UNIT 21 WORKING LENGTH DETERMINATION AND APEX LOCATORS

Structure

21.0 OBJECTIVES

After reading this unit, you should be able to:

- discuss the importance of calculating the working length;
- list the methods for calculation of working length;
- describe the procedure to determine the canal working length; and
- determine the use of apex locators.

21.1 INTRODUCTION

Following the completion of adequate coronal access and canal exploration, the most critical act in ensuring the success of root canal therapy is the accurate determination of the length of the tooth before radicular preparation. Working length is the distance from the coronal reference plane to the apical construction. The apical constriction, also referred to as cementodentinal junction (CDJ), represents the transition between the pulpal and the periodontal tissues. Accurate working length (AWL) establishes the apical extent of instrumentation and the ultimate apical level of root canal filling. One of the main concerns in root canal treatment is to determine how far working instruments should be advanced within the root canal, and at what point the preparation and obturation should be located. The significance of the apical constriction in the root canal treatment is well recognised. It is generally accepted that root canal treatment procedures should be confined within the root canal system. To achieve this objective the canal terminus must be detected accurately during canal preparation and precise control of working length during the process must be maintained. In this unit, you will learn about the various methods for determination of this critical position during endodontic treatment. You will also read more about the use of electronic apex locators in determining the working length.

21.2 RATIONALE OF DETERMINATION OF WORKING LENGTH

The significances of determining the working length are the following:

1) The calculation determines how far into the canal the instruments should be placed and worked and thus how deeply into the tooth the tissues, debris, metabolites, end products, and other unwanted items should be removed from the canal.

2) You will realise that by determining the working length you will be able to limit the depth to which the canal filling may be placed.

3) It will affect the degree of pain and discomfort that the patient will feel following the appointment.

4) If calculated within correct limits, it will play an important role in determining the success of the treatment and, conversely, if calculated incorrectly may lead the treatment to failure.

The working length determination establishes the apical extent of instrumentation and the ultimate apical level of root canal filling. Failure to accurately determine the length of the tooth may lead to apical perforation and overfilling with increased incidence of post-operative pain. In addition, you might expect a prolonged healing period and increased failure due to the incomplete regeneration of cementum, periodontal ligament, and alveolar bone. Failure to determine the working length of the tooth accurately may also lead to incomplete instrumentation and under filling with attendant problems like persistent pain and discomfort from inflamed shreds of retained pulp tissue. In addition, ledge formation may be developed, short of the apex, making adequate treatment or re-treatment extremely difficult. Finally, apical percolation may develop into the unfilled “dead space” at the apex. This could result in a continued peri-radicular lesion and increased incidence of failure.

It is normally felt that the proper point to which the 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. The cementodentinal junction (CDJ) is the anatomical and histological landmark where the periodontal ligament begins and the pulp ends. Root canal preparation techniques aim at to make use of this potential barrier between the contents of the canal and the apical tissues. It is generally accepted that the preparation and obturation of the root canal should be at or short of the apical constriction.

Check Your Progress 1

Describe the importance of calculating the working length of a tooth in endodontic preparation.

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21.3 METHODS FOR CALCULATION OF WORKING LENGTH

There are a number of methods that can be employed for calculating the working length. These are :

1) Radiography
2) Digital Tactile Sense
3) Apical Periodontal Sensitivity
4) Paper Point Measurement, and
5) Apex Locators.

Anatomy of the Apical Foramen

To appreciate fully the concept of working length, it is important to understand the apical anatomy. The root canal has two main sections: a longer conical section in the coronal region consisting of dentin and a shorter funnel-shaped section consisting of cementum located in the apical portion. The shape of this apical portion is considered to be an inverted cone: its base being located at the major apical foramen. The apex of the inverted cone is the minor foramen that is often thought to coincide with the apical constriction regarded as being at or near the cementodentinal junction (CDJ) [Figure 21.1]. This means that the most apical portion of the root canal system narrows from the opening of the major foramen, which is within cementum, to a constriction (minor foramen) before widening out in the main canal. The major apical foramen does not have a uniform shape but can be asymmetrical and its position on the root tip varies. The deviation of the major foramen from the root tip can occur as a result of increasing age or due to pathological changes, the most common being external root resorption. It also depends on the type of tooth. The root canal terminus is often considered to be CDJ. In many instances, the CDJ coincides with the pulp and periodontal tissue junction, where the pulp tissue changes into apical periodontal tissue. Theoretically, the CDJ is the appropriate apical limit for root canal treatment as preparation to this point results in a small wound site and optimal healing conditions. The term 'theoretically' is applied here because the CDJ is a histological site and it can only be detected in extracted teeth following sectioning; in clinical situation it is impossible to identify its position. The minor apical foramen is a more consistent anatomical feature that can be regarded as being the narrowest portion of the canal system and thus the preferred landmark for the apical end-point for root canal treatment.

