Original Article

# Comparative evaluation of the accuracy of two electronic apex locators in detecting simulated incomplete vertical root fractures: An *in vitro* stereomicroscopic study

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## Abstract

**Aim:** The aim of this study was to compare the accuracy of two different electronic apex locators (EALs) in detecting simulated incomplete vertical root fractures (VRFs).

**Materials and Methods:** Thirty freshly extracted single-rooted teeth were randomly divided into three groups of 10 teeth each labeled as Groups A, B, and C. Incomplete VRFs were simulated in the coronal, middle, and apical one-third of the roots for Groups A, B, and C, respectively. The teeth were embedded in alginate mold and fracture location was determined with Root ZX and Propex EALs for each sample and each group. To calculate the actual length (AL), each sample was sectioned at the upper level of the vertical fracture, and the length was measured by setting the stopper of the #10 K file under a stereomicroscope at ×30 magnification. The electronic lengths and ALs were compared using computer software, and the results were analyzed using SPSS 28.0 at a 95% confidence level.

**Results:** No significant differences were seen in the accuracy of the two EALs when compared with ALs. Root ZX showed significantly longer measurements than ALs in groups B and C.

**Conclusion:** The tested EALs showed low accuracy (20%) in detecting simulated incomplete VRFs with a tendency for longer measurements compared to ALs.

**Keywords:** Electronic apex locator; propex; root ZX; stereomicroscope; vertical root fracture

## INTRODUCTION

Incomplete vertical root fractures (VRFs) are quite difficult to diagnose in clinical endodontic practice. These fractures are commonly present in endodontically treated teeth but may be present before endodontic treatment. Diagnosing the existence and extent of a VRF is imperative before any restorative or endodontic treatment since these cracks can dramatically affect the overall success of treatment. Early diagnosis of VRF is crucial to prevent alveolar bone loss that may interfere with or delay definitive treatment like implant placement after tooth extraction. Conventionally, radiographs are used to diagnose root fractures; however, most of the time fractures are oblique and are in a plane that is not perceptible from a periapical radiograph. In one study, investigators determined that when a VRF is present, it is observed in a radiograph only 35.7% of the time.[1] In fact, the width of early VRFs may be below the detection

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level of even the modern CBCT machines due to the extremely low voxel size required. In such circumstances, electronic apex locator (EAL) can be a useful diagnostic tool.[2] These devices technically detect the point of contact between the file and the periodontium. Modern EALs have several advantages like ease of use, no radiation exposure, and immediate results. Various authors have confirmed the efficacy of EALs to detect radicular fractures, perforations, and lateral canals.[3,4] EAL would theoretically mark "apex" from the beginning of the defect because of the periodontal connection. This may aid in diagnosis and selection of treatment options. The aim of this *in vitro* study was to evaluate two different EALs, Root ZX (third generation) and Propex (fourth generation) regarding their accuracy to detect simulated incomplete VRFs.

