Shiraz University of Medical Sciences
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CLINICAL EVALUATION OF WORKING LENGTH DETERMINATION BY ELECTRONIC APEX-LOCATOR OR RADIOGRAPHY ON ADEQUACY OF FINAL WORKING LENGTH

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Dedicated to:

True appreciations of my life, may father and mother.

The oldest escorts, my sisters and brother.

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Abbreviations

EAL	Electronic Apex Locator
AF	Apical Foramen
AC	Apical Constriction
AC	Alternative Current
DC	Direct Current
EBD	Evidence Based Dentistry
EBM	Evidence Based Medicine
RCT	Randomized Controlled(Clinical) Trial
LED	Light Emitting Diode

1 Introduction

One problem that clinicians face in endodontics is how to accurately identify and maintain the biological length of the root canal systems. It has been established that the junction of the dentin and the cementum (CDJ) is the landmark that determines the end of this biological length (64, 147). It is well established that successful root canal treatment is strongly influenced by length control during root canal treatment (116, 117). Thus Root fillings should terminate at the apical constriction to provide optimal healing conditions with minimal contact between the filling material and the apical tissue, and consequently reducing tissue destruction, persisting inflammatory responses and foreign body reactions (139, 140). Although debated for decades, there is considerable controversy concerning the exact termination point for root canal therapy procedures (11, 130). But in clinical practice, the minor apical foramen is a more consistent anatomical feature (135), 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.

Various techniques have been used for determining the position of the canal terminus and thus measure the working length of root canals. Radiographic and electronic length measurement, are two modalities which are common in today's practice. Radiographic method has been the most popular method for length

measurement and still remains as the most trusted way in the field of endodontics. It has advantages like direct observation of the anatomy of the root canal system, the number and curvature of roots, the presence or absence of disease, and acting as an initial guide for working length. There are however number of disadvantages which make this technique not quite suitable in every situation. For example danger of overestimation of root canal length even when it seems to be short of radiographic apex due to normal anatomic variations in the apical region (43). Technique sensitivity and subjectivity (84, 191), danger of unizing radiation (129), and errors of superimposition due to two-dimensional image of a three dimensional object (42) are among other shortcomings of this technique.

One of the innovations in root canal treatment has been the development and production of electronic devices for detecting the canal terminus. Their advantages include equal or higher accuracy compare to radiographic method as shown by in-vivo extraction studies (89, 158, 70), continuous monitoring of working length in combination with intelligent rotary systems like Tri Auto ZX®, discriminating between impenetrable and penetrable canals (120), and reducing the total needed radiographs and radiographic exposure as a result. There are also some limitations reported for Electronic Apex Locators like over preparation in retreatment in combination rotary systems such as Tri Auto ZX® and TCM Endo V® (179), premature showing of apex in rare occasions, and unstable measurement in some brands like Root ZX® (182).

Although lots of in-vitro and in-vivo extraction studies were done to compare the accuracy of these two method, there are a very few clinical studies which compare the results of these two modalities in a truly clinical setting and comparing the results based on clinical criteria rather than laboratory criteria (158, 53) (refer to section 4).

This study was designed to provide an evidence based answer for the following PICO formatted question which may be asked in every visit by the clinician.

(Patient) In patients who receive root canal therapy

(Intervention) does using apex locator

(Comparison) compared to radiographic working length measurement

(Outcome) lead to more acceptable results regarding length adequacy of final obturation?

This question can also be translated to "Can Electronic Apex Locators be considered as an acceptable replacement for radiographic length measurement?"

2 Root Canal Length Measurement

2.1 Significance Of Length Determination

Root canal treatment involves removing microorganisms from within the pulp space, and the filling of the root canal system to prevent reinfection. Furthermore, restoring the tooth to prevent recontamination and reinfection is essential (67). In other words, the goal of root canal treatment is to control infection through the debridement, disinfection and filling of the root canal system (100). It is well established that successful root canal treatment is strongly influenced by length control during root canal treatment (116, 117). It is generally accepted that root canal treatment procedures should be limited to within the root canal system (139, 140). Under-instrumentation of root canals, particularly in cases of infected necrotic pulps and asymptomatic apical periodontitis, leads to significantly lower success rates compared cases where an accurate working length was achieved (157, 26). On the other hand, over instrumentation with enlargement of the apical constriction, trauma to the apical tissues, extrusion of infected material apically and destruction of the apical binding point for the root filling can affect the outcome of root canal treatment negatively (157, 26, 160). Thus Root fillings should terminate at the apical

constriction to provide optimal healing conditions with minimal contact between the filling material and the apical tissue, and consequently reducing tissue destruction, persisting inflammatory responses and foreign body reactions (150, 1969, 139).

To attain this objective the endpoint of the root canal system, the canal terminus, should be detected as precisely as possible during preparation of the canal. Therefore, one of the main concerns in root canal treatment is to determine how far instruments should be advanced within the root canal and at what point the preparation and filling should terminate (80).

