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A review on Electronic apex locators

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Abstract

For the success of an endodontic therapy proper cleaning and shaping, disinfection and three dimensional obturation is necessary. To achieve this working length has to be precise. In modern endodontics, electronic apex locators have a high accuracy in determining the working length and its use have become an integral part of the endodontic therapy. This article aims to briefly explain electronic apex locators.

Keywords: Electronic apex locator, working length

Introduction

For a successful endodontic therapy, the pulp tissue, necrotic material and microorganism has to be removed from the root canal space throughout its entire length within the canal followed by canal disinfection and three-dimensional filling to prevent reinfection. The working length plays an important role for the success of endodontic therapy.[5] According to the glossary of endodontic terms, working length has been defined as the distance from a coronal reference point to the point at which the canal preparation and obturation should terminate.[3] Endometrics is the science of determining working length in endodontics and it holds a high significance in the success of endodontic therapy.[9] A correct working length will reduce the occurrence of procedural errors, damage to the periapical tissues and endodontic failures due to over-extension or under-extension of the root canal filling material.[4, 1]

Initially the position of termination of root canal space preparation and obturation was determined using radiographs, tactile sensation and by using paper points. But it was difficult to locate the apical constriction as its

location was highly variable. [3, 5] Since the invention of Electronic Apex Locator (EAL), the working length has been more definite, exact and predictable in verifying the apical limit of the root canal space and the position of canal terminus.[3, 1] The term "apex locator" is a misnomer. It attempts to locate the apical constriction, the cemento-dentinal junction, or the apical foramen and is not capable of routinely locating the radiographic apex.[11] The canal terminus is detected by an EAL by measuring the electrical properties of the tooth such as resistance and impedance.[5]

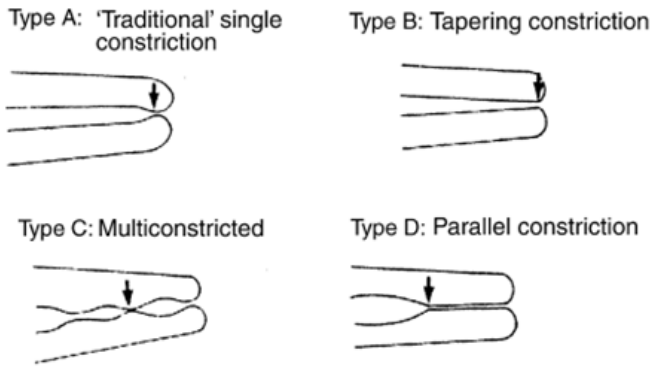
Factors that do not interfere with the working length measurements include gender, age, tooth type, presence of apical pathology, intracanal humidity, and the type of apex locator. Factors that may have influence in the working length measurements include pulp diagnosis and endodontic retreatment.[6] This article is aimed at briefly explaining electronic apex locators.

Anatomy of the root canal terminus

To understand how an electronic apex locator works, one must have an understanding of the anatomical features of the apical terminus.[1]

Grove in 1930 stated that the root canal has to be filled till the junction of the dentin and cementum and the pulp has to be cut at the point of its union with the periodontal membrane. The cementodentinal junction (CDJ) is the anatomical and histological landmark where the pdl begins and the pulp ends.[8] According to Kuttler in 1955, the root canal has a longer conical section which has dentin and a shorter funnel shaped section consisting of cementum at the apical portion. The apical portion is an inverted cone with the apex as the minor foramen and base as the major apical foramen. The minor foramen is thought to coincide with apical constriction. The apical area of the root canal has an hour glass appearance.[10]

The apical constriction is the narrowest part of the root canal which forms the border between dental pulp and periodontal area. It has the smallest diameter and the preparation to this point will cause a small wound site with optimal healing conditions. It is a more consistent anatomical feature and thus a preferred landmark for the apical end point for root canal treatment. Its anatomy changes with age. Its location varies from root to root and its relationship with the cementodentinal junction also varies. The cementdentinal junction can be higher on one wall compared to the opposite wall. [8, 10] The apical constriction is classified into 4 distinct types by Dummer et al (1984), and it was thought that it would lead to under-preparation in type B and over-preparation in type D. [8]



Topography of apical constriction (Dummer et al. 1984)

If the working length is overextended and if sealer or gutta-percha extends beyond the minor apical diameter, it will damage the periapical region and cause severe inflammatory reaction without the presence of pain. [8,7] If the working length is underestimated, the root canal will not be cleaned effectively and it may lead to the failure of the endodontic therapy.[7]

Significance of working length [11]

1. It determines how far into the canal the instruments can be placed and worked.
2. The degree of pain and discomfort which patient will experience following appointment by the virtue of

over or under instrumentation is affected by working length.

