

Electronic Apex Locators

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INTRODUCTION

Working Length Determination

The objective of working length determination is to establish the length (distance from the apex) at which canal preparation and subsequent obturation are to be terminated.

Importance of accurate working length determination:

- Confine the instrumentation to the canal system (within dentin).
- Create and maintain an apical stop or seat at the minor constriction.
- Prevent under-instrumentation that could leave tissue and debris in the apical segment.
- Prevent over-instrumentation which could cause patient discomfort, damage periapical tissue, or potentially cause an infection or cyst development from the placement of irritating materials beyond the apex.

Methods for determining working length:

- Radiographs
- Electronic apex locators
- Tactile sense

Additional adjunctive methods:

- Paper points
- Microscopic magnification
- Average tooth length

Ricucci D. Apical limit of root canal instrumentation and obturation, part 1. Literature review. Int Endod J 1998;31:384-93.

Review article. The literature supports instrumentation and obturation short of the radiographic foramen.

Electronic Apex Locators:

A. Background

The principle design and development of electronic apex locators date back to research undertaken by Suzuki in 1942. He found that electrical resistance between the periodontium and oral mucous membrane in dogs was a constant value.

Sunada, I. New method for measuring the length of the root canal. J Dent Res 1962; 41:375.

This study carried Suzuki's findings one step further. Using a simple DC ohmmeter, the electrical resistance between the periodontium and the oral mucous membrane was measured in 124 teeth.

- Resistance between the periodontium and the oral mucous membrane in humans was constant at 6.5 KΩ, regardless of the age of the patients or the shape and type of teeth. Contents of the canal (vital pulp vs. necrotic pulp) also had no effect upon the resistance.
- Bottom Line: It was found that the resistance between the periodontium and the oral mucous membrane in humans was 6.5 KΩ.

B. Types Available

Direct Current:	Original Ohmmeters used by Suzuki and Sunada			
Alternating Current:	Resistance type:	Root Canal Meter/The Endodontic Meter (Onuki) Sono Explorer (Salatec) Neosono-D, MC, and Ultima EZ (Amadent) Apex Finder (EIE – old version)		
	Impedance type:	Endocator (Hygienic) uses 400 kHz		
	Frequency type:	Subtraction (difference) type:	Endex/Apiti (Osada) uses 1kHz and 5kHz Neosono Ultima EZ (Amadent)	
		Ratio type:	2 frequencies	Root ZX (J. Morita) uses 0.4kHz and 8kHz
	5 frequencies		The AFA Apex Finder (Sybron) Elements Diagnostic Unit (Sybron)	

Ingle JI, Himel VT, Hawrish CE, Glickman GN, Serene T, Rosenberg PA, Buchanan LS, West JD, Ruddle CJ, Camp JH, Roane JB, and Cecchini SCM. Endodontic cavity preparation. In Ingle JI, Bakland LK (eds). Endodontics. 5th ed. Baltimore: Williams & Wilkins, 2002:517-22.

Apex locators are also divided into 1st, 2nd, 3rd, and 4th generation.

- First-generation apex location devices, also known as resistance apex locators, measure opposition to the flow of direct current or resistance. When the tip of the reamer reaches the apex in the canal, the resistance value is 6.5 kilo-ohms (current 40 mA).
- Second-generation apex locators, also known as impedance apex locators, measure opposition to the flow of alternating current or impedance.
- The principle on which “third-generation” apex locators are based requires a short introduction. In biologic settings, the reactive component facilitates the flow of alternating current, more for higher than for lower frequencies. Thus, a tissue through which two alternating currents of differing frequencies are flowing will impede the lower-frequency current more than the higher-frequency current. Since the impedance of a given circuit may be substantially influenced by the frequency of the current flow, these devices have been called “**frequency dependent**”. Since it is impedance, not frequency that is measured by these devices, and since the relative magnitudes of the impedances are converted into “length” information, the term “**comparative impedance**” may be more appropriate.
- The proposed “fourth-generation” apex locators are marketed by Sybron Endo and included the AFA Apex Finder and the Elements Diagnostic Unit. Both are ratio type

apex locators that determine the impedance at 5 frequencies and both have built-in electronic pulp testers.

McDonald, N. The electronic determination of working length. Dent Clin N Ame r 1992; 36:293-307. Good review of apical anatomy and of radiographic interpretation. Details the pitfalls of a two-dimensional picture representing a three-dimensional object, including anatomical difficulties that are commonly encountered. An excellent review of the basic operating principals behind the resistance, impedance and frequency type apex locators. The advantages/disadvantages of these different types of electronic apex locators are discussed.

