating the canal terminus have been a revolutionizing innovation in root canal treatment. Their advantages include comparable or better accuracy compared with the radiographic method, constant monitoring of the WL when coupled with advanced rotary systems, thus decreasing the total radiographs needed and thereby the radiation exposure too.**[4,5,6]**

The first generation of electronic apex locators (EALs) were resistance based, whereas the second generation EALs were based on impedance.**[7]** To overcome the inaccuracies that occur with these apex locators in the presence of irritants and pulp tissue, third generation EALs were introduced.**[8]**Root ZX II (J. Morita Corp, Tokyo, Japan) is a third generation EAL that uses the "ratio method" to measure the root canal length. This method measures impedance values at two frequencies (8 KHz and 0.4 KHz) simultaneously and calculates a quotient that expresses the position of the file tip in the canal.**[9]** The Root ZX II apex locator is considered as a standard to which newer EALs are compared.

The iPex II (NSK Technologies, Japan), is a fourth generation apex locator that automatically selects the best possible frequency according to the canal condition by tip in the canal.**[7]**

Raypex 6 (VDW Dental, Germany) is a recently introduced apex locator that claims accuracy in almost all canal conditions. The device works by micro signals consisting of dual frequencies that are sent from the unit and which return to the unit after travelling along the electric circuit that is composed of: unit -probe cord – file holder -file -patient -lip holder -probe cord. The impedance of the electric circuit may be changed depending on the distance between the end of a file and the apex of the root canal, which results in a change in the micro signals that are input back into the unit. The microprocessor of the unit calculates the change in micro signals to convert the difference into a distance value, which will be displayed on the Raypex 6 liquid crystal display (LCD) display.**[10]**The manufacturer does not specify any other technical characteristics, and no studies are present in current literature on the ex vivo or in vivo accuracy of this EAL.

Many studies have addressed the benefits and clinical performance of the various models of EALs that have been developed in the recent years and when faced with the contrasting assertions of the manufacturers, it becomes difficult for the practitioner to choose from the various EALs available.

In spite of the high chances of image distortion, conventional bisecting angle technique of radiography is still the most often used method, and hence a comparison of EAL readings with the WL obtained using a radiograph made using short-cone technique can be extrapolated more easily to routine dental practice.**[11,12]**There have not been many published reports on the correlation of WL obtained using EAL and the radiographic WL. The objective of the present study was to test in vivo a new apex locator, the Raypex 6 along with iPex II and Root ZX II as to their correlation with the radiographic WL. The study also compared the proximity of the EAL readings with the radiographic WL.

## Materials and Methods

This study was conducted in the Department of Dentistry and GMERS Medical College & Hospital, Himatnagar (Gujarat). Informed written consent in full accordance was obtained from each patient before the treatment was initiated.

Nineteen maxillary central incisors with mature root apices indicated for nonsurgical root canal treatment were chosen for the study. Teeth with incomplete apical closure, calcifications, internal and external root resorption, and those which presented with uncontrollable bleeding on access opening were excluded from the study. Pregnant patients and patients with cardiac pacemakers were also excluded from the study.

A periapical radiograph was exposed for each tooth. After administering local anesthesia (2% lignocaine with 1:100,000 adrenaline), the teeth were isolated using rubber dam and access cavity preparation was done. After canal identification, coronal flaring was done using Pro Taper SX rotary file (Dentsply Maillefer, Ballaigues, Switzerland) and the pulp extirpated using a No. 15 barbed broach. The canals were irrigated with 2 ml of 3 % sodium hypochlorite solution. Excess fluid was removed from the pulp chamber, but the attempt was not made to dry the canal.

A single K-type file with a silicon stop was used to record WL readings in each canal using the three different EALs: Root ZX II Mini (J. Morita), iPex II (NSK), Raypex 6 (VDW Dental, Germany). The apex locator to be used first was selected in a random manner.

The EALs were used according to the manufacturer's instructions. For all the three devices, the clip was attached to the patient's lip and the electrode was connected to a No. 15 K-file. While using the Root ZX II, the file was advanced within the root canal to a point just beyond the apical foramen, as indicated by the flashing APEX bar and the solid tone. The file was withdrawn until the flashing bar on the display corresponded with the 0.5 marking on the meter.

While using the iPex II apex locator, the file was advanced until the "APEX" signal was seen on the LCD and then withdrawn until the display showed the 0.5 mm mark. With the Raypex 6, the file was inserted slowly into the root canal until the periodontal membrane was touched as indicated by the red bar appearing at the "APEX" on the screen. The insertion of the file into the canal was continued until the display changes to −0.1 and then the file was moved back until the reading 0.0 was displayed on the screen which confirmed the location of the apex according to the manufacturer.
After recording the WL with the first EAL, the file was removed and the length was measured and recorded to the nearest 0.5 mm. This was repeated in a similar manner for the second and third apex locator.