3. It plays an important role in determining the success of treatment if placed within correct limits.
4. When working length is short, it leads to apical leakage and thus poor success rate.

Methods of determining working length [11]

a. Radiographic method

1. Grossman's Method
2. Ingle's Method
3. Kuttler's Method
4. Best's Method
5. Bregman's Method
6. Bramante's Method
7. X-ray Grid System
8. Xero Radiography
9. Direct Digital Radiography

b. Non-radiographic method

1. Apex Finder
2. Audiometric Method
3. Tactile Method
4. Paper Point Evaluation Method
5. Electronic Apex Locators.

History of electronic apex locator [3]

- Custer (1918)- use of electric current for working length
- Suzuki (1942)- studied the flow of direct current through the teeth of dogs using clinical device.
- Gordon (1960's)- second to report use of clinical device for measurement of length.
- Sunada (1962)- (1st generation) Sunada adopted the principle reported by Suzuki and developed a basic device that used direct current to measure the working length. This device by Sunada became the basis for most EAL's
- Inove (1970)- significant contribution to the evolution of apex locators in North America-Sono Explorer
- Kobayashi (1980s)- developed a 3rd generation apex locator
- Pratten and McDonald (1996)- compared the efficacy of three parallel radiographs and Endex apex locators in Cadaver.
- 1997- (4th generation)- a cordless engine-driven canal preparation system with built in electronic canal measuring device (Root ZX) was introduced as Tri Auto ZX
- 2003- (5th generation) dual and multiple frequency
- 2009-2010- (6th generation) adaptive apex locators

Classification [3,5]

I. Based on the current involved

A. Based on direct current

Original ohm-meter used by Suzuki and Sunanda

B. Based on alternating current

1. Resistance type
2. Impedance type
3. Frequency type

a. Subtraction type

b. Ratio type

-2 Frequency

-5 Frequency

II. Based on generations

a. 1st generation
b. 2nd generation
c. 3rd generation
d. 4th generation
e. 5th generation
f. 6th generation

Components

- Lip clip

- File clip
- Electronic device
- Cord which connects above three parts

Mechanism of action

To complete a circuit the EAL uses the human body. Apex locator's circuit is connected to the oral mucosa through a lip clip on one side and the other side to a file. When the file is in the root canal and when it reaches the apical end, its tip touches the periodontal tissue at the apex causing the circuit to complete. Device show apex when resistance of EAL and the resistance between the file and oral mucosa are equal.[5] Depending upon the devices, this sudden current flow signaled by a beep, a buzzer, digital readout, flashing light or pointer on screen display.[3]

The tooth is compared to a capacitor. The dentine and cementum act as insulators of current and the periodontal ligament (PDL), the apical constriction and a file in the root canal are all conductors of electricity. An advancing file in the root canal and the PDL surrounding the radicular dentine will act as the conductors in a capacitor. The dentine, cementum and any associated fluid or tissue within the root canal will act as the insulator of the system. [1]

Uses of apex locator [5, 3]

Apex locators can be used to detect root perforations, suspected periodontal or pulpal perforation, horizontal or vertical root fractures and cracks. It has the ability to detect vitality of the tooth and diagnose external and internal resorption. It can be used in teeth with incomplete root formation which requires apexification and to determine working length in primary teeth. It can also be used to manage patients who are concerned about radiations.

Advantages [11]

Electronic apex locator can be used to measure the length up to the apical foramen, not to the radiographic apex. It is accurate, easy and fast. It reduces the x-ray exposure. Artificial perforation can be recognized. It can be used in pregnant women – no risk of radiation and in patient with gagging reflex. It can be used when dense zygomatic arch is over lapping the apices of upper molars, and when unerupted impacted tooth over shadows the apex and in patients who have a phobia of radiographic exposure.

Disadvantages [5]

A special device is essential; the electrical condition of the canal can affect the accuracy of the EAL. Difficult to determine working length in teeth with open apex and the results are very inconsistent in case of vital teeth.

