Electronic Apex Locators – A Review

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Abstract

The establishment of a correct working length is one of the fundamental parameters for endodontic success. Traditionally this has been determined using radiography, but electronic apex locators are increasingly being used. Electronic apex locators reduce the number of radiographs required and assist where radiographic methods create difficulty. The use of an electronic apex locator in combination with the radiograph is greater precision in the determination of root canal length. The aim of this paper is to review the electronic determination of the length of the root canal.

Introduction

The success rate of conventional root canal treatment is predictably high, as long as the basic principles of endodontic treatment are followed. Accurate determination of root canal length is particularly important to the success of root canal treatment: cleaning, adequate shaping and complete filling of the root canal system cannot be accomplished unless the correct working length is established, and if the canal length is known, damage to the periapical tissues and procedural accidents such as ledging, zipping, elbow formation, etc. can be avoided by confining instruments and root filling materials within the root canal system[1].

The radiograph is one from the traditional method for the determination of the root canal length, but it is difficult to achieve accuracy of canal length because the apical constriction (AC) cannot be identified, and variables in technique, angulations and exposure distort this image and lead to error[2]. Thus, in addition to radiographic measurements, electronic root canal working length determination has become increasingly important.

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Electronic apex locators (EALs) have been used clinically for more than 40 years as an aid to determine the file position in the canal. These devices, when connected to a file, are able to detect the point at which the file leaves the tooth and enters the periodontium. An electronic method for root canal length determination was first investigated by Custer[3]. In 1962, Sunada[4] constructed the first EAL. Since then, different generations of EALs have been developed to measure root canal length[5]. It is most important advantage over radiography is that it can measure the length of the root canal to the end of the apical foramen (AF), not to the radiographic apex[6].

DETERMINATION OF THE WORKING LENGTH

The cemento-dentinal junction (CDJ), where the pulp tissue changes into the apical tissue, is the most ideal physiologic apical limit of the working length. It is also is referred to as the minor diameter. However, the CDJ and minor constriction do not always coincide, particularly in senile teeth as a result of cementum deposition, which alters the position of the minor diameter. Therefore, setting the Apical Constriction as the apical limit of the working length, where it is easy to clean and shape or obturate the canals, is recommended[7].

The major AF is not always located at the anatomical apex of the tooth. The AF may be located to one side of the anatomical apex, sometimes at distances of up to 3.0 mm in 50-98%. Kuttler reported that the distance between the AC and the AF is 0.659 mm in adults, whereas it is 0.524 mm in young people[8] (Figure 1)

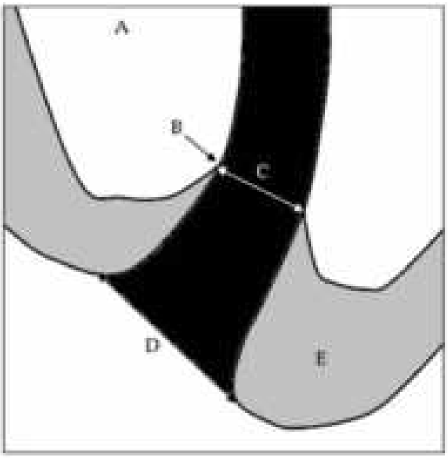

Figure 1: Anatomy of the root apex (A) dentin, (B) cemento-dentinaljunction (CDJ), (C) minor foramen (AC), (D) major foramen (AF) and (E) cementum

1. Determination of the working length using radiography

The working length is most commonly determined using radiography. The practitioner places an endodontic instrument into the root canal to the depth corresponding roughly to the AC, and then a radiograph is taken. The working length is considered to be between 0.5 and 1.0 mm from a radiographic profile of the apex. A radiograph for root canal length determination has been reported to be accurate in only 80% of cases.

Currently, direct digital radiography has not been shown to exceed conventional radiograph in quality, even with enhancement and measuring features, but is useful for it is speed and lower doses of radiation. This innovation was achieved because new hardware and software was available to evaluate the metrical data created by micro CT, thus allowing geometrical changed in prepared canals to be determined in more detail[9,].