The WL radiograph was then made and the length was determined using Ingle's radiographic method.**[13]**The radiographic WL and the values obtained from the three apex locators were tabulated as given in **Table 1**.

The data were then analyzed using the correlation coefficient and Z-test. To calculate the agreement of the readings from the EALs with that of radiographic WL, interclass correlation coefficient was calculated. The correlation coefficient (R) was obtained **Table 2**. Scatter plots were also plotted for each EAL with the readings against the radiographic WL **[Figures 1-3]**. To compare the correlation with radiographic WL among the three devices, Z-test was carried out **Table 3**. Significance was set at $P < 0.05$.

**Table 1: Radiographic WL and EAL values**

| **Tooth No.** | Radiographic (mm) | iPex II (mm) | Root ZX II (mm) | Raypex 6 (mm) |
|---|---|---|---|---|
| **21** | 20 | 19 | 19 | 19.5 |
| **11** | 18 | 18 | 18 | 18.5 |
| **21** | 19 | 18 | 18 | 19.5 |
| **11** | 19 | 19 | 19 | 19 |
| **11** | 22.5 | 22 | 22.5 | 22 |
| **21** | 25 | 22.5 | 25 | 24 |
| **21** | 23 | 21.5 | 22.5 | 22 |
| **21** | 20 | 20.5 | 20.5 | 20.5 |
| **11** | 20 | 21 | 20.5 | 20.5 |
| **21** | 23.5 | 22.5 | 23 | 23 |

| | | | | |
|---|---|---|---|---|
| **11** | 21.5 | 21.5 | 21 | 21 |
| **21** | 24.5 | 24.5 | 24.5 | 24.5 |
| **21** | 20 | 19 | 20 | 19.5 |
| **11** | 21 | 20 | 21 | 21 |
| **21** | 21.5 | 21.5 | 21.5 | 21 |
| **21** | 23 | 22 | 23 | 22 |
| **11** | 15.5 | 15 | 15.5 | 15.5 |
| **11** | 16 | 16 | 16 | 17 |
| **21** | 23.5 | 22.5 | 23 | 23.5 |

**Table 2: Interclass coefficient (correlation coefficient -R)**

| EAL | R | L |
|---|---|---|
| iPex II | 0.950 | 19 |
| Root ZX II | 0.988 | 19 |
| Raypex 6 | 0.973 | 19 |

**Table 3: Correlation of the three EAL values with radiographic working length – Z test**

| Pair | Z | P |
|---|---|---|
| iPex II & Root ZX II | 2.03 | <0.05 |
| iPex II & Raypex 6 | 0.87 | >0.05 |
| Root ZX II & Raypex 6 | 1.16 | >0.05 |

## Results

Statistical analysis of the correlation of the reading from the three apex locators and the radiographic length were performed by calculating the correlation coefficients.

The maximum value of the correlation coefficient was shown by Root ZX II ($R = 0.9881$), which indicated that Root ZX II had the most readings which had exact match with the radiographic values (11/19). This was followed by Raypex 6 ($R = 0.9731$) and iPex II ($R = 0.9508$).

The pair wise comparison of correlation with radiographic WL between the apex locators shows that Root ZX II had a statistically significant higher correlation with radiographic WL in comparison with iPex II ($P < 0.05$).

There was no significant difference in the correlation with radiographic WL when Raypex 6 was compared with Root ZX II or iPex II ($P > 0.05$).

Although the number of EAL values that matched with radiographic readings were more with using iPex II (6/19) than with Raypex 6 (5/19), but their difference when they did not precisely match with the radiographic values were less in case of Raypex 6 when compared with iPex II. This is clear from the scatter plots which show a higher dispersion of the values in case of iPex II than Raypex 6. The least dispersion among the three was shown by the scatter plot of Root ZX II.

## Discussion

Electronic methods for WL determination have advanced considerably and have been increasingly incorporated into the current endodontic practice. The accuracy of apex locators has been investigated by several researchers by various in vitro and ex vivo studies.**[6,14,15]**Most of these studies tried to compare the values of the EAL with WL measured till different target points such as apical foramen and apical constriction. However, these cannot be a true representative of clinical situations in which the entire treatment is done in the mouth.

