

Apical Limits in Root Canal Therapy: A Review of Techniques and Success Rates

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ABSTRACT

The evolution in root canal therapy over the past few decades has been toward improving treatment outcomes and long-term success. One of the most important factors influencing the success of RCT is the accurate establishment of the apical limit or working length, where cleaning, shaping, and filling should precisely terminate within the root canal. This limit is very important since both over- and under-instrumentation could equally lead to postoperative discomfort, complications, and potential treatment failure. This paper reviews the different methods of determination of the apical limit, including radiographic techniques, electronic apex locators (EALs), tactile sensation, and cone-beam computed tomography (CBCT). The advantages and limitations of each technique are diverse: radiography is widespread but prone to distortion; EALs are highly accurate but environmentally sensitive.

Many studies have proven that accurate apical limit management is strongly related to the successful result of RCT. Combined EAL with radiographic methods demonstrated very high success rates in managing difficult canal anatomies. This review is to stress the importance of precise apical limit determination in reducing complications and enhancing the long-term results of RCT, while also presenting the potential of emerging technologies in further sharpening endodontic accuracy.

The root canal therapy forms the basis of endodontic treatment in order that teeth that could otherwise be lost because of infection or necrosis may be saved. Success in RCT depends upon effective debridement, disinfection, and sealing of the root canal system with special care given to the apical limit or the endpoint of instrumentation and obturation. This article reviews the concept of apical limits, explores the different techniques used to establish these limits, and discusses their influence on success rates in root canal therapy.

KEYWORDS: root canal therapy, apical limit, working length, electronic apex locators, radiographic methods, cone-beam computed tomography, treatment outcomes.

Introduction

RCT has undergone serious evolution in the last decades, with continuous improvements in techniques and technology for better treatment outcomes and success rates in the long run[1]. Apical limit management forms one critical factor in the success of RCT; it refers to the endpoint where cleaning, shaping, and filling take place in the root canal. Establishment of the correct apical limit is of paramount importance to avoid over-instrumentation and under-instrumentation. Both can lead to a lot of postoperative discomfort and complications and even failure of treatment.

The apical limit in RCT is defined as the point at which instrumentation and filling should be terminated within a root canal system. Traditional views recommended that instrumentation should be terminated at the radiographic apex. However, more recent studies show a more precise apical termination to avoid procedural errors and improve success rates [1]. Proper determination of the optimal apical limit is thus of utmost importance, as over- and under-instrumentation may cause post-treatment complications and influence therapeutic success.

This review covers techniques for determination of apical limit, advantages, and disadvantages associated with each, and their correlation with success rate of treatment.

Importance of Apical Limits in Root Canal Therapy

For example, the apical bound-the so-called working length-is a very precise position within the root canal where instrumentation, cleaning, and filling must be stopped. It usually lies shortly before the level of the apical foramen, which in cases of over-instrumentation may frequently expose the apex tissues to bacterial invasion and debris and thereby prolong infection and pain after treatment.

Accurate determination of the apical limit is vital for cleaning and shaping within the canal system and achieving control over obturation material[2]. Long-term results have been superior with those treatments that have been performed with precise maintenance of a defined apical limit, having fewer complications associated with the treatment.

An accurate apical limit is mandatory for the removal of bacteria and necrotic tissue while preserving periapical health [2]. Several studies have linked errors in apical determination to poor treatment results, such as continuing pain, periapical pathology, and treatment failure [3]. The apical limit has to be accurately determined to preserve the integrity of the apical constriction, which is believed to act as a natural barrier with minimal irritation of the periapical tissues.

Correct estimation of the apical limit is regarded as being important for the removal of bacteria and necrotic tissue with maximum preservation of the health of the tissues periapically [2]. Poor treatment outcomes associated with apical determination

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include reports of persistence of pain, pathology at the area of the periapical area, and failure of treatments [3]. A well-defined apical limit maintains the integrity of the apical constriction, which is regarded as a natural barrier, minimizing irritation to tissues of the periapical

Techniques for Determining Apical Limits

The determination of the apical limit can be done by several methods during root canal treatment. Each method has certain advantages and disadvantages, and thus, specific techniques could be chosen in accordance with clinicians' skill or experience, patient anatomy, and availability of advanced equipment.

1. Radiographic Methods

Radiographic estimation is one of the most frequent methods. Based On the radiographic image, clinicians measure the working length by evaluating the anatomy of the canal and estimating the position of the apical foramen with respect to the apex of the root[3].

The radiographic technique is based on an educated estimation of the apical limit by visual inspection, using periapical radiographs and taking into account the anatomy of the root and apex position. In turn, this method is very straightforward and accessible but usually is very inaccurate due to superimposition, angulation errors, or a lack of depth perception [4].

Pros: Radiography is available in most practices and offers a visual estimate of the length of the canal, therefore making the measurement easy.

Cons: Distortions and inability to correctly estimate canals with complicated curvatures are some of the drawbacks. These Radiographic methods expose the patients further to ionizing radiation, though in minimal amounts.

2. Electronic Apex Locators (EALs)

Electronic apex locators measure the electrical resistance between the root canal and the surrounding tissues. Because of their precision and detection of the apical foramen more precisely in some cases compared to radiographs, electronic apex locators have recently become very popular[4].

The electronic apex locators measure impedance between two electrodes and thereby identify the apical constriction more precisely. Several studies have pointed out that the EALs are reliable and more accurate when compared with radiographs in teeth with complex root canal anatomy or those with resorption or calcification of the canal [5]. However, EALs may be affected by conductive irrigants presented in the canal and require careful handling and adaptation of technique [6].

