Electronic Devices for Determining the Working Length in Root Canal Therapy

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Abstract — The paper refers to the modern electronic devices that can be used for determining the working length in a root canal, in the most important phase of endodontic treatment. It briefly presents new generations of such devices and some possible developments based on electronic improvements

***IndexTerms* — root canal, endodontic therapy, electrical impedance**

I. INTRODUCTION

Endodontics is a specialty in dentistry used to diagnose and treat diseases of dental pulp tissues. The name comes from Greek ”endo” meaning inside and ”odont” meaning tooth (Fig.1).

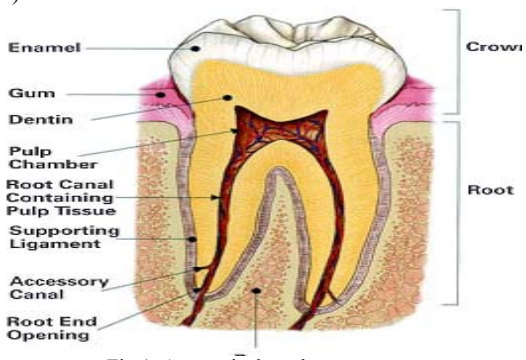

Fig.1. Anatomical tooth

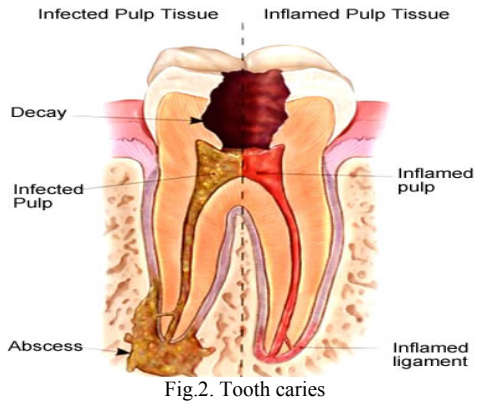

Fig.2. Tooth caries

If the tooth pulp becomes sick from various reasons, as caries and its complications (fig.2), it must be treated in order to keep the tooth in function in the patient's mouth. This involves the following steps [1]:

1. Opening the crown of the tooth
2. Entrance in pulp chamber
3. Finding canals
4. Locate canals
5. Root canal therapy (cleaning, removal of all pathological processes, enlarging, disinfection) until tip which sometimes does not correspond to the root tip
6. Determination of root canal lengths
7. Finally filling root canals with materials for sealing tooth from the surrounding bone. If the root filling remains incompletely or pushes the materials beyond the apex canal the result in time will be the tooth loss. In consequence one of the most important steps in tooth root canal treatment is to determine precisely the working length.

Determination of root canal length may be tactile, based on average length knowledge of the tooth root, radiographic or, recently, using electronic devices.

Radiographic method [2, 3, 4] for determining the root canal gives errors as:

1. As radiographic image is two-dimensional, tips root canals are often not visible.
2. If in order to determine the canal length a needle is used, on the X ray it looks as reaching the tip canal while in fact the needle tip is near to the tip of the tooth, but outside tooth (Fig. 3).
3. The poor accuracy
4. The poor quality of radiological film
5. Depe ndence on the angle on which x-ray is projected

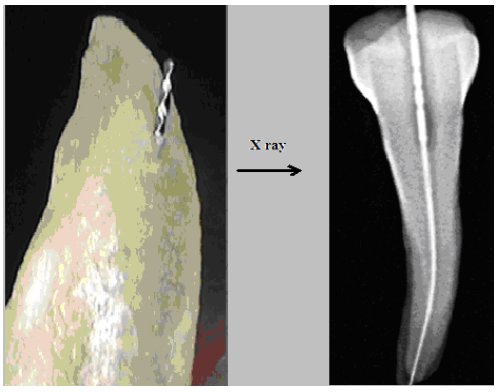

Fig.3. The needle position in reality (left) and the misinterpreted Xray (right)

Determining the working length using an electronic device is more accurate and effective [4, 5]. Priority in determining the length of work is to understand that root canal finishes at the cement-dentin junction (known as *apical constriction*) and not at the radiographic apex [6, 7]; in fact the apical constriction is located inside the radiographic apex to 1-2 mm (Fig.4).

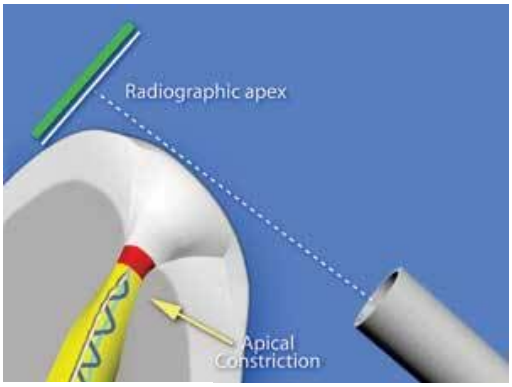

Fig.4.The apical constriction is located inside the radiographic apex

The research of electronic devices for determining the working length in root canal therapy started in 1962 when Sudata noticed that using a simple DC electrical circuit there is an electrical resistance between the channel apex and the oral mucosa of about 6.5kohms[6].

