TRABAJO DE FIN DE GRADO Grado en Odontología

APEX LOCATOR. DESCRIPTION, COMPARISON AND USES

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Summary

Introducción: Medir con precisión la longitud de trabajo de un conducto radicular es imprescindible para el éxito de un tratamiento de endodoncia. La capacidad de un localizador de ápice para determinar con precisión la ubicación de la constricción apical tiene una correlación directa con el pronóstico del procedimiento. Por lo tanto, la capacidad de precisión de un localizador de ápices para ser preciso es esencial. Los localizadores de ápice ahorran tiempo y también reducen la cantidad de exposición a la radiación que experimentada por el paciente en comparación con el simple uso del método radiográfico. Hay muchas elementos que pueden mejorar y disminuir la precisión de un localizador de ápice, incluida la proximidad del localizador de ápice a la constricción apical, la presencia de irrigantes en el canal y las diferentes condiciones técnicas y clínicas del procedimiento endodóntico en sí. **Objetivos**: El principal objetivo de esta revisión científica es comparar la precisión entre los localizadores de ápice y la técnica radiográfica estándar. Los objetivos secundarios de esto están todos en relación con diferentes aspectos que podrían afectar la precisión de los localizadores de ápice durante un tratamiento de endodoncia. **Metodología**: La presente investigación se realizó a partir de una extensa revisión bibliográfica, utilizando Pubmed, Medline y la biblioteca en línea de la Universidad Europea. **Conclusión**: Los localizadores de ápice son más precisos que la técnica radiográfica. Sin embargo, esto no significa que la técnica radiográfica deba descartarse, ya que, con todo, el resultado más preciso y predecible se obtiene utilizando una combinación de los dos métodos.

Palabras clave: localizador de ápice, foramen apical, constricción apical, endodoncia, longitud de trabajo, generación, precisión, eficacia.

Abstract

Introduction: Measuring accurately the working length of a root canal is imperative to the success of an endodontic treatment. The ability of an apex locator to accurately determine the location of the apical constriction has a direct correlation to the prognosis of the procedure. Therefore, the ability for an apex locator to be accurate is essential. Apex locators are time saving and also decrease the amount of radiation exposure that the patient experiences in comparison to just using the radiographic method. There are many things that can improve and decrease the accuracy of an apex locator, including the proximity of the apex locator to the apical constriction, presence of irrigants in the canal and different technical and clinical conditions of the endodontic procedure itself. **Objectives:** The main objective of this scientific review is to compare the accuracy between apex locators and the standard radiographic technique. The secondary objectives of this are all in relation to different aspects that could affect the accuracy of apex locators during an endodontic treatment. **Methodology:** The present research was carried out based on an extensive bibliography review, using Pubmed, Medline and the online library of Universidad Europea. **Conclusion:** Apex locators are more accurate than the radiographic technique, however this does not mean that the radiographic technique should be discarded as the most accurate and predictable outcome of an endodontic procedure is still produced using a combination of the two methods.

Keywords: Apex locator, apical foramen, apical constriction, endodontics, working length, generation, accuracy, efficacy.

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Introduction

It is generally accepted that the elimination of pulp tissue, microorganisms and necrotic tissue followed by proper technique of root filling is necessary for a complete endodontic treatment and positively correlates to the prognosis of the treatment also (1,2). To achieve a successful endodontic treatment, it is imperative that an accurate working length is found, and the accuracy of this finding is critical to the success rate of the procedure (3). Failure to establish an accurate working length can lead to damage of periradicular tissues (4). Traditionally, the working length has been found using tactile sensation or radiographs (3). Nowadays electronic apex locators are used as a way of increasing the efficiency and precision of the endodontic procedure, efficiency in reference to the time taken to complete the procedure and precision in reference to the accuracy of the procedure (5).

Apical foramen

To understand the concept of the working length, an understanding of the apical anatomy is necessary. It is universally agreed that there are three aspects of the apex that require attention. These are the apical foramen, the apical constriction and the tooth apex. Figure 1 shows the tooth apex (1), the apical foramen (2) and the apical constriction (3). The apical foramen usually is not found at the root apex and this is due to the modification of the of the shape of these structures with age. Primarily the apical foramen is located directly at the root apex and then it shifts, with time, more coronally as seen Figure 2. As we can see in Figure 3 which illustrates the different apical constrictions that can be present in the apex of the tooth.

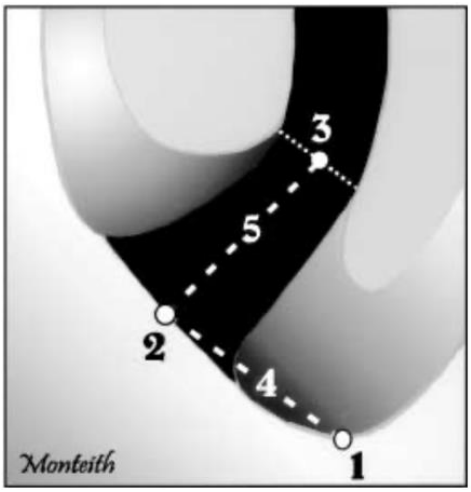

Figure 1: Anatomy of root apex, (adapted Kuttler 1955) (6)

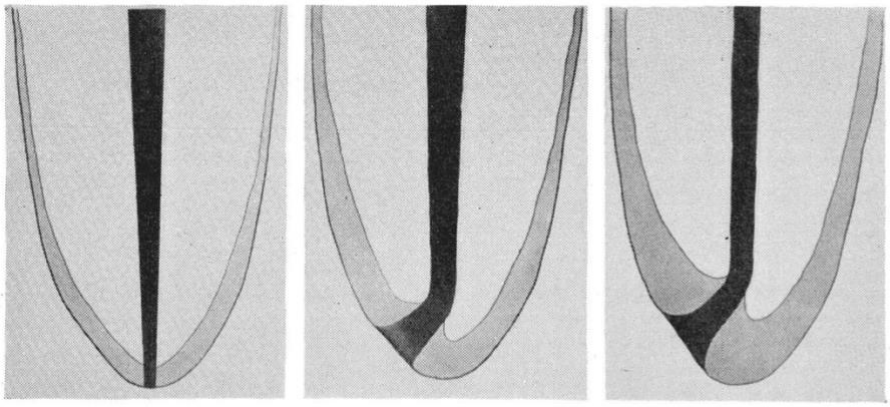

Figure 2: Erroneous concept of apex (Gordon *el al.* 2004) (7)

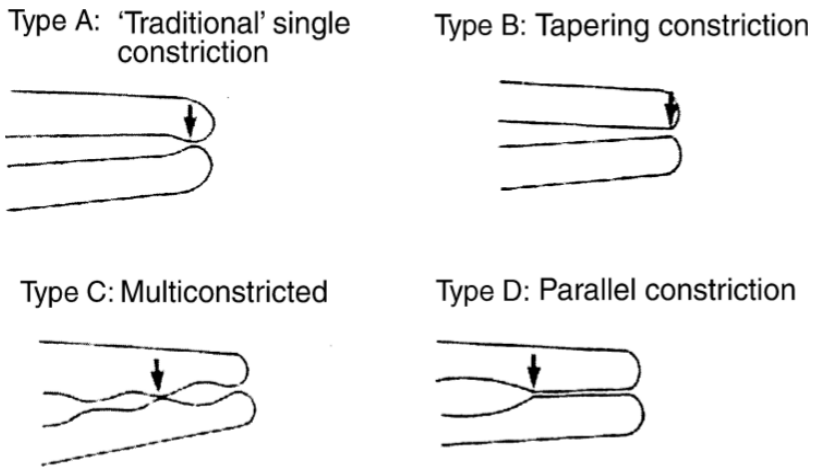

Figure 3: Topography of apical constriction (Dummer *et al.* 1984) (8)

Working length

The working length is defined as the distance from a coronal reference point to the point at which canal preparation and obturation terminate, this termination usually corresponds to the apical constriction (9). Using anatomical study averages as well as the assumption that the cemento dentinal junction is at the apical constriction, we can determine that the working length is between 1-2mm short of the root apex (6). There are also differing shapes of apical constrictions which serve as an obstacle in obtaining an accurate reading for the working length (8).

Tactile sensation technique

Tactile sensation technique is known to be the oldest method of finding the working length (3). The advantages of this technique being the simplicity of the technique and the virtual effectiveness are factors that drive endodontic clinicians to still use this technique (10). This technique is performed by a clinician entering a number 15 K-file into the canal until tactile resistance is felt by the clinician, the rubber stop is then placed on the file at a point of reference (incisal edge) and the file is removed and the working length is measured using an endodontic ruler (10). This value is called the tactile working length (TWL) (11).

Radiographic technique

The radiographic technique is the standard measuring tool for acquiring the working length in an endodontic procedure (12). It is also known as the most commonly used method (13). Although it is the ‘standard’ when it comes to determining the working length, it does not come without its limitations. Some of these limitations include shortening, elongation, distortion and finally interpretation variability (14). An effort has been made to try and reduce these errors with techniques such as the paralleling technique, however even with this technique implemented a

study showed that 5% of radiographs taken still showed elongation (15). Therefore although the radiographic technique is relatively accurate, we strive to find a technique with less errors and more accuracy (14).

Apex locators

Apex locators are instruments used in endodontics to determine the working length of a canal undergoing an endodontic procedure. They are used as a supplementary tool alongside radiography (3). They are used to locate the apical constriction or cemento dentinal junction (8). Apex locators have evolved from the initial first generation of apex locators through to the latest fourth generation, each generation has used a more advanced electronic measurement to improve and make them more reliable (16,17).

1st generation:

These apex locators use resistance to determine the working length, these instruments measure the opposition to flow of direct current i.e. resistance (16). It is based on the principle that the resistance offered by the oral mucous membrane and the periodontal ligament is the same at any point and a constant value (6.5 K ohms) (17). Initially an alternating current of 150 Hz Sine wave was used but patients reported pain due to the high currents, therefore alterations were made, and machines were made using less than 5µA were introduced (6). However, the machines were not accurate and also gave false readings in the presence of irrigants, chelating agents, pus and blood in the root canal. Research in this field of endodontics continued (16,17).

2nd generation:

These apex locators use the principles of impedance (16). Impedance is a measure of the overall opposition of a circuit to a current, how much the circuit impedes the flow of charge (6). They utilize the current of a single frequency to locate the apex (17). A major disadvantage of 2nd

generation apex locators is that the root canal has to be free of electro-conductive material to obtain accurate readings, especially irrigants (16).

3rd generation:

These apex locators use impedance also however they use two frequencies instead of one in order to find the working length (16). They are categorized as frequency dependent locators and are also called comparative impedance type locators (6). They use the fact that different sites in the canal give a difference of impedance, low values being 400Hz frequencies and high values being 8KHz (16). The difference in impedance is smallest in the coronal part and becomes greater and greater as you travel down the canal until you reach the cemento dentinal junction where it is the greatest difference (6). It determines a quotient value by dividing 8KHz value by 400Hz value. The reading of the minor diameter is given i.e. the apex when the quotient is equal to 0.67 (16).

4th generation:

These apex locators use 2-5 frequencies (multiple) to measure the impedance to determine the working length (16). These measure the resistance and capacitance separately rather than the resultant impedance value of which some manufactures claim to be more accurate (17). There can be a difference in the combination of values of resistance and capacitance that provides the same impedance and therefore the same foraminal reading (6). This technology leads to less sampling errors and more consistent readings and for a clinician who searches for high reliability and accuracy regarding the working length this generation of apex locator can be trusted the most and therefore is the most ideal (16).