2.2 Morphology Of The Root Canal Terminus

2.2.1 Anatomic Landmarks

The classic concept of apical root anatomy is that there are three distinct aspects of the apex that must be appreciated. Figure 1 shows these as the tooth apex (1), the apical foramen (AF) [major foramen (2)] and the apical constriction (AC) [minor foramen (3)] which is also described as the CDJ. Kuttler concluded that a root canal had two main sections, a longer conical section in the coronal region consisting of dentine and a shorter funnel shaped section consisting of cementum located in the apical portion (94). The shape of this apical portion is considered to be an inverted cone (Figure 1); 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 cemento-dentinal junction (CDJ) (95). In other words, 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 to produce an hour-glass shape (Figure 1).

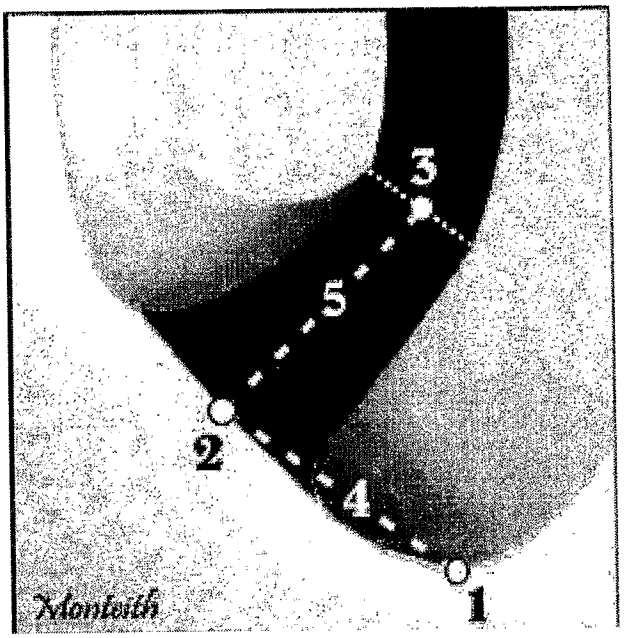

Figure 1. Anatomy of the root apex (adapted from Kuttler 1955).

2.2.2 Normal Variations

There are two distances in apical anatomy which are the main cause of variability. Root Apex to Apical Foramen (AF) (Figure 1,4) and Apical Foramen (AF) to Apical Constriction (AC) (Figure 1,5).

2.2.2.1 Variations in Apex to AF distance

The apical foramen is not always located at the anatomical apex of the tooth. The foramen of the main root canal may be located to one side of the anatomical apex, sometimes at distances of up to 3 mm in 50–98% of roots (94, 62, 132). Dummer *et al.* reported the mean apex to foramen distance (Figure 1, 4) in anterior

teeth to be 0.36 mm (38). Kuttler measured the apex to foramen distances as 0.48 mm for a young group and 0.6 mm for an older group (94). Green reported the distance to be 0.3 mm in anterior teeth and 0.43 mm in posterior teeth (61,62). The general trend is that the apex to foramen distance is greater in posterior teeth and older teeth than in anterior and younger teeth.

Mizutani *et al.* prepared serial cross-sections of 90 maxillary anterior teeth and found that the root apex and main AF coincided in 16.7% of central incisors and canines and in 6.7% of lateral incisors. Both the root apex and AF of the central incisors and canines were displaced distolabially while those of the lateral incisors were displaced distolingually (109).

The Apical Foramen is the circumference or rounded edge, like a funnel or crater, that differentiates the termination of the cemental canal from the exterior surface of the root'. Kuttler determined that the diameter of the Apical Foramen in individuals in the age range of 18–25 was 502 μm and in those over 55 years of age was 681 μm, demonstrating its growth with age. The Apical Foramen does not normally exit at the anatomic apex but is offset 0.5–3.0 mm. This variation is more marked in older teeth through cementum apposition. Studies have demonstrated that the AF coincides with the apical root vertex 17–46% of the time (16, 186, 132).

It is well known that the major apical foramen is not a uniform shape but can be asymmetrical (14). Furthermore, its position on the root tip varies. For example, Stein & Corcoran reported that with increasing age the deviation of the major foramen from the root tip increased, whilst others have reported that the frequency of the deviation depended on the type of teeth (14, 162). Moreover, deviation of the foramen can occur as a result of pathological changes, the most common being external root resorption (101).

2.2.2.2 Variations in AF to AC distance

The location of the apical constriction varies considerably from root to root and its relationship to the CDJ is also variable as the CDJ is highly irregular and can be up to 3 mm higher on one wall of the root compared with the opposite wall (135). Radiography can, at best, give an estimate of this histological structure and although clinically desirable, averages used to define the apical constriction from the anatomical or radiographic apex could lead to over or under filling.

The foramen to apical constriction (Figure 1,5) is approximately 0.5 mm in the younger group and 0.8 mm in the older group for all tooth types (94, 38, 162).