Terminologies [1,10]

- Voltage (V): Also known as potential difference and is measured in volts
- Current (I): The movement of charged particles (electrons or ions) throughout a circuit and is measured in amperes.
- Direct current (DC): fixed amount of current per unit time
- Alternating current (AC): amount of current alternating over time.
- Resistance (R): opposition to direct current.
- Impedance: In a circuit that has both capacitors and resistors, the total amount of opposition to an alternating current is called impedance.
- Capacitor: An insulator placed between two conductive materials.
- Capacitance: The charge that a capacitor can accumulate.

First generation apex locator

They are also known as resistance-based apex locators since they measure the opposition to the flow of direct current.[5]

Advantages [3]

Easy to operate, uses K files, digital readout and built-in pulp tester.

Disadvantages [2,5,7,10]

Requires a dry environment since it is not accurate in presence of strong electrolytes, excessive hemorrhage, and pus or pulp tissue. As soon as the file tip touched an electrolyte, the direct current (DC) voltage would polarize the tissue, complete the circuit and incorrectly register that the PDLS had been reached. And it often causes an electric shock sensation to be felt by the patient. Files cannot contact the metal restorations, calibration is required, patient sensitivity-pain and discomfort was often felt with using this type of apex locator. Perforations can give false reading. Unreliable when compared with radiographs, as many readings were being significantly longer or shorter than the accepted working length. Inaccurate reading in patients with cardiac pacemakers

Examples: [5,7]

Root canal meter, Endodontic Meter S, Endodontic Meter S II, Dentometer, Endo Radar

Second generation

Also known as impedance apex locator since they measure the opposition to the flow of direct current.[9] Because of the transparent dentin it operates on the principle that there is electrical impedance across the walls of the root canal. Apically the electric impedance across the walls is more when compared to coronal part and at the dentinicemental junction the impedance reduces drastically. The unit detects the sudden change and indicates it on the analogue meter.[3]

Advantages [3]

Analogue meter, no patient sensitivity and detect perforations.

Disadvantages [10]

There is a need for individual calibration at the periodontal sulcus in each tooth. The technique involved inserting a file with a silicon plastic-sheath into the gingival crevice of the tooth to be measured and the sound produced was named the ‘gingival crevice sound’. This is followed by placing the endodontic file in the root canal and when the sound produced by the file and the gingival crevice is the same, the rubber stopper was placed in line with the reference point, and the readings taken.

Canals should be dried, since the electro-conductive materials in canal affects its accuracy.[7] Also they required coated probes instead of normal endodontic instrument, no digital readout was present and it was very difficult to operate. The sheath caused problems because it would not enter narrow canals, could be rubbed off and was affected by autoclaving.[3]

Examples [7]

Sono-Explorer, Endo Cater, DigipexI,II,III, Exact-A-Pex, Formatron IV, Endodontic Meter S II, Sono-Explorer Mark II, Sono-Explorer Mark II Junior, Apex Finder

Third generation

They are also known as high frequency apex locators. They differ from the 2nd generation apex locators as they utilize multiple frequencies to determine working length. They have powerful microprocessor and they use multiple frequencies. The microprocessors give accurate readings. They are based on the principle of comparative impedance.[8]

The Root ZX (J. Morita, Tokyo, Japan) (Kobayashi & Suda 1994). Kobayashi et al. (1991) introduced the ratio method. The ratio method works on the principle that two electric currents with different sine wave frequencies will have measurable impedances that can be measured and

compared as a ratio regardless of the electrolyte in the canal. Root ZX works on the basis of change in electrical capacitance. Root ZX does not require any adjustment or calibration and works in the presence of a strong electrolyte or when the canal is empty and moist. Root ZX has been found to be more accurate in the presence of sodium hypochlorite even when the file was much smaller than the diameter of the canal. Root ZX could be used to determine the working length in teeth with apical root resorption. [4,8]

Advantages [3]

Easy to operate, operates in fluid environment, low voltage electric output.

Disadvantages [7]

Must calibrate each canal, sensitivity to canal fluid level and needs a fully charged battery.

Examples [4]

Justwo or Justy II, Mark V Plus, Endox, Endy, Apex Finder AFA Model 7005, Apex Finder, Neosono-D, Neosono Ultima EZ, Apex NRG, Apit 7, Neosono MC, NovApex, ProPex, Bingo 1020, Elements-Diagnostic, Raypex 5

Fourth generation

They are also known as ratio type apex locators. They determine the impedance at five frequencies. They have a built-in electronic pulp tester. To determine the distance to the apex of root canal, these devices take the resistance and capacitance measurement and compare them with a database.[5]

Disadvantage [5]

Does not work in presence of heavy exudate or blood and needs completely or partially dry canals.