Electrical features of tooth structure

Cementum and dentine surround the root canal in the tooth structure and act as electrical current insulators. However, located at the minor apical foramen there is a small hole which acts as an electrical channel and connects the conductive materials in the root canal to the periodontal ligament which is the conductor of the electric current. There are resistive materials in the canal which include tissue, fluid and dentine, and these components together create a resistor. The value of resistance is dependent on a number of factors which include cross-sectional area of the canal, length of the canal and the material's resistivity. When the endodontic file enters the canal and advances toward the terminus of the canal there is a decrease in the resistance between the end of the instrument and the apical section of the canal, and this is a result of the effective length of the resistant material positioned in the root canal decreasing (18).

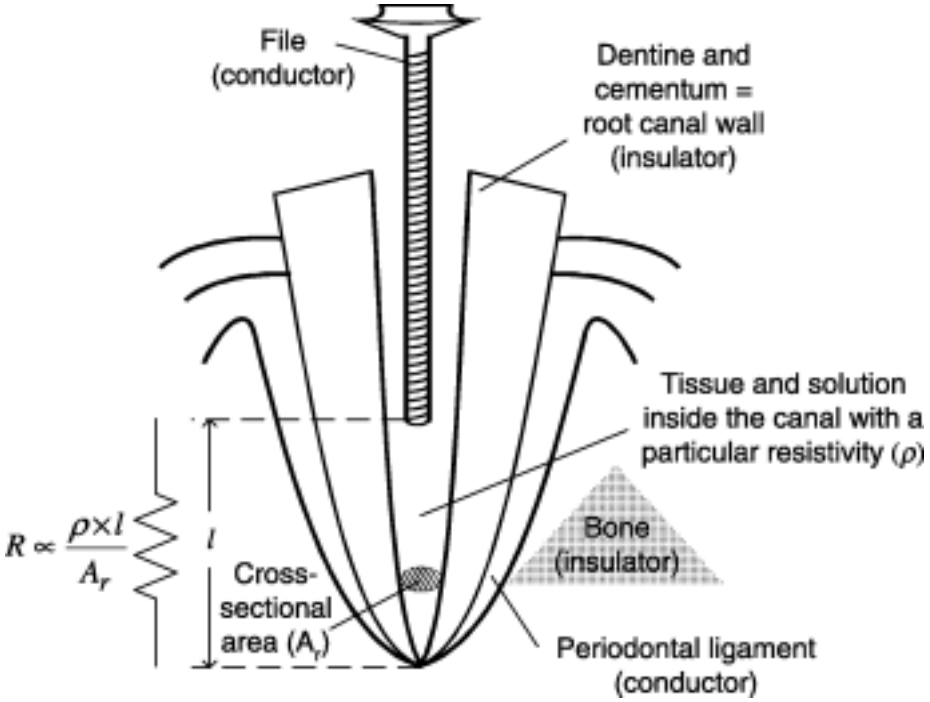

Figure 4: Anatomy of tooth during root canal treatment with regards to electrical conductivity and resistance (18)

Another important characteristic to understand is the capacitive characteristic of a tooth. A capacitator has two sides, in regard to the root canal treatment model the first side is the file inserted into the canal which has a specific surface area and the second side of the capacitator is the conductive material outside of the dentine which is the periodontal ligament. In between the capacitator there needs to be a separator. In the root canal model the separator is made up of tissue and fluid inside the canal as well as dentine and cementum of the canal wall. The separator between the capacitator plates is what we use to calculate the dielectric constant ε. Everything explained above combined forms the capacitator and a simplified model of said capacitator can be seen in Figure 6 (18).

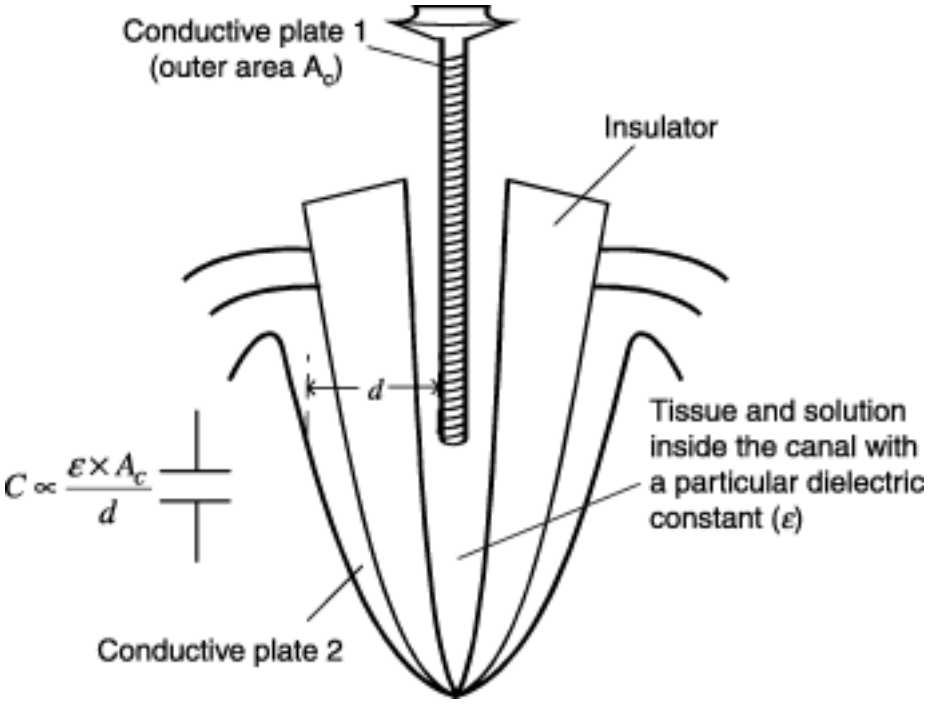

Figure 6: Capacitance model of a tooth during a root canal procedure (18)

Tips for clinical success

- Radiograph: A radiograph taken preoperatively is necessary to assess the anatomy of the roots and also the shape and number of the individual canals themselves (11).

- The cavity access: metallic restorations need to be removed to improve the accuracy of the apex locator and also to prevent electrical shunting. The pulp chamber needs to be dried sufficiently so it contains no fluids. This can be achieved with delicate drying using an air-jet device. And then drying with paper points is recommended (19).
- Irrigation: The presence of an irrigating material in the canal is necessary for the correct disinfection and cleaning of the root canal. However the irrigant should not be left to pool in the pulp chamber (4).
- Endodontic file: The correct size file should be selected. This is a file that makes contact with all of the surface are of the wall of the canal. The type of metal that is used in the file does not affect the apex locators accuracy (17).
- Apex reading: Advance the file into the canal until the visual analog shows apex or 0. At this point it is advised to retract the file 0.5mm – 1mm to provide the correct working length (20).
- Reevaluating the working length: It is essential that the working length is revisited after the preparation of the coronal 2/3's has been completed. When preparing the coronal 2/3's there is a chance of altering the shape of the canal by altering the curvature, this may cause an alteration to the working length so it is imperative that it is rechecked (17).
- Battery: using an apex locator that has low battery can cause low voltage errors, so ensure that the apex locator that you are using has sufficient charge to complete the procedure accurately (17).
- Perforations: apex locators can be used to test the integrity of the root canal and therefore are able to detect canal perforations. When a perforation is detected and trying to be located it is important to use the apex locator with a small file to not cause further damage to the canal (21).

Objectives

The basis of this paper lies in determining the accuracy of apex locators as well as providing information on how they can be used to increase the efficiency and precision of an endodontic treatment without decreasing the accuracy of the treatment. Therefore, the primary objective of this paper is:

- To evaluate the accuracy of apex locators to measure the position of the apical constriction compared to the accuracy when measuring apical constriction using radiographic methods

The research also aims to evaluate other deficiencies that apex locators may have, and the secondary objectives will be aimed towards looking into these deficiencies. These secondary objectives will include:

- To evaluate the effectiveness of apex locators to measure the apical constriction in dry canals verses canals containing irrigants
- To evaluate the relationship of proximity to apical constriction to accuracy of reading
- To evaluate the different technical and clinical conditions that affect the accuracy of apex locators

Methodology

This study was carried out exclusively based on a thorough bibliographical review of the literature on apex locators. The online library of Universidad Europea was used as the principal source of information and through this Medline was accessed, as well as PubMed. Initially, the limit for the year of publishing of the articles was set at a maximum of 10 years, i.e. between 2010-2020. However, to get a complete understanding of early radiographic methods, apex locators and apical anatomy, these limits were discarded, taking into consideration the difference in relevance of findings between the older articles compared to the newer ones. Other inclusion criteria for the articles were: publication in the English language, adult sample population and a preference for experimental and original studies. Exclusion criteria were: studies conducted on animals and studies published in a language other than English. Additionally, Google scholar was consulted to find additional articles on the various aspects of the topic presented in this research. The chosen articles were searched for through the 'advanced search' option in the online library of UEM and the following keywords were used: Apex locator, apical foramen, apical constriction, endodontics, working length, generation, accuracy, efficacy.

Discussion

The correct determination of the working length is a critical part of the endodontic treatment. Both techniques used to determine the working length have their own disadvantages. Regarding the radiographic technique there are many disadvantages. Brunton et al stated that there are too many radiographic images taken whilst a root canal retreatment is performed, the use of radiography solely would be insufficient in determining the working length, and that the patient would be exposed to excessive radiation (22). The determination of the working length is based around an estimation of the location of the apical constriction. This estimation is made from the knowledge from former literature (23). It is impossible whilst using the radiographic technique to detect the minor and major foramina or the cemento-dentinal junction (24). They only provide a two dimensional image of a three dimensional structure and they provide very little information of the curvature of the root within the plane of the film, visualisation of the file in the canal can also pose a challenge when the patient presents very dense bone and also around anatomical structures such as the zygomatic process (25). It is also limited as the apical foramen and the apical constriction cannot be seen using the radiographic technique (26). The disadvantage of the electronic apex locator is that it cannot identify the apical constriction in 100% of the cases and therefore cannot be relied on solely (23). They can also give inaccurate measurements of the length because of dentinal debris present in the canal caused by a lack of patency or other anatomical pathologies such as calcification. Other aspects that effect the accuracy of the reading of an apex locator are generally caused by the presence of something in the canal, this can include vital tissue, blood and inflammatory exudate all of which can conduct an electric current and therefore will effect the accuracy of the reading. Short circuiting can occur in the presence of

caries, metallic restorations, saliva or ,in the situation with multiple root canals, an instrument in an adjacent canal (25).

Accuracy of radiographic technique vs electronic apex locators

The main objective of this review was to compare the accuracy of apex locators against the accuracy of the standard radiographic method in regard to calculating the working length of a root canal. Both of these techniques have been described in the introduction

Studies in the past by Stavrianos et al, have provided data that shows with regards to the latest generation of apex locators could accurately determine the working length from 75% - 96.5% of the time whilst measuring teeth with mature root apexes (27). A more recent study has taken place by S Vijay Singh et al, and their results have corresponded with the study previously. However their results have been able to be more specific and they have factors that cause this range between 75% - 96.5%. Their study has shown that the electronic apex locator has a 75% accuracy when the measurement is taken at the minor constriction but when the measurement was taken 0.5mm short of the minor apical constriction the accuracy increased 90% (25). Whereas the clinical estimated working length showed a 25% accuracy of working length at the minor apical constriction, 45% when the working length was considered at or 0.5 mm short of the minor apical constriction and 30% beyond the minor apical constriction. The least amount of accuracy of working length was observed with operative adjusted working length using the radiographic method, in which only 10% accuracy of working length at the minor apical constriction, 45% when the working length was considered at or 0.5 mm short of the minor apical constriction, and 45% beyond the minor apical constriction thereby showing more

accuracy than the operator adjusted radiographic working length taken by the operator using a radiographic method of determining working length (25).

