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Digital Working Length in Endodontics - A Review

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Abstract:- Working length is defined as the distance from a coronal reference point to a point at which the canal preparation and obturation should terminate. Accurate determination of working length is crucial to prevent under-instrumentation or over-instrumentation, which can lead to complications such as apical leakage, patient discomfort, and treatment failure. The standard technique for determining canal length uses the radiological interpretation of file length in respect to the radiographic apex, but this method has limitations due to distortions and errors in interpretation. Therefore, digital working length determination namely electronic apex locators, cone-beam computed tomography, and audio metric methods are being investigated for better precision and accuracy. The paper concludes that a combination of digital and radiographic methods is the best approach for determining working length accurately.

Keywords:- *Working Length, Digital Working Length, Apex Locators, CBCT.*

I. INTRODUCTION

The most crucial part of endodontic therapy is correct cleaning and shape of the canal space which is made possible by accurately determining the working length followed by a proper three-dimensional obturation. The glossary of endodontics defines working length as "*the distance from a coronal reference point to a point at which the canal preparation and obturation should terminate*".

➢ *The Importance of the Working Length are as follows:*

- Preventing under-instrumentation that can leave tissues and debris in the apical section and might lead to apical leakage.
- Over-instrumentation that could irritate the patient, disrupt the periapical tissue, or perhaps lead to the development of a cyst or infection from the positioning of irritant materials beyond the apex.[2]
- It determines the extent of pain and discomfort ,the patient will experience following the treatment.
- If appropriately confined, the role of treatment success is significantly influenced by it.

Henceforth, the determination of operational span ought to be executed with proficiency, employing methodologies that are pragmatic and efficacious, as well as strategies that have been demonstrated to yield worthwhile and precise outcomes. The best criteria for establishing the working length of the tooth are precision, simplicity, reproducibility, and confirmativeness.[1]

II. CONVENTIONAL WORKING LENGTH DETERMINATION

The standard technique for determining canal length uses radiological file length in respect to the radiographic apex. The image is captured and stored on X-ray film in traditional systems.

Due to the two-dimensional nature of the radiograph image in contrast to the three-dimensional aspect of the tooth, there exist distortions and consequent inaccuracies in the interpretation of the working length. The apical foramen is situated at the anatomical apex or upto 3mm away of the same, and root canal preparation aim to terminate the BMP at the apical constriction.

Due to its 2-dimensional structure, intraoral radiography has significant limitations; information may be tricky to understand, particularly under adverse circumstances where the anatomy and backdrop pattern are complicated. The determination of the precise working length may be negatively impacted by some limitations, such as distortion, magnification, and superimposition. In addition, periapical radiography is ineffective at determining the precise location of the apex when an eccentric apical foramen is present.

Due to these shortcomings along with search for better precision & accuracy digital working length determination and development of electrometric instruments is currently the subject of numerous continual investigations.[3,4]

A. Digital WL Determination

➢ *Electronics Apex Locator*
➢ *Cone-Beam Computed Tomographic (CBCT)*
➢ *Audio Metric Method*

➢ *Electronics Apex Locator*

The phrase "apex locator" is in fact, a misnomer even though it has been commonly employed,as the primary objective of these instruments is to locate the apical constriction, cemento-dentinal junction, or apical foramen, rather than routinely identifying the radiographic apex. In

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1918, Custer conducted an inquiry on the electronic approach to ascertain the wavelength determination by examining the direct current movement through the teeth of canines.This was subsequently explored by Suzuki in 1942. Suzuki's findings revealed the presence of an electrical resistance of approximately 6.5 kΩ between an electrode applied to the oral mucous membrane and the root canal instrument inserted into the root canal, which exhibited a consistent value. Sunanda and colleagues have reported that there exists a consistent electrical resistance between the periodontium and the mucous membrane, regardless of the age of patients or the shape/type of their teeth.[5]

