EVOLUTION OF APEX LOCATORS

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ABSTRACT

Determining the root canal length accurately had been a challenge in endodontics. It is generally accepted that root canal treatment procedures should be confined within the root canal system. To achieve this objective the apical constriction must be detected accurately during canal preparation and precise control of working length during the process must be maintained. Several methods have been used for determining the apical constriction including electronic methods. Introduction of apex locators have definitely served as an effective adjuvant to radiographs. The basic fundamental opinion with all electronic length measuring devices is that human tissues have certain characteristics that can be modelled by combination of electronic components. Therefore, by measuring electrical properties of the model, such as resistance and impedance, it should be possible to detect the apical constriction 1. The development of the electronic apex locator has helped make the assessment of working length more accurate and predictable (Fouad & Reid 2000). This article reviews the historical development, functions, application and types of electronic apex locators.

Keywords:- apex locators, apical constriction, root apex, working length.

INTRODUCTION

Complete cleaning of the root canal is the most critical step for a successful endodontic therapy that cannot be accomplished unless an accurate working length is determined. Working length is defined as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate (American Association of Endodontists, 1998). 2

The determination of working length is of paramount importance so as to confine the instrumentation to the canal system (within apical constriction), to create and maintain an apical stop or seat at the minor constriction, to prevent under-instrumentation that could leave tissue and debris in the apical segment, and to prevent over-instrumentation which damages periapical tissue, extrusion of the debris and bacteria and their by-products which causes periapical pathology and finally discomfort to the patients.

Grove (1930) stated that "the proper point to which root canals should be filled is the junction of the dentin and the cementum and that the pulp should be severed at the point of its union with the periodontal membrane" 3.

The cementodentinal junction (CDJ) is the anatomical and histological landmark where the periodontal ligament begins and the pulp ends. Root canal preparation techniques aim to make use of this potential natural barrier between the contents of the canal and the apical tissues (Schilder 1967).

The traditional methods to determine working length are tactile sensation, radiographic interpretation, paper point determination, etc.

These methods alone are not accurate enough to determine the working length. The electronic apex locator is an instrument, which when used with appropriate radiographs, allows for much greater accuracy of working length control (McDonald 1992, Pratten & McDonald 1996, Segura-Egea et al. 2002) 4.

The aim of this article is to have an overview of the different types of apex locators, its evolution and the need for their use in endodontic treatment.

HISTORY OF APEX LOCATORS

An electronic method for root length determination was first investigated by Custer (1918). It was again emphasized by Suzuki in 1942 by studying the flow of direct current through the teeth of dogs. He found that...
electrical resistance between the periodontium and oral mucous membrane in dogs was a constant value. In 1960, Gordon was the second to report the use of a clinical device for electrical measurement of root canals. In 1962, Sunada using a direct current device with simple circuit demonstrated that consistent electrical resistance between periodontium and mucous membrane was 6.5 K ohms. Inoue made significant contributions to the evolution of apex locators in North America with his reports on the Sono-Explorer. In 1970s, frequency measurements were taken through the feedback of an oscillator loop by calibration at periodontal pocket depth of each tooth. In mid-1980s, there occurred the development of a relative value of frequency response method where apical constriction was picked by filtering the difference between the two direct potentials after 1 KHz wave was applied to canal space. A third generation EAL was developed in late 1980s by Kobayashi. He used multiple channel impedance ratio based technology to simultaneously measure the impedance of two different frequencies; to calculate the quotient of impedance and express it in terms of the position of electrode, that is, file in the canal.

**EVOLUTION OF DIFFERENT TYPES OF APEX LOCATORS**

The **first generation** apex locators (RESISTANCE TYPE) measure opposition to the flow of direct current or resistance. One end of the apex locator is attached to the patients lip and the other end is attached to the endodontic instrument. The instrument is then advanced into the canal until it touches the periodontal tissue at the apex which then completes the circuit. When the tip of the instrument reaches the apex in the canal, the resistance value is 6.5 kilo-ohms (current 40 mA).

Some of the devices that were used initially were Root Canal Meter/The Endodontic Meter (Onuki), Sono Explorer (Salatec), Neosono-D, MC, and Ultima EZ (Amadent), Dentometer (Dahlman Electromedicine, Copenhagen, Denmark) and the Endo Radar (Elettronica Liarre, Imola, Italy).

It was not so popular as it gave inaccurate readings in a wet canal, in obstructed canals, in carious/defective restorations, in case of perforations and in patients with cardiac pacemakers. Also when the instrument came in contact with metallic restorations, false readings were observed.

The **second generation** apex locators (IMPEDANCE TYPE) 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 cemento-dentinal junction (CDJ), the level of impedance drops dramatically.

Sono-Explorer (Hayashi Dental Supply, Tokyo, Japan), Endocate (Yamaura Seisokushu, Tokyo, Japan), Formatron IV (Parkell Dental, Farmingdale, NY, USA), Digipex II were some of the devices that came under this category.

