# Comparative Evaluation of Accuracy of 2 Electronic Apex Locators with Conventional Radiography: An *Ex vivo* Study

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## Abstract

**Introduction:** The aim of this *ex vivo* study was to evaluate the accuracy of the Raypex 5 (VDW, Munich, Germany) and Apex NRG XFR (Medic NRG Ltd, Tel Aviv, Israel) electronic apex locators (EALs) in determining the working length when compared with radiographs. **Methods:** Twenty-five human single-rooted teeth were selected, and the access cavity was prepared. The working length (WL) was determined radiographically and electronically by using 2 EALs. The files were fixed at the WL, and the teeth were extracted. The apical 4 mm of each canal was trimmed to expose the file tip, and the samples were observed under a stereomicroscope. The distance from the file tip to the point 0.5 mm coronal to the anatomic apex was measured. The data were analyzed by using 1-way analysis of variance and the Tukey Honestly Significant Difference test. **Results:** There was no significant difference between the Raypex 5 and the Apex NRG XFR devices with respect to their accuracy in determining the final WL. When compared with radiography, both the EALs had no significant difference. When comparing EALs and radiographic measurements with control measurements, accuracy results were found to be 20%, 36%, and 52% for the Raypex 5, Apex NRG XFR, and radiography, respectively. Overestimations of WL determination by the Raypex 5, Apex NRG XFR, and radiography were 4%, 0%, and 40%, respectively. Underestimations of WL determination by the Raypex 5, Apex NRG XFR, and radiography were 76%, 64%, and 8%, respectively. **Conclusions:** Both the EALs had the same accuracy in determining the WL when compared with radiography. *(J Endod 2015;41:201–204)*

## Key Words

Apex locator, Apex NRG XFR, radiograph, Raypex, working length

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The removal of infected pulp tissue, necrotic material, and microorganisms from the root canal system is essential for endodontic success (1). This can be achieved if the length of the root canal is determined with accuracy. A correct distance from the coronal reference point to the cementodentinal junction (ie, the working length [WL]) is a critical factor for endodontic treatment outcome (2). Failure in determining the correct WL might result in overfilling or underfilling and has the potential for root canal treatment failure after a 10-year observation period ranging from 10% to 50% (3). It has been stated that the WL for instrumentation and obturation of the root canal system should be established at the apical constriction (AC) (4). Anatomic studies have shown the AC to be located 0.5–1.0 mm from the external or major foramen or anatomic apex (4). Traditional methods of determining the WL include the following (5):

1. The use of anatomic averages and knowledge of anatomy
2. Tactile sensation
3. The paper point method
4. Apical periodontal sensitivity
5. Radiography
6. Electronic apex locators (EALs)

However, the radiographs are subjected to distortion, magnification, interpretation variability, and lack of 3-dimensional representations. The magnification error has been found to be 5.4% with the paralleling technique (6). Also, vertical and horizontal cone angulations, film-processing issues, tooth inclination, and film position will influence WL determination from the radiographs (7). A WL established beyond the minor diameter may cause apical perforation and overfilling of the root canal system. This may increase postoperative pain and delay or prevent healing. Alternately, a WL established short of the minor diameter may lead to inadequate debridement and underfilling of the root canal system (2). However, the tactile sense is quite variable, and accuracy is questionable (8). Root canals with excessive curvature, an immature apex, or calcified canals will hinder the tactile sensation of the AC.

EALs have been developed with the aim of increasing the success of endodontic treatment and reducing the disadvantages associated with conventional radiography. Studies have shown that EALs provide a more accurate estimation of the WL than radiographs (9, 10). Additionally, the use of EALs reduces patient exposure to ionizing radiation by reducing the number of radiographs to determine the WL. The use of electronic devices to determine the WL was first proposed by Custer (11), and the first EAL was developed after the investigation by Suzuki (12) based on the electrical resistance properties of oral tissues. In recent years, many different models of EALs have been developed (5). Among them are the Raypex 5 (VDW, Munich, Germany) and the Apex NRG XFR (Medic NRG Ltd, Tel Aviv, Israel). Modern EALs determine the WL by measuring the impedance with different frequencies between the file tip and the canal fluid. Current EALs have a high reliability, high accuracy, and high reproducibility in locating the major apical foramen regardless of the electrolyte (13).

The Raypex 5 claims to be a fourth-generation device; the unit uses 2 separate frequencies (ie, 400 Hz and 8 kHz), and its measurements are based on the root mean square of the signals. It was able to detect the correct working length (±0.5 mm) in 80%–85.59% of cases (14). The Apex NRG XFR, a fifth-generation apex locator, is portable, completely digital, and does not use analog readings for measurement. The

technology of this apex locator is based on digital signal processing technology and uses square, multifrequency currents. The device takes the basic analog signal emanating from the file and, before it is exposed to any distortion, converts it into a digital signal configuration, which is then analyzed. Although modern EALs can locate the apical foramen and the apical constriction with high precision, it is unclear how accurate these devices are as they approach the apical region and how precise the meter readings correlate with the file position. A study by Higa et al (15) showed that there were differences between EALs depending on the distance of the measurement file to the apical foramen. To date, no studies have compared the accuracy of the Raypex 5 with the Apex NRG XFR. Hence, the aim of this *ex vivo* study was to evaluate the accuracy of Raypex 5 and Apex NRG XFR EALs in determining the WL when compared with radiography.