2. Determination Of The Working Length Using Electronic Apex Locators

History of Electronic Apex Locators

Although the term "apex locator" is commonly used and has become accepted terminology. Some authors have used other terms to be more precise such as electronic root canal length assuring instruments[10] or electronic canal length measuring devices. These devices all attempt tolocate the apical constriction, cement-dentinal junction, or the apical foramen. They are not capable of routinely locating the radiographic apex.

In 1918, Custer[3] was the first to report the use of electric current to determine working length. In 1962, Sunada[4] reported that there is a constant value (6.5 k&!) of the electrical resistance between the mucous membrane and the periodontium, and he stated that it is possible to use this value of resistance in the estimation of the root length. The device by Sunada in his research became the basis for most EALs[4].

How to measure the root canal by using EAL?

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

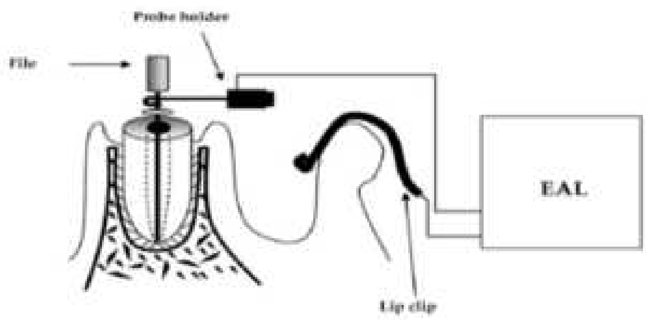

Fig. 2. Typical circuit for electronic determination of working length

There is evidence that electronic devices measure mainly the impedance of the probing electrode (contact impedance with the same fluid) rather than tissue impedance itself. In 1987, Huang[11] reported that the principle of electronic root canal measurement could be explained by physical principles of electricity alone. On the other hand, Ushiyama and colleagues presented the "voltage gradient method" that could accurately measure working length in root canals filled with electrolyte. A major disadvantage with this method was that it used a special bipolar electrode that was too large to pass into narrow root canals.

CLASSIFICATION AND ACCURACY OF ELECTRONIC APEX LOCATORS

1. First Generation Electronic Apex Locators (1GEALs)

First-generation EAL devices, also known as resis-tance apex locators, measure opposition to the flow of direct current or resistance. When the tip of the file reached the apex in the canal, the resistance value is 6.5 k&![4]. The disadvantage of 1GEAL devices is the pain was often felt due to high electric currents. Today, most 1GEAL devices are out of the market.

Example: 1. Root canal meter (Onuki medical Co.tokyo, Japan)

2. Dentometer (Dahlinectromedicine, Copenhagen, Denmark)

2. Second Generation Electronic Apex Locators (2GEALs)

Second-generation EALs, also known as impedance apex locator, measure opposition to the flow of alternating current or impedance. The major disadvantage of 2GEALs is that the root canal has to be reasonably free of electroconductive materials to obtain accurate readings. The presence of tissue and electroconductive irrigants in the canal changes the electrical characteristics and leads to inaccurate, usually shorter measurements

Examples : 1. Foramatron IV (Parkell Dental, Formingdale, New York, USA).

2. Digipex I, II, III (Mada Equipment Co., Carlstadt)

3. Third Generation Electronic Apex Locators (3GEALs)

Third-generation EALs 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 calculations required to give accurate readings.

Example : 1. Root ZX (J.Morita, Tokyo, Japan)

2. Mini Apex Locator (Sybron Endo, Anaheim, CA, USA)

4. Fourth Generation Electronic Apex Locators (4GEALs)

Fourth generation apex locators using two or more non-simultaneous continuous frequencies in order to measure the difference or ratio between two currents

Examples: 1. Propex II (DentsplyMaillerfer, Ballaiques, Switzerland)

2. I-ROOT (E-Magic Finder)(S-DentiSEoul, South Korea)

5. Fifth Generation Electronic Apex Locators (3GEALs)

Fifth generation apex loctors measures the capacitance and resistance of the circuit separately

Examples: 1. Apex Locator Joypex 5 (Henan, CBD Neihuan Road, Zhengzhou, China)