A major disadvantage of these devices was that the root canal had to be free of electroconductive materials to obtain accurate readings. Also they required calibration and complicated calculations, required coated probes instead of normal endodontic instruments, no digital read-out was present and it was very difficult to operate.

The **third generation** apex locators (FREQUENCY DEPENDANT / COMPARATIVE IMPEDANCE TYPE) are similar to the second generation except that they use multiple frequencies to determine the distance from the end of the canal. 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”. These units have more powerful microprocessors and are able to process the mathematical quotient and algorithmic calculations required to give accurate readings. More appropriately, they should be termed as “comparative impedance” because they measure relative magnitudes of impedance that are converted into length information.

Various third generation apex locators include The Endex/Apit, The Apex Finder AFA (all fluids allowed), The Neosono Ultima EZ (Satelec Inc., Mount Laurel), Justwo or Justy II (Yoshida Co., Tokyo, Japan), Mark V Plus (Moyco/Union Broach, Bethpage, USA), Endy 5000 (Loser, Leverkusen, Germany), The Root ZX, Tri Auto ZX with integrated handpiece, and more recently as the Dentaport ZX.

The **fourth generation** apex locators (RATIO TYPE) determine the impedance at 5 frequencies and both have built-in electronic pulp testers. They are marketed by Sybron Endo and include the AFA Apex Finder and the Elements Diagnostic Unit.
Also, ROOT ZX II and PROPEX II come under this category.

These devices do not process the impedance information as a mathematical algorithm, but instead takes the resistance and capacitance measurements and compares them with a database to determine the distance to the apex of the root canal (Lively 2003, personal communication). It uses a composite waveform of two signals, 0.5 and 4 kHz. The signals go through a digital-to-analogue converter to be converted into an analogue signal, which then goes through amplification and then to the patient circuit model which is assumed to be a resistor and capacitor in parallel. The feedback signal waveforms are then fed into a noise reduction circuit. The manufacturer claims that this allows less sampling error per measurement and more consistent readings. 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, and with heavy exudate or blood the method becomes inapplicable.

4TH GENERATION APEXLOCATORS
To cope with those problems, a measuring method has been developed based on comparisons of the data taken of the electrical characteristics of the canal and additional mathematical processing.

And so the fifth generation apex locators (DUAL FREQUENCY RATIO TYPE) are now being used. E-Magic Finder Series as it is popularly known as. They have the best accuracy in any root canal condition (dry, wet, bleeding, saline, EDTA, NaOCl, etc.). LCD panel could show the moving trace of file in the root canal.

ROOTs, EMF 100 DELUXE, JOYPEX 5 come under this category. Devices employing this method perform very well in the presence of blood and exudate but they experience considerable difficulties while operating in dry canals. Therefore, additional insertion of liquids in the canal is required. Low accuracy of measurement in dry canals, as well as the need to insert extra liquid still predetermine the preferences of doctors in dental medicine in favour of fourth generation devices.

5TH GENERATION APEXLOCATORS
Analysis of the advantages and disadvantages of apex locators of the so-called fourth and fifth generation have led to the invention of the sixth generation apex locators (ADAPTIVE APEX LOCATORS) which have come up in the market just recently and its efficacy in the long-term use is yet to be established. A major advantage of measurement with the adaptive apex locator is that it eliminates the necessity of drying or moistening of the canal, as well achieving high degree of measurement precision in the presence of blood, of additionally imported liquid /sodium hypochlorite/, or while manipulating dry canals.

Other uses of Apex locator are to detect root perforations to clinically acceptable limits and equally able to distinguish both large and small perforations, to accurately determine the location of root or pulp floor perforations, to detect horizontal fractures, to confirm suspected periodontal or pulpal perforation during pinhole preparation, to recognize any connection between the root canal and the periodontal membrane such as root fracture, cracks and internal or external resorption. Some have ability to detect vitality of the tooth. They are also helpful in the root canal treatment of teeth with incomplete root formation, requiring apexification and to determine working length in primary teeth.

CONCLUSION
There is a general opinion that root canal procedures should be limited within the confines of root canal, with the logical end point for preparation and filling being the narrowest part of canal at its apical end. It is not possible to predictably detect the position of the apical constriction clinically, indeed, the constriction is not uniformly present or may be irregular. Equally, it is not logical to base the end point of root canal procedures on an arbitrary distance from the radiographic apex as the position of apical foramen is not related to the apex of the root.
In routine endodontic practice, there is a need for 3-4 radiographs to complete endodontic treatment successfully. If accurate use of apex locator can avoid one radiograph for 85% of our patients, we feel that the equipment can be added to our armamentarium for regular use. 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. Hence, it can be concluded that the newer apex locators can be very useful in endodontic practice for length determination.

REFERENCES: