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Working Length Determination: A Review

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***Abstract*---**The determination of accurate working length is one of the most critical step in the endodontic therapy. The cleaning, shaping and obturation cannot be accomplished accurately unless the working length is determined precisely. Thus, the predictable endodontic success demands an accurate working length determination of the root canal. This article reviews about working length determination and its clinical implications.

***Keywords*---**cemento-dentinal junction, dentistry, electronic apex locater, radiographic tooth length, working length determination.

Introduction

The explicit location of the physiological apex of root canal is a prerequisite for a successful endodontic therapy. Working length is defined in the endodontic glossary as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate. According to Kuttler (1955), the narrowest diameter of the canal is not at the site of exit of the canal from the tooth but usually occurs within the dentin, just prior to the initial layers of cementum. According to Ricucci and Langeland, the apical constriction is the narrowest part of the canal with the smallest diameter of blood supply, thus creating the smallest wound site and best healing condition.[1] This anatomical landmark can be called the minor diameter of the canal. However, the cemento-dentinal junction (CDJ) and apical constriction do not always coincide, particularly in senile teeth as a result of cementum deposition, which alters the

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position of the minor diameter.[2] The minor diameter represents the transition between the pulpal and the periodontal tissue, located in the range of 0.5 to 1.0 mm from the external foramen or major diameter on the root surface.[3]
A working length established beyond the minor diameter may cause apical perforation and overfilling of the root canal system. This may increase postoperative pain and delay or prevent healing. Alternately, a working length established short of the minor diameter may lead to inadequate debridement and underfilling of the canal. Retained pulp tissue may persist and cause prolonged pain. In addition, microleakage into the canal space may result in impaired healing.[4]

The generally accepted method of working length determination is the radiographic method, but the apical constriction cannot be accurately determined radiographically. The electronic apex locator has attracted a great deal of attention as it operates based on electronic principles rather than by a visual inspection. The electronic apex locator is one of the breakthroughs that brought electronic science into the traditionally endodontic practice. [4,5]

Various methods for calculating working length[6]

- Radiographic method:
  - Ingle's technique[6]
  - Best's method
  - Bregman's method
  - Bramante's technique
  - Grossman's method[6]
  - Weine's method
  - Kuttler's method
  - X-ray grid method
  - Xeroradiography
  - Direct digital radiography[6]

- Electronic apex locators[6]
- Non-radiographic method:
  - Tactile sense[6]
  - Apical periodontal sensitivity
  - Paper point method[6]

Radiographic method

Though used many years ago, still several excellent clinicians use the radiographic apex as the site of canal termination. Those who endorse this concept state that it is impossible to locate the cemento-dentinal junction (CDJ) clinically and that the radiographic apex is the only reproducible site available in this area. Grove, Green and Kuttler reported on a common finding that the apical foramen exits at a distance 1 – 3mm from the root tip.[4,5] The vertical position of the cement-dentinal junction (CDJ) varies with each tooth. It may be located 0.5 to 2 – 3mm from the radiographic apex, produces aesthetically pleasing radiographs.[6,7,8]

The position of the radiographic apex depends on several factors:

- The angulations of the tooth
- Position of the film
- Holding agent for the film (finger, X-ray holder, haemostat, cotton roll) [6]
- The length of the X-ray cone
- Horizontal and vertical positioning of the cone
- The use of intentional distortion of the cone (for angled views)
- Anatomic structures adjacent to the tooth & several other factors. [6]

Grossman's method[6]

The original diagnostic radiograph is used to estimate the working length of the tooth from occlusal to root apex. This length is later verified by placing instruments to the estimated working length in the root canal and taking an instrumentation radiograph. The exact working length for each canal is determined by adjusting the length of insertion so the tip of the instrument ends 0.5mm from the root apex. [6]

Step by step procedure

Initially the diagnostic file (usually no. 10-20 K file) that fits into the root canal is inserted through the access cavity with a slight wiggling motion to bypass any obstruction or debris and is gently teased along the entire canal length until it has been inserted to the estimated working length of the canal. A radiograph is taken to compare the exact position of the instrument in the root canal with the measure depth of insertion. [5,6]

