Electronic Apex Locators- An overview

Amruta Khadse[1,*], Pratima Shenoi[2], Vandana Kokane[3], Rajiv Khode[4], Snehal Sonarkar[5]

[1,4,5]Senior Lecturer, [2]Professor & HOD, [3]Reader, Dept. of Conservative Dentistry & Endodontics, VSPM Dental College, Nagpur, Maharashtra

***Corresponding Author:**
Email: amrutakhadse@gmail.com

Abstracts

Successful root canal treatment depends on thorough cleaning & shaping and 3- dimensional fluid impervious obturation of tooth within the confines of canals. To achieve this objective the apical constriction must be detected accurately during canal preparation and precise control over working length during the procedure must be maintained. There are many methods of working length determination including electronic method. Introduction of apex locators have definitely served as an effective adjuvant to radiographs. This article highlights the details of electronic apex locators which are available till now including development, generations, historical background, mode of action, classification, problems associated with the use and clinical acceptance.

Keywords: Apex locators, Apical constriction, Endodontics, Resistance, Working length

Introduction

It is generally accepted that root canal treatment procedures should be confined within the root canal system. This can only be achieved if the length of the tooth and the root canal is determined with accuracy.[(1)] Several techniques have been used for determining the apical canal terminus. Traditionally, the point of termination for endodontic instrumentation and obturation has been determined by taking radiographs. The development of the electronic apex locators (EALs) has helped to assist working length more accurate, precise and predictable.[(2,3)]

Working length is defined as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate," - according to Glossary of Endodontic terms. An electronic apex locator is an electronic device used in endodontics to determine the position of the apical constriction (AC) and thus determine the length of the root canal space.

The aim of this paper is to review the development, mode of action, fundamental operating principles, classification, various generations available, problem associated, clinical acceptance of variety of Electronic Apex Locators.

Development of Electronic Apex Locators: Although the term "apex locator" is commonly used and has become accepted terminology, it is a misnomer. Some authors have used other terms to be more precise such as Electronic Root Canal Length Measuring Instruments or Electronic Canal Length Measuring Devices.[(3,5)]

Electronic apex locators have been used clinically for more than 40 years as an aid to determine the file position in the canal. The apex of the root has a specific resistance to electric current which is measured using a pair of electrodes i.e. endodontic fie & lip clip. These devices, when connected to a file, are able to detect the point at which the file leaves the tooth and enters the periodontium.[(3,5)]

An electronic method for root length determination was first investigated by **Custer** (1918). The idea was revisited by **Suzuki** in 1942 who studied the flow of direct current through the teeth of dogs. He registered consistent values in electrical resistance between an instrument in a root canal and an electrode on the oral mucous membrane and speculated that this would measure the canal length.[(1)] **Sunada in 1962** took these principles and constructed a simple device that used direct current to measure the canal length which work on the principle that the electrical resistance of the mucous membrane and the periodontium registered 6.0 kΩ in any part of the periodontium regardless of the person's age or the shape and type of teeth.[(1)]

In 1960 **Gordon** was the second to report the use of a clinical device for electrical measurement of root canal. **Inoue** made significant contribution to the evolution of apex locators in North America with his reports on the Sono Explorer in 1970. Later, frequency measurements were taken through the feedback of an oscillator loop by calibration at periodontal packets depth of each tooth. A third generation EALs developed in late 1980s by **Kobayashi;** he used multiple channel impedance ratio based technology to simultaneously measure the impedance of two different frequencies.[(5)]

Mode of action: EALs functions by using the human body to complete an electrical circuit. One side of the apex locator's circuit subsequently connected to the oral mucosa through a lip clip and the other side to a file. (Fig. 1) When the file is placed into the root canal and advanced apically until its tip touches periodontal tissue at the apex, the electrical circuit is completed. The electrical resistance of the EALs and the resistance between the file and oral mucosa are now equal, which results in the device indicating that the apex has been reached.[(2,3)]

When a circuit is complete (tissue is contacted by the tip of the file), resistance decreases markedly and current suddenly begins to flow. Depending upon the devices, this sudden current flow signaled by a beep, a buzzer, digital readout, flashing light or pointer on screen display. The electrical characteristic of the tooth structure are measured and exact position of the instrument in the tooth is determined.[2,3]