All apex locators operate via the utilization of the human body to perform an electrical circuit. The circuitry of the apex locator is connected on one end to an endodontic instrument, while the other end is linked to the patient's body through contact with the patient's hand. Once the endodontic instrument is inserted apically into the root canal and comes into contact with periodontal tissue, the electrical circuit is completed. The apex locator's display denotes attainment of the apical region. This rudimentary and widely acknowledged interpretation of the electronic phenomenon has been thrown into question. From a clinical perspective, it would be advantageous to adopt the apical constriction as the ultimate apical foramen. Moreover, deliberation ought to be given to employing a margin of error between -0.5 to 0.0 m as the most optimal clinically. [1]

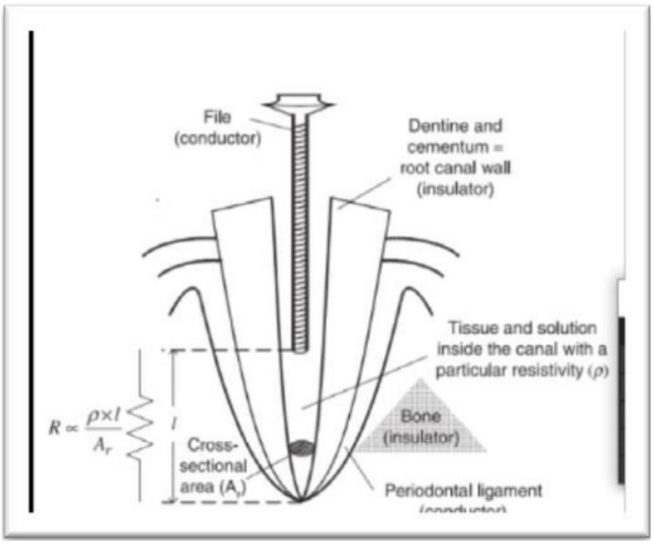

Fig 1 Tooth Structure Circuit During Root Canal Treatment in Terms of Electrical Conductivity

- *The First Generation*

These are resistance-based devices that function under the guise that the circuit formed between the lip clip and the endodontic file at the apical constriction might be a typical resistive circuit. In that circuit, a very small direct current is provided in order to measure the voltage. Resistance is calculated by applying Ohm's law and dividing the voltage value by the current value. With modest changes to the circuit architecture and display qualities, other versions have been developed utilising the same basic concept. [6]

The Root Canal Meter (Onuki Medical Co. Tokyo, Japan) was the first apex locator that was developed in 1969. First-generation apex locators have the significant drawback of being moisture sensitive and providing inaccurate values in damp canals. Inaccurate results were caused by the presence of strong ions like pulp tissue, haemorrhage, pus, or endodontic irrigants The high current machine also caused patients' suffering.. E.g. Endodontic meter, Dentometer.[5]

Fig 1 1ST Generation Ohmmeter

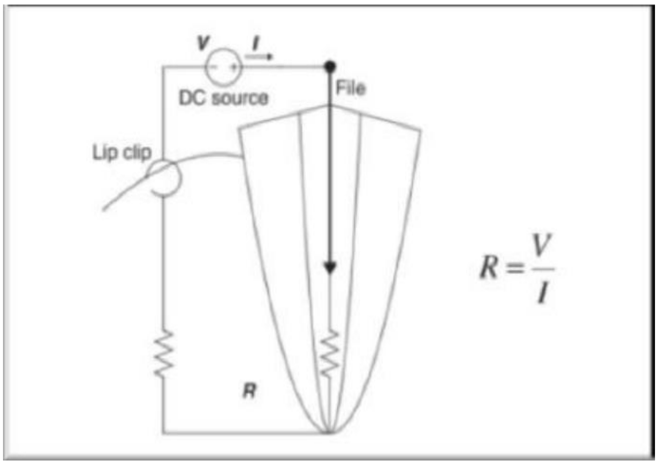

Fig 2 Resistance-Based Circuit

- *The Second Generation*

These operate on the basis of low frequency oscillation and are impedance and single-frequency based. They are formed by the capacity and resistance between the oral mucous membrane and the gingival sulcus, which is similar to the frequency between the periodontal ligament and the oral mucous membrane. Detects variations in the canal's impedance using a single frequency of alternating current