If necessary, the measured length is adjusted so that the instrument tip is inserted up to 0.5 mm from the apical exit of the root canal to the reference point on the crown of the tooth. If the K-file is 1 mm longer or shorter of the radiographic foramen one should add or subtract the necessary length to obtain the root canal length, but if the differences are greater than 1 mm, one should make necessary adjustments on the file and take another radiograph. [6] By measuring the length of radiographic images of both the tooth and the measuring instruments as well as the actual length of the instrument, the clinician can determine the actual length of the tooth by a mathematical formula. [6]

$$\text{Actual length of tooth} = \frac{ALI \times RLT}{RLI}$$

ALT -Actual length of tooth
ALI -Actual length of instrument
RLT -Radiographic length of tooth
RLI -Radiographic length of instrument

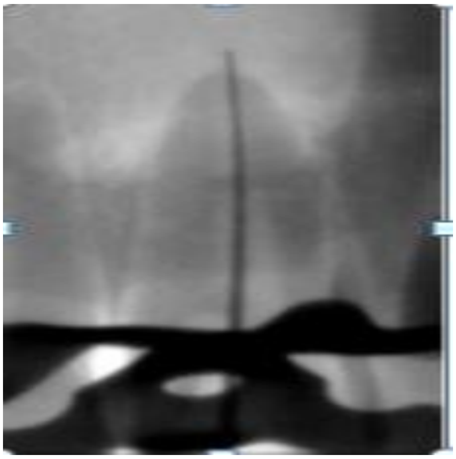

Figure 1. A working length instrumentation radiograph is taken to compare the exact position of the instrument in the root canal with the measured depth of insertion[6]

Ingle's method [3,6]

In order to establish length of tooth, a reamer or file with a rubber 'stop' on the shaft is needed. The exploring instrument size must be small enough to negotiate the total length of the canal.

Step by step procedure for Ingles method

- Measure the tooth on the preoperative radiograph [3]
- Subtract at least 1 mm, which is for safety factor for possible image distortion or magnification.
- Set the instrument at this tentative working
- Place the instrument in the canal until the stop. In case the instrument is left at that level and the rubber stop readjusted to this new point of reference. [3]
- On the radiograph measure the difference between the end of the instrument and the end of the root. Add this amount to the original measured length; if the instrument through some oversight has extended beyond the apex subtract the difference.
- From this adjusted length of the tooth subtract about 1 mm "Safety factor" to conform the instrument within the apical termination of the root canal at the CDJ.
- Set the endodontic ruler at this new corrected length and readjust the stop on the exploring instrument. [3]
- A confirmatory radiograph of the new adjusted W.L. is highly desirable because of the possibility of radiographic distortion, sharply curving roots and operator measuring errors. [3,6]

Weine's modification[6,8]

If periapical bone resorption is evident in a radiograph, the working length should be reduced 1.5 mm short of the radiographic apex as the apical constriction would have been destroyed by the resorption. If apical root resorption is seen, the working length is reduced to 2 mm short of the radiographic apex. In such an event, an apical stop is created short of the radiographic apex to prevent over instrumentation and subsequent overfilling of the root canal. [6,8]