Examples [7]

Bingo1020, Raypex4, Element Dianostic Unit & Apex Locator, Neosono MC, Propex, Novapex, Apex NRG XFR, Apex DSP, AFA Apex Finder, Model 7005, iPex, Romi Apex D-30.

Fifth generation

Dual Frequency Ratio Type; developed in 2003 as E-magic Finder series. The capacitance and the resistance of the circuit is measured separately. Their accuracy in any root canal condition is the best. It is supplied by diagnostic table that includes the statistics of the values at different positions to diagnose the position of the file. [3,11]

Advantages: It is not affected by root canal conditions (dry, wet, bleeding, saline, EDTA, NaOCl. [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.[3]

Disadvantages: Difficulties while operating in dry canals.[3]

Examples [7]

Propex II, Top of Form Bottom of Form Apex Locator Joypex 5, I-ROOT (E-Magic Finder), Raypex 5.

Sixth Generation

Known as adaptive apex locators. It combines the advantages of fourth and fifth generation. The method of measuring the working length depends on canals moisture characteristics. Due to modern technology, the sixth-generation adaptive apex locator is a pleasant, small-sized device no larger than a dentist's palm.[5]

Advantage: Eliminates the need for drying and moistening the canal. 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.[3]

Combination of EAL and Handpiece

The cordless Tri Auto ZX now recently known as Dentaport ZX is an endodontic handpiece with a built-in apex-locator, providing the capability to monitor the root canal before, during and after instrumentation

electronically. It offers control and flexibility with the adjustable torque settings and also versatility is provided by having choice of both automatic or manual mode operations.[5] It has additional safety features such as auto-reverse when working length is reached.[8]

Advantages: Accurate, lightweight & portable handpiece, excellent torque for instrumentation and no zero adjustment.[5]

Disadvantages: Inaccurate readings during automatic mode operation, necessitate use of 30-mm long files many times, manual mode button is difficult to activate.[5]

Problems faced with the use of EAL [8]

1. The presence of blood, exudate and intact vital tissue can conduct electricity. They will cause inaccurate readings, so their presence should be reduced before accepting apex readings. Restorations, caries, saliva can cause short circuiting.
2. Lack of patency and calcifications can affect accurate working length determination with electronic apex locators and it has been suggested that preflaring of root canals would increase the accuracy of readings.
3. Dentin debris can derange the electrical resistance between the canal and the pdl. Continual recapitulation and constant irrigation ensure that the readings of the EAL is correct.
4. In an immature tooth or a tooth with 'blunderbuss' apices, the working length given by the EAL is short because the instrument is loose within the canal and does not touch the dentinal walls.
5. If the size of the major foramen is more than 0.2mm the EAL showed that the distance from the foramen increased.

Problem solving: [5]

1. Unstable electronic signal and rapid wandering signs

   The reasons could be

   a) File touching the metallic restoration- remove the metallic restoration
   b) Cervical leak through subgingival caries- blow air onto the wet chamber
2. Apex Sign from the beginning

   The reason could be that there is too much electrolyte in the canal- need to be blot dried
3. Sharp drop of the signal at the apical foramen

   The reason could be

   a) Very dry canal- gentle irrigation of the canal
   b) When file is at the extremely dry point there is little or no electric contact even at high frequencies- the operator must carefully judge the appropriate position by sharp dropping.

Tips for clinical success[2]

1. Before using an EAL, a preoperative radiograph has to be taken.
2. Metallic restoration should be removed from the access cavity to prevent electric shunting
3. The presence of irrigating agents does not impact the performance of 3rd and 4th generation EAL
4. The endodontic file should contact the walls of the canal and the accuracy of the EAL is not affected by the metal the file is made up of.
5. Advance the file till the apex reading is shown and then subtracts 0.5mm from the working length.
6. The working length has to be rechecked after preparing the coronal 2/3rd.
7. If a perforation is present, a contact with the pdl will complete the circuit.
8. The apex reading is only accurate if the visual analogue is stable and move in coordination with the

movement of the file. If it flashes intermittently, moves erratically or displays no bars at all the reading should not be accepted.

Conclusion

To determine the accurate working length is very difficult and more than one technique is needed to obtain the correct working length. The use of radiographs along with EAL is recommended. The contemporary EAL have more than 90% accuracy with some limitations hence the practitioner should have a proper knowledge of the apical anatomy. It is recommended to invest in a 3rd or 4th generation EAL, since they are more accurate.

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