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and displays the change on an analog metre. Electrical impedance across the root canal walls of the tooth increases, and this rise is greater apically than coronally.[7] In light of the aforementioned, the year 1971 saw the development of the Sono-Explorer by Hayashi Dental Supply in Tokyo, Japan. This device necessitated calibration at the periodontal pocket of each tooth. One of its primary limitations, however, is its susceptibility to moisture and its consequent capacity to provide inaccurate electrolyte measurements in both wet and dry canals. Notable examples of such devices include Sono-Explorer, Endocator, Apex finder, Endoanalyzer, Digipex, Digipex II, and Formation IV.[6]

Fig 3 Second Generation Sonoexplorer

- *The Third Generation*

These are either based on the ratio of the two frequencies or impedances, such as Root ZX (J. Morita, Tokyo, Japan), or on the discrepancies between them, such as endex/apit (Endex, Osada Electric Co., Tokyo, Japan). They have a more potent microprocessor that can compute the mathematical quotient and algorithm, which are thought to generate readings that are accurate. Without the need for calibration in each canal, this gadget can measure the length regardless of the canal's electrical conditions.[8] The accuracy of the Root ZX was assessed in an in-vitro investigation by Jenkins et al.. The findings showed that regardless of the irrigants, the lengths were precisely measured to within 0.31 mm in all other cases. However, departure from true length was found when NaOCl was present in the canal.it is suggested that 90% accuracy is provided by the Root ZX to within 0.5 mm of the CDJ or the apical foramen. The third generation of apex locators comes in a variety of versions that are utilised all over the world, including Raypex5, Apex NRG, ProPex, Bingo 1020, Mark V Plus , Apit7etc. Though superior to their predecessors, the precision of these apex locators were impacted by electroconductive materials.

Fig 4 Third Generation Root ZX Apex Locater

- *The Fourth Generation*

They are ratio type apex locators that have an integrated electronic pulp tester and can measure impedance at five different frequencies. To calculate the distance to the root canal's apex, they do not use a mathematical technique to interpret the impedance data but rather compare the resistance and capacitance measurements to a database. They include the AFA Apex Finder, ROOT ZX II and PROPEX II and Bingo 1020 / Ray Pex 4 etc. Instead of measuring the signal's amplitude or phase, RMS (Root Mean Square) level is used. The RMS value is substantially more resistant to different types of noise than other measured signal characteristics. The great accuracy and dependability of this generation's apex locators make them the best in their category thus far. [6] The two distinct frequencies 400 Hz and 8 kHz used by the Bingo 1020 (Forum Engineering Technologies, Rishon Lezion, Israel). According to an in-vitro investigation by Ashish Kalhan et al. , Bingo 1020's reliability was shown to be on par with that of the Root ZX. Compared to the Root ZX at 8 and 0.4 kHz, the Elements Diagnostic Unit uses a composite waveform of two signals at 0.5 and 4 kHz.19 These apex locators have limits in that they must be used in canals that are only partially dried, as well as in cases of thick exudates or blood when they are rendered useless.[8]