2. Raypex 5 (VDW, Munich, Germany)

COMBINATION OF APEX LOCATOR WITH ENDODONTIC HANDPIECE

The Root ZX has been combined with a handpiece to measure canal length when a rotary file is used. This is marked as the Tri Auto ZX (J. Morita Co., Kyoto, Japan). The handpiece uses nickel-titanium rotary instruments that rotate at 240 to 280 rpm. Kobayashi et al. suggested that "to get the best results, it may be necessary to use some hand instrumentation" in combination with the Tri Auto ZX, depending on the difficulty and morphology of the root canal being treated. The Tri Auto ZX has a reported accuracy similar to the Root ZX of 95%. Alves et al. evaluated *in vitro* the capacity of the Tri Auto ZX to locate the AF following removal of root filling material during root canal treatment. They found that the Tri Auto ZX was accurate to 0.5 mm in more than 80% of teeth when used following removal of root filling.

Recently, the Dentaport ZX (J. Morita Co., Kyoto, Japan and J. Morita Mfg. Co., Irvine, California, USA) was introduced to the Japanese and United States markets . The Dentaport ZX is comprised of two modules: the Root ZX and the Tri Auto ZX. The handpiece uses nickel-titanium rotary instruments that rotate at 50 to 800 rpm.

Other apex-locating handpieces:

1. Kobayashi et al. reported the development of a new ultrasonic system called SOFY ZX (J. Morita Co., Kyoto, Japan), which uses the Root ZX to electronically monitor the location of the file tip during all instrumentation procedures. The device minimizes the danger of overinstrumentation.
2. The Endy 7000 (Ionyx SA, Blanquefort Cedex, France) is available in Europe.

PROBLEMS ASSOCIATED WITH THE USE OF ELECTRONIC APEX LOCATORS

Most studies have reported that pulpal vitality or canal irrigants do not affect 3GEALs accuracy. Fan et al. used different diameters of glass tubules in their study to mimic root canals. When they filled the canals with less conductive elec-trolytes such as 3% hydrogen peroxide the accuracy of the real length 1.0 mm was 75–100% despite the increase in tubule diameter. When they filled the canals with strong electrolytes such as 0.9% saline solution, 2.5% sodium hypochlorite solution and 17% ethylenediamine tetraacetic acid (EDTA), the accuracy of the Root ZX decreased as the tubule diameter increased.

In 1962, Sunada suggested the possibility of using 1GEALs to detect root perforations[4]. It was later reported that 2GEALs could accurately determine the location of root or pulpal floor perforations. The method also aided in the diagnosis of external root resorption that had invaded the dental pulp space or internal root resorption that had perforated to the external root surface. Zmener et al. found that the Tri Auto ZX (3GEALs) was able to detect and measure endodontic root perforations within a range of clinically acceptable variations.

The electronic measured canal length (2GEALs) is adversely affected by different circumstances such as the diameter of the AF. In 1987, Huang[11] used 2GEALs and found that when the size of the major foramen was less than 0.2 mm measurements were not affected, even in the presence of conductive irrigants, but as it increased above 0.2 mm measured distances from the foramen increased. Stein et al. also concluded that as the width of the major foramen increased the distance between the file tip and the foramen increased. They found that in measuring the CDJ to the probe tip, 31 of the 47 canals (66%) were short of the CDJ. Measuring from the major foramen opening to the probe tip, 43 of the 47 canals (91%) were short of the major foramen opening. Ebrahim et al. evaluated four 3GEALs: Root ZX, Foramatron D10, Apex NRG and Apit 7, to determine the working length in teeth with various foramen diameters. They reported that as the diameter of the AF increased, the length measured with small size files became shorter. This suggests that the size of the root canal diameter should be estimated first and then a snugfitting file should be chosen for root canal length determination[12]. The four EALs were unreliable in determining the working length of teeth with a wide AF when using a small size file. The Root ZX and Foramatron D10 showed significantly better scores than the Apex NRG and Apit 7, and may be reliable todetermine the working length of teeth with a wide AF if a tight-fit file is used[13].