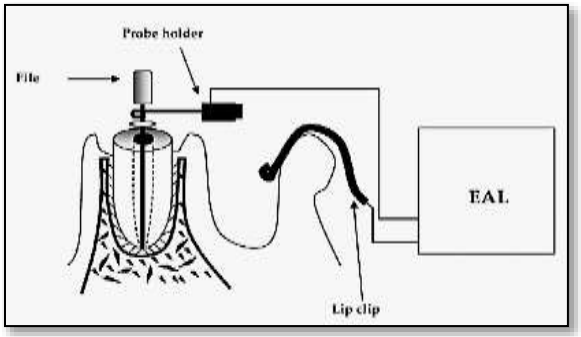

Fig. 1: Circuit for electronic determination of working length

Classification

The classification of apex locators was given by ***Mc Donald*** (1992)[6] based on

- Type of current flow (operating principle)
- Opposition to the current flow and as well as on number of current frequencies involved.

a. Depending upon type of current involved (Table 1)

Table 1

Direct current	Original Ohmmeters used by Suzuki and Sunada (1942)			
Alternating current	Resistance type	• Root canal meter/the endodontic meter (Onuki) • Sono explorer (Satelec) • Neosono-D, MC • Ultima EZ (Amadent) • Apex finder (EIE-old version)		
	Impedance type	Endocator uses 400 kHz		
	Frequency type	Subtraction type	Endex/Apex (Osada) uses 1kHz and 5kHz Neosono Ultima EZ (Amadent)	
		Ratio type	2 frequencies	Root ZX (J Morita) uses 0.4 kHz & 8 kHz
			5 frequencies	The AFA apex finder (Sybron) Elements Diagnostic unit (Sybron)

b. Resistance type apex locators (Table 2): These apex locators has a built in resistance value of 6.5 kilo Ohms. The apex locators are attached to the patient's 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.[5]

Table 2

Apex locator	Advantages	Disadvantages
Resistance type	• Easy to operate • Uses K-type files • Digital readout • Detects perforations • Built in pulp tester	• Requires a dry environment • There should be no caries or defective restorations • Requires calibration • Requires a lip clip with good contact • Patient sensitivity • Perforations can give false readings • Contraindicated in patients with pacemakers

c. **Impedance type apex locator** (Table 3)**:** Operate 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 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.[5]

Table 3

Apex locator	Advantages	Disadvantages
Impedance type	• Operate in fluid environment • Analogue meter • No patient sensitivity • Operated with RC Prep • No lip clip • Detect bifurcated canals • Detect peroration	• Requires calibration • Requires coated probes • No digital readout • Difficult to operate

d. Frequency dependant apex locators (Table 4): Operate very similarly to the impedance type because it measures the impedance of tooth at two different frequencies. In the coronal portion of the canal, the impedance difference between the frequencies is constant. As the file advanced apically, the difference in the impedance value begins to differ greatly with maximum differences at the apical area.[5]

Table 4

Apex locator	Advantages	Disadvantages
Frequency type	• Easy to operate • Operates in fluid environment • Operates with RC prep • Low voltage electrical output	• Must calibrate each canal • Sensitive to canal fluid level • Needs fully charged battery

Classification according to Generations of EALs (Evolution of EALs) -

1. **First Generation Electronic Apex Locators (1st GEALs)** (Resistance Type)**:** These are also known as Resistance Based Apex Locator, measures opposition to the flow of direct current or resistance. These devices were found to be unreliable when compared with radiographs, with many of the readings being significantly longer or shorter than the accepted working length.[5]

The Root Canal Meter (Onuki medical Co. Japan) (Fig. 2) was developed in 1969. It used the resistance method and alternating current of 150 Hz sine wave. Pain was often felt due to high current in the Endodontic Meter and the Endodontic Meter S II (Onuki medical Co. Japan) which used a current of less than 5 um. Other devices in the first generation include the Dentometer (Dahin Electro medicine, Denmark) and the Endo Radar (Electronica Liarre, Italy).[5,7] It was not as popular as it gave inaccurate readings in wet canals, obstructed canals, in carious/ defective restorations, in case of perforations and in patients with cardiac pacemakers. Also when the instruments came in contact with metallic restorations, false readings observed.[1,5]