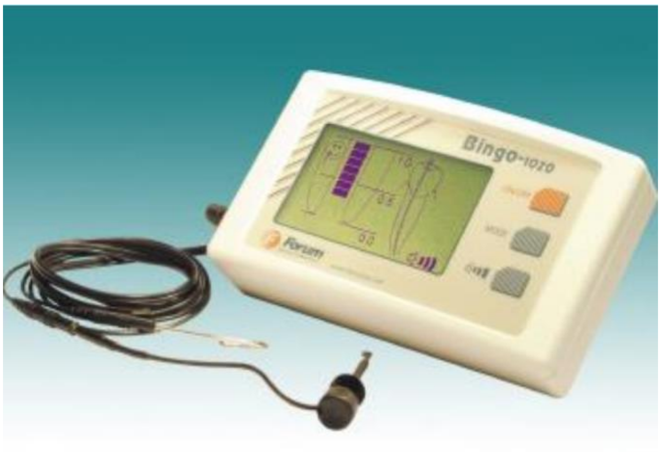

Fig 5 Fourth Generation Bingo 1020 Apex Locater

- *The Fifth Generation*

In 2003, the fifth generation apex locators were created. It measures the circuit's resistance and capacitance independently. A diagnostic table is provided to determine the position of the file and gives statistics of the values at various positions. When functioning in dry canals, devices using this technology have significant difficulties.The comparison of data derived from the electrical characteristics of the canal and extra mathematical processing are the foundations upon which fifth generation apex locators operate. In the presence of blood and exudate, these devices function very effectively, but in dry canals, they have significant issues. As a result, additional liquids need to be placed in the canals. *Eg-Raypex 5, ProPex Pixi, ProPex II.*[1]

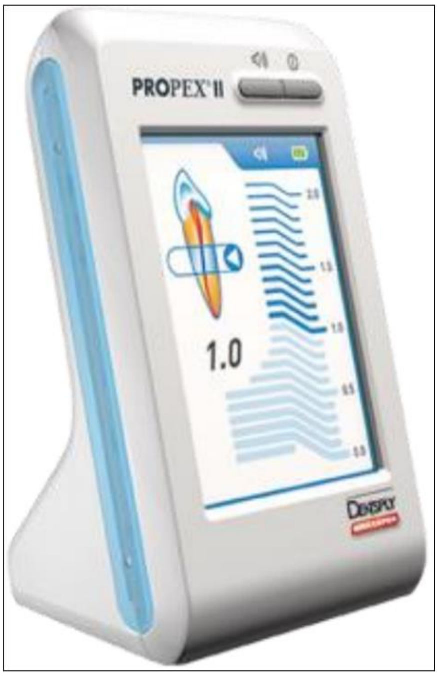

Fig 6 Fifth Generation PROPEX II Apex Locater

- *The Sixth Generation*

Recently, a sixth generation adaptive type apex locator that combines the benefits of fourth and fifth generation appliances was created.While attaining a high degree of measurement precision in the presence of blood, sodium hypochlorite, or while handling dry canals, measuring utilising the adaptive apex finder eliminates the need to dry or moisten the canal. The adaptive apex locator continuously determines the canal's humidity and quickly adjusts to a dry or wet canal. In this way, it can be used both dry and in additional wet canals, canals with blood or exudates, and canals with pulp that hasn't yet been extruded. An in-vitro study was conducted to evaluate the accuracy of Root ZX and Raypex 6 in teeth with varying apical diameters. The study concluded that these two apex locators are dependable in teeth with mature apices. However, their accuracy is vulnerable when foramen diameters exceed 0.57 mm. The sixth generation adaptive apex finder, made possible by modern technology, is a captivating, compact object no bigger than a dentist's palm.

Fig 7 Sixth Generation Raypex 6 Apex Locater

Table 1 Apex Locator Generations based on De Moor et al., 1999; Gordon and Chandler, 2004; Inoue, 1972; Kim, 2014; Kobayashi, 1995; Kobayashi et al., 1991; Pagavino et al., 1998)

Year of invention	**1969**	**1971**	**1991**	**2003**	**2003**	**2013**
Mode of action	Measures electrical resistance.	Measure electrical impedance.	Use two different frequencies at the same time in order to measure the difference or ratio between two currents.	Use two or more non-simultaneous continuous frequencies to measure the difference or ratio between two currents.	Measure the capacitance and resistance of the circuit separately.	Adaptive devices that have a steady algorithm for measuring the working length of the root canal depending on the canal's moisture characteristics.
Advantage	Electronic readout Audible signal Checks for perforation	Does not require a lip clip No patient sensitivity	Have powerful microprocessors that give precise readings. Easy to operate Audible indication Can operate with electrolytes	Accurate determination of the apical terminus	Error free in many conditions (with blood, irrigants) Digital read out Graphic	Precise measurement Quick results Immediately adapt to dry or wet canal