Accuracy of apex locators in dry canals versus canals containing irrigants

The way that a lot of studies have decided to test the accuracy of electronic apex locators accuracy in dry canals versus canals containing irrigants is the ability of the apex locator to detect the location and size of the root perforations, which we know is a key factor in successful root perforation treatment (21,28). A study was performed in which they tested three different apex locators on 30 extracted straight mandibular premolars all containing a single root. The three different apex locators (Root ZX mini, iPex and Epex pro) were then tested in four different canal environments which were in a dry canal, in a canal containing NaOCl, in a canal containing Chlorhexidine and a canal containing EDTA. All three of the canals produced clinically acceptable detection of the root perforations in all of the study conditions. Each apex locator produced the most accurate results in the dry canal when compared to the results with the canals containing solutions. However it was only with Root ZX mini that showed a significant difference comparing its accuracy in a dry canal compared to the canals containing solutions and even though the discrepancy was significant it was not significant enough to make the reading clinically unacceptable (21). Other literature has also provided information that shows very similar results that the presence of irrigants had no effect on the accuracy of different types of apex locators in determining the location or size of perforations of root canals (29). However one specific study did have contrasting results, which stated that the contents of the root canal did have an impact on the accuracy of the apex locator that they tested, which was a Root ZX apex locator (30). Even though this study has a contrasting result there are many other studies that

have disproved it using different devices, irrigants and methodologies that can explain the discrepancies shown in the previous study. Duran-Sindreu et al conducted a study that reported that using chlorohexidine or NaOCl had no influence on the measurements attained with the Root ZX or iPex (31). A study conducted by Koçak et al using Vdw gold electronic apex locator to measure the working length in dry conditions produced an accuracy reading of 83.5% which produced an acceptable level of quality of the root canal filling (32). Shabahang et al were evaluating electronic apex locator accuracy in detecting root perforation in the presence of NaOCl and came to the conclusion that the largest deviation of accuracy was in the presence of NaOCl (33). Shin et al produced a study that looked at the different concentrations of solutions used as irrigants and tested how the different concentrations would effect the electronic apex locator accuracy. They concluded that the electrical conductivity of water is 100-1000 μS/cm and when you compare that to the electrical conductivity of 1% NaOCl which is 1,72,420 μS/cm this shows a significant difference and these significant differences are stated to affect the accuracy of electronic apex locators in their determination of the working length (30). In one specific study where they concentrated on the accuracy of an iPex apex locator in the dry canal it showed a deviation of 0.76mm from the actual length of the perforation site, in the presence of 3% NaOCl it showed a standard deviation of 0.7mm from the actual length of the perforation site and in the presence of 2% chlorohexidine a standard deviation of 0.13mm from the actual perforation site (28). This was explained because of the lower electrical conductivity of chlorohexidine which is much lower than any of the other irrigants used in the study and this can be stated as the main contributing factor (28,30). When using the iPex apex locator in the presence of 3% NaOCl and 2% Chlorohexidine, NaOCl and chlorohexidine both present great evidence towards a null hypothesis ($P<0.05$) and the same is to be said in a dry canal ($P=0.02$).

However these studies need to be recreated in more clinical trials to present more realistic and accurate results (28).

Relationship of proximity to apical constriction to accuracy of reading

As stated before electronic apex locators have an accuracy rating rated between 75% and 96.5% with mature apices (18,25). These studies mention the difference between the accuracies depending on the reference point but is not the main objective of the studies. Many authors measure from the minor constriction (apical constriction) (25,34), whereas others measure from the major constriction (35). Electronic apex locators have allowed a certain amount of acceptable error in locating the terminal part of the canal, because of this there are many different ranges that have been used to evaluate the accuracy of an electronic apex locator (18). It is widely accepted that the minor constriction measured by electronic apex locators to be between 0.5mm – 1mm and this is considered to be highly accurate (20). This range has been seen as acceptable as there is a large range of different shapes in the anatomy of the apical third and in many studies the apical constriction is placed in between the mentioned range of 0.5mm – 1mm (24), Regardless of the apical limit the device must be able to be used accurately and must be reliable and repeatable over many operators (36). Radiographic estimations of the anatomic foramen can be located anywhere from 0.0mm – 3.0mm. A study was completed by Luigi Cianconi et al, that agreed with previous studies in which 15 of 22 files (68.2%) that appeared to be short on the buccolingual projection on the radiographic apex in fact had the tip of the file exceeding the desired working length (37). These results are in agreement with other studies that state that the accuracy of electronic apex locators are 10% - 40% more accurate than radiographic methods in locating the minor diameter (38). There was also an interesting relationship between diameter of the apical endpoint and the size of the file used. Many manufacturers of electronic apex locators

recommend to used the largest file that registers a working length value. Briseño-Marroquin et al conducted a study that measured the accuracy of four different electronic apex locators that had three different instrument sizes of hand files. They concluded that there was no difference in the accuracy of the determination working length when using the file sizes #08, #10 or #15 (39). In vitro studies have shown that the RootZX when within 0.5mm of the minor diameter to be between 62.7% - 68% accurate, however when we move to within 1mm of the minor diameter the accuracy improves and is between 90% - 97.5%. (38,40) Siu et al proved in an in vitro study that the average distance to the minor constriction was between 0.16mm – 0.22mm (40). Lucena-Martin et al also did an in vitro study which tested the accuracy of three electronic apex locators which provided the data that in 5% of the canals the measurements that were recorded exceeded the apical foramen (41). These results agree with another study undertaken by Luigi Cianconi et al which proved that in canals where the apex was marked on the dial the file tip was found past the apical foramen in 51.4% of said canals of extracted teeth used in their study (37). These findings must be seriously considered as it shows the comparison of results between clinical trials and in vitro studies, there is a larger variation that can be expected due to ideal and favourable circumstances for more accurate readings that are not available clinically and therefore an overestimation of the working length would result in a poorer prognosis of the treatment (42). This raises the question of whether the apical foramen should be stated at where the electronic apex locator states it to be, or some distance should be subtracted coronally from this calculated point to increase the prognosis of the treatment. Mayeda et al provided information that each individual operator would need to correlate their own radiographic and clinical findings with the reading provided on the analogue dial of the electronic apex locator to calculate where on the dial the operator would like to call his apex. (43) Using this method

authors are in agreement that withdrawing the electronic apex locator 0.5mm – 1mm has been advised and this will assure that the tip of the file does not extend past the apical constriction and therefore root canal overpreparation is avoided (44,45).

Technical and clinical conditions that affect the accuracy of apex locators

A study was conducted by De Camnargo et al examining the effect that preflaring had on the accuracy of finding the working length using four different electronic apex locators. There results showed that preflaring increased the accuracy of the Root ZX And Root ZX mini apex locators but did not have an effect on the accuracy of the other electronic apex locators in their study (40). The method of coronal flaring was also tested by Morgental et al and they concluded that for increased accuracy of finding the working length, the determination should be performed after coronal flaring (46). It must be stated that preflaring only improved that accuracy of some apex locators (47). Carneiro et al conducted a study that compared the accuracy of Tri Auto ZX devices in root canals that had been prepared by ProTaper instruments versus root canals prepared by routine methods. They concluded that the canals prepared with the ProTaper instruments produced a shorter working length that those prepared by the routine methods, however the differences were was not significant enough to be of clinical significance (48). Two studies were performed by Thomas et al and Briseno-Marroquin et al that both were examining the effect of different sizes of files used on the accuracy of the apex locators and both study were in agreement with the conclusion that there was no significant difference in the accuracy of the apex locator regardless of the size or type of file used (39,49). Ding et al and Tang et al held similar studies that examined the effect of root anatomy including curvature, tooth type, tooth location, apical anatomy and calcification of the canal and came to a conclusive conclusion that

these factors did effect the accuracy of electronic apex locators and also made accessing the canal in the form of canal preparation more difficult (50,51). However a study performed by Uzan et al studied the effect of the presence of lateral canals and its effect on the accuracy of apex locators and they came to the conclusion that the presence of lateral canals did not have an effect on the accuracy (52). Herrera et al conducted multiple studies that investigated the correlation between the size of the file used in the determination of the working length and the size of the apical constriction itself. They concluded that when a file with the diameter of 0.6mm was used that all of the outcomes were accurate, when files of diameters 0.7mm and 0.8mm for a measurement with the exact working length measurement the file size needed to be the same diameter as the apical constriction and finally whilst using a file with the diameter of 0.9mm regardless of the correlation with the diameter of the apical constriction the accuracy of the determination of the working length was low. The conclusion of their studies was that for a best outcome with regards to acquiring an accurate working length determination that the file diameter should be approximately the same as the diameter of the apical constriction (53,54). Goldberg et al investigated the effect of root resorption on the accuracy of the Root ZX apex locator and came to the conclusion that it did not have an effect on the accuracy of this apex locator (55). With regards to the effect of pulp conditions on the accuracy of apex locators there have been some contrasting studies. Pommer et al tested the accuracy of apex locators in both teeth with vital pulp and also teeth with necrotic pulp. They came to the conclusion that electronic apex locators were more accurate in vital teeth (56). However Ansiue et al concluded that the pulp condition did not have an effect on the accuracy of the Novapex apex locator when they performed their study (57). Piasecki et al performed a study in which they were testing the Root ZX II apex locator accuracy when preforming apical foramen detection in teeth with apical

periodontitis. They concluded that the accuracy was not effected when locating the apical foramen in these teeth with apical periodontitis (58). However Kuzminski et al had a contradictory opinion from the results that they acquired from their study in which they stated that apical lesions do have a negative effect on the accuracy of electronic apex locators (59).

Conclusions

The conclusions of this review are as follows:

- The use of electronic apex locators to measure the position of the apical constriction is more accurate than the radiographic measures. However, the recommended technique is still to use a combination of the electronic apex locators and the radiographic measure to utilize the advantages of both techniques which will produce the most chance of a successful treatment.
- The use of electronic apex locators does show a disparity in accuracy when used in a dry canal versus a canal containing irrigants. The studies reviewed have shown that the apex locator preforms more accurately in a dry canal. However, the difference in the accuracies is not significant and the apex locators perform within the range of clinical acceptance.
- Based on the studies that have been reviewed to produce the most accurate reading for the apical constriction it is advised that the 1mm should be deducted from the point marked as the apical constriction when using an electronic apex locator, as this showed this number gave the greatest increase in accuracy when applied in the studies reviewed.
- Based on the studies reviewed in this review the technical and clinical conditions do not have a profound affect with any clinical significance on the efficacy of apex locators in general however there is variability between brands of apex locators therefore it would be wise to identify the technical and clinical conditions that do affect your specific apex locator to achieve the most accurate result.