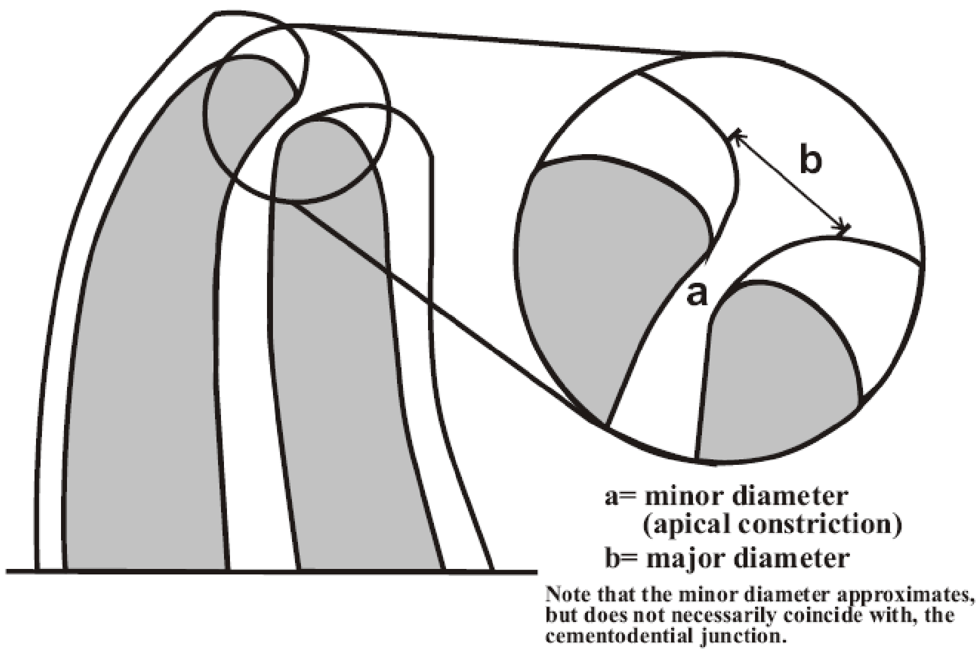

Fig.21.1: Anatomy of apical foramen

Methods

1) ***Radiographic Apex Location***

Radiographic determination of working length has been used for many years. This method of determining the working length is based on the concept that it is impossible to locate the CDJ clinically and that the radiographic apex is the only reproducible site available in this area. The radiographic apex is defined as the anatomical end of the root as seen on the radiograph. However, although it is generally accepted that the minor apical foramen and apical constriction is on average located 0.5-1.0 mm short of the radiographic apex, there are wide variations in the relationship of these landmark. Also when the apical foramen exits to the side of the root or in a buccal or a lingual direction, it becomes difficult to locate its position using radiographs. You must also keep in mind that the position of the radiographic apex depends on many factors: the angulation of the tooth, the position of the film, the holding agent for the film (finger, X-ray holder, hemostat, cotton roll), the length of the X-ray cone, the vertical and horizontal positioning of the cone, the anatomic structure adjacent to the tooth, and many other factors. A radiograph is a two-dimensional image of a three-dimensional structure and is technique sensitive in both its exposure and interpretation.

Procedure of Calculating the Working Length

In order to establish the length of the tooth, you would normally require a reamer or a file with a rubber instrument 'stop' on the shaft, an endodontic millimeter ruler, and a good, undistorted, pre-operative radiograph showing the total length and all the roots of the involved tooth. The exploring instrument size must be small enough to negotiate the total length of the canal, but not so small as to be loose in the canal.

1) Measure the tooth on a pre-operative radiograph.

2) Subtract atleast 1mm “safety allowance” for possible image distortion or magnification.

3) Set the endodontic ruler at this tentative working length and adjust the stop on the instrument at that level.

4) Place the instrument in the canal until the stop is at the plane of reference, unless pain is felt. In case pain is felt the instrument is left at that level and the rubber stop readjusted to this new point of reference.

5) Expose, develop and clear the radiograph.

6) 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 of the instrument extended into the tooth. If through some oversight the exploring instrument has gone beyond the apex, subtract this difference.

7) From this adjusted length of the tooth subtract a 1.0 mm “safety factor” to conform to the apical termination of the root canal at the cementodentinal junction. According to Weine F if radiographically there is no resorption of root end or bone, shorten the length by the standard 1.0 mm. If peri-radicular bone resorption is apparent, shorten by 1.5mm, and if both root and bone resorptions are apparent, shorten by 2.0mm Figure 21.2.

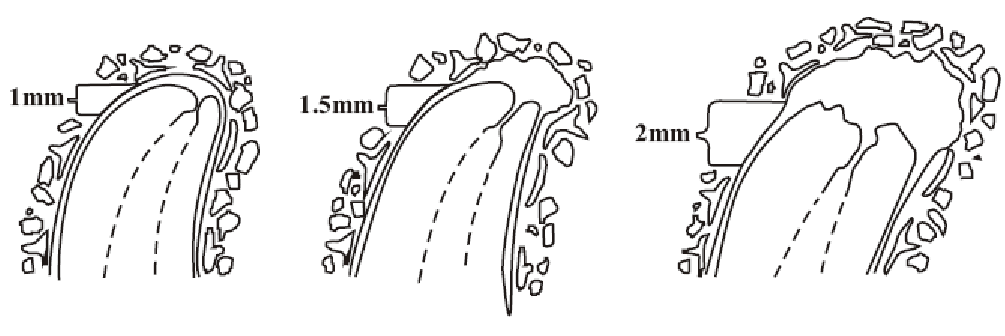

Fig. 21.2: Measurement of apical foramen for taking working length

8) Set the endodontic ruler at this new corrected length and readjust the stop on the exploring instrument.

9) A confirmatory radiograph of the adjusted length is desirable because of the possibility of radiographic distortion, sharply curved roots, and sometimes the measuring error Figure 21.3.

The working length can be determined by a number of methods. Let us read more about each in the following subsections.

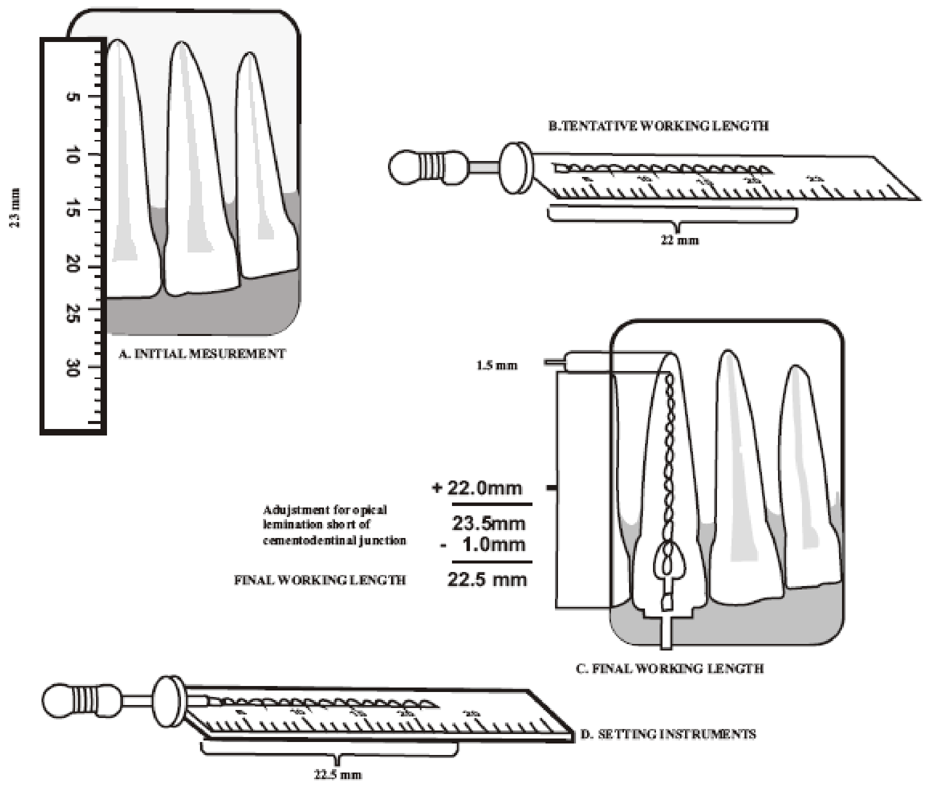

Fig. 21.3: Working length radiograph

21.3.1 Digital Tactile Sense

An experienced clinician may detect an increase in resistance as the file approaches the apical 2 to 3 mm provided the coronal portion of the canal is not constricted. This detection is by tactile sense. In this region, the canal frequently constricts (minor diameter) before exiting the root. There is also a tendency for the canal to deviate from the radiographic apex in this region.