## MATERIALS AND METHODS

This study was approved by the Institutional Ethics Committee (NIMSUR/IEC/2023/0134) and was designed according to the CRIS guidelines.[5] Thirty freshly extracted, single-rooted, and mature human teeth were collected. Teeth with visible radicular resorptions or fractures were discarded. After collection, teeth were stored in 2% NaOCl solution (CanalPro, Coltene) for 5 min to remove the periodontal ligament[6] and then stored in normal saline until the experiment. Direct digital radiographs of the sample teeth were taken in both buccolingual and mesiodistal directions to reveal the root canal anatomy. Teeth with accessory canals or those where the main canal was not visible were excluded. The crowns of the teeth were removed at the cemento-enamel junction with a diamond disc (Mani, Japan) under copious water cooling standardizing the root length to 15 mm and establishing a stable coronal reference plane for the measurements. The canals were debrided by irrigating with 5 ml of 3% NaOCl solution (CanalPro, Coltene) after which canal patency was evaluated by inserting a size 10 K file (Dentsply) until the tip of the file became visible at the major apical foramen. The tooth with canal obstruction was discarded. The teeth were then randomly divided into three groups of 10 teeth each, namely, Groups A to C. In Group A, an incomplete VRF was simulated by preparing a vertical straight incision with a TC-11 diamond bur (Mani, Tochigi, Japan) to expose the canal all the way from the coronal to the middle portion of the root in the longitudinal plane. In Group B, a similar fracture was prepared in the middle portion of the root, and in Group C, from the middle to the apical portion of the root. The thickness of the simulated VRFs was approximately 0.25–0.35 mm. After fracture simulation, sterile saline (2 ml) was injected into each canal using a syringe without excessive pressure. Saline leakage from the simulated fracture site was examined visually with the help of cotton pellets to verify canal exposure. To detect fractures with EALs, an alginate model developed and used in previous studies to test apex locators were used[7,8] [Figure 1a]. The model consisted of a rectangular plastic box (19 cm × 6 cm × 2 cm). The box was filled with alginate (Zelgan 2002, Dentsply) mixed to a flowable consistency and all teeth of one particular group were embedded into it, leaving a coronal 1 mm of the root. To establish an electrical circuit for the EALs, a metal clip was connected to a stainless steel screw, and the instrument clip was connected to a size 10 K file, to be inserted into the root canal.[9] Detection of simulated VRFs was established with the reading "APEX" on each EAL. Then, a rubber stop on the file was carefully adjusted to the reference level and the file was then withdrawn from the canal. The distance between the base of the rubber stop and the file tip was measured with a digital Vernier caliper (Cen-Tech) to the nearest 0.1 mm. Three readings were taken for each sample, and the mean value for each tooth and each apex locator was recorded as Root ZX length (RL) and Propex length (PL), respectively. To confirm the location of each simulated fracture in Groups A, B, and C, the root was removed from the alginate and sectioned horizontally at the upper level of the vertical fracture with a disc. The length up to the coronal end of the simulated fracture was then measured with a size 10 K file under a stereomicroscope at ×30 magnification. This was recorded as the actual length (AL) for each sample. Using a morphometric scale developed using sophisticated computer designing software, each specimen was digitally photographed along with a normal "foot" scale with millimeter graduations [Figure 1b]. The photographed image was then transferred to the computer using CorelDRAW Version 13.0. Now, the image was viewed at ×1000 magnification and a reference box was plotted along the millimeter scale to obtain the reference marker (RM) [Figure 1c]. While drawing the scale, the constant midpoint of each millimeter line was taken at the middle of the reference scale constant box being drawn. The length of the RM was recorded. Similarly, a marker box was drawn along the length of the file used. This marker box was termed a working length marker (WLM) [Figure 1d]. Scale values were noted for both RM and WLM. The process was repeated for all the specimens. To obtain the reference length for each sample, the following formula was devised:

$$\text{Reference length} = \frac{\text{Scale value for WLM}}{\text{Scale value for RM}}$$

The above formula provided the reference length in millimeters. This reference length will be referred to as AL. The recorded AL was compared with the values obtained with the EALs (RL and PL).

The data were analyzed using the Statistical Package for the Social Sciences (SPSS, IBM, Chicago, IL, USA) Version 28.0 and represented as mean ± standard deviation (SD) of working length achieved. To see the difference in the distribution of mean values among different groups, the Chi-square test was used. The confidence level of the study

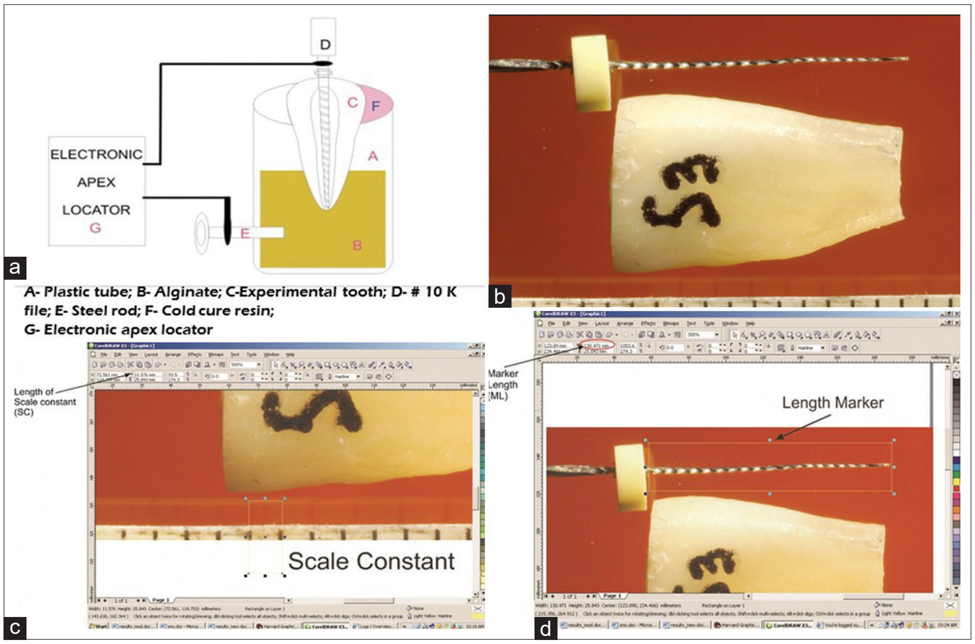



**Figure 1:** (a) Diagram of the experimental setup. (b) Sample digitally photographed with a millimeter marker under the stereomicroscope (×30). (c) Reference marker plotted along the millimeter scale. (d) Marker box drawn along the length of file used (working length marker)