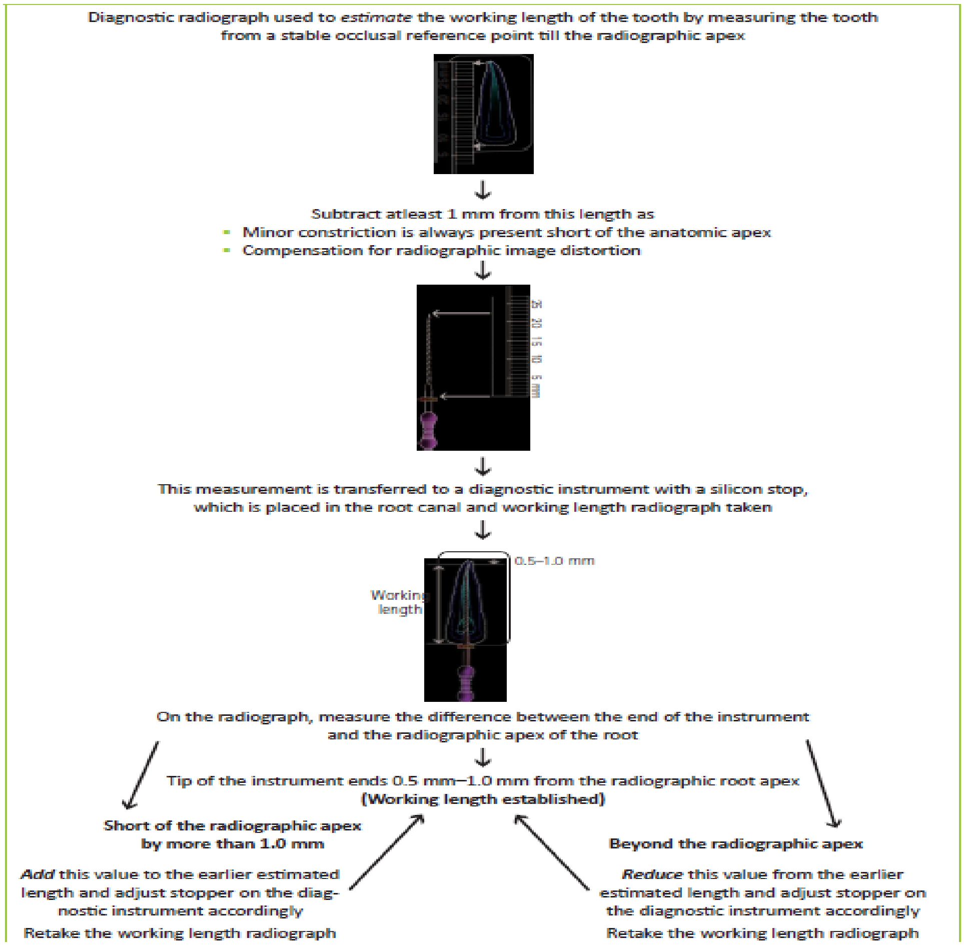

Figure 2. [6]-Ingle's radiographic method of working length determination

Kuttler's method[4,5]

According to Kuttler the narrowest diameter is not at the site of exit of the canal from the tooth but usually occurs within the dentin, just prior to the initial layers of cementum. He referred to this position as the 'minor diameter' of the canal (apical constriction). In 1955 Kuttler measured the distance among 20 different anatomic positions these calculations were for e.g. – from major to minor diameter or width of either diameters. The diameter of the canal at the site of exiting from the tooth was found to be approximately twice as wide as the minor diameter this is the "major diameter" [4]

Technique for calculation of working length: Before starting endodontic treatment, the dentist must identify the probable i.e. [4,5]

- The canal configuration present
- The estimated length of the root (s)
- The estimated width of the canal (s)

This is done by analysing the pre-op radiograph available using both straight – for site (s) of exiting, root (s) length, canal (s) width & angled views – for canal configuration (s) and sites of exiting. [4]

Step-by-Step technique for calculation of working length by Kuttler's method[4,5]:

- Using the information from the straight and angled radiographs about the expected canal configuration prepare a correct access cavity. Remove whatever pulp tissue and debris needs to be removed prior to taking the length. [4,5]
- Locate the major diameter and minor diameter on the pre-op x ray. In some cases, the exact site may not be seen, only that the radiolucent line of the pulp canal space stops near the tip of the root.
- Estimate the length of the root (s) either by measuring the length with a – mm – ruler on the pre-op radiograph or using the tables in the opposite page.
- Estimate the width of the canals (s) on the radiograph. If the canal estimates is narrow, consider using a size 10 or 15 file, if average select – a size 20 or 25 file, if wide choose a size 30 or 35, if very wide choose size 50 or larger. [4,5]
- Using the file selected by step (iv) Set the stop for the W.L. according to the measurement estimated in step (iii), Place the file in the access cavity and take an initial radiograph if the file seems to stop at a length that could be accurate stop and take a radiograph rather than force the file into the periapical tissues.
- If the file appears too long or too short by more than 1 mm from the minor diameter, make the interpolation and use that as the calculated working length. [4,5]
- If your file reaches the major diameter exactly, subtract .5mm from the length if the patient is 35 years old or younger, reduce .67 mm from that length if the patient is older.
- If the file reaches the site that you believe is the minor diameter use that as the calculated working length. If it is obvious that a great deal of cementum has been deposited at the root tip, subtract a greater amount from the site of the major diameter to rectify the increased distance. [4,5]

