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Advancement and role of electronic apex locators

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Abstract
The electronic apex locators are the devices that are used in measuring the working length of canal which is very much needed for root canal treatment in the practice of endodontics. Apart from this, they also play important role for other conditions of tooth. They have passed through the evolution from 1st generation to 6th generation with their own merits and demerits. These devices are very much needed before starting the treatment the root canal treatment in the practice of endodontics and reduce the requirement of taking multiple radiographs for the same. Though they can't replace radiograph for the purpose measuring working length with much accuracy but of course they do support to a great extent for the same.

Keywords: Apex locator, RCT, working length (WL), generations

Introduction
One of the most important part of root canal treatment (RCT) is canal preparation, with removal of all soft tissues and microorganisms from the root canal which can be accomplished by correct determination of the working length [1, 2]. Prior to RCT, at least one clear radiograph is required to assess canal morphology. It is here the electronic apex locators find their role to play and their proper usage reduces the number of radiographs required and assist where radiographic methods have difficulty [3]. Apart from this they also help in detection of root perforations, cracks, fractures resorption

The working length (WL) determination is one of the most important step of RCT, which determines the apical limit of cleaning and shaping and obturation which ensure that instruments during biomechanical preparation and filling, avoid injury to the periapical tissues [1, 2] The 7th edition of endodontic glossary of endodontic terms defines the working length as "the distance from a coronal reference to a point at which canal preparation and obturation terminates." [4] The accurate determination of WL prevents the over‐instrumentation/ over‐filling and under-instrumentation /underfilling of the root canal, and also leads to optimisation of healing of peri-radicular tissue [5].

Techniques to determine the working length (WL)
There are various techniques available, which are used to determine the real working length of the root canal but they have their own limitations e.g. digital sensitivity technique can not accurately locate the apical constriction because of the complex internal anatomy of root canals [6] and the radiographic techniques have certain disadvantages like distortion, overlapping, elongation, and interference of anatomical structures etc [7]. Therefore, the electrical property of tooth is now also being used to determine the same.

Electronic apex locator
It is an electronic device used in endodontics to determine the position of the apical constriction and length of the root canal space [8]. It determines the apical constriction on the basis of electrical properties of tooth like resistance, impedance, capacitance etc. and minimize the technical limitation of complex root canal anatomy [9]. Various studies have proposed that apex locators do the work more precisely than other techniques. Currently, these devices have gained much popularity in endodontics and are becoming indispensable in day to day clinical practice. They all are based on the assumption that human tissues consist of characteristics that can be used by a combination of electrical components and they work by establishing the

circuit, between the lip clip, placed on oral mucous membrane and endodontic file via the attached probe, which goes apically and touch the PDL [10].

Associated problems

The intact vital tissue, inflammatory exudates, blood, carries and saliva can conduct electric current and cause inaccurate readings and short circuiting. Further lack of patency, the accumulation of dentine debris and calcifications can affect accurate working length determination and immature or 'blunderbuss' apices tend to give short measurements.

Advancement of apex locator

The term electronic apical foramen locator or electronic root canal length measurement device is more appropriate [11, 12] than the electronic apex locator as it does not assess the position of the root apex. The idea of using electrical conductance to measure root length was first suggested by Custer (1918). Suzuki (1942) noticed a constant value of electrical resistance between an instrument in the root canal and an electrode on the oral mucous membrane and speculated for measurement of canal length. Sunada (1962) constructed a simple device that used direct current to measure canal length. The classification of apex locators was given by Mc Donald (1992) [9] on the basis of on-type of current flow and opposition to the current flow as well as number of current frequencies involved. These devices have undergone tremendous amount of changes through the time as described below;

1. First generation apex locator

These are resistance-based devices that work on the presumption that the circuit formed between the endodontic file at the apical constriction and the lip clip could be a simple resistive circuit. Thus, a small direct current is applied to that circuit and the voltage is measured. By using ohm's law resistance is calculated by dividing the value of the voltage by the value of the current. With the minor difference in the design of circuit and their display characteristics, many variants have been developed following the same principle.

The major disadvantage of first generation apex locators is that they are moisture sensitive and don't give accurate measurements in wet canal as they do in dry canal [13]. In the presence of electroconductive solution (electrolyte), before reaching the apical constriction and device incorrectly indicates that apical constriction has been reached [14]. Another disadvantage is that an electric shock can be felt by the patient [15].

2. Second generation apex locator

These are impedance and single frequency based and work on the principle of low frequency oscillation, as produced by the resistance and capacity between the oral mucous membrane and the gingival sulcus similar to the frequency between the periodontal ligament and the oral mucous membrane [16]. Based on this Inoue's developed a device, the Sono-Explorer that measures the impedance to locate the canal terminus .Further, another variant Endocater [17] introduced by Hasegawa *et al*. is capable in accurate measurement even in the presence of fluids in the canal. The major disadvantage is that they are moisture sensitive and give inaccurate readings with electrolytes in both the wet and dry canals

3. Third generation apex locator

These are either based upon differences between two frequencies/impedances e.g. endex/ apit or their ratio e.g. root zx. They contain a stronger microprocessor to process the mathematical quotient and algorithm which has been thought to give accurate readings. In reality the difference between voltages is measured inspite of impedance which is proportional to the voltage values. The endex /apit apex locator is able to give accurate readings even in the presence of electrolyte but have a disadvantage that it has to be calibrated while using in each canal. These apex locators can be used in determination of apical constriction even in wet canal, in vital pulp as well as in non-vital pulp [18].