However, you should be aware that this method, by itself, is often inaccurate. It is ineffective in root canals with an immature apex and is highly inaccurate if the canal is constricted throughout its entire length or if the canal has excessive curvature. This method should be considered as supplementary to high-quality, carefully aligned, parallel, working length radiographs and/or an apex locator.

21.3.2 Apical Periodontal Sensitivity

If an instrument is advanced in the canal toward inflamed tissue, the hydrostatic pressure developed inside the canal may cause moderate to severe, instantaneous pain. At the onset of the pain, the instrument tip may still be several millimetres short of the apical constriction. When pain is inflicted in this manner, little useful information is gained by the clinician, and considerable damage is done to the patient’s trust.

When the canal contents are totally necrotic, however, the passage of an instrument into the canal and past the apical constriction may evoke only a mild awareness or possibly no reaction at all. The latter is common when a peri-radicular lesion is present because the tissue is not richly innervated. It would appear that any response from the patient, even an eye squint or wrinkling of the forehead, calls for reconfirmation of working length by other methods available and/or profound supplementary anaesthesia.

21.3.3 Paper Point Measurement

In a root canal with an immature (wide open) apex, one way of determining the working length is to gently pass the blunt end of a paper point into the canal after profound anaesthesia has been achieved Figure 21.4. The moisture or blood on the portion of the paper point that passes beyond the apex may be an estimation of working length or the junction between the root apex and the bone. In cases in which the apical constriction has been lost owing to resorption or perforation, and in which there is no free bleeding or suppuration into the canal, the moisture or blood on the paper point is an estimate of the amount the preparation is overextended.

Again, it must be kept in mind that this paper point measurement method is a supplementary one.

The newer paper points have millimetre markings. These paper points have markings at 18, 19, 20, 22, and 24 mm from the tip and can be used to estimate the point at which the paper point passes out of the apex. These paper points were designed to ensure that they could be inserted fully to the apical constriction.

Check Your Progress 2

1) Explain the major and minor foramen.

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2) List the methods for calculating the working length.

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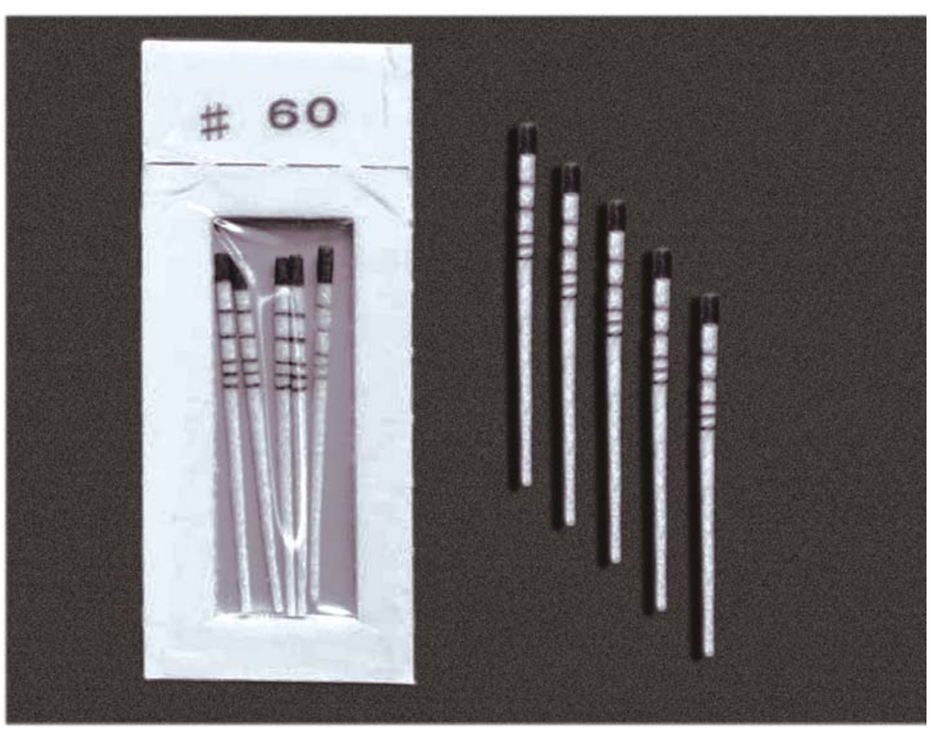

Fig. 21.4: Paper point measurement

21.3.4 Electronic Means

This will be dealt separately in detail in the next section.