was kept at 95%; hence, a $P < 0.05$ depicted a statistically significant difference that was analyzed by the Wilcoxon signed-rank test [Table 1].

### Qualitative analysis

In the reported literature, a variation of 0.5–1 mm has been accepted. However, in the present study, there were some dimensions where the values themselves were within the range of 1 or 2 mm; if we take here the variation of 0.5–1 mm, then it would mean allowing an error of up to 25%–50%. This is the reason that fixed variation (0.5–1 mm) has been discarded in favor of a newly developed fluctuating variation. The concept of fluctuating variation instead of taking a fixed amount of variation considers it from case to case and group to group. In the present study, there were three groups, Groups A to C, using the same methodology, but for different lengths – under such conditions, if a fixed variation is taken into account, then the scale variation would be too great for the smaller lengths while it would be negligible or minimum for greater lengths. It has been assumed that ±5% variation in assessing the length can be offset by the proper use of the clinical skill of the operator; hence, the fluctuating variation has been taken as the ±5% from the mean length measured in a group.

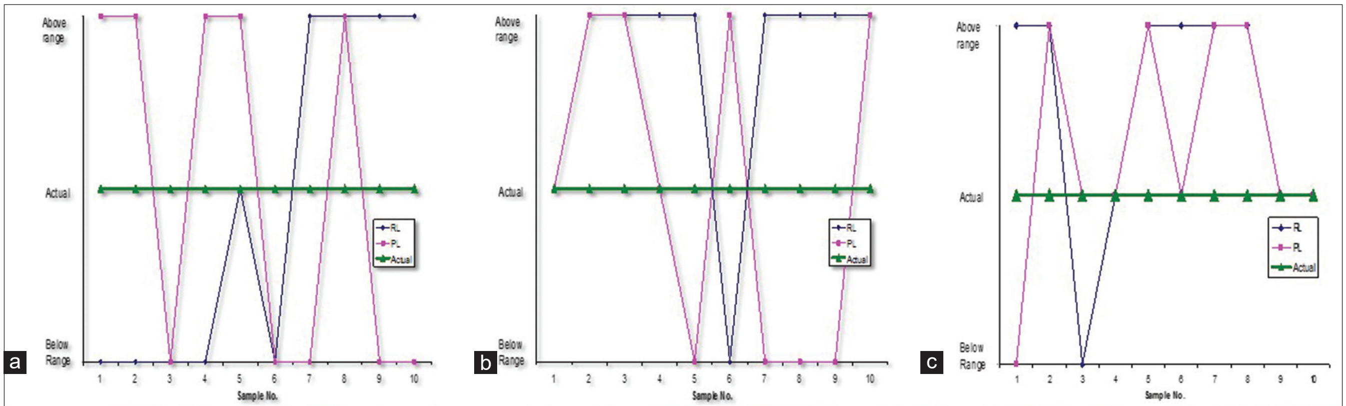
## RESULTS

No significant differences were observed in the accuracy of both EALs when compared to ALs; however, in Groups B and C, the RL was significantly higher than AL ($P = 0.036$) [Figure 2].

## DISCUSSION

The main purpose of this *in vitro* study was to evaluate the accuracy of two different EALs in detecting simulated incomplete VRFs. Accuracy is generally accepted as the ability of a variable to indicate what it is intended to measure. It has been suggested that EALs operate based on the principle of electricity rather than the biologic properties of the tissues involved. Therefore, *in vitro* models in which extracted teeth are immersed in media with similar electrical resistance to the periodontium can provide valuable information on the function of EALs. In this study, alginate was used as an embedding media as suggested by Kaufman.[4] Alginate is a good medium to establish the necessary electric circuit for a correct EAL measurement because it mimics well the electric impedance of the human periodontium.[10] A size 10 K-file was used in this study for taking AL and EAL measurements, which was in accordance with the study conducted by Briseño Marroquín *et al*.,[11] whereby a tendency to make unstable measurements with instrument size 15 and above was observed. For determining the electronic working length and the AL by measuring the distance from the base of the stopper to the file tip, a digital Vernier caliper having an accuracy of 0.1 mm was used, as in another study.[12]