			Analogue read out		illustration May incorporate pulp tester	
Dis-advantage	A dry field is necessary Calibration is necessary Requires good contact with lip clip Patient sensitive	No digital read out Difficult to operate problems with dry canals as well as electrolytes in the canals	Requires lip clip	Low accuracy in working in wet canals Chances of short circuit	Difficulty in working in dry canals and require additional wetting	

➢ *Cone Beam Computed Tomography*

Due to the failure of the first few generations of electronic apex locators, the "multiple frequencies" or "ratio method" has emerged as a solution to address these EALs' major drawbacks in modern EALs. Although the EAL outperforms the radiograph in terms of dependability and accuracy, its performance could be compromised by a number of factors, such as a lack of patency, the restoration's electric conductivity, or the complexity of the anatomical relationship. Cone-beam computed tomographic (CBCT) imaging is a modern radiographic imaging method that addresses multiple concerns with conventional radiographic modalities and apex locators. The endodontic WL may also be determined in CBCT images. Cone beam computed tomography or digital volume tomography is an extra-oral imaging system which was developed in the late 1990s to produce three-dimensional scans of the maxillo-facial skeleton at a considerably lower radiation dose than CT (Arai et al. 1999, Mozzo et al. 1999). [9]

Cone-beam computed tomography (CBCT) is a distinct imaging modality from conventional computed tomography (CT) in that it enables the acquisition of the entire three-dimensional volume of data in a single scanner sweep, utilizing a straightforward, direct correlation between the sensor and source, which rotate synchronously around the patient's head. Depending on the particular CBCT scanner employed, the X-ray source and detector may rotate anywhere from 180◦ to 360◦ around the patient's head. In contrast to CT scanners, most CBCT scanners accommodate patients in a seated or upright position. The technique derives its name from the cone-shaped X-ray beam that captures a cylindrical or spherical volume of data, referred to as the field of view. Voxel size, typically ranging between 0.08 and 0.4 mm, is another key differentiator between CBCT and CT. The use of a streamlined approach enables CBCT images with a voxel size of 0.2 mm to accurately ascertain endodontic working length.[10]

The CBCT images are acquired by, operating at manufacturer recommended kVp, mA and an exposure time according to the model used with suggested field of view and voxel size. The process of mounting tooth samples onto a wax block model is a crucial step in dental imaging. To ensure standardization of imaging, a working model is placed on a dental impression holder onto a 3D bite block support in the chin rest base. The resulting image is examined using the 3D Object Acquisition Interface. In order to accurately measure the length of each root, a reference point is taken from the occlusal plane while following the visible canal curvature in the respective cone beam computed tomography slice. The CBCT records are placed in parallel alignment to the long axis of the root measured, and a scrolling tool is employed to locate the maximum length of each root in both the coronal and sagittal sections of the CBCT image. The software measurement tool is then utilized to measure the lengths of the different canals. These lengths are determined by measuring from the cusp tips to the radiographic apex after scrolling through to find the maximum length.[11]

➢ *Audiometric Method*

It is based on the idea that similarities in electrical resistance can be detected by a low frequency oscillation sound, which can be used to signal when it has happened. The length of the tooth can be measured by inserting an instrument into the gingival sulcus and applying an electric current until a sound is made. Next, inserting the instrument into the root canal and waiting for the same sound to be made, one can determine the length of the tooth..[12]

III. CONCLUSION

With the advancing of technology in production of more and more modern root canal instruments and the complexity of the root canal morphology, the correct endodontic working length determination is must for a successful outcome of root canal treatment.There is no individual modality that completely satisfies all requirements of working length determination. From the current article it can be concluded that the best method in determining the working length is a combination of digital and radiographic methods that completes and integrates the concepts of anatomic and radiographic apex allowing the clinician to obtain accurate results.

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