II. PRINCIPLE OF ELECTRICAL IMPEDANCE FOR DETERMINING THE WORKING LENGTH IN ROOT CANAL

Such electronic devices use human body as an electrical circuit and measure the electrical impedance between the lip and a needle introduced into a tooth. The electronic device, connected by wires between the lip clip and this needle (Fig.5), detects the impedance changes that can be displayed for example on an LCD screen. When the needle tip reaches the apical constriction the measured impedance also reaches the known value of the resistance between oral mucosa and apical constriction, giving an acoustic or/and optic advertising [10, 11].

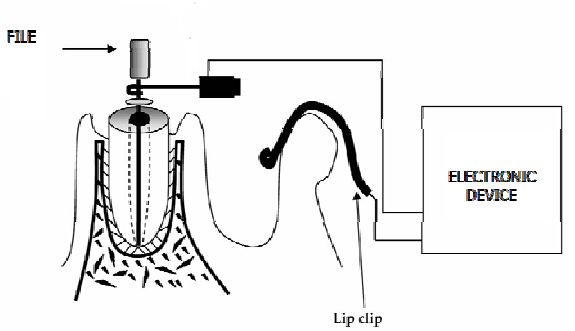

Fig.5. Principle of the electronic device for determining the working length in root canal

III. GENERATIONS OF ELECTRONIC DEVICES FOR DETERMINING THE CHANNELS

First-generation of electronic devices, also known as resistance apex locators, measures the resistance using a DC adequate voltage supply. When the tip of the needle reaches the apex in the canal, the resistance value is 6.5 kilo-ohms (current 40 μA). [6, 12] Such simple electronic devices are for example: Endodontic Meter II, Endodontic Meter S II, Endo Radar, Root Canal Meter

Advantages

1. Easy to operate
2. Digital readout.
3. Detects perforation.

Disadvantages

1. Requires a dry environment.
2. The result is not reliable in presence of neighbor metal restorations.
3. Requires calibration.
4. Patient sensitivity as (a) applying DC electrical current on the apical root increases the interstitial fluid pressure and blood flow, which affects the sensory nerves, and (b) the sensitivity on root canal depends on the diameter and on file size [13].
5. Perforations can give false reading.
6. Contraindicated in patients with pacemakers.

Second generation of electronic devices uses a single frequency of alternating current to detect changes in the impedance of the canal; the unit detects the change and indicates it on an analogue meter. [12, 14]

As shown in Fig. 6, the equivalent circuit of an apical constriction consists in three-element equivalent network: Rp and Cp refer to the electrode impedance, while Re corresponds to the electrolyte resistance. [13,15]

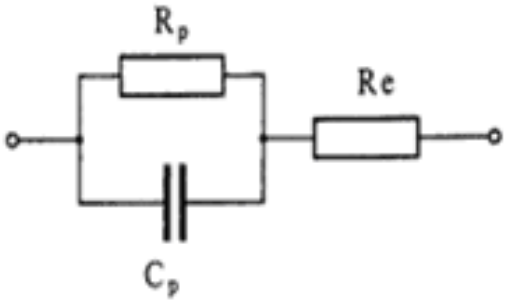

Fig.6. Equivalent circuit for apical area

As shown by measurements, the total impedance does not change with the size of the electrode, so the dominant resistance in the circuit is electrolyte resistance, Re, rather than electrode impedance. Electric current flows throughout the electrolyte, but current density will be the highest at the apical foramen and it will affect overall electrolyte resistance.

Examples of such commercial devices are: Dentometer, Digipex I, II şi III, Endo Analyzer, Endocater (Fig.7), Forameter, Sono-Explorer

Advantages

1. No patient sensitivity since AC current is used
2. Detects bifurcated canals
3. Detects perforations

Disadvantages

1. Requires calibration
2. Requires coated probes
3. No digital read-out
4. Difficult to be used

Fig. 7 Endocater

The third generation measures the impedance of the tooth at two different frequencies (a high one as 8 kHz and a low one as 400 Hz). In the coronal portion of the canal, the impedance difference between the frequencies is constant. As the file is advanced through apical constriction, the difference in the impedance value will increase and reach a maximum value at the apical area. [12, 13]

In comparative with second generation, such units may be equipped with powerful microprocessors and are able to process the mathematical quotient or other calculations required to give accurate readings.

As the magnitude of impedance depends on the measurement frequency the use of two frequencies give the opportunity of observing the difference between the two results as the needle advances in the root canal. We can also say that this is a "comparative impedance" method because it measures the impedance difference which can be converted into length information.