In the present study, different shapes of root fractures were simulated with a diamond disc or bur, producing an incision of approximately 0.25–0.35 mm thickness. Clinical situations may differ from those incisions, which are probably narrower or of different shapes and could




| Group | | Mean RL | Mean PL | AL |
|---|---|---|---|---|
| A | Minimum | 1.033 | 0.900 | 1.333 |
| | Mean | 1.983 | 1.957 | 1.943 |
| | Std. Deviation | 0.774 | 0.770 | 0.313 |
| | Maximum | 3.567 | 3.400 | 2.427 |
| B | Minimum | 4.200 | 3.667 | 3.456 |
| | Mean | 5.460 | 4.967 | 4.843 |
| | Std. Deviation | 0.984 | 1.220 | 0.693 |
| | Maximum | 7.167 | 7.667 | 5.834 |
| C | Minimum | 10.833 | 10.300 | 10.151 |
| | Mean | 11.973 | 11.767 | 11.408 |
| | Std. Deviation | 0.854 | 1.120 | 0.829 |
| | Maximum | 13.467 | 13.700 | 12.859 |

d

**Figure 2:** (a-c) Graphs comparing Root ZX length, Propex length, and actual length for the samples in Groups A, B, and C, respectively. (d) Minimum, maximum, mean, and standard deviation values (in mm) for each group

be oblique. Hence, it is still unclear how accurate the EALs would be in fractures with a minimum separation of fragments. Thus, the thickness of the fracture as detected by EALs under clinical conditions might be subject to further studies. In the present study, two popular EALs were used, i.e., the Root ZX and the Propex. Root ZX (J. Morita Co., Japan) was developed by Kobayashi and Suda, which is based on the "ratio method" for measuring canal length. This is a third-generation apex locator that simultaneously measures impedance values at two frequencies (8 KHz and 0.4 KHz) and calculates a quotient of the impedances. This quotient is expressed as the position of the file in the canal. When the file touches the periodontium, the quotient approaches a value of 0.67. This constant value is reliable in the presence of electrolytes or pulp tissue and needs no calibration.[13]

Propex (Dentsply Mailefer, Ballaigues, Switzerland) is a multifrequency-based apex locator, which is a fourth-generation apex locator based on the same principle as the other modern devices, which use multiple frequencies to determine root canal length. One important characteristic of Propex is that the calculation is based on the energy of the signal, whereas the other apex locators usually use the amplitude of the signal. The manufacturer claims that energy measurement is more precise.[14]

For Groups A, B, and C, both Root ZX and Propex were able to detect vertical fractures in the apical one-third more accurately than those in the middle or the coronal one-third. For Group A, Root ZX and Propex had an accuracy of 30% (three cases) and 50% (five cases), respectively. Both apex locators were least accurate in detecting vertical fractures in the coronal one-third (Group A). No obvious reason could be found for such a result. In addition, no statistically significant difference was found between Root ZX and Propex for Groups A, B, and C. Both showed a tendency toward slightly longer measurements than the ALs, as shown in some previous studies.[15,16] The results of the present study were in agreement with those of Azabal *et al*.[17] and Ebrahim *et al*.[18] who found that the EALs were not reliable in detecting the position of simulated VRFs. The accuracy of apex locators in detecting root fractures, in the present study, was lower quantitatively compared to the previous studies.[19] This difference could be explained because; in the present study, the apex locators were evaluated on a stricter criterion (5% fluctuating variation) compared to a more lenient parameter of ± 0.5 mm used in the previous studies.[20-23] Within the confines of this *in vitro* study results, we can conclude that both Root ZX and Propex showed a tendency toward slightly longer than actual measurements, and no statistically significant difference was found between

**Table 1: Statistical analysis of data obtained from qualitative analysis (Wilcoxon signed-rank test)**

| Group | *Z* | *t* |
|---|---|---|
| A | −0.090 | 0.928 |
| B | −1.444 | 0.149 |
| C | −0.816 | 0.414 |

the two. The apex locators detected incomplete VRFs with a low overall accuracy of 20%.

## CONCLUSION

Within the limitations of the present *in vitro* study, it can be concluded that

a. The modern EALs have a low overall accuracy in the detection of incomplete VRFs
b. The EALs have a tendency to record slightly longer than actual measurements
c. Further research is needed to expand the horizon of applications of the EALs.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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