There are several variants of 3rd generation of apex locators being used worldwide like Mark V Plus, Endox, Endy, Apex NRG, Apit7, Neosono MC, Nov Apex, ProPex, Bingo 1020, Raypex5 etc. These apex locators had the upper hand over their predecessors when compared in terms of accuracy as well as reliability. However, the disadvantage is that electro-conductive materials in the canal may affect its accuracy [19].

4. Fourth generation (ratio type) apex locator

They are ratio type apex locators which determine the impedance at five frequencies and have an inbuilt electronic pulp tester. They do 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 include the AFA Apex Finder, ROOT ZX II and PROPEX II and Bingo 1020 / Ray Pex 4 etc [10]. The RMS (Root Mean Square) level of the signal is measured, rather than its amplitude or phase. The RMS value is much more immune to various kinds of noises than other parameters of the measured signal. The apex locators of this generation, so far, are the best in their category owing to their high accuracy and reliability. For a clinician, looking for high accuracy and reliability in their WL determination, the fourth-generation apex locators would be the most ideal, for they can be trusted upon the most. However, in a study no significant level of difference was found in the accuracy of measurements between 3rd and 4th generations [20]. But low accuracy on working in wet canals have been reported in some studies.

5. Fifth generation apex locator

For these devices, a measuring method has been developed based upon comparisons of the data taken for electrical characteristics of the canal with the additional mathematical processing. They have increased in accuracy of determining the place of apical foramen by several per cent. Further, they perform very well in the presence of blood and exudate but they experience considerable difficulties in dry canals difficulty on working in dry canals and need compulsory, additional wetting. They were developed in 2003 as E-magic Finder series and measure the capacitance and resistance of the circuit separately. They have best accuracy in any root canal condition The Neosono-copilot is the most recent innovation in apex location in form of a combination of an electronic apex locator and pulp tester.

6th generation apex locator

These are the adaptive type of devices that provide for graphic information on colour multimedia displays. The prolonged direct and juxtaposing studies have made it possible to create a steady algorithm for adapting the method for measuring the working length of the root canal depending on the canal's moisture characteristics. The adaptive method has been implemented in such type of apex locators. They retrieve

audio information either through the familiar beeping signals typical of the 5th generation apex locators, or through sensible speech messages. The symbol of a moist canal is displayed means it is duly adapted to measure within liquid.The appearance of the message "apex" means that the tip of the instrument is between the physiological narrowing and the anatomical foramen. The message "over" means that the tip has passed through the anatomical foramen. The results of the experimental studies of extracted human teeth show that the adaptive apex locator combine the advantages of the measuring method of both fifth and fourth generations.

Within just a thousandth of the second, during the penetration of the tip of the canal instrument, precise measurement, mathematical analysis and determination of the canal moistness are performed. They have overcome the disadvantages of 4th generation for low accuracy on working in wet canals, as well the disadvantages of devices and that of 5th generation for difficulty on working in dry canals and necessarily of compulsory, additional wetting. They continuously define humidity of the canal and immediately adapt for dry or wet canal [8]. The clinical observations are yet to come to help the assessment of the device's ability to determine the working length of root canals under different conditions [20].

Multiple-function apex locators are becoming more common and several have vitality testing functions. Combination electronic apex locators and electric handpieces are also becoming common and are able to achieve excellent results with the same accuracy as the stand-alone units (Steffen *et al*. 1999). Kobayashi *et al*. (1996) reported the development of a combination ultrasonic unit the SOFY ZX (J. Morita) which uses the Root ZX to monitor file length. Other handpiece combinations are the Dentaport ZX (J. Morita) and the Endy 7000 (Ionyx SA, Blanquefort, France) [21].

Combination of Apex Locator with Endodontic Handpiece [8]

The Root ZX has been combined with a handpiece to measure canal length when a rotary file is used. The handpiece uses nickel-titanium rotary instruments that rotate at 240 to 280 rpm74. 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%.

Conclusion

The electronic apex locators have passed through successive stages of evolution with some improvements over the previous ones. Now the 6th generation of apex locators are in use that are vehemently supporting the root canal treatment in the practice of endodontics and conservative dentistry when it comes for measuring the working length of root canal. Though the presently used apex locators can determine the working length with high accuracy but there remain some inherent limitations with each generation of the apex locators. The knowledge of anatomy, prudent use of radiographs, experience of user in a correct manner, the electronic apex locators will help in most of the clinical situations but the technology never remains constant so next generations of electronic apex locators with further improvements are always welcome to support this practice.

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