21.4 USE OF APEX LOCATORS

One of the innovations in the root canal treatment has been the development and production of electronic devices for detecting the canal terminus. The pre-operative radiograph is essential in endodontics to determine the anatomy of the root canal system, the number and curvature of the roots, the presence or absence of disease, and to act an initial guide for working length. The electronic apex locator is an instrument, which when used with appropriate radiographs, allows for much greater accuracy of working length control.

History of Electronic Apex Locators

An electronic method for root length determination was first investigated by Custer in 1918. The electrical conductivity of the tissues surrounding the apex of the root is greater than the conductivity inside the root canal system provided the canal is either dry or filled with a non-conductive fluid. It has been found that the electrical resistance between a root canal instrument inserted into a canal and an electrode applied to the oral mucous membrane registered consistent values and speculated that this would measure the canal length. There are a number of apex locaters. There can be first generation, second generation, third generation and fourth generation.

21.4.1 First Generation

These are the Resistance-based devices. The first-generation (resistance) locators detected the point where the file displaces from within the canal to the periodontal ligament. These merely used direct current and the known constant resistance as a basis for working length determination. Their major drawback was the need for the canal to be thoroughly debrided and dry. Devices in the first generation include: the Root Canal meter, the Dentometer, the Endo Radar.

21.4.2 Second Generation

The second generation apex locators were of the single frequency impedance type which used impedance measurements instead of resistance to measure location within the canal. Impedance is comprised of resistance and capacitance. These apex locators, also known as impedance apex locators, measure opposition to the flow of alternating current or impedance. The property is utilised to measure distance in different canal conditions by using different frequencies. The change in frequency method of measuring was developed by Inoue in 1971 as the Sono-Explorer which calibrated at the periodontal pocket of each tooth and measured by the feedback of the oscillator loop. The beeping of the device indicated when the apex was reached.

A high frequency (400 kHz) wave measuring device, the Endocater was introduced in 1986. With an electrode connected to the dental chair and a sheath over the probe it was able to make measurements in canals even with conductive fluids present. The sheath caused problems because it would not enter narrow canals, could be rubbed off and was affected by autoclaving. The major disadvantage of second-generation apex locators is that the root canal has to be reasonably free of electroconductive materials to obtain accurate readings. The presence of tissue and electroconductive irrigants in the canal changes the electrical characteristics and leads to inaccurate, usually shorter measurements.

21.4.3 Third Generation

The third-generation apex locators are similar to the second-generation except that they use multiple frequencies to determine the distance from the end of the canal. These units have more powerful microprocessors and are able to process the mathematical quotient and algorithm calculations required to give accurate readings.

The *Endex/Apit* is the original third generation apex locator. The relative values of frequency response method detect the apical constriction by calculating the difference between two direct potentials picked up by filters when a 1 kHz rectilinear wave is applied to the canal. The Apit is able to measure lengths with electrolytes in the canal but needs to be calibrated in each canal (Figure 21.5).

Fig. 21.5: Apex locator

The Root ZX: The main shortcoming of early apex locators (erroneous readings with electrolytes) was overcome with the introduction of the ratio method and the subsequent development of the self-calibrating Root ZX (Figure 21.6). The ratio method works on the principle that two electric currents with different sine wave frequencies will have measurable impedances that can be measured and compared as a ratio regardless of the type of electrolyte in the canal. The capacitance of a root canal increases significantly at the apical constriction, and the quotient of the impedances reduces rapidly as the apical constriction is reached.