Responsibility

The current research is looking into increasing the accuracy and identifying limiting factors in apex locators. With an increased level of accuracy and less limiting factors of apex locators this will allow for a decreased number of radiographs needed to be taken during a procedure and also less radiographs needed to be taken in general. This will not only benefit the social aspect of responsibility as the patients who undergo endodontic treatments will be exposed to less x-ray radiation but also environmentally as less x-ray radiation will be produced. With a higher level of accuracy of apex locators this can ensure a higher rate of successful endodontic procedures as the prognosis percentage will be increased which will result in less failures and therefore less retreatments needing to be performed. By increasing the success rate of RCT and, therefore, retaining more teeth there is less need for more complex restorative procedures such as bridgework or implants to replace missing teeth following extraction which reduces costs to patients. Also maintaining occlusal function for patients by avoiding spaces when teeth are extracted benefits them.

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Annex

1.

Periapical health related to the quality of coronal restorations and root fillings

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Abstract

Hommez GMG, Coppens CRM, De Moor RJG. Periapical health related to the quality of coronal restorations and root fillings. *International Endodontic Journal*, **35**, 680–689, 2002.

Aim To evaluate the impact of the quality of coronal restorations scored on a clinical and radiographic basis and the quality of root fillings on periapical health.

Methodology Periapical radiographs were taken of 745 root-filled teeth, randomly selected from patients attending the Ghent University Dental School. The teeth had not received restorative treatment in the previous year. The coronal status was scored both clinically according to modified Ryge's criteria, and radiographically by evaluating the presence of signs of marginal leakage or decay. The quality of the root filling was scored according to criteria of length and homogeneity and the periapical status was categorized on the basis of presence or absence of radiographic signs of apical periodontitis. The relationship between coronal status, quality of root filling and periapical health was determined. The data were analyzed using χ^2 test, Odds ratio, Spearman's r_S and logistic regression.

Results Thirty-three percent of the teeth had apical periodontitis as diagnosed radiographically. Teeth with good and poor coronal restorations scored clinically had apical periodontitis in 31.1 and 36.8%, respectively; this difference was not statistically significant. The quality of the coronal restorations scored radiographically had a statistically significant influence on the periapical condition ($P < 0.001$) with apical periodontitis in 23.8 and 49.1%, respectively, for acceptable and unacceptable restorations. Marginal decay did not influence the periapical status. Teeth restored without a base under the coronal filling had apical periodontitis in 41.3%, whereas teeth with a base had significantly less ($P < 0.005$) apical periodontitis (25.9%). Composite-restored teeth exhibited apical periodontitis in 40.5% of cases whilst amalgam-restored teeth had apical periodontitis in 28.4% of cases; this difference was statistically significant ($P < 0.01$). Root-canal posts had no influence on periapical health. The length and homogeneity of the root-canal fillings had a significant influence ($P < 0.01$ and $P < 0.001$, respectively) on the presence of apical periodontitis, as well as the quality of the coronal restoration scored radiographically ($P < 0.001$).

Conclusion The importance of a good coronal restoration, as well as of a good root filling should be emphasized as the technical quality of both influencing the periapical status.

Keywords: apical periodontitis, clinical and radiographic evaluation, coronal leakage, coronal restoration, quality of endodontic treatment, root-canal treatment.

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Introduction

Follow-up studies on root-canal treatment (Grossman *et al.* 1964, Sjögren *et al.* 1990, Eriksen 1991, Friedman 1998) have reported the impact of the quality of the root-canal filling on the prognosis of root-canal treatment. In addition, several authors have described the importance of apical leakage on the treatment outcome of root-canal treatment (Strindberg 1956, Schilder 1967, Harty *et al.* 1970, Adenubi & Rule 1976, Ingle *et al.* 1985, Cohen & Burns 1998). The first to point out the effect of coronal leakage were Marshall & Massler (1961), although it was some time before this failure mode was

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2.

International Endodontic Journal

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In vivo accuracy of three electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II

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Abstract

Somma F, Castagnola R, Lajolo C, Paternò Holtzman L, Marigo L. *In vivo* accuracy of three electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II. *International Endodontic Journal,* **45**, 552–556, 2012.

Aim To compare *in vivo* three different electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II.

Methodology Thirty single-rooted permanent teeth scheduled for extraction because of periodontal disease were selected from 10 adult patients (ranging from 45 to 67 years) and divided into three groups of 10 teeth. Before the extraction, an access cavity was prepared and the crown was adjusted to establish a stable reference point for all measurements. The working length in Group 1 was determined using the Dentaport ZX apex locator. A K-file with the largest diameter that could reach the last green bar on the screen was stabilized in the canal using a dual-curable flow resin composite. The same procedure was used for the Raypex 5 (the file reached the last yellow bar) and Propex II (0.0 orange bar) apex locators. The teeth were then extracted and cleared. The distance between the tip of the file and the major foramen was then calculated for each tooth using digital photography according to Axiovision AC software (Carl Zeiss). Positive values were assigned when the file tip passed beyond the major foramen, negative values when the tip was short of the foramen and zero value when the file tip and the foramen coincided. Statistical analysis was performed using the chi-squared test or Fisher's exact test ($P \leq 0.05$).

Results Dentaport ZX, Raypex 5 and ProPex II produced, respectively, 6, 2 and 4 out of 10 correct measurements, 0, 6 and 5 long measurements and 4, 2, and 1 short measurements. The differences between the three electronic root canal length measurement devices were not significant ($P = 0.507$).

Conclusions Under the *in vivo* conditions of this study, the three electronic root canal length measurement devices were not significantly different in terms of locating the major foramen.

Keywords: electronic root canal length measurement devices, Endodontics, working length.

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Introduction

Accurate working length determination is a prerequisite for successful root canal treatment, reducing the chance of residual debris and bacteria in the canal or of damaging the periapical tissues because of over-instrumentation (Sjögren *et al.* 1990, Ricucci & Langeland 1998, Chugal *et al.* 2003).

The determination of the correct length at which the instrumentation and filling should be terminated is determined by the apical anatomy. It is usually accepted that there are different anatomical parts of the apical region: the apical foramen (major foramen) and the apical constriction (minor foramen) (Gordon &

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3.

Original Research Article

Comparative evaluation of three methods to measure working length - Manual tactile sensation, digital radiograph, and multidetector computed tomography: An *in vitro* study

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Abstract

Aim: Compare the measurement of working length with three different methods manual tactile sensation, digital radiography and Mutidetector computed tomography(MDCT).

Materials and Method: 40 human premolar extracted for orthodontic purpose were selected. Teeth were store in sodium chloride (0.9%) during the study. Access cavity was prepared and canal patency was seen with no 10 file in each tooth. Manually no 15 K file was inserted from access cavity until the tip was visible at the foramen, a silicon stopper was adjusted to the corresponding buccal cusp tip and the root canal length was measured. After that in each tooth with no-15 K file inserted from access cavity with stop at tip of buccal cusp until tip appear at foramen and x-ray was taken with digital radiograph (RVG,Satelac) and canal length was measured. After that all teeth are mounted in wax block,MDCT scan was done and in the scan images of teeth, root canal length is measured from buccal cusp tip to root end. After taking measurement of working length with all three methods and the data was stastically analyzed with One Way Analysis of variance (ANOVA) followed by Turkey's Test.

Results: ANOVA and turkeys test showed that there was no significant difference in the measurements by the three procedures ($p>0.05$).

Conclusion: Working length measurement with MDCT scan and other two conventional methods does not show significant difference in measurement. Use of newer 3D imaging technique is useful in root canal treatment for measuring working length.

Keywords: Digital radiograph; multidetector computed tomography; root canal; tactile sensation; working length

INTRODUCTION

Working length determination is an important step in endodontic therapy. Success of endodontic treatment depends on perfection in the negotiation of working length. Conventionally, working length of a tooth means "the distance from a coronal reference point to that point at which canal preparation and obturation should terminate." Hence, cement-enamel junction and apical constriction are two most crucial anatomical landmarks of a tooth a clinician must negotiate to achieve success in endodontic treatment.

Various methods are used to determine endodontic working length. Manual tactile sensation, being the oldest and most common technique in working length determination, requires a learning curve to achieve expertise. Conventional intraoral imaging is another commonly used modality for working

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4.

Original Article

Efficiency of an Integrated Apex Locator in Determining Working Length in Various Irrigating Solutions: An *In Vivo* Study

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ABSTRACT

Objective(s): The objective of this *in vivo* study was to compare and evaluate the accuracy of VDW Gold (VDW, Munich, Germany) integrated apex locator (IAL) and Root ZX Mini (J. Morita Corp., Kyoto, Japan) in two different irrigating solutions. **Materials and Methods:** Forty patients who required extraction were included in the study. Following local anesthesia, access opening was performed under rubber dam isolation. Initial negotiation of canal was performed using size 10 K-Files (M-Access, Dentsply Maillefer, Ballaigues, Switzerland). Cervical preparation was carried out using Rotary ProTaper SX files (Dentsply Maillefer, Ballaigues, Switzerland) under copious irrigation with 3% sodium hypochlorite. Patients were divided into two groups of 20 each: Group I (NaOCl) and Group II (CHX). The working length (WL) was determined in triplicates for each tooth using Root ZX apex locator and with S1 ProTaper rotary file in continuous motion in case of VDW Gold IAL in the presence of 3% sodium hypochlorite and 2% chlorhexidine. Therapeutic extraction was performed and WL was determined using size 15 K-Files under 20× magnification. **Results:** The paired sample independent *t* test showed that there was no significant difference between the Root ZX and VDW apex locator in determining the minor foramen in NaOCl group (P = 0.234, 0.453 respectively) and CHX group (P = 0.085, 0.087) when compared with actual working length. **Conclusion:** Both the apex locators were equally effective in determining WL at 0.5 mm from the apex in presence of irrigating solutions, that is, NaOCl and chlorhexidine.

KEYWORDS: *Chlorhexidine, electronic apex locators, integrated apex locator, irrigating solutions, minor foramen, sodium hypochlorite, working length*

INTRODUCTION

For a successful endodontic therapy, the ability to precisely measure the working length (WL) plays a vital role.[1-5] The steps of root canal therapy, that is, biomechanical preparation and obturation, cannot be accomplished unless accurate length of the tooth is measured. Failure to establish proper WL leads to the damage of periradicular tissues and various procedural errors.[6]

The most popular and commonly used method of WL determination is the radiographic method.[7] However, distortion, shortening and elongation, and interpretation variability are the common drawbacks.[8] Many drawbacks of radiographic WL determination are eliminated by the electronic method. Measuring the length from the coronal reference point to the apical

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5.