Exemple: Apex Finder AFA, Endex Endex, Neosono Ultima EZ, Root ZX(Fig. 6)

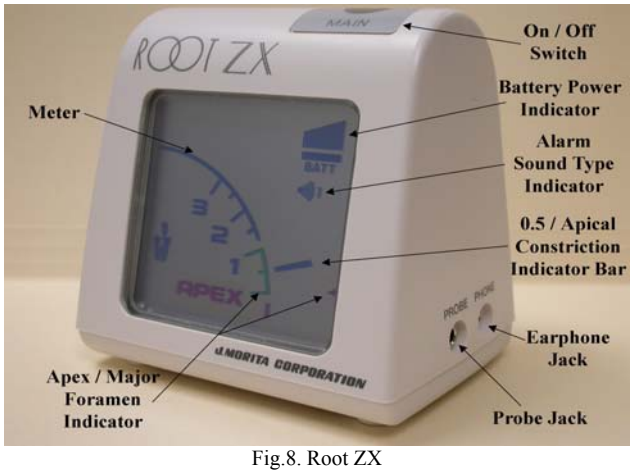

Fig.8. Root ZX

Advantages:

1. Easy to operate
2. Operates in fluid environment
3. Analogue read-out
4. Low voltage electrical output

Disadvantages:

1. Each canal must calibrate
2. Sensitive to canal fluid level
3. Needs fully charged battery

Typical for the *fourth generation* devices is that they measure and compare the complex electrical characteristic features of the root canal at two or more frequencies of electrical impulses [6, 7, 14].

These devices measure resistance and capacity separately, rather than the resultant impedance. There can be different combinations of values of capacitance and resistance that determine the same impedance (and thus the same apical constriction reading). Separate measurements of primary components permit a better accuracy. In addition, the device named *Elements* use a lookup matrix rather than making any internal calculations [15].

Example: Elements Diagnostic, SybronEndo, Orange, iPex (Fig.8)

Fig.9 iPex from NSK

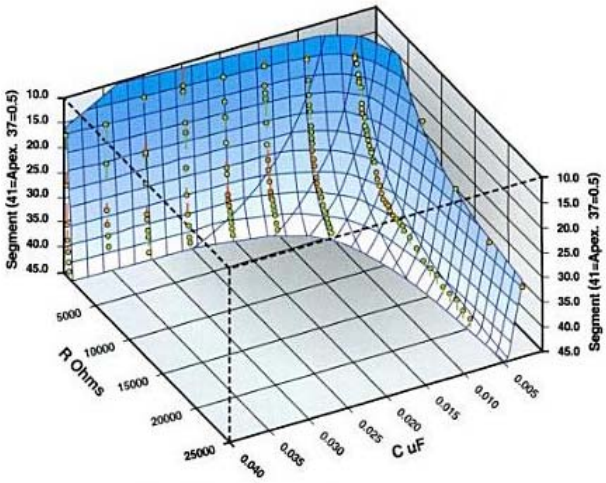

Fig.10. Matrix database for the Element Diagnostic software: left axis identifies measured resistance in ohms, the right axis identifies measured capacitance in microfarad and the vertical axis illustrates the resultant apex location that is displayed. It is shown in segments on the unit display: "41 segments" being the "0" reading, "37 segments" being "0.5" and so on.

Disadvantages:

1. They must perform in relatively dry or in partially dried canals
2. Extra dry to the canal

The fifth generation was created to make comparisons of the data taken for electrical characteristics of the canal and additional mathematical processing. Example: E-Magic Finder Apex Locator, I-Root (Fig. 11).

Fig. 11 I-Root

Advantages:
Best accuracy in the presence of blood and exudates.
It can be connected to the computer.

Disadvantages:
Difficulties in dry canals, for best measurement needs additional insertion of liquids, like sodium hypochlorite.

In a future *sixth generation* – called the adaptive type – it will be possible to create a steady algorithm for adapting the method of measuring the working length of the root canal depending on the canal moisture characteristics. The method must eliminate the necessity of drying or moistening of the canal in order to achieve a high degree of precision to locate the apical constriction, even if blood or additionally imported liquid such sodium hypochlorite is present, or while manipulating the needle in dry conditions.

IV. CONCLUSIONS

Technological evolution is the hallmark of all scientific and clinical effort.

Electronic devices find their usefulness when root canals are covered by anatomical structures (zygomatic arch, teeth overlapping roots, excessive density bone) or there are pathological processes on the tooth (root fracture, intern land external resorption of root, open apex).

The medical doctors make use of these devices on different patients:

1. Women pregnancy, who must avoid the X ray
2. Children who may not tolerate the radiological film
3. Disabled people
4. Who have gag reflex.

Electronic devices are highly sensitive devices that can be used to accurately determine the location of the apical constriction. The use of electronic devices can reduce radiographic exposure for the patient, as the operator may need fewer radiographs to correctly determine the working length.

Electronic devices are user friendly, less time consuming and reliable in most of the clinical situations. It is important to note that electronic devices are not an absolute substitute for radiographs and should be used as an adjunct. However, it can be concluded that the electronic devices can be very useful in endodontic practice for length determination.

We presented above a comparison between different generations of electronic devices for determining the working lengths in root canal therapy, emphasize on the advantages and disadvantages of them. From my researching and my own medical practice I am sure that every dentist having such an electronic device in his dental surgery, will improve his work and performance.

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