An *in vivo* study has evaluated the usefulness of an 2GEALs in endodontic treatment of teeth with incomplete root formation requiring apexification. They reported that in all cases, the Exact-A-Pex apex locator was 2 to 3 mm short of the radiographic apex at the beginning of apexification therapy. When the apical closure was complete, the EAL was then 100% accurate[14].

McDonald recommended the use of files with sizes comparable with the root canal diameter, claiming that this would result in more accurate readings. The length of the enlarged canals was measured using small-sized files and large size files matching the canal diameter. They found that the Root ZX was accurate even when the file was much smaller than the diameter of the canal and the measured lengths obtained with small and large size files were comparable[15]. Ebrahim et al. evaluated *in vitro* the effect of file size on the accuracy of Root ZX when sodium hypochlorite or blood was present during electronic measurements in enlarged root canals. They found that as the diameter of the root canal increased, the measured length with the smaller size files became shorter. A file of a size close to the prepared canal diameter should be used for root length measurement in the presence of blood, and possibly serum or pus. In the presence of sodium hypochlorite, the Root ZX was highly accurate even when the file was much smaller than the diameter of the canal[16].

An *in vitro* study evaluated the accuracy of the Root ZX in determining working length of primary teeth. Electronic determinations were compared with direct anatomic and radiographic working lengths. They reported that the electronic determinations were similar to the direct anatomic measurements (–0.5 mm). Radiographic measurements were longer (0.4 to 0.7 mm) than electronic determinations. An *in vivo* study, Kielbassa et al. reported that the Root ZX can be strongly recommended for clinical implementation of endodontics in primary teeth, particularly when treating fidgety children[17].

Nahmias et al. and Chong & Pitt Ford reported that if there is any connection between the root canal and the periodontal membrane, such as root fracture, cracks and internal or external root resorption, it would be recognized by the EALs. Azabal et al. found the Justy II apex locator (3GEALs) was able to detect simulated horizontal root fractures but was unreliable when measuring simulated vertical root fractures.

It does not appear that the type of alloy used in the instrument for length assessment affects accuracy, with the same measurements obtained in the same root canal using stainless steel and nickel-titanium instruments[18]. Nekoofar et al. evaluated the accuracy of Neosono Ultima EZ apex locator (3GEALs) using nickel-titanium and stainless steel files. The accuracy of the nickel-titanium and stainless steel was 94% and 91%, respectively, and there was no statistically signif-icant difference.

Lack of patency, the accumulation of dentin debris and calcifications can affect accurate working length determination with 2GEALs. It has been suggested that preflaring of root canals as used in modern crown-down preparation techniques would increase the accuracy of readings. This was found to be true for tactile sensation and accuracy with the Root ZX. Canal patency appears to be more important, as dentin debris may disrupt the electrical resistance between the inside of the canal and the periodontal ligament. Constant recapitulation and irrigation ensures accurate electronic length readings during instrumentation[19].

Pommer et al. compared *in vivo* the influence of the root canal status on the determination of the root canal length by an 3GEAL in vital and necrotic canals and canals with root canal obturation retrieval. They stated that the AFA Apex Finder is a reliable tool for determining the root canal length in vital and necrotic teeth, with an accuracy of 86% within 0.5 mm range of the radiographic apex. Goldberg et al. evaluated *invitro* the accuracy of three 3GEALs in determining theworking length of teeth during retreatment. They found that the ProPex, NovApex, and Root ZX were accurate within 0.5 mm 80%, 85%, and 95% of the time, and within 1.0 mm 95%, 95%, and 100% of the time, respectively.