Clinical Efficacy of Electronic Apex Locators: Systematic Review

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Abstract

Introduction: Apical constriction has been proposed as the most appropriate apical limit for the endodontic working length. Despite being the most used, some limitations are attributed to the radiographic method of working length determination. It lacks precision because it is based on the average position of the apical constriction. The electronic apex locators have been presented as an alternative to the odontometry performed by radiography. These devices detect the transition of the pulp to the periodontal tissue, which is anatomically very close to the apical constriction and may perform with improved accuracy. **Methods:** A systematic review was performed to compare the radiographic and electronic methods. Clinical studies that compared both methods were searched for on 7 electronic databases, a manual search was performed on the bibliography of articles collected on the electronic databases, and the authors were contacted to ask for references of more research not detected on the electronic and manual search. **Results:** Twenty-one articles were selected. The majority were comparative or evaluation studies, and very few clinical studies comparing both methods are available. Several methodological limitations are present on the collected articles and debated in this review. **Conclusions:** Although the available scientific evidence base is short and at considerable risk of bias, it is still possible to conclude that the apical locator reduces the patient radiation exposure and also that the electronic method may perform better on the working length determination. At least one radiographic control should be performed to detect possible errors of the electronic devices. *(J Endod 2014;■:1–19)*

Key Words

Electric impedance, electronics, odontometry, radiography

The presence of microorganisms inside the root canal system is generally accepted as the main cause for root canal treatment failure (1). Therefore, maximum disinfection and obturation of the root canal system are mandatory. Moreover, the apical constriction is usually considered as the anatomic reference point where the root canal instrumentation and obturation should end (2). However, locating the apical constriction within a clinical perspective is very difficult, mostly because of its position and conformation, which are highly variable (3, 4). The distance between a coronal reference point and the apical constriction is referred to in endodontology as the working length. Methods of determining the working length include tactile sensation, knowledge of root canal lengths and anatomy, assessment of preoperative radiographs, and electronic apex locators (EALs) (5). Traditionally, radiography has been the most used method in obtaining information on the anatomy of the root canal and its surrounding tissues (6, 7). However, the working length measurement performed radiographically presents several limitations, namely radiation exposure (8), time expenditure, and difficulty of interpretation because it is a 2-dimensional image that is often overlapped with anatomic structures (9) and is subject to the interpretation of the observer (10). The EALs have been presented as valid instruments for identifying the apical constriction and determining working length alternatively to the radiographic method. Nevertheless, the electronic technique does not have an unquestionable reliability, because it may produce interference with metal restorations, submit wrong lengths and unstable readings (11, 12), and is more expensive. Despite the latter, the use of EAL has become increasingly popular, but an unequivocal consensus about the comparative accuracy between both methods is lacking and therefore needed. A preliminary search was conducted between July 1 and July 7, 2013 from the inception until present time on PubMed, Lilacs, Science Direct, Cochrane Collaboration, Evidence Based Dentistry (EBD), *Journal of Evidence-Based Dental Practice* (JEBDP), and NHS Evidence databases. This search used the terms "endodontics" and also the Portuguese and Spanish translations ("Endodontia") and ("Endodoncia"), respectively, which were used to take into account the large number of publications from Latin American countries included in the Lilacs database, and whenever possible also the use of a filter for "systematic reviews" and "meta-analysis". However, no types of systematic studies related to the comparison of working length determination methods were unearthed. Therefore, the aim of this systematic review was to assess the comparative clinical effectiveness of the working length determination with the use of radiographs or EAL.

The purpose of this systematic review was to answer to the following question: "In adult patients with permanent dentition, is the electronic apex locator more accurate

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6.

REVIEW

Electronic apex locators

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Abstract

Gordon MPJ, Chandler NP. Electronic apex locators. *International Endodontic Journal*, **37**, 425–437, 2004.

Prior to root canal treatment at least one undistorted radiograph is required to assess canal morphology. The apical extent of instrumentation and the final root filling have a role in treatment success, and are primarily determined radiographically. Electronic apex locators reduce the number of radiographs required and assist where radiographic methods create difficulty. They may also indicate cases where the apical foramen is some distance from the radiographic apex. Other roles include the detection of root canal perforation. A review of the literature focussed first on the subject of electronic apex location. A second review used the names of apex location devices. From the combined searches, 113 pertinent articles in English were found. This paper reviews the development, action, use and types of electronic apex locators.

Keywords: apex locators, endodontics, root apex, working length.

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Introduction

The removal of all pulp tissue, necrotic material and microorganisms from the root canal is essential for endodontic success. This can only be achieved if the length of the tooth and the root canal is determined with accuracy. The outcome of treatment of roots with necrotic pulps and periapical lesions is influenced significantly by the apical level of the root filling (Sjögren *et al.* 1990). Traditionally, the point of termination for endodontic instrumentation and obturation has been determined by taking radiographs. The development of the electronic apex locator has helped make the assessment of working length more accurate and predictable (Fouad & Reid 2000). The aim of this review is to examine the variety of apex locators available and overview their development. Contemporary endodontic texts were consulted and a database search performed using Medline to identify general studies on electronic apex locators. This resulted in 70 published articles in English. As apex locators have evolved over more than 60 years a number of older texts were consulted. Data from manufacturers was also studied, especially where identical instruments appeared to be marketed under different names around the world. A list of electronic apex locators was compiled and Medline searches were created for information on current electronic apex locators and accuracy studies for first, second and third generation apex locators based on the units name. This search resulted in a further 43 published articles in English.

Study results were standardized in the comparison tables by using accuracy data for plus or minus 0.5 mm from the apical foramen. Some studies used the apical constriction as a measure of accuracy but also included the apical foramen data.

The importance of working length

Grove (1930) stated that 'the proper point to which 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

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7.

Microscopic investigation of root apexes

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The necessity for an exact and complete knowledge of the topographic and microscopic anatomy of the dental apex has been recognized. That these studies have not been made has been acknowledged by Orban,[1-4] Blayney,[5-8] Skillen,[9,10] Grove,[11-16] Ono[17] and others.

Anatomy, of course, is the foundation of the art and science of healing. The terminal part of the root canal and the tissues which surround it are the center of the most activity and the greatest concern in the treatment and filling of the root canal. The works of Preiswerk,[18] Fischer,[19,20] Hess,[21] Barrett[22] and Davis[23,24] and others which date from the end of the last century and from the beginning of the present one, had as their almost exclusive center of interest the number of root canals and their divisions.

Up to the present time the endodontist has worked with extremely poor data. The roentgenogram of the apex seldom offers a clear view of the terminal part of the canal; therefore, one is obliged to use information not scientifically proved. Much of the information available was obtained from a limited number of studies, mostly macroscopic, of apexes principally in transverse sections of the root.

The prevailing idea of the topographic and microscopic anatomy of the apex, that is, the direction, form, diameter and so forth of the terminal part of the canal, the location of the foramen, its size and the thickness of the cementum, is completely erroneous. Blayney, Grove and many other authors share this same opinion. The extreme assertions about the

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8.

International Endodontic Journal (1984) 17, 192–198

The position and topography of the apical canal constriction and apical foramen

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Abstract. Two hundred and seventy extracted human teeth of unknown age were evaluated for apex to foramen and apex to constriction distances, in addition the topography of the apical portion of the root canal was studied under ×20 magnification. The mean A–F distance was 0.38 mm and the mean A–C distance 0.89 mm, although it must be stressed that a wide range of values was observed. Four distinct types of apical constriction were routinely found, whilst a proportion of canals were apparently blocked. The study confirms the view that it is impossible, with complete certainty, to establish the position of the apical canal constriction during root canal therapy, but indicates that a combination of methods might be more successful than reliance on one.

Introduction

The significance of the apical canal constriction in endodontic therapy is well recognized (Ingle 1965, Chanoch 1966, Harty 1982), and all modern canal preparation techniques attempt to make use of its potential to act as a natural barrier between the contents of the canal and the apical tissues (Schilder 1967, Christie & Peikoff 1980a, b, Weine 1982). Although some of the complexities of the apical portion of the root canal have been reported in the past (Kuttler 1955, Green 1956, 1960, Chapman 1969), very little prominence has recently been given to the detailed anatomy of this region and, in particular, to the position and topography of the apical canal constriction.

This lack of emphasis is unfortunate, for it is only with a greater understanding of the anatomy of the root canal that operators will be able to make intelligent assessments of the end point of preparation for each tooth being treated. This is especially relevant today, as it is apparent that reliance on the dictum that canal preparation should terminate 1 mm short of the radiographic apex is becoming increasingly unacceptable (Levy & Glatt 1970, Palmer *et al.* 1971, Kerekes & Tronstad 1977a, b).

The present study was, therefore, carried out in order to obtain further information about the topography of the apical portion of root canals of human teeth, and to see whether the shape or form of the apical constriction could influence root canal therapy procedures.

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Materials and methods

A total of 270 extracted human teeth of unknown age, but with completely formed apices, were included in the study (Table I).

The position of the apical foramen was determined after briefly dipping the apices of the roots into molten blue inlay wax, and then immediately removing the excess with a paper tissue. This always left a small quantity of wax in the foramen. The distance from the apex of the root to the centre of the foramen was then measured at ×20 magnification using a dissecting microscope and a graduated scale. A reference mark on the microscope stage was used to ensure that all measurements were taken in an identical position in order to eliminate any possible error due to parallax. By these means it was possible to work to an accuracy of 0.01 mm.

The root canal and apical constrictions were then exposed by carefully sectioning the root apices in a longitudinal direction using a diamond disc in a straight handpiece against the hand-held teeth. The area was then stained

9.

Original Article

Determination of Working Length of Root Canal

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Abstract

Background: This study was undertaken to determine the working length of root canal by microprocessor controlled impedance quotient apex locator and conventional radiographic method.
Methods: Patients whose teeth were to be extracted were selected for this study. A total of 100 teeth in the same or different patients were identified. Biomechanical preparation of the canal was done for smooth negotiation of the entire canal. The electrode of the Root ZX™ was attached to the selected file and the length adjusted till the beep of the Root ZX™ indicated the apical foramen. The electrode was removed but the file was stabilized with the help of soft gutta percha. An intraoral periapical (IOPA) radiograph was taken using basic guidelines. The tooth was then extracted under local anaesthesia along with the file in the tooth. A window was cut on one surface of the root apex approximately 4mm from the apex to expose the root canal. The file tip was identified. The distance of the file tip from the apex was measured under 3X magnification and the reading recorded. Similarly the distance from the file tip to the radiographic apex was measured on the radiograph under magnification and the reading recorded. All the readings were tabulated. The actual distances measured between the extracted tooth, the electronic apex locator and on the radiograph were compared using a paired 't' test to determine the accuracy of each method in relation to the minor diameter.
Result: It was observed that the radiographic method had a significant variation from the electronic method when compared to the actual measurement on the extracted tooth.
Conclusion: The electronic method is a more accurate method as compared to radiographic method for determination of working length of the root canal.

MJAFI 2010; 66 : 231-234

Key Words : Working length; Root canal; Cementodentinal junction; Electronic apex locators

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 definitely 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 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 on the basis of 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 [5]. Electronic apex locators are particularly useful when the apical portion of the canal is obscured by anatomic structures, such as impacted teeth, tori, the zygomatic arch, excessive bone density,

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10.

ORIGINAL RESEARCH

Evaluation of working length determination methods: An *in vivo* / *ex vivo* study

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ABSTRACT

This comparative study was done to determine the accuracy in measuring the working length of root canal using tactile method, electronic apex locator and radiographic method, *in vivo*, and comparing the lengths so measured to the actual working length, *ex vivo*, after extraction. Thirty single-rooted teeth scheduled for extraction were selected for the study. After obtaining the consent from patients, a preoperative radiograph was taken and access opening was done. Working length was determined by tactile method, by using Ingle's radiographic method and by using a Foramatron-IV digital apex locator. The teeth were then extracted and the actual working length was determined by placing an endodontic file in the root canal 0.5 mm short of the apex. The results indicated that among the three methods, the electronic apex locator showed the highest accuracy and the highest reliability for working length determination.

Key words: Electronic apex locator, radiographic tooth length, working length determination

The determination of the working length and its maintenance during cleaning and shaping procedures are key factors for successful endodontic treatment. The procedure for establishment of working length should be performed with skill, using techniques that have been proven to give valuable and accurate results and by methods that are practical and efficacious.