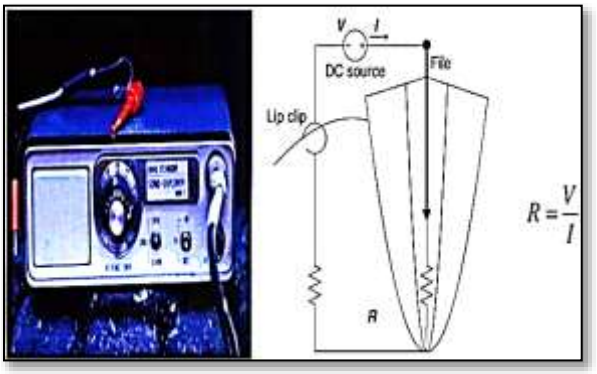

Fig. 2: Root Canal Meter

2. **Second Generation Electronic Apex Locators (2nd GEALs) (**Impedance Type): Second generation apex locators are impedance type operates on the principle that there is electrical impedance across the wall of the root canal due to the presence of transparent dentin. The tooth exhibit increase in electrical impedance across the walls of the root canal, which is greater apically than coronally. At the cemento-dentinal junction the level of impedance drops dramatically.

The change in frequency method of measurement of root canal was developed by **Inoue** in 1971 as the Sono-Explorer (Hayashi Dental Supply, Japan) which calibrated at the periodontal pocket of each tooth and

measure the feedback of the oscillator loop. A later method, the Sono-Explorer M-III uses a meter to indicate distance to apex.[8] With an electrode connected to the dental chair and a sheath over the probe it was able to make measurements in canal even with conductive fluids present.[1,8]

An increasing number of second generation apex locators were designed and marketed but all suffered similar problems of incorrect readings with electrolytes in the canal and also in dry canals. The Endo Analyzer (Analytic/ Endo, Orange, USA) (Fig. 3) is self calibrating with a visual indicator but have had variable reports of accuracy.[1]

A major disadvantage of these devices was that of electro-conductive materials gives inaccurate readings. The root canal has to be free of electro-conductive materials to obtain accurate reading.[9] Also they required calibration and complicated calculations, required coated probes instead of normal endodontic instrument, no digital readout was present and it was very difficult to operate.[10] The sheath caused problems because it would not enter narrow canals, could be rubbed off and was affected by autoclaving.[1,5]

Fig. 3: Endoanalyzer

3. **Third Generation Electronic Apex Locators (3rd GEALs)** (Frequency dependent comparative impedance Type): Third generation EALs are similar to the 2nd generation EALs except that they use multiple frequencies to determine the distance from the end of the canal. These units have more powerful microprocessors and are able to process the mathematical quotient and algorithm calculation required to give accurate readings. Since the impedance of given circuit may be substantially influenced by the frequency and the current flow, these devices have been called "Frequency Dependent"

In Europe and Asia, this device is available as the Apit or Endex/Apit –Endex (Osada, Japan) (Fig. 4 a). The device operates most accurately when the canal is filled with electrolyte such as saline or sodium hypochlorite. The disadvantage of this device needs "reset" or "calibrated" for each canal.[1,3]

The Root ZX (J. Morita Japan) (Fig. 4b) is a 3rd generation EAL that uses dual-frequency and comparative impedance principle, was described by **Kobayashi**. The electronic method employed was the "ratio method." It simultaneously measures two impedances at two frequencies (8 kHz and 0.4 kHz) inside the canal. The Root ZX mainly detects the change in electrical capacitance that occurs near the AC. The advantages of the Root ZX are that it requires no adjustment or calibration and can be used when the canal is filled with strong electrolyte or when the canal is "empty" and moist.[1,3,10]

There is several other 3rd generation EALs in use worldwide. These include-

1. Justy II (Yoshida Co., Japan)
2. Apex Finder AFA Model 7005 (EIE Analytic Endodontics, USA).
3. Apex Finder (Endo Analyzer 8001; Analytic Technology, USA).
4. Neosono-D (Amadent Medical and Dental, Co, USA)
5. Apit 7 (Osada, Japan).
6. ProPex (Dentsply-Maillefer, Switzerland)
7. Bingo 1020 (Forum Engineering Technologies)
8. Elements-Diagnostic (Sybronendo)
9. Raypex_5, VDW, Munich, Germany).