APEX LOCATORS IN CARDIAC PACEMAKER

Electrical devices such as electric pulp tester, EALs, and electrosurgical instruments has been potential interfere with cardiac pacemaker. As there are many therapeutic uses and types of pacemakers some may not be influenced by electric pulp tester's use. A 1996 case reported on a patient with a fixed-rate cardiac pacemaker requiring root canal treatment. Under consultation with the patient's cardiologist, an EAL was used. The patient experienced no adverse effects immediately or with follow-up. In 2002, Garofalo et al. reported that four out of five 3GEALs tested with a single cardiac pacemaker showed normal pacing and only one produced an irregular pace recording on an oscilloscope[20]. Recently, Wilson et al. was determine *in vitro* if EALs or electric pulp testers interfere with the function of implanted cardiac pacemakers or cardioverter/defibrillators. They found that no evidence of any interference was encountered when the 3GEALs or electric pulp tester were used as described by patients with working, implanted cardiac devices. They concluded that EAL or electric pulp testers are safe for use in patients with cardiac pacemakers or cardioverter/defibrillators.

Conclusions

The EAL device has attracted a great deal of attention because it operates on the basis of the electrical impedance rather than by a visual inspection. EALs are particularly useful when the apical portion of the canal system is obscured by certain anatomic structures, such as impacted teeth, tori, the zygomatic arch, excessive bone density, overlapping roots, or shallow palatal vaults. In the presence of metallic restorations, severely undermined caries, serous, purulent or hemorrhagic exudates or when there are cracks, root fractures, internal or external root resorption, wide-canal, or a wide-open apex —a comparison of the EAL readings with the radiograph will assist practitioners to achieve predictable results.

References

1. Ingle J. Endodontic instruments and instrumentation. Dent Clin North Am 1957;1,805-815.
2. Katz A, Tamse A, Kaufman AY. Tooth length determination: a review. Oral Surg Oral Med Oral Pathol 1991;72:238-242.
3. Custer C. Exact methods for locating the apical foramen. J Nat Dent Assoc 1918;5:815-819.
4. Sunada I. New method for measuring the length of the root canal. J Dent Res 1962;41:375-387.
5. Gordon MPJ, Chandler NP. Electronic apex locators. In Endod J 2004;37:425-437.
6. Kobayashi C. Electronic canal length measurement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:226-231.
7. Kobayashi C, Suda H. New electronic canal measuring device based on the ratio method. J Endod 1994;20:111-114.
8. Kuttler Y. Microscopic investigation of root apexes. J Am Dent Assoc 1955;50:544-552.
9. Martinez-Lozano MA, Forner-Navarro L, Sanchez-Cortes JL, et al. Methodological considerations in the determination of working length. Int Endod J 2001;34:371-376.
10. Nahmias Y, Aurelio JA, Gerstein H. Expanded use of the elec-tronic canal length measuring devices. J Endod 1983;9:347-349.
11. Huang L. An experimental study of the principle of electronic root canal measurement. J Endod 1987;13:60-64.
12. Ebrahim AK, Yoshioka T, Kobayashi C, et al. The effects of file size, sodium hypochlorite and blood on the accuracy of Root ZX apex locator in enlarged root canals: an *in vitro* study. Aust Dent J 2006;51:153-157.
13. Ounsi HF, Naaman A. *In vitro* evaluation of the reliability of the Root ZX electronic apex locator. Int Endod J 1999;32:120-123.
14. Fouad AF, Krell KV. An *in vitro* comparison of five root canal length measuring instruments. J Endod 1989;15:573-577.
15. Arora RK, Gulabivala K. An *in vivo* evaluation of the ENDEX and RCM Mark II electronic apex locators in root canals with different contents. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:497-503.
16. Goldberg F, Marroquín BB, Frajlich S, et al. In vitro evaluation of the ability of three apex locators to determine the working length during retreatment. J Endod 2005;31:676-678.
17. Kielbassa AM, Muller U, Munz I, et al. Clinical evaluation of the measuring accuracy of Root ZX in primary teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;95:94-100.
18. Thomas AS, Hartwell GR, Moon PC. The accuracy of the Root ZX electronic apex locator using stainless-steel and nickel-tita-nium files. J Endod 2003;29:662-663.
19. Rivera EM, Seraji MK. Effect of recapitulation on accuracy of electronically determined canal length. Oral Surg Oral Med Oral Pathol 1993;76:225-230.
20. Garofalo RR, Ede EN, Dorn SO, et al. Effect of electronic apex locators on cardiac pacemaker function. J Endod 2002;28:831-833.