- Bottom Line: Reviews differences between different types of electronic apex locators available. The EAL is a useful tool to be used in conjunction with radiographs.

Resistance-Type Apex Locators.

The apex locator has a built in resistant value of 6.5 kilo Ohms. The apex locator is attached to the patients lip on one side and the other side is attached to the file. The file is then advanced into the canal until it touches the periodontal tissue at the apex which then completes the circuit.

<i>Apex locator</i>	<i>Advantages</i>	<i>Disadvantages</i>
Resistance type	<ol style="list-style-type: none"> 1. Easy to operate 2. Uses K-type files 3. Operates w/ RC Prep 4. Digital readout. 5. Detects perforation. 6. Built in pulp tester. 	<ol style="list-style-type: none"> 1. Requires a dry environment. 2. Files cannot contact the metal restorations. 3. There should be no caries or defective restorations. 4. Requires calibration. 5. Requires a lip clip with good contact. 6. Patient sensitivity. 7. Should use a file that fits the canal snugly. 8. Perforations can give false reading. 9. Contraindicated in patients w/ pacemakers.

Impedance-Type Apex Locators.

Operates on the principle that there is electrical impedance across the walls of the root canal due to the presence of the transparent dentin. The tooth exhibits an increasing electrical impedance across the walls of the root canal, which is greater apically than coronally. At the DCJ, the level of impedance drops dramatically. The unit detects the sudden change and indicates it on the analogue meter. To overcome the problem of a wet environment, insulated probes are utilized.

<i>Apex locator</i>	<i>Advantages</i>	<i>Disadvantages</i>
Impedance type	<ol style="list-style-type: none"> 1. Operate in fluid environment 2. Analogue meter 3. No patient sensitivity 4. Operates with RC Prep 5. No lip clip 	<ol style="list-style-type: none"> 1. Requires calibration 2. Requires coated probes. 3. Can not use files. 4. No digital read-out. 5. Difficult to operate.

	6. Detect bifurcated canals 7. Detect perforations.	
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Frequency-Dependent Apex Locators

Operates very similarly to the Impedance-type because it measures the impedance of the tooth at two different frequencies. In the coronal portion of the canal, the impedance difference between the frequencies is constant. As the file is advanced apically, the difference in the impedance value begins to differ greatly with maximum difference at the apical area.

<i>Apex locator</i>	<i>Advantages</i>	<i>Disadvantages</i>
Frequency type	1. Easy to operate 2. Operates in fluid environment 3. Uses K-Type files 4. Analogue read-out 5. Operates with RC Prep 6. Low voltage electrical output	1. Must calibrate each canal 2. Sensitive to canal fluid level 3. Needs fully charged battery

ACCURACY

Shabahang S, Goon WWY, Gluskin AH. An in vivo evaluation of Root ZX electronic apex locator. J Endodon 1996;22:616-8.

In vitro study, Root ZX was 96% accurate to within +/-0.5 mm of the apical foramen.

Nguyen HQ, Kaufman Y, Komorowski, Friedman S. Electronic length measurement using small and large files in enlarged canals. Int Endod J 1996;29:359-64.

In enlarged canals, the Root ZX identified the narrowest canal diameter even in the absence of the anatomic apical constriction, and the lengths obtained with small and large size files were comparable. *(use the largest file that fits passively within the canal, i.e. the file should not be able to move up or down without intervention from the operator).*

Ounsi HF, Naaman A. In vitro evaluation of the reliability of the Root ZX electronic apex locator. Int Endod J 1999;32:120-23.

The Root ZX is not capable of detecting the '0.5 mm from the foramen' position and thus, should only be used to detect the foramen (major diameter). *(i.e. Contrary to manufacturer claims, Apex Locators can only reliably determine when the file is actually touching the PDL at the apex. Set your working length 1 to 1.5 mm back from this length to avoid over-instrumentation).*

Ibarrola JL, Chapman BL, Howard JH, Knowles KI, Ludlow MO. Effect of preflaring on Root ZX apex locators. J Endodon 1999;25:625-6.

Within the limitations of this study, the preflaring of canals was found to increase the efficiency of the Root ZX apex locator.

Jenkins JA, Walker WA, Schindler WG, Flores CM. An in vitro evaluation of the accuracy of the Root-ZX in the presence of various agents. J Endodon 2001;27:209-11

The purpose of this study was to evaluate the accuracy of the Root ZX in vitro in the presence of a variety of endodontic irrigants. The following irrigants were tested: saline, 2% lidocaine with 1:100,000 epi., 5.25% NaOCl, RC Prep, Liquid EDTA, 3% hydrogen peroxide, and Peridex. The most deviation (raw numbers) occurred with NaOCl, but it was not statistically significant.