Radiographic method described by Ingle is one of the most common and reliable methods used in determining the working length. However, accuracy is difficult to achieve in this technique because the apical constriction cannot be identified; and the variables in techniques, angulation and exposure distort this image and lead to error due to laterally situated foramina.[1,2] In addition, there is radiation hazard both to the patients and the dental personnel. The observer's bias in radiographic interpretation may lead to errors.

The tactile perception because of the simplicity of the technique and its virtual effectiveness are factors that motivate a few clinicians in endodontic practice to still follow this technique. But this technique is in general inaccurate in root canals with immature apex, excessive curvature and if the canal is constricted throughout its length.

The electronic root canal working length determination has become increasingly popular as it eliminates many of the problems associated with radiographic methods. Its most important advantage over radiographic method is that it can measure the length of the root canal to the end of cementodentinal junction.[3] It is more accurate, easy and fast, with no requirements of X-ray exposures. But its accuracy is influenced by electrical condition of the canal, and it is inaccurate in teeth with wide-open apex and calcified canals. The possible variation between the radiographic apex and anatomic foramen with various techniques of determining the working length should be compared and analyzed with that of the electronic apex, to evaluate its accuracy. So this *in vivo* and *ex vivo* study was done to determine the accuracy in measuring the working length of root canal using tactile method, electronic apex locator and radiographic method, *in vivo,* and comparing the lengths so measured to the actual working length, *ex vivo,* after extraction.

MATERIALS AND METHODS

Thirty human single-rooted teeth scheduled for extraction with mature apices were selected for the study. Informed written consent was obtained from each patient before treatment. Teeth with open apices, calcification in the pulp chamber or root canal and resorped apex were excluded from the study.

A good quality preoperative radiograph was taken employing the extension cone paralleling technique by using Rinn XCP instruments, which minimizes dimensional distortion and presents the objects being radiographed in their true anatomical relationship and size. The reference point was marked on the preoperative radiograph at the incisal edge, and the tooth length was measured using a graduated metal scale from the reference point to the radiographic apex; the measurements were then recorded.

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11.

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ORIGINAL RESEARCH

the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com

An *in vivo* Evaluation of Different Methods of Working Length Determination

Jyoti Mandlik, Nitin Shah, Kalpana Pawar, Paras Gupta, Sarita Singh, Shoaib Ali Shaik

ABSTRACT

Objective: The purpose of this *in vivo* study was to compare the ability of digital tactile, digital radiographic and electronic methods to determine reliability in locating the apical constriction.

Materials and methods: Informed consent was obtained from patients scheduled for orthodontic extraction. The teeth were anesthetized, isolated and accessed. The canals were negotiated, pulp chamber and canals were irrigated and pulp was extirpated. The working length was then evaluated for each canal by digital tactile sensation, an electronic apex locator (The Root ZX) and digital radiography. The readings were then compared with post-extraction working length measurements.

Results: The percentage accuracy indicated that EAL method (Root ZX) shows maximum accuracy, i.e. 99.85% and digital tactile and digital radiographic method (DDR) showed 98.20 and 97.90% accuracy respectively.

Clinical significance: Hence, it can be concluded that the EAL method (Root ZX) produced most reliable results for determining the accurate working length.

Keywords: Working length, Cementodentinal Junction, Apical Constriction, Radiographic Terminus (RT) Radiovisiography (RVG), EAL, Root ZX.

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Conflict of interest: None declared

INTRODUCTION

Determining the working length is one of the most important steps in canal preparation. While determining the working length, locating the appropriate apical position has always been a challenge in clinical endodontics. Theoretically, the cementodentinal junction (CDJ) is the most ideal physiologic limit of the working length.[1] However, the CDJ is a histological landmark, not a morphologic landmark.[2] Hence, the other anatomical landmark for limiting instrumentation is the apical constriction (AC).[3]

To achieve the highest degree of accuracy in working length determination, a combination of methods should be used. Traditionally, conventional radiography is the most common method (and remains so), but radiographs necessitate exposing the patient to ionizing radiation and are two-dimensional images of a three-dimensional object that do not consistently reveal the root canal portals of exit. In recent years new imaging techniques have been developed to improve the clarity of the image, while reducing the radiation dose. Radiovisiography is a digital imaging technique that has 77% reduction in radiation dose and has the ability to alter the displayed image so that it may improve the identification of details.

Electronic methods locate the apical constriction without the need to irradiate the patient and get a near accurate working length. However; they too have remained adjuncts to radiography. Kobayashi and Suda have developed an apex locator, the Root ZX, which simultaneously calculates the ratio of two impedances in the same canal using two different frequencies, and is able to determine canal length in the presence of an electrolyte or vital pulp tissue.[4]

This study compared *in vivo* the diagnostic efficacy of an apex locator, digital tactile sensation and digital radiography (DDR), in determining the working length.

MATERIALS AND METHODS

Thirty-one premolars and a supernumerary mandibular incisor that had to be extracted for orthodontic reasons were selected according to the following criteria: (a) Intact crowns without restorations, so that the rubber stop could be adjusted to a clear anatomical reference, (b) normal X-ray anatomy, presenting roots without excessive curvatures or abnormal shapes and (c) closed apices.

Patients from the Department of Orthodontia, who had teeth fulfilling the selection criteria, were selected. The

12.

Radiographic "working length" revisited

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The desired "working length" for the biomechanical preparation and resultant obturation of the root canal system is one of the most important phases of endodontics. Traditionally, radiographs are used to confirm working length of the root length and to evaluate the subsequent obturation of the root canal system. This study attempts to determine if radiographs are an accurate method of root length determination in a period when electronic apex locators are proposed as their replacement. Eighty-seven vital and 24 nonvital teeth were accessed and files placed to and the radiographic working length before the file and teeth were extracted for sectioning. Results showed that the radiographic distance of the file from the apical vertex was 0.7 mm shorter than the actual file position. This discrepancy can lead the clinician to try to get closer to the radiographic apex, when in reality the end of the file is closer to the vertex than is suspected. The average distance short of the vertex as established by Kuttler should be increased to lie between 1.5 and 2.0 mm from the apical vertex to prevent overfilling the root canal.
(ORAL SURG ORAL MED ORAL PATHOL 1992;74:796-800)

Radiographic *working length* is the standard measure for endodontic instrumentation[1] in the dentinal portion of the root canal.[2-3] This measurement is difficult to achieve because the cementodentinal junction, the most apical portion of the dentinal canal, cannot be determined from a radiograph. Also, the cementodentinal junction can vary in relationship to the major foramen.[4-6] As a result of this variation, an average distance, as determined by Kuttler,[4] suggests that the cementodentinal junction lies 0.507 mm short of the apical foramen in persons 18 to 25 years of age and 0.784 mm short in persons 55 years of age and older. Variables in the radiographic technique, angulation, and exposure distort this image and lead to clinician error.[7-11]

There has always been doubt as to the degree of accuracy of the radiographic methods used to establish the desired working length.[12-15] The accepted apical goal of the obturation of the root canal system is between 0.500 mm to 1.000 mm short of the apical foramen.[16] This goal is difficult to achieve because the apical foramen cannot be seen on a radiograph. The only measuring point that can be viewed on a radiograph is the apical vertex. The apical vertex is the most apical portion of the tooth, but not necessarily the desired measuring point. The radiographic vertex does not always coincide with the funnel-shaped major foramen, minor foramen, or cementodentinal junction, locations that are important for both the biomechanical instrumentation and obturation procedures performed in endodontics.[17-18]

The purpose of this paper is to determine the relationship of the endodontic file as seen on working length radiographs to the actual position of the file in sectioned specimens. In addition, I wish to evaluate whether an average distance as seen on radiographs can be used to establish working lengths.

MATERIAL AND METHODS

There were 87 vital and 24 nonvital teeth for a total of 111 specimens from 47 patients. The patients were scheduled for extractions as a result of caries or periodontal involvement. The mean age of the patients was 48.9 years, with a range from 26 to 77 years.

In vivo bisecting angle radiographs were taken with HSG-58 X-ray film, adult size No. 2, (Schein, Inc., Port Washington, N. Y.) to obtain the initial radiographic measurements. After the radiographs, access into the pulp chamber was made with a No. 6 round bur with a high speed water spray. A Kerr No. 15 file (Kerr, Sybron Corporation, Romulus, Mich.) was

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13.

INTERNATIONAL ENDODONTIC JOURNAL

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Influence of instrument size and varying electrical resistance of root canal instruments on accuracy of three electronic root canal length measurement devices

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Abstract

Aggarwal V, Singla M, Bhasin SS. Influence of instrument size and varying electrical resistance of root canal instruments on accuracy of three electronic root canal length measurement devices. *International Endodontic Journal.*

Aim To evaluate the influence of instrument size and the effect of the electrical resistance of endodontic instruments on the accuracy of three electronic root canal length measurement devices (ERCLMDs).

Methodology Thirty single-rooted extracted human teeth were divided into three groups (n = 10) on the basis of the ERCLMD used: Root ZX II (J. Morita, Kyoto, Japan); ProPex (Dentsply Maillefer, Ballaigues, Switzerland); and iPex II (NSK, Tochigi, Japan). The electronic working length measurements (EWL) were made with K-files in the sequence sizes 08, 10, 15, 20, 25 and 30. The actual working length (AWL) was calculated by fixing a size 30 K-file in the canal and exposing the apical 5 mm of the root. The minor foramen was identified under an optical microscope, and its distance from the file tip was calculated. The accuracy of the ERCLMDs was evaluated in terms of percentages of accurate measurements (0.0 mm tolerance) and measurements with tolerance limits of ±0.5 mm and ±1.0 mm. The findings were analysed with the McNemar test, Pearson's chi-square tests and two-way analysis of variance. The multiple comparison procedures were carried out using Holm–Sidak method. The maximum electrical resistance tolerated by ERCLMDs was evaluated by connecting commercially available resistors between the file clip and the root canal instrument. The resistance was gradually increased until it started to affect the ERCLMD readings.

Results The ERCLMDs were able to actually locate the minor foramen in 7% of samples. File size did not affect the accuracy of ERCLMDs (P > 0.05). Overall, the ERCLMDs gave 65% readings within a tolerance limit of ±0.5 mm and 90% within a tolerance of ±1.0 mm. The electrical resistance of endodontic files was less than the maximum electrical resistance tolerated by ERCLMDs (0.6–1 Ω vs. 2500–4000 Ω).

Conclusions The size of the root canal instrument did not affect the accuracy of ERCLMDs in this laboratory study.

Keywords: electrical resistance, electronic root canal length measurement devices, root canal length, working length.

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Introduction

It is accepted that root canal instrumentation should be limited to the minor apical foramen (Gordon & Chandler 2004, Nekoofar *et al.* 2006, Simon *et al.* 2009, Martins *et al.* 2014). The minor apical foramen

14.

In vivo accuracy of conventional and digital radiographic methods in confirming root canal working length determination by Root ZX

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ABSTRACT

Objectives: To compare, *in vivo*, the accuracy of conventional and digital radiographic methods in determining root canal working length. Material and Methods: Twenty-five maxillary incisor or canine teeth from 22 patients were used in this study. Considering the preoperative radiographs as the baseline, a 25 K file was inserted into the root canal to the point where the Root ZX electronic apex locator indicated the APEX measurement in the screen. From this measurement, 1 mm was subtracted for positioning the file. The radiographic measurements were made using a digital sensor (Digora 1.51) or conventional type-E films, size 2, following the paralleling technique, to determine the distance of the file tip and the radiographic apex. Results: The Student "t" test indicated mean distances of 1.11 mm to conventional and 1.20 mm for the digital method and indicated a significant statistical difference ($p<0.05$). Conclusions: The conventional radiographic method was found to be superior to the digital one in determining the working length of the root canal.