Bregman's method [6,7]

It is a method in which 25 mm length flat probes are prepared and each has a steel blade fixed with acrylic resin as a stop, leaving a free end of 10 mm for placement into the root canal? This probe is place in the tooth until the metallic end touches the incisal edge or cusp tip of the tooth. Then a radiograph is taken. In the radiographic image the following is measured. [6,7]

ALT-Apparent length of the tooth (as seen in the radiograph)
RLI-Real length of the instrument
ALI-Apparent length of the instrument
Now RLT (Real length of the tooth) is calculated from the formula.
RLT-ALI x ALT / RLI 6.

Best's method[6,7]

In 1960 BEST described a technique for determining the tooth length. In this method a steel pin measuring 10 mm is fixed to the labial surface of the root with utility wax keeping the pin parallel to the long axis of the tooth and a radiograph obtained. The radiograph is then carried to a gauge, which would indicate the tooth length. [6,7]

X-ray grid system

Everett & Fixott in 1963 designed a diagnostic X-ray grid system for determining the length of the tooth. The diagnostic X-ray grid designed consists of lines 1 mm apart running lengthwise and crosswise. A heavier line to make the reading easier on the radiograph accentuates every fifth millimetre. [6,7] Enameled copper wires are placed in plexiglass and fixed to a regular periapical film. The grid is taped to film to lie between the tooth and film during exposure so that the pattern becomes incorporated in the finished film. The incorporated grid is used for accurate measurement of working length. [7]

Xeroradiography

Xeroradiography is a highly accurate electrostatic imaging technique that used a modified xerographic copying process to record images produced by diagnostic x-rays. Xero-radiography records images produced by x-radiation but differs from conventional radiography in that it does not require wet chemicals or dark room for processing. In endodontics, Xero-radiographs permit better visualization of pulp chamber morphology, root canal configuration and root outline.[7] This is especially evident in maxillary molars and premolars, in which zygomatic arch and maxillary sinus superimpositions will hinder accurate visualization of dental structures. The lamina-dura is also clearly observed. A dental Xero-radiograph is also useful diagnostic tool in determining root canal length. It has been stated that although there is no diagnostic difference between Xeroradiography and conventional radiography in determining the actual length of root canals, Xero-radiographic images of the fire for determining length are sharper and can be measured faster. These might be useful in detecting carious lesions, especially proximal surface caries of adult and primary teeth. According to Macro in 1984, Xeroradiography gave closer to accurate results in measurement compared to conventional radiographs.[6,7]

Electronic Apex Locator

The working length is determined by comparing the electrical impedance of the periodontal membrane with that of the oral mucosa both of which should be similar at 6.5 KΩ. This is done with the help of an electronic apex locator cord that has two ends. One end is termed as a "lip hook" that is kept in contact with the oral mucosa of the patient while the other end is termed as "file holder" that is a probe which is attached to an endodontic instrument (K file or rotary file). The attached file is slowly inserted into the root canal up to the estimated working length. When the endodontic file touches the soft tissues of the periodontal membrane, the electrical-resistance gauges for both oral mucosa and periodontal ligament would have similar readings. By measuring the depth of insertion of the endodontic file, one may determine the exact working length of the root canal.[2,6]

Classification of electronic apex locators[6]:
Resistance-based electronic apex locator

These are the first generation of apex locators which were developed based on the resistance principle. They worked best in dry canals. However, the presence of pus, pulpal tissue, blood, and irrigants leads to inaccurate readings. The first apex locator based on this principle was the root canal meter. The other models based on the same principle include endodontic meter and endodontic meter S II. [6]