Fig. 4: a) Endex apex locator, b) Root ZX

4. **Fourth Generation Electronic Apex Locators (4th generation EALs)** (Ratio Type): These are Ratio Type apex locators which determine the impedance at five frequencies and have built in electronic pulp tester. These devices not process the impedance information as a mathematical algorithm, but instead take the resistance and capacitance measurement and compare them with a database to determine the distance to the apex of the root canal.

They are marketed by Sybron Endo and include the AFA Apex Finder and Elements Diagnostic Unit; also ROOT ZX II (Fig. V a) and PROPEX II (Fig V b) come under this category. It uses a composite wave form of two signals, 0.5 and 4 kHz, the signals go through a digital to analogue converter into an analogue signal, which then goes through amplification and then to the patient circuit model.[9]

A significant disadvantage of the fourth generation devices is that they need to perform in relatively dry or in partially dried canals. In some cases, this necessitates additional drying. Also in heavy exudates or blood it becomes inapplicable.[1,5]

Bingo 1020/Raypex (Forum Engineering technologies, Israel) claims to be a fourth generation device. This unit uses two separate frequencies 400 Hz and 8 KHz similar to the current third generation unit.[10]

Fig. 5: a) Root ZX II, b) Propex II

5. **Fifth Generation Electronic Apex Locators (5th GEALs)** (Dual Frequency Ratio Type): To cope with associated problems associated with previous generations of apex locators a new measuring method has been developed based on comparison of the data taken from the electrical characteristic of the canal and additional mathematical processing. And so the fifth generation apex locators (Dual Frequency Ratio Type) are now being used.

5th generation apex locators was developed in 2003 as E-magic Finder series. (Fig. 6). It measures the capacitance and resistance of the circuit separately. It is supplied by diagnostic table that includes statistic of the file. They have best accuracy in any root canal condition (dry, wet, bleeding, saline, EDTA, NaOCl).[11,12]

Devices employing this method experience considerable difficulties while operating in dry canals. During clinical work it is noticed that the accuracy of electronic root canal length measurement varies with the pulp and periapical condition.[5]

The device provides with a digital read out, graphic illustration and an audible signal. The built in pulp tester can be used to access tooth vitality.[5]

Fig. 6: E-Magic Finder

6. **Sixth Generation Electronic Apex Locators (6th GEALs)** (Adaptive Apex Locators): The efficacy of 6th generation EALs in long term use yet to be established. A major advantage of adaptive apex locator is eliminating necessity of drying and moistening of the canal.[5] Adaptive apex locators continuously define humidity of the canal and immediately adapts to dry or wet canal. This way it is possible to be used in dry or wet canals, canals with blood or exudates.[10]

Other uses of Electronic Apex Locators-

Other uses of apex locators are-

- To detect root perforations to clinically acceptable limits
- Determine the location of root and pulpal floor perforations[3]
- To detect horizontal fractures
- To confirm suspected periodontal or pulpal perforations during pinhole preparation
- Recognize any connection between the root canal & periodontal membrane such as root fracture, cracks & internal or external resorption.

Some have ability to detect vitality of the tooth, also helpful in root canal treatment of teeth with incomplete root formation, requiring apexification & to determine working length of primary teeth.(2)[13,14]

Combination of EALs & electronic handpiece (Ex. Root Zx II) are also becoming common and are able to achieve excellent result with same accuracy as the stand alone units.[15]

Problems associated with the use of apex locators

- The majority of present generation apex locators are not affected by irrigants within the root canal and the Root ZX has been found to be more accurate in the presence of sodium hypochlorite.[16]
- Intact vital tissue, inflammatory exudates and blood can conduct electric current and cause inaccurate readings so their presence should be minimized before accepting apex reading.[1,3]
- Canal shape, Lack of patency, the accumulation of dentine debris and calcifications can affect accurate working length determination with electronic apex locators.