Key words: Radiography. Odontometry.

INTRODUCTION

One of the main difficulties during endodontic treatment is to establish the root canal working length. Theoretically, this point would have to be the apical constriction. Clinically, however, identifying the apical constriction is a challenge, for it presents wide anatomical variations in the apical third of the root canal[14].

Preparation and filling should end 1 mm coronal to the radiographic apex of the root. The conventional radiographic method is traditionally used to determine the root canal working length. During this process, the distance between the tip of the file inserted in the root canal and the tip of the radiographic apex is measured. Based on this measurement the full working length can be estimated[7,12,13,16]. However, the conventional radiographic method presents some inconveniences, like the overlapping of anatomical structures and mainly the position of the apical foramen in relation to the apex, which in most cases does not coincide[13], and the film-processing time.

The digital radiographic method produces images using a sensor instead of radiographic film. The digital x-ray has some advantages over the conventional method, mainly a speedier image acquisition, a much lower radiation dose and image editing ability to more clearly study the details[9,19].

Nevertheless, the literature is not conclusive on whether the digital radiographic method is more efficient than the conventional radiographic method for root canal working length determination. Thus, the objective of this study was to compare the

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Endodontics

American Association of Endodontists

I. B. Bender, Editor

Estimating endodontic "working length" with paralleling radiographs

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UNIVERSITY OF IOWA COLLEGE OF DENTISTRY

Accurate determination of tooth length is an important consideration in endodontic procedures, for, once mechanical cleansing and sterilization of the root canal are completed, the success of endodontic therapy depends to a great extent on how adequately the root canal is sealed at the apex.

Most endodontists use a combination of diagnostic films, tactile sense, and test file or reamer with radiographs to determine working length,[1-3, 6-9, 16] which is usually defined as the length of the tooth from the incisal edge to the apical constriction.

This study was designed to increase the usefulness of right-angle paralleling diagnostic films as a guide in estimating the length to which the root canals of anterior teeth should be filed or reamed during endodontic therapy.

The correlation of length measurement data was obtained from three sources: (1) pre-extraction right-angle paralleling diagnostic radiographs; (2) extracted upper and lower anterior teeth; and (3) test file length determinations made on the extracted teeth.

Right-angle paralleling radiographic technique is based on principles used in medical radiography since 1895. Weston Price[15] described the use of these principles for dental radiography in 1901. McCormack[12A] published a plea for a standardized paralleling x-ray technique in 1920. Others, including LeMaster,[12] Fitzgerald,[4] and Updegrave,[17-19] have since suggested a variety of devices to minimize film-image distortion, including cotton roll backings, bite blocks, hemostats, and plastic film holders.

Adapted from a thesis submitted as a partial requirement for the Master of Science degree, granted in June, 1965.

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16.

Singh *et al. Stomatological Dis Sci* 2019;3:4
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Stomatological Disease and Science

Review

Open Access

Generations of apex locators: which generation are we in?

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Abstract

Endometrics is one of the key factors responsible for the success of endodontic therapy. Electronic determination of working length has gained enormous popularity, owing to its extreme accuracy and predictability. The literature is flooded with the self-proclaimed generations of the apex locators. This article is aimed at concise description of the actual scientific rationale behind the generations in order to diminish the related perplexity.

Keywords: Apex locators, endometrics, generations, working length

INTRODUCTION

Endometrics, the science of determining working length (WL) in endodontics holds high significance in the success of endodontic therapy. In the world of modern endodontics, the electronic WL determination by the use of electronic apex locators has become an integral component of the treatment protocol. The literature is full of the details regarding these fascinating electronic machines. However, the categorisation in the chronological order has somehow always been confusing. One of the convenient methods of segregating the apex locators is based on dividing them into different generations. This paper deals with simplifying the details of apex locators belonging to different generations so as to make it more easy and convenient for the readers. This particular classification is entirely based on the working principles of the apex locators. The clinical correlation can be interpreted from the fact that the more the machine can work in extreme environments and the more accurate it is, the better it is for the dental professionals.

17.

An overview of electronic apex locators: part 2

R. Ali,[*1] N. C. Okechukwu,[2] P. Brunton[3] and B. Nattress[4]

VERIFIABLE CPD PAPER

PRACTICE

IN BRIEF

- Describes the different generations of electronic apex locators, how they function and their relative accuracies.
- Describes how the use of third and fourth generation electronic apex locators are recommended to help clinicians determine the apical limit of the root canal system.
- Describes clinical tips to help optimise the use of an electronic apex locator whilst carrying out orthograde root canal therapy.

A number of electronic apex locators are available for use during endodontic treatment. The use of third and fourth generation electronic apex locators (EAL) are recommended to help clinicians determine the apical limit of the root canal system (RCS). The presence of different irrigating media in the RCS does not impact significantly on the performance of third/fourth generation apex locators. The devices are most accurate at determining the apical limit when the attached endodontic file contacts the periodontal ligament space and the visual analogue displays 'Apex' or '0.' Given the accuracies of modern generation EALs, the clinician should be able to consistently identify the apical limit of the tooth under treatment. Their use in conjunction with appropriate radiographs and the clinician's knowledge of average RCS lengths and anatomy will maximise the successful outcome of any orthograde endodontic treatment.

INTRODUCTION

In Part 1 of this series, readers were introduced to the micro-anatomical features of the apical terminus and the ability of a tooth to function as a capacitor. In the second part of this series, readers will be introduced to: (a) the different types of electronic apex locator (EAL); (b) their modes of action; (c) their relative accuracies and (d) methods to optimise their success in clinical practice.

RESISTANCE BASED (FIRST GENERATION) APEX LOCATORS (RBEALS)

Sunada[1] carried on earlier work by Custer[2] and Suzuki[3] and determined that the electrical resistance between an endodontic instrument at the apical foramen and an electrode attached to oral mucous membrane was approximately 6.5 kW. RBEALs (such as the Root Canal Meter (Onuki Medical Co., Tokyo) and Dentometer (Dahlin Electromedicine, Copenhagen) are based on a simple model. They apply a small direct current to the tooth under investigation of known voltage. The resistance at each level of the RCS can be calculated using these two variables using Ohm's Law. At the periodontal ligament space (PDLS), the resistance of the circuit will equal 6.5 kΩ and the RBEAL are programmed to detect this value (Fig. 1).

Although these devices were accurate under dry conditions, their accuracy decreased when electrolytes, pulp tissue, inflammatory exudate or excessive haemorrhage were associated with the RCS.[4,5] As soon as the file tip touched an electrolyte, the direct current (DC) voltage would polarise the tissue, complete the circuit and incorrectly register that the PDLS had been reached. The devices also ignored the capacitance component of the circuit. Furthermore, the use of a DC would often cause an electric shock sensation to be felt by the patient which is clearly disadvantageous.[6] The fact that these devises were less reliable than using radiographs to determine RCS length[7] led practitioners to stop using them.

IMPEDANCE BASED (FIRST GENERATION) APEX LOCATORS (IBAL)

To overcome the aforementioned problems, the next set of EALs were based on the impedance of the circuit set up within the RCS. This would in theory be more accurate than the solely resistive devices. However, the impedance (and therefore capacitance) of the RCS was dependent on many variables and would vary between different RCSs. Consequently, the biggest disadvantage for IBALs was the need for

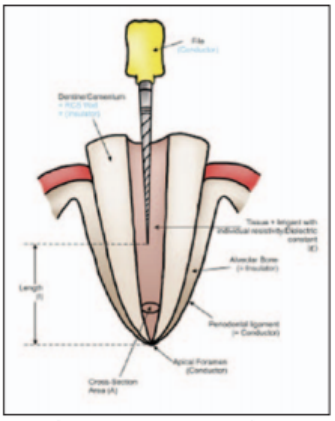

Fig. 1 Schematic representation of an endodontic instrument, the root canal system and the periodontium functioning as a capacitor. (From Nekoofar *et al.*[14]). The resistance of the system is 6.5 kW when a file touches the PDLS at the apical foramen. Different irrigants in the RCS will have different diaelectric constants (ε) (Part 1 of this series, Fig. 4) EALs need to take this feature into account to avoid generating inaccurate readings

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18.

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REVIEW

The fundamental operating principles of electronic root canal length measurement devices

M. H. Nekoofar[1,2], M. M. Ghandi[3], S. J. Hayes[2] & P. M. H. Dummer[2]

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Abstract

Nekoofar MH, Ghandi MM, Hayes SJ, Dummer PMH. The fundamental operating principles of electronic root canal length measurement devices. *International Endodontic Journal*, **39**, 595–609, 2006.

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. Several techniques have been used for determining the apical canal terminus including electronic methods. However, the fundamental electronic operating principles and classification of the electronic devices used in this method are often unknown and a matter of controversy. The basic assumption with all electronic length measuring devices is that human tissues have certain characteristics that can be modelled by a combination of electrical components. Therefore, by measuring the electrical properties of the model, such as resistance and impedance, it should be possible to detect the canal terminus. The root canal system is surrounded by dentine and cementum that are insulators to electrical current. At the minor apical foramen, however, there is a small hole in which conductive materials within the canal space (tissue, fluid) are electrically connected to the periodontal ligament that is itself a conductor of electric current. Thus, dentine, along with tissue and fluid inside the canal, forms a resistor, the value of which depends on their dimensions, and their inherent resistivity. When an endodontic file penetrates inside the canal and approaches the minor apical foramen, the resistance between the endodontic file and the foramen decreases, because the effective length of the resistive material (dentine, tissue, fluid) decreases. As well as resistive properties, the structure of the tooth root has capacitive characteristics. Therefore, various electronic methods have been developed that use a variety of other principles to detect the canal terminus. Whilst the simplest devices measure resistance, other devices measure impedance using either high frequency, two frequencies, or multiple frequencies. In addition, some systems use low frequency oscillation and/or a voltage gradient method to detect the canal terminus. The aim of this review was to clarify the fundamental operating principles of the different types of electronic systems that claim to measure canal length.

Keywords: apex locators, canal length, endodontics, root canal terminus.

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Introduction

The presence of bacteria and their by-products within the root canal system predisposes to apical periodontitis. In essence, treatment of a microbial inflammatory disease is directed at the elimination of the antigenic

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19.

An overview of electronic apex locators: part 1

R. Ali,*[1] N. C. Okechukwu,[2] P. Brunton[3] and B. Nattress[4]

IN BRIEF

- Describes the micro-anatomy of the apical terminus for a root canal system and different methods of measuring root canal system length.
- Describes basic physics, current electricity and how teeth can function as capacitors.
- Describes how this capacitor model represents a starting point upon which all apex locators are based.

PRACTICE

To effectively carry out root canal therapy, the clinician must accurately determine the apical limit of the root canal system as well as the position of the canal terminus. Its position can be estimated using a variety of techniques, including radiographs, tactile feedback from endodontic instruments and electronic apex locators. This article describes the micro-anatomy of the apical terminus, different methods of measuring root canal system length and how a tooth can function as an electrical capacitor. This capacitor model represents a starting point upon which all apex locators are based. An understanding of this model can help the practitioner to optimise the use of apex locators, understand their limitations and avoid errors that can occur.