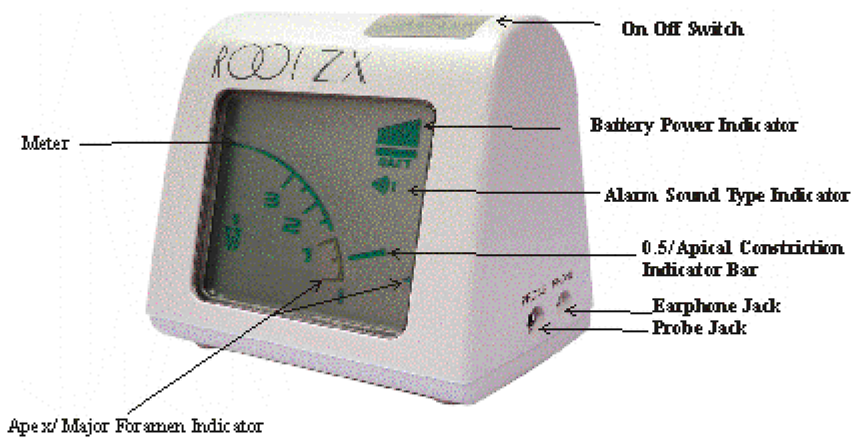

Fig. 21.6: Root ZX

The Root ZX has also been combined with a handpiece to measure canal length as a rotary file is used. This is marketed as the *Tri Auto ZX* with integrated handpiece, and more recently as the *Dentaport ZX*. The Tri Auto ZX is a cordless electric endodontic handpiece with a built-in Root ZX apex locator**.** The handpiece uses nickel-titanium rotary instruments that rotate at 280 ± 50 rpm. The position of the tip of the rotary instrument is continuously monitored on the LED control panel of the handpiece during the shaping and cleaning of the canal.

Fig. 21.7: Root ZX combined with handpiece

The Tri Auto ZX has three automatic safety mechanisms:

a) **The auto-start-stop mechanism**: The handpiece automatically starts rotation when the instrument enters the canal and stops when the instrument is removed.

b) **The auto-torque-reverse mechanism:** The handpiece also automatically stops and reverses the rotation of the instrument when the torque threshold (30 grams/centimetre) is exceeded, a mechanism developed to prevent instrument breakage.

c) **The auto-apical-reverse mechanism:** The handpiece automatically stops and reverses rotation when the instrument tip reaches a distance from the apical constriction that has been preset by the clinician; a mechanism controlled by the built-in Root ZX apex locator and developed to prevent instrumentation beyond the apical constriction.

The Apex Finder AFA (All Fluids Allowed) claims to have five signal frequencies and to read four amplitude ratios. The unit is self-calibrating and can measure with electrolytes present in the canal (Figure 21.8).

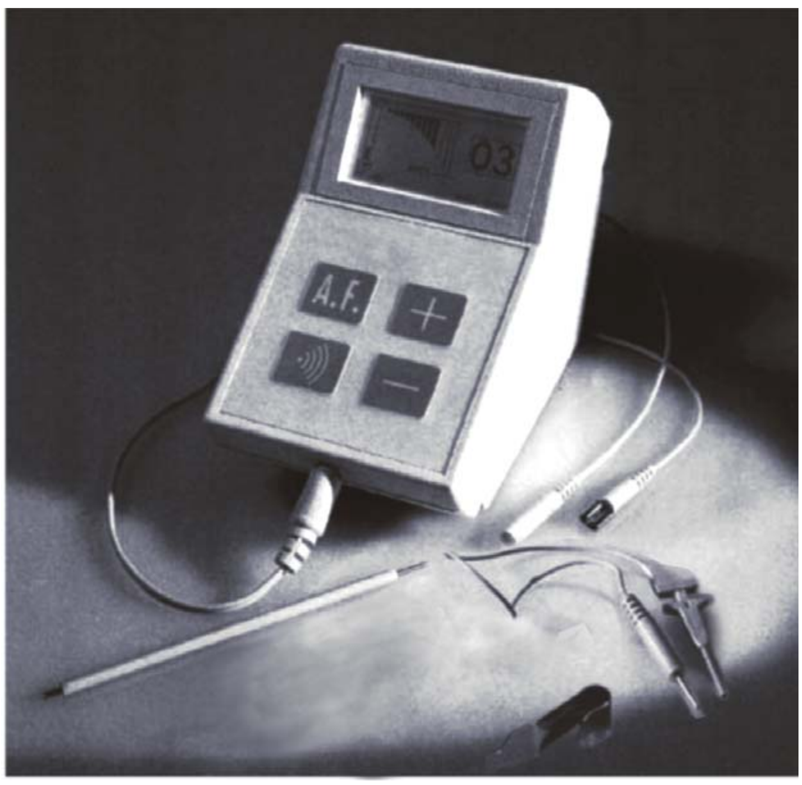

Fig. 21.8: Apex finder

21.4.4 Fourth Generation

The Bingo 1020/ Ray-Pex 4 claims to be the fourth generation device and the unit uses two separate frequencies 400 Hz and 8kHz similar to the current third generation units (Figure 21.9).