- It has been suggested that prefacing of root canals as used in modern crown-down preparation techniques would increase the accuracy of reading.[1,10]
- Electronic apex locators have the potential to interfere with cardiac pacemakers. The manufacturer of electronic apex locators specifically warns against their use with patients with cardiac pacemaker. As there are many therapeutic uses and types of pacemakers some may not be influenced by apex locator use.[1,17]

Clinical acceptance

Use of the electronic apex locators to determine working length has still not gained worldwide acceptance. This may be due to early devices which suffered from poor accuracy and did not function properly in the presence of common irrigants. Cost of the instruments and lack of exposure to the technology by the operator are also factors.[1]

The use of apex locators alone without a preoperative and postoperative radiograph is not a recommended practice due to the large variation in tooth morphology and medico-legal record keeping requirement.

Conclusion

No individual technique is truly satisfactory in determining endodontic working length. Modern electronic apex locators can determine this position with accuracies of greater than 90% but still have some limitations. Knowledge of apical anatomy, prudent use of radiographs and the correct use of an electronic apex locators are user friendly, less time consuming and reliable in most of the clinical situations. Though at this stage apex locators cannot replace radiographs, but will definitely serve as an effective adjuvant.

References

1. M.P.J. Gordon & N.P. Chandler, "Electronic Apex Locators. Review" International Endodontic Journal (2004) 37, 425-437.
2. Nekoofar et al, "The Fundamental Operating Principles of Electronic Root Canal Length Measuring Devices." International Endodontic Journal (2006) 39, 595-609.
3. A.K. Ebrahim, R. Wadachi and H. Suda, "Electronic Apex Locators – A Review." J Med Dent Sci. (2007) 54, 125-136.
4. Fouad AF. Reid LC," Effect Of Using Electronic Apex Locators On Selected Endodontic Treatment Parameters." Journal of Endodontics (2000) 26, 364-367.
5. Sonal Soi. Sumit Mohan, Vineet Vinayak, Prabhjot Kaur, "Electronic Apex Locators" Journal of Dental Sciences & Oral Rehabilitation (2013) Jan-March, 24-27.
6. Mc. Donald. NJ, "The Electronic Determination of Working Length." Dent. Clin North. Am (1992) 36, 293.
7. Tidmarsh BG, Sherson W, Stalker NL, "Establishing Endodontic Working Length: A Comparison of Radiographic and Electronic Methods." N Z Dent J. (1985) 81, 936.
8. Inoue N. Skinner DH, "A Simple & Accurate Way to Measuring Root Canal Length." Journal of Endodontics (1985) 11, 421-427.
9. AF, Krell KV Fouad "An in Vitro Comparison of Five Root Canal length measuring Instruments." Journal of Endodontics (1989) 15, 557.
10. Ashish Kalhan, Ronak Choudhary, Shraddha Chokshi, Rupal Vaidya, "Evolution of Apex Locators." The Journal of Ahmedabad Dental College and Hospital. (2010.) 1 (1), Mar-Aug, 4-7.
11. Salvcho Dimitrav, Dimitur Rashkev, "Sixth Generation Adaptive Apex Locator." Journal of IMAB (annual proceeding scientific papers) (2009) Book 2.
12. Kovacevic M. Tamarut T, "Influence Of The Concentration Of Ions And Foramen Diameter On The Accuracy Of Electronic Root Canal Length Measurement- An Experimental Study." Journal of Endodontics (1998) 24, 346-351.
13. Kaufman A, "The Sono-Explorer as an Auxiliary Device in Endodontics." J Dent Med (1976), 25-27.
14. Hulsmann M. Pieper K, "Use of Electronic Apex Locators in the Treatment of Teeth with Incomplete Root Formation." Endod Dent Traumatol (1989) 5, 238.
15. Steffen H., Splieth CH, Behr K, "Comparison of Measurement Obtained with Hand File or the Canal Leader Attached to with Apex Locators: An in vitro study." Int. Endod J (1999) 32, 10-37.
16. Tinaz AC, Sevimli LS, Görgül G, et al, "The effects of sodium hypochlorite concentrations on the accuracy of an apex locating device." Journal of Endodontics (2002) 28, 160-162.
17. Woolley LH, Woodworth J, Dobbs JL "A preliminary evaluation of the effects of electrical pulp testers on dogs with artificial pacemakers." Journal of the American Dental Association. (1974) 89, 1099–1101.