Low-frequency apex locator

In order to overcome the problems associated with the resistance- based apex locators, Inoue introduced the concept of impedance-based apex locators, the Sono Explorer apex locator. This device would indicate the apex when two impedance values approach each other. This apex locator had to be calibrated with the periodontal sulcus prior to each use. This procedure was technique sensitive and error prone. [6]

High-frequency apex locator

These locators were based on the principle that a high-frequency (400 kHz) wave, as a measuring current, produces a more stable electrode. This device can perform even in the presence of electrolytes due to the presence of a special coating on the file. Endocater is an example of this type of apex locators. [6]

Voltage gradient apex locator

Ushiyama introduced both monopolar and bipolar electrodes which were coated with lacquer with separate electrodes applying the current and recording the voltage gradient. However, these thickened electrodes are not effective in constricted canals. [6]

Dual-frequency apex locator

These apex locators determine the canal terminus as the difference between two impedance values at two different frequencies. This was introduced as the Endex apex locator and was to be superior to other apex locators in the presence of fluids and electrolytes. [2,6]

Multiple-frequency apex locator

A newer apex locator was introduced (Root ZX by J. Morita, Japan) that uses two wavelengths: one high (8 kHz) and one low (400 Hz) frequency. It assesses the apical terminus by the simultaneous measurements of the impedance of two different frequencies that are used to calculate the quotient of the impedances. The other apex locators which follow the similar principle include Propex II (Dentsply Maillefer), Elements Diagnostic EAL (SybronEndo), Formatron D 10 (Parkell Co.), and Apit 7 (Osada) [2,6]

Figure 3. [6]-Root ZX/Dentaport ZX apex locator. (Courtesy: J. Morita Inc.)

Figure 4. [6]-Propex II apex locator. (Courtesy: DENTSPLY Maillefer.)

Non Radiographic Methods

Apex finder

M.M..Negm in 1982 introduced a novel method of determining the length of root canal without the use of radiographs. The new instrument apex finder is used to locate the apex as well as measuring the root length. The application of this method is based on insertion of a fine plastic tapered bared shaft through a bevelled tube into the root canal. When resistance to withdrawal is felt which indicates that some barbs have engaged the apical margin, the shaft is marked at the level of the cusp tip. The distance between the mark and the barbs, which caused the resistance, is measured.[7,8]

Audio metric method

It is based on the principle of electrical resistance of comparative tissue using a low frequency oscillation sound to indicate when similarity to electrical resistance has occurred by a similar sound response. By placing an instrument in the gingival sulcus and including an electric current until sound is produced and then repeating this by placing an instrument through the root canal until the same sound is heard, one can determine the length of the tooth. [7,8]

Tactile method

The experienced clinician develops a keen tactile sense and can gain considerable information from passing an instrument through the canal. Following access, when interferences in the coronal third of the canal are removed, the observant clinician can detect a sudden increase in resistance, as a small file approaches the apex. Careful study of the apical anatomy discloses two facts that make tactile identification possible. [6,7,8]

- The unresorbed canal commonly constricts just before exiting the root.
- It frequently changes course in the last 2- 3 mm. Both structures apply pressure to the file. A narrowing presses more tightly against the instrument, whereas a curvature deflects the instrument from a straight path. Both consume energy and sensitive instrument with which the experienced clinician can accurately determine passage through the foramen. At this point, it also has access to pass through the apical accessory canal. [7,8]

Paper point evaluation

The paper point may be used to detect bleeding or apical moisture. A bloody or moist tip suggests an over extended preparation. Further assessment of the apical preparation and working length should be made. The point of wetness often given an approximate location to the actual canal end point. A wet or bloody point may also indicate that the foramen has been zipped or the apex perforated during preparation. These conditions would require additional canal shaping in addition to adjustment of working length. [6,7,8]

Conclusion

It can be concluded from the current article that electronic apex locater are not superior to the radiograph in determining the working length. Thus, long term follow up studies evaluating post-operative success comparing radiographic and no radiographic methods are needed to appreciate the best method of working length determination in endodontics.

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