The mean distance between the major and minor diameters has been determined to be 0.5 mm in a young person and 0.67 mm in an older individual. The increased length in older individuals is due to the increased buildup of cementum.

There is also a great inconsistency between Apical Constriction and CDJ. Ponce and Vilar Fernandez evaluated serial histologic sections of maxillary anterior teeth to determine the location and diameter of the CDJ and the diameter of the AF. They found that the extension of cementum from the AF into the root canal differed considerably on opposite canal walls. Cementum reached the same level on all canal walls only 5% of the time. The greatest extension generally occurred on the concave side of the canal curvature. This variability reconfirmed that the CDJ and AC are generally not the same area and that the CDJ should be considered just a point at which two histologic tissues meet within the root canal. The diameter of the canal at the CDJ was highly irregular and was determined to be 353 μm for maxillary centrals, 292 μm for lateral incisors and 298 μm for canines (135).

2.2.2.3 Different Configurations

Using the averages from the anatomical studies and using the assumption that the CDJ occurs at the apical constriction has led to the common teaching practice of determining working length to be 1–2 mm short of the anatomic apex as seen on a radiograph. Dummer *et al.* classified the apical constriction into four distinct types (Figure 2) and speculated that using this assumption would lead to under-preparation in type B and over preparation in type D (38).

2.2.3 Different concepts of root canal terminus

Although debated for decades, there is considerable controversy concerning the exact termination point for root canal therapy procedures (11, 130). Clinical determination of apical canal morphology is difficult at best.

The root canal terminus is considered by many to be the CDJ (94, 139, 140, 135). In some instances the CDJ coincides with the pulp and periodontal tissue junction, where the pulp tissue changes into apical periodontal tissue (152). Theoretically, the CDJ is the appropriate apical limit for root canal treatment as at this point the area of contact between the periradicular tissues and root canal filling material is likely to be minimal and the wound smallest (128, 152, 80, 139). 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 the clinical situation it is impossible to identify its position. In addition, the CDJ is not a constant or consistent feature, for example, the extension of the cementum into the root canal can vary (135). Therefore, it is not an ideal landmark to use clinically as the end-point for root canal preparation and filling.

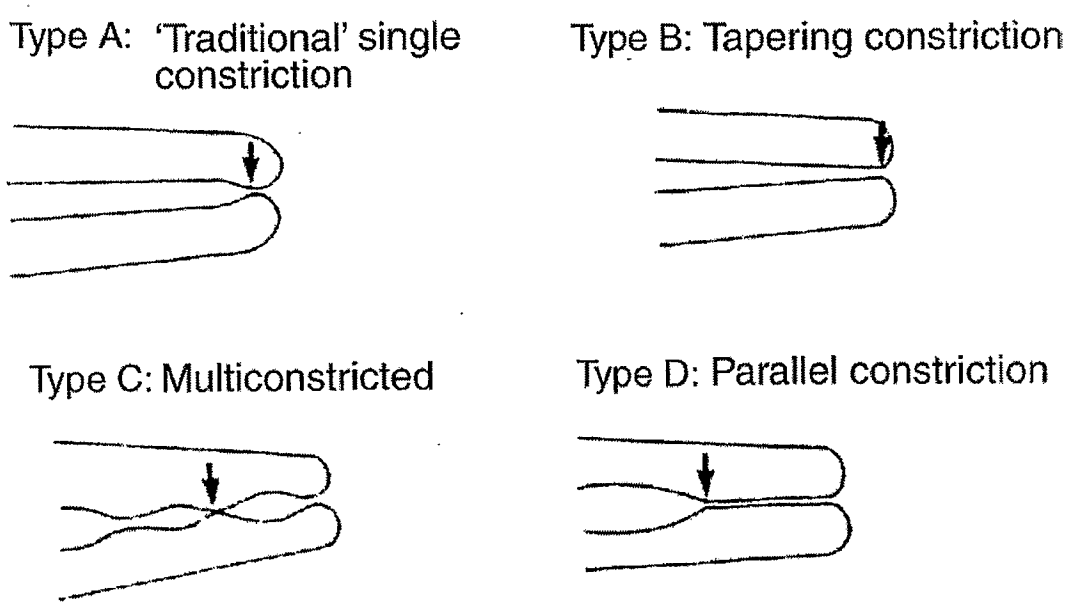

Figure 2 Topography of the apical constriction (from Dummer *et al.* 1984).

The existence of an AC may be more conceptual than actual. Dummer *et al.* determined that a traditional single AC was present less than half the time (38). Frequently, the apical root canal is tapered or parallel or contained multiple constrictions. Other authors have suggested that an apical constriction is usually not present, particularly when there is apical root resorption and periradicular pathology (156, 28).

Defining the canal terminus as the apical constriction and not the CDJ is also problematical, as the topography of the apical constriction is not constant (38). Indeed, the apical constriction can have a variety of morphological variations that makes its identification unpredictable. But in clinical practice, the minor apical foramen is a more consistent anatomical feature (80, 135) that can be regarded as