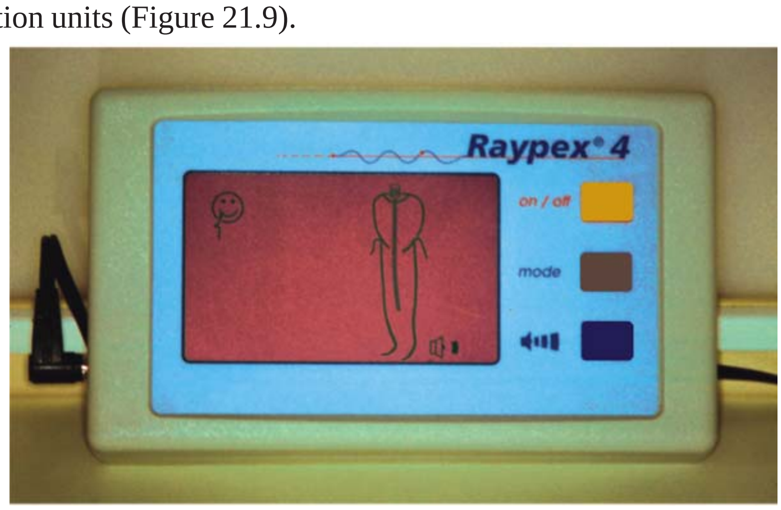

Fig. 21.9: Ray-pex 4 fourth generation device

The Elements Diagnostic Unit and Apex Locator was developed in 2003.

Fig. 21.10: Apex locator

The device does 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 (Figure 21.10). It uses a composite waveform of two signals, 0.5 and 4 kHz, compared with the Root ZX at 8 and 0.4 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.

Other Uses of Apex Locators

All modern apex locators are able to detect root perforations to clinically acceptable limits and are equally able to distinguish both large and small perforations. This aids in decision making and consideration of treatment options. Suspected periodontal and pulpal perforation during the pinhole preparation can be confirmed by all apex locators, as a patent perforation will cause the instrument to complete a circuit and indicate the instrument is beyond the 'apex'. Any connection between the root canal and the periodontal membrane such as root fracture, cracks and internal or external resorption will be recognised by the apex locator which serves as an excellent diagnostic tool in these circumstances. Multiple function apex locators are becoming more common and have several vitality testing functions as well.

Problems Associated with the Use of Apex Locators

The biological phenomena such as inflammation can have an effect on the accuracy of the apex locators. Intact vital tissue, inflammatory exudates and blood can conduct electric current and cause inaccurate readings so their presence should be minimised before accepting apex readings. Other conductors that can cause short-circuiting are metallic restorations, caries, saliva and instruments in a second canal. Care must be taken if any of these variables exist.

Lack of patency, the accumulation of dentine debris and calcifications can affect accurate working length determination with electronic apex locators. It has been suggested that pre-flaring of root canals as used in modern crown-down preparation techniques would increase the accuracy of readings. Canal patency appears to be more important, as dentine debris may disrupt the electrical resistance between the inside of the canal and the periodontal ligament. Constant recapitulation and irrigation ensures accurate electronic length readings during instrumentation. The size of the apical foramen also has an influence on electronic length determination. Immature or 'blunderbuss' apices tend to give short measurements electronically due to the instruments not touching the apical dentine walls. Other methods for length determination such as the use of paper points are deemed to be more effective in these cases.

Electromagnetic interference from dental equipment including electronic apex locators has the potential to interfere with cardiac pacemakers. The manufacturers of electronic apex locators specifically warn against their use with patients with cardiac pacemakers, as there are many therapeutic uses and types of pacemakers some may not be influenced by apex locator use. To use apex locator safely in patients with pacemakers it might be prudent to confer with the patients' cardiologist prior to treatment.

Check Your Progress 3

Discuss the principle behind the use of apex locators.

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21.5 LET US SUM UP

There is a general consensus that root canal procedures should be limited within the confines of the root canal, with the logical end-point for preparation and filling. 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 the apical foramen is not related to the 'apex' of the root.

You have learnt that the electronic root canal length measuring devices offer a means of locating the most appropriate end-point for root canal procedures, although indirectly. The principle behind most apex locators is that human tissues have certain characteristics that can be modelled by means of a combination of electrical components. Then, by measuring the electrical properties of the model (e.g., resistance, impedance) it should be possible for you to detect the canal terminus. Thus, most modern apex locators are capable of recording the point where the tissues of the periodontal ligament begin outside the root canal, and hence from this a formula can be applied to ensure that preparation is confined within the canal.

You must realise that the use of apex locators alone without a pre-operative and post-operative radiograph is not a recommended practice due to the large variation in tooth morphology and medico-legal record keeping requirements.

No individual technique is truly satisfactory in determining endodontic working length. The CDJ is a practical and anatomic termination point for the preparation and obturation of the root canal and this cannot be determined radiographically. Modern electronic apex locators can determine this position with accuracies of greater than 90 per cent but still have some limitations. Knowledge of apical anatomy, prudent use of radiographs and the correct use of an electronic apex locator will assist practitioners to achieve predictable results.