## Materials and Methods

Twenty-five human single-rooted teeth scheduled for extractions because of orthodontic or periodontal reasons were selected. Ethical clearance was obtained from institution review board. Informed consent was obtained from each patient. Cases were selected based on inclusion and exclusion criteria. The inclusion criteria were as follows:

1. A single-rooted tooth with single canal and a completely formed apex
2. Vital teeth

Exclusion criteria were as follows:

1. A tooth with incompletely formed apex or open apex
2. A tooth with root resorption/cracks

Preoperative radiographs of the patients were taken to confirm the morphology of the tooth. The teeth were isolated with a rubber dam under local anesthesia (Neon Lab, Ltd, Mumbai, India). Endodontic access was obtained, and the coronal portion of each canal was enlarged with a SX ProTaper file (Dentsply Maillefer, Ballaigues, Switzerland). The pulp tissue was extirpated using a barbed broach (Mani Inc, Tochigi Ken, Japan), and the canals were instrumented until size 20 using K-files (Mani Inc). The canal was then irrigated with 2.5% sodium hypochlorite (NaOCl) (KMC Pharmacy, Manipal, India), and excess irrigant was removed from the pulp chamber using a cotton pellet. The Raypex 5 and the Apex NRG XFR apex locators were then used in accordance with the manufacturers' instructions. For both the devices, the clip was attached to the lip of the patient, and the electrode was connected to a 15 K-file (Mani Inc). For Raypex 5, the file was advanced within the root canal to a point just beyond the anatomic apex (indicated as a red line in the apex locator). The file was then withdrawn, and the reading was recorded when all 3 green bars were reached. For the Apex NRG XFR, the file was advanced until the "APEX" signal was seen on the light-emitting diode display of the apex locator and then withdrawn until the display showed the 0.5-mm mark. The WL obtained from each apex locator was then recorded. Measurements were considered to be correct if the instrument remained stable for at least 5 seconds.

The WL was determined radiographically using the method of Ingle and Bakland (16). A 15 K-file (Mani Inc) with a length 1 mm less (safety allowance) than the tooth length as determined from the preoperative radiograph was placed in the root canal, and a WL radiograph was taken. On the radiograph, the difference between the tip of the file and the radiographic apex was measured. This amount was added to the original measured length if the instrument extended into the tooth or was subtracted if the instrument had gone beyond the apex. From this adjusted length of tooth, 1 mm was subtracted (safety factor) to confirm the apical termination of the root canal at the AC.

The file was then inserted to the WL as determined by the radiographic method. This was considered as the insertion length. The file was then cemented in the canal using light-cured glass ionomer cement (GC Corp, Tokyo, Japan). The handle of the file was then removed with a high-speed bur, and the tooth was extracted without disturbing the file. The extracted teeth were placed in 2.5% NaOCl for 20 minutes to clean the root surface and stored in a saline solution containing 0.01% sodium azide (Sigma-Aldrich, St Louis, MO).

The apical 4-mm portion of each root was trimmed in the longitudinal direction by using a fine diamond bur (Horico, Berlin, Germany) to expose the file tip. The additional tooth structure was removed carefully with a Soflex disk (3M ESPE, St Paul, MN) until both the file tip and the root canal was visible. The apical portions of the specimens were then observed under a stereomicroscope (Zeiss, Thornwood, NY) at a magnification of 10×, and the distance from the file tip to the apex was measured with the help of an ocular-built micrometer scale and the images were captured. The distance from the file tip to the anatomic apex was recorded as negative if the file tip was short of the anatomic apex or positive if it was beyond the anatomic apex. Then, the distance from the coronal reference point to the anatomic apex was calculated by adding or subtracting the distance from the file tip to the anatomic apex to the insertion length. The actual WL was established to be 0.5 mm coronal to the anatomic apex and was calculated by subtracting 0.5 mm from the distance between the coronal reference point and the anatomic apex that was calculated. The actual WL measurements were considered as controls (17).

Statistical analysis was performed using SPSS software (SPSS 14.0; SPSS Inc, Chicago, IL). Data were analyzed by 1-way analysis of variance to determine whether there was a significant difference between groups. Pairs of groups were compared using the Tukey HSD test. The level of significance was set at $P < .05$. The accuracy of WL measurements calculated by each of the methods was determined by the percentage of samples equal to the control (actual WL measurements). Over- and underestimation of the WL was determined by the percent of measurements above or below the control, respectively.

**TABLE 1.** Mean and Standard Deviation Measurements (in mm) of Different Experimental Groups When Compared with the Control Group

| Experimental groups | *n* | Mean (mm) | Standard deviation (mm) | *P* value |
|---|---|---|---|---|
| Raypex 5 | 25 | 20.180 | 1.6763 | .46 |
| Apex NRG XFR | 25 | 20.200 | 1.7440 | .48 |
| Radiography | 25 | 21.040 | 1.6951 | .99 |
| Control | 25 | 20.900 | 1.8371 | — |

## Results

The mean measurements and standard deviations obtained are shown in Table 1. The results showed that there was no significant

**TABLE 2.** Intergroup Comparison (*P* values) of Measurements Obtained with the 2 Apex Locators and Radiography

| Experimental groups | Raypex 5 | Apex NRG | Radiography |
|---|---|---|---|
| Raypex 5 | — | 1.000 | .305 |
| Apex NRG XFR | 1.000 | — | .325 |
| Radiography | .305 | .325 | — |

Pairs of groups were compared using the Tukey HSD test. The level of significance was set at $P < .05$.