Pros: EALs are not invasive and very accurate particularly when dealing with curved canals. They minimize the use of multiple radiographs, reducing the radiation to which the patient is exposed.

Cons: EALs have a tendency to be expensive, while their use also poses problems

where there is excessive moisture or when dealing with patients with metal restorations. Poor calibration and malfunction of the device lead to measurement errors.

3. Tactile Sensation

Tactile sensation was conventionally used to detect the apical limit by sensing a slight resistance when the instrument reaches the apical constriction. This method is highly dependent on the experience and expertise of the clinician.

This technique relies on resistance encountered by the practitioner when the file reaches the apical constriction. This technique, while effective for some clinicians, is not consistent and perhaps more subjective with inexperienced operators. It has been described in numerous articles as less predictable than EALs and radiographs and, as such, is considered an adjunctive rather than a principal technique [7].

Pros: Tactile sensation is easy to perform and requires no additional tools; hence, it is available for all practitioners, even in resource-poor settings.

Cons: this method is that it is subjective and less precise with the use of modern techniques, especially in narrow or curved canals where almost no kind of tactile feedback will be provided.

4. Cone-Beam Computed Tomography (CBCT)

CBCT is a three-dimensional imaging technique that provides highly detailed images of the canal structure and its relation to surrounding anatomical features. This Allows for the identification of the apical limit more precisely[2,4].

CBCT, by contrast, provides three-dimensional imaging, and therefore it enhances the visibility of root canal anatomy and the position of the apical foramen. It presents an advantage in very complex cases and in establishing anatomic variations. However, the use of CBCT is extremely costly, the radiation dose is greater to the patient, and may not be justified in routine cases.

Pros : CBCT provides a very accurate 3D view of the canal system. It is superior in cases with complex canal anatomy and when conventional radiographs have failed to give enough detail. The added advantage in such cases is high resolution and free from superimposition errors because of the nearby structures.

Cons: Its routine use is restricted because it is highly expensive and produces higher dose exposure compared to normal radiography.

Success Rates and Correlation with Apical Limit Determination

Studies show that the determination of the apical limit correlates strongly with successful RCT. These studies, from Ng et al. in 2011 and Schaeffer et al. in 2005, calculated success rates for treatments which terminated at the correct apical limit as lying between 86 and 94%, but treatment termination away from the correct apical limit was low and between 75 and 80%. Over-instrumentation is more problematic, associated as it is with lower success rates due to an increased incidence of periapical

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Precise establishment of the apical limit is of paramount importance in root canal treatment, as it greatly affects the overall success rate. Overinstrumentation, defined as extension of instrumentation beyond the apical constriction, may result in a high incidence of periapical inflammation with failure of resolution and delayed healing [9]. On the other hand, under-instrumentation enables residual necrotic tissue to remain at the apex, perpetuating an increased risk of recurrence of infection [10].

The best success rates have indeed been achieved by combining electronic apex locators with radiographic confirmation of the apical limit, with results citing up to 90% success rates. This technique has proved especially useful for curved or complex canal anatomies in which only a tactile sensation would yield an imprecise apical termination.

1 Success Rates of Radiographic Techniques

Given its many limitations, the radiographic technique is still widely used. RCTs performed by radiographic techniques alone have an average success rate of 85%; however, results have varied with practitioner experience and case complexity [11].

2 Success Rates of Electronic Apex Locators

Success rates are higher for RCTs using EALs, and studies have reported rates of more than 90% in cases where EALs were used to guide apical determination [12]. This improved accuracy contributes to faster healing times and fewer postoperative complications.

3 Combined Techniques

A few studies have concluded that the use of radiographic and EAL techniques together produces the best results. EALs combine accuracy with the verification advantages of radiographs. In situations where the anatomy is complicated and the radiographic images are not clearly understandable, success rates of approximately 92-94% were achieved with the combined approach.

Discussion and Recommendations

The optimal apical limit technique likely varies with the case, experience of the practitioner, and available resources. In most clinical situations, electronic apex locators will offer a more reliable and accurate means of identifying the apical constriction and are particularly valuable when visibility is constrained or anatomy is intricate. The use of EALs in combination with radiographs may be indicated in cases that present difficulties and where further accuracy is desirable. Future research can now focus on the refinement of EAL technology, optimization of the techniques in combination, and innovative methods such as artificial intelligence-guided imaging analysis for more precise apical limit determination.

Conclusion

Determination of apical limits is one of the most important stages in the treatment of root canals, which will define the success and duration of treatment. Conventional radiographic methods, while widely practiced, already have more precise modern alternatives; electronic apex locators and cone-beam computed tomography at least complicated cases. Further research and development is bound to be more toward refinement in the precision of apical limit determination and availability of those techniques.

Proper determination of the apical limit, regardless of the applied method, is a fundamental skill in endodontics. Relationship to improved success rates underlines this aspect as an important one regarding root canal treatment. Precise management of the apical limit constitutes a part of minimizing postoperative complications and attaining the ultimate objective of endodontic therapy, which is the conservation of natural teeth.

In root canal therapy, determining the apical limit is essential for successful outcomes. Techniques such as EALs and combined methods with radiographs have shown higher success rates and fewer complications, while radiographs alone remain a viable option for straightforward cases. By understanding the strengths and limitations of each method, clinicians can improve treatment outcomes and ensure the long-term success of root canal therapy.

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