21.6 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The significances of determining the working length are many. The calculation determines how far into the canal the instruments should be placed and worked and thus how deeply into the tooth the tissues, debris, metabolites, end products, and other unwanted items should be removed from the canal. It will limit the depth to which the canal filling may be placed. It will affect the degree of pain and discomfort that the patient will feel following the appointment. If calculated within correct limits, it will play an important role in determining the success of the treatment and if calculated incorrectly may lead to endodontic failure.

Check Your Progress 2

1) The apical constriction i.e., minor apical diameter or minor foramen is the apical portion of the root canal having the narrowest diameter. This position may vary but is usually 0.5 to 1.0 mm short of the centre of the apical foramen. The minor diameter widens apically to the foramen i.e., major foramen and assumes a funnel shape.

2) The methods for calculating the working length of a tooth during an endodontic procedure are:

   a) Radiography

   b) Digital Tactile Sense

   c) Apical Periodontal Sensitivity

   d) Paper Point Measurement

   e) Apex Locators.

Check Your Progress 3

The apex locators function by using the human body to complete an electrical circuit. One side of the apex locator's circuitry is connected to an endodontic instrument. The other side is connected to the patient's body, either by a contact to the patient's lip or by an electrode held in the patient's hand. The electrical circuit is complete when the endodontic instrument is advanced apically inside the root canal until it touches periodontal tissue. The display on the apex locator indicates that the apical area has been reached. However, different generation apex locators work on different principles.

a) First generation: Resistance apex locators, measure opposition to the flow of direct current or resistance.

b) Second generation: Impedance apex locators, measure opposition to the flow of alternating current or impedance.

c) Third generation: Similar to second generation but use multiple frequencies to determine the distance from the end of the canal.

21.7 FURTHER READINGS

Endodontics; Fifth Edition; *Ingle and Bakland*.

Endodontic Therapy; Franklin S.Weine.

Pathways of the Pulp; Cohen S, Hargreaves KM

Appendix I

Table of Tooth Length, Roots, Canal & Access Cavity of Maxillary and Mandibular Tooth

Tooth	Average Tooth Length (in mm)	Number of Roots	Type of Canals	Outline form of Access Cavity
MAXILLARY				
Central Incisor	23	One	Type I	Round but slightly triangular
Lateral Incisor	22.5	One	Type I	Ovoid, funnel shaped only slightly skewed toward mesial
Cuspid	27	One	Type I	Extensive, ovoid, funnel-shaped
First Bicuspid	21	Two most frequent (60%), buccal and palatal;	Each root I	Thin oval, with the greatest width in the bucco-lingual direction.
		One (40%)	III most frequent; II less frequent	
Second Bicuspid	21	One (85%)	I most frequent; II less frequent; III least frequent	Thin oval, with the greatest width in the bucco-lingual direction.
		Two (15%) Buccal and palatal	Each Type I	
First Molar	20.5	Three: One buccal and Two palatal	Disto-buccal and palatal: Type I each Mesio-buccal: Type I, II or III.	Quadrilateral with rounded corners
Second Molar	20	Three: Two buccal and one palatal (90%)	Disto-buccal and palatal: Type I each Mesio-buccal: Type I, II or III.	Quadrilateral with rounded corners
		Two: one buccal and one palatal (10%)	Each: Type I most frequent; buccal root may have II or III infrequently.	
MANDIBULAR				
Incisors (Central and Lateral)	21	One	I most frequent; II less frequent; III least frequent	Oval but wide labio-lingually
Cuspid	24	One; Rarely two- buccal and lingual	I most frequent; II less frequent; III least frequent	Oval
First Bicuspid	21.5	One	I most frequent; II less frequent	Oval
		Two: buccal and lingual (rare)	Each; Type I	

Second Bicuspid	22	One	I most frequent; II or III rare IV – very rare	Round but may be slightly oval
		Two: buccal and lingual very rare	Each Type I	
First Molar	21	Two most common: mesial and distal	Mesial: Type III most frequent II less frequent Distal: I most frequent II less frequent III least frequent	Trapezoidal with rounded corners
		Three: one mesial and two distal	Mesial: same as above Distal: each Type I	
Second Molar	20	Two most common: mesial and distal	Mesial: I, II or III Distal: I most frequent; II or III rare.	Trapezoidal with rounded corners
		One	II most frequent; I less frequent; III least frequent	