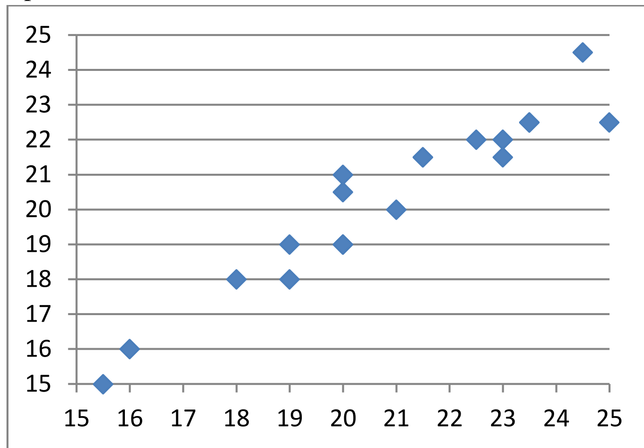


**Figure 1: Scatter plot for IPex II values against the radiographic working length**

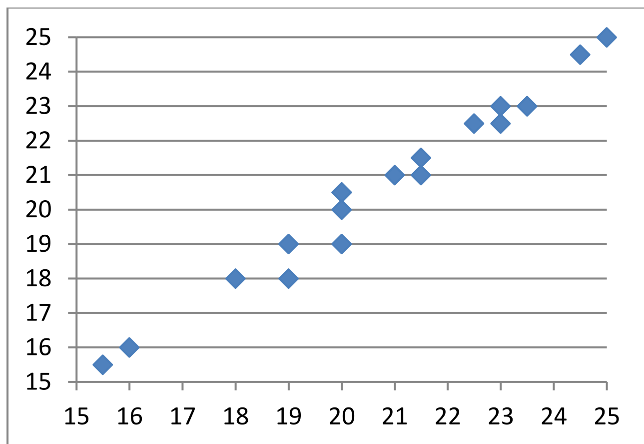


**Figure 2: Scatter plot for Root ZX II values against the radiographic working length**

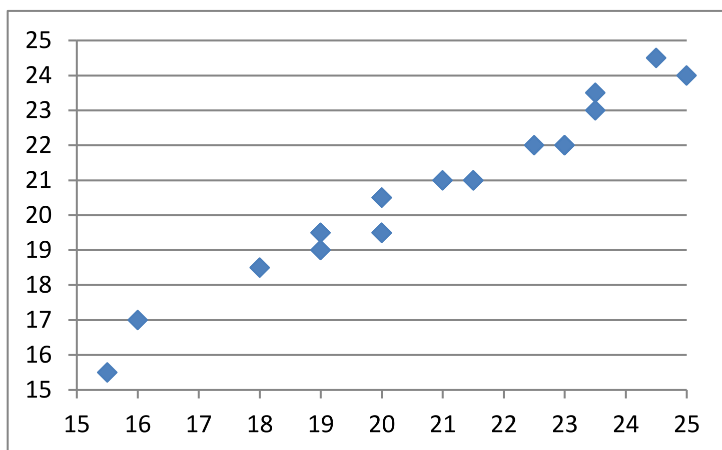


**Figure 3: Scatter plot for Raypex 6 values against the radiographic working length**

This study, however, was a true reproduction of what occurs during a routine endodontic treatment. Radiographs are the universally accepted, easily available, and meaningful method of WL assessment in the clinic. In the present study, Ingle's method of radiographic measurement was taken as the control against which all the values of the EALs were compared.

In this comparative study, Root ZX II was found to show the maximum correlation with the radiographic WL. Previous studies dating from mid 1990s have confirmed the accuracy of Root ZX II.**[3,8,14,16]** and have even named it the benchmark for comparison with other apex locators.**[17,18]**

Ravanshad et al. concluded in their study that the results of endodontic treatment using EAL are quite comparable to radiographic length measurement. Study also showed that Root ZX II had a statistically significant higher correlation with radiographic WL when compared with iPex II only. In vitro comparative evaluation of conventional radiography and Root ZX II apex locator in determining WL by Javidi et al. showed an almost complete correlation between the two (correlation coefficient = 0.983).**[19]**In vivo radiographic evaluation by Paludo et al. showed 82% of values obtained using iPex II as acceptable, 20 whereas a comparative in vivo evaluation of Root ZX II and iPex II have demonstrated a lower accuracy for iPex II.**[14]**

In an in vitro comparison of the accuracy of radiographic and electronic WL determination using Root ZX II compared with the actual root canal length obtained with stereoscope, Root ZX II apex locator gave accurate measurements, but not superior to digital radiographic methods.

In our study, Root ZX II and Raypex 6 showed a correlation coefficient of 0.9881 and 0.9731, respectively. A literature search revealed no in vivo or ex vivo studies evaluating the accuracy of Raypex 6 EAL. In the present study, there was no significant difference in the correlation with radiographic WL when Raypex 6 was compared with Root ZX II or iPex II ($P > 0.5$). Raypex 6, but when compared to iPex II, showed lesser dispersion of values in those cases where there was no perfect match of the electronic values with radiographic readings. The least dispersion in values was shown by Root ZX II.

But, the results do not suggest that the EAL replace radiographs. However, they are the ideal tools for complementing radiographic methods of WL determination and thus can help in reducing the number of radiographs taken in this regard.

## Conclusion

Under the conditions of this study, Root ZX II showed the maximum correlation with radiographic WL which was followed by Raypex 6 and then by iPex II. Moreover, Raypex 6 when compared to iPex II showed greater proximity of readings with the radiographic WL.

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## Conflicts of interest

There are no conflicts of interest.

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