- **Bottom Line:** The Root ZX was able to consistently determine the location of the apical foramen (within approximately $\pm 0.4\text{mm}$) in the presence of any of the tested irrigants. *(however, irrigants or files must not contact metallic restorations; and preferably should only fill the canal, not the chamber during EAL use).*

Goldberg F, De Silvio AC, Manfre S, Nastri N. In vitro measurement accuracy of an electronic apex locator in teeth with simulated apical root resorption. J Endodon 2002;28:461-3.

The purpose of this in vitro study was to evaluate the accuracy of Root ZX apex locator to determine the working length in teeth with simulated apical root resorption. A #3 carbide bur was utilized to create a simulated apical root resorption on 50 extracted human single rooted teeth. A K-file was placed into the canal and attached to the Root ZX. Three independent evaluators inserted the file until the display on the EAL displayed "0.5mm" (which generally confirms the instrument at the apical constriction) and recorded the length. The file was then placed through the foramen and measured to obtain actual tooth length.

- **Bottom Line:** The Root ZX was 62.7%, 94.0%, and 100.0% accurate to within 0.5 mm, 1 mm, and 1.5 mm of the direct visual measurements. This study concluded that Root ZX may be used to determine working length in teeth with apical root resorption.

COMPARISONS AND PRECAUTIONS

Rohde TR, Hutter JW. Apex locators. NDS Clinical Update 1994;16(3).

An excellent review of the three generations of apex locators.

- The use of apex locator does not preclude the need for radiographs for determining working length.
- Apex locators are useful adjuncts in situations where the apices are superimposed by anatomic structures or if the use of radiographs is limited because the patient is pregnant, handicapped, sedated, or has a extreme gag reflex.

Electronic apex locators should be used in caution on patients with pacemakers, and consultation with the patient's cardiologist is well advised. (However, provide the cardiologist with the information below if they request any input on their safety)

Garofalo RR, Ede EN, Dorn SO, Kuttler S. Effect of electronic apex locators on cardiac pacemaker function. J Endodon 2002;28:831-3.

The purpose of this study was to assess the effects of five electronic apex locators on pacemaker function in vitro. Five EALs were tested for pacemaker interference: Root ZX, Justwo, EIE, Neosono and Bingo-1020. A Biotronik Actros DR+ pacemaker with an atrial lead set to 60 pulses/min was evaluated at maximum sensitivity. The study design consisted of directly connecting the pacemaker lead, EAL and oscilloscope (a condition that does not occur clinically when using the EAL). **The Root ZX caused no interference in pacemaker activity.** The Justwo

and EIE showed the absence of two paced beats within the test period, whereas the Neosono showed the absence of five paced beats. However, all three showed normal pacing on the oscilloscope. The Bingo-1020 device produced an irregular pace recording and oscilloscope pattern.

- Bottom Line: All modern pacemakers are shielded in a hermetically sealed metal case with capacitors that effectively filter out EMI signals. Four of five EALs tested can be used safely in patients with pacemakers.
- Even though no interaction occurred, it is advised to consult with the patients cardiologist prior to the use of an EAL.

Ruddle CJ. “Cleaning and Shaping the Root Canal System” in Cohen S, Burns RC (eds). Pathways of the Pulp. 8th ed. St. Louis: Mosby pg. 242-58

Electronic apex locators, although still imperfect, represent a significant improvement over radiographs because they more accurately identify the position of the foramen. Working arbitrarily short of the radiographic terminus based on statistical averages encourages the accumulation and retention of debris... which predisposes the patient to ledges and perforations. Working short has led to many frustrations, inter-appointment flare-ups, failures, surgical procedures, and even extractions.... Apex locators do not replace films; however, they are an invaluable adjunct to be used in conjunction with radiographs.

Brunton PA, Abdeen D, Macfarlane TV. The effect of an apex locator on exposure to radiation during endodontic therapy. J Endodon 2002;28:524-6.

In group A, the working length was determined by a radiographic technique. In group B, the working length was determined by the electronic method, supplemented by radiographs. Results showed that group A required retake radiographs whereas group B did not. This difference was highly significant. The working lengths determined by the EAL were all within 0.5 mm of the anatomical apex.

- Bottom Line: The apical foramen location was more accurate with combination techniques, EAL and radiographs, than radiographs alone. The use of the EAL reduced the number of retake radiographs, by aiding in correct file placement.