INTRODUCTION

An inflammatory response in the pulp-dentinal complex can lead to complete pulpal necrosis, apical periodontitis and ultimately the formation of a dental abscess. If the tooth is to be asymptomatically retained, root canal therapy (RCT) must be implemented. The aims of RCT include:

1. Accessing the root canal system (RCS)
2. Chemo-mechanical debridement of the RCS[1]
3. Shaping the RCS to accept a root canal filling (RCF) material
4. Obturating the RCS
5. Providing cuspal coverage post endodontic treatment for posterior teeth[2] (Fig. 1).

To effectively carry out the above stages, the clinician must accurately determine the apical limit of the RCS as well as the position of the canal terminus. The latter is especially true as the systematic review by Ng *et al.*[3] strongly suggests that RCFs which extend beyond or are more than 2 mm short of the radiographic apex are associated with a higher chance of endodontic failure. It is therefore imperative that the clinician can identify the point at which the root canal system terminates.

Electronic Apex Locators (EALs) can be used to determine the length of a RCS and the position of the canal terminus. This two-part series of articles will update readers on our current understanding of apex locators. This first part will focus on (a) the anatomy of the apical terminus, (b) methods of determining the apical limit of the RCS and (c) basic physics of the instrument. The second part will discuss (a) how EALs work (b) how accurate they are in clinical practice and (c) practical points on how best to use them.

THE ANATOMY OF THE APICAL TERMINUS

To appreciate the workings of an EAL, an understanding of the micro anatomical features of the apical terminus is essential.

Kuttler elegantly described the anatomy of the apical terminus.[4] The foramen of the main root canal (the major apical foramen) is not always coincident with the radiographic or anatomical apex. It is situated at the tip of the root but is often located to one side of the anatomical apex (Fig. 1). Reported mean apex to

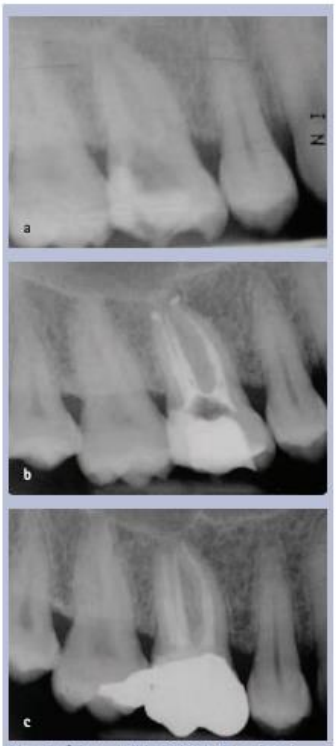

Fig. 1 a) Irreversible Pulpitis Associated with the UR6; b) UR6 Post irrigation with sodium hypochlorite/instrumentation with protaper files and medicated with Vitapex; c) UR6 post obturation with gutta percha and restored with a full gold crown

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20.

SCIENTIFIC ARTICLE

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Ex vivo evaluation of the ability of four different electronic apex locators to determine the working length in teeth with various foramen diameters

AK Ebrahim,* R Wadachi,† H Suda‡

Abstract

Background: The aim of this *ex vivo* study was to evaluate the accuracy of four electronic apex locators (EALs) to determine the working length in teeth with various foramen diameters. Our previous study revealed that electronically measured canal length was influenced by the root canal diameter. It is not known whether foramen size would interfere with the reading accuracy of an EAL.

Methods: A total of 36 extracted human lower single rooted premolar teeth were divided into four groups of nine teeth each. In groups A, B and C, the root canals were instrumented using #10–80, #10–100 and #10–120 K-files, and the tip of size #80, #100 and #120 K-files were permitted to pass through the apical foramen to a length of 1mm, respectively. In group D, the teeth were instrumented using #10–140 K-files and the tip of #140 K-file was permitted to pass through the apical foramen to a length of 5mm. Thus, the average apical foramen diameters in groups A, B, C and D were approximately 0.82mm, 1.02mm, 1.22mm and 1.5mm, respectively. The teeth were then mounted in 1% agar and four EALs were used: Root ZX, Foramatron D10, Apex NRG and Apit 7. For electronic measurement, sizes #10 and #80, #10 and #100, #10 and #120, and #10 and #140 K-files were used for groups A, B, C and D, respectively. During electronic measurement the canals were flushed with 6% sodium hypochlorite solution.

Results: Three-way ANOVA and Bonferroni test showed that EAL, file size and foramen size all had a significant influence on the measurement error ($P<0.0001$), with all the interactions between these three factors being significant ($P<0.0001$).

Conclusions: The four EALs were unreliable to determine the working length of teeth with a wide apical foramen, when using a small size file. The Root ZX and Foramatron D10 showed significantly better scores than the other two EALs and may be more reliable to determine the working length of teeth with a wide apical foramen, if a tight-fit file is used.

Key words: Agar, apical foramen, electronic apex locators, root length determination, root canal preparation.

Abbreviations and acronyms: ANOVA = analysis of variance; CDJ = cementodentinal junction; EAL = electronic apex locator; NaOCI = sodium hypochlorite solution.

(Accepted for publication 7 February 2006.)

INTRODUCTION

Accurate determination of working length is a crucial part of successful root canal therapy.[1] Root canal instrumentation should ideally terminate at the apical constriction. This statement was supported by Kuttler, who showed that the average distance from the apical foramen to the apical constriction is approximately 0.52mm in young age groups and 0.65mm in older age groups.[2] The apical constriction has traditionally been determined by digital-tactile sense and radiography.[3]

Electronic apex locators (EALs) have been used clinically for more than 40 years as an aid to determine the file position in the canal. These devices, when connected to a file, are able to detect the point at which the file leaves the tooth and enters the periodontium. Development of the EAL was initiated in 1942 by Suzuki.[4] He conducted *in vivo* studies on dogs, and using direct current, discovered that the electrical resistance between the periodontal ligament and the oral mucosa was constant. In 1962, Sunada applied this principle to clinical practice based on Suzuki's findings.[5] However, accurate readings were not always obtained in the presence of vital pulp tissue, root canal irrigants and intracanal fluids such as serous, purulent or haemorrhagic exudates. Finally, Kobayashi and Suda

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21.

EUROPEAN ENDODONTIC JOURNAL

ORIGINAL ARTICLE

Comparative Evaluation of Accuracy of Ipex, Root Zx Mini, and Epex Pro Apex Locators in Teeth with Artificially Created Root Perforations in Presence of Various Intracanal Irrigants

Sakshi BILAIYA, Pallav Mahesh PATNI, Pradeep JAIN, Sanket Hans PANDEY, Swadhin RAGHUWANSHI, Bhupesh BAGULKAR

ABSTRACT

Objective: The study aimed to compare and evaluate the accuracy of iPex, Root ZX mini, and Epex Pro Electronic apex locators (EALs) in diagnosing root perforations in both dry and in different wet conditions: 5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), and 17% Ethylenediaminetetraacetic acid (EDTA).

Methods: Thirty extracted, human single rooted mandibular premolars were artificially perforated with a diameter of 1.5 mm in middle third of root. Actual canal lengths (ALs) in millimetre (mm) were evaluated for all teeth up to perforation location, and alginate mould were used to embed the teeth. After this, the electronic measurements were calculated by all EALs up to perforation site using a 20 K-file in both dry and wet canal conditions. Up to the perforation sites, the ALs were subtracted from the electronic length. Statistical analyses were done using One-way ANOVA with post hoc tukey's test for pairwise comparison and the level of significance was set at 0.05.

Results: All three EAL's detected canal perforations which were clinically acceptable. There was significant difference for dry and wet conditions. Most accurate measurement were seen in dry canals for all three EALs. Root ZX mini in dry condition showed most accurate reading and there was a significant difference when compared with other groups. No significance difference was observed in iPex and Epex Pro Apex locator, and between NaOCl and CHX, CHX and EDTA.

Conclusion: Perforations were determined within a clinical acceptable range of 0.03–0.05 mm by all three EALs. Root ZX mini in dry canals gave most accurate measurement. The presence of irrigating solution influenced the accuracy of all the apex locators.

Keywords: Electronic apex locator, root perforations, root ZX mini

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HIGHLIGHTS

- This study evaluated the accuracy of various electronic apex locators in presence of different canal conditions to detect root perforations.
- All three apex locators detect canal perforations within clinical acceptable range.
- There was no significant difference in accuracy of different apex locators when used with different irrigants.
- Root ZX mini in dry conditions gave most accurate reading.

INTRODUCTION

Endodontic failure may occur because of root perforations, which is considered as one of the important reasons for failure (1). These perforations are artificial communication that are formed between root canal and the oral cavity or periodontium (2). These perforations result in periodontal involvement which may further result in the loss of tooth. Perforations may be caused iatrogenically, resorption, or caries (1). Root perforation prognosis depends on size, site, and time elapsed before the perforation is detected and treated (3).

To reduce the chances of irrigating material to extrude into surrounding peri-radicular tissues and to prevent instrumentation going beyond the perforation during root canal treatment, clinical diagnosis of location of perforations is essential (4). Diagnosis of iatrogenically created perforations can be achieved with the aid of clinical findings and radiographic interpretation. Root perforations can be identified by (a) Placing reamer or file into an opening, which get loose rather than snugly fit in a true canal, (b) direct observation of bleeding, (c) indirect observation

22.

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The Effect of an Apex Locator on Exposure to Radiation During Endodontic Therapy

Paul A. Brunton, PhD, MSc, BChD, FDS (Rest Dent), FDSRCS (Edin), Dilshan Abdeen, BDS, and Tatiana V. Macfarlane, BSc, PhD

The objective of this study was to investigate whether the use of an electronic apex locator results in a reduction in X-ray exposure during endodontic therapy. Fifty, sound, extracted, single-rooted canine and incisor teeth were selected and randomly divided into two groups (A and B) of 25 teeth. The working length was determined radiographically with (group B) and without (group A) adjunctive use of an apex locator by one operator. After working length determination, the teeth were sectioned and the actual working length measured for comparison. For group A, 14 retake radiographs were required to determine the working length, whereas group B required no retake radiographs; this difference was highly significant ($p < 0.001$). The electronic apex locator was extremely accurate in locating the apical foramen with all teeth tested within 0.5 mm of the anatomical apex and 11 (44%) teeth at the apical foramen. In contrast, 15 (60%) teeth tested using radiographs alone were within 0.5 mm of the anatomical apex and only 4 (16%) teeth were actually at the anatomical apex. It was concluded that using an electronic apex locator as an aid to endodontic therapy could potentially reduce the number of diagnostic radiographs required for working length determination. Location of the apical foramen using a combination of an electronic apex locator and radiographs to determine working length is more accurate than using radiographs alone.

The concept of measuring root canal length electrically as part of endodontic treatment was first reported over 30 yr ago (1). Electronic apex locator devices, which rely on the ratio of two electrical impedances between an electrode in contact with the oral mucosa and one passed through a root canal in contact with the periodontal ligament, are being used to a greater extent (2). The accuracy of electronic apex locators has been studied in depth, and they have been proven to locate the apical foramen effectively and reproducibly (3–5). Even in the presence of canal irrigants, such as ethanol, local anesthetic solution, and sodium hypochlorite, as well as pus and necrotic tissue, apex locators are still able to maintain their high level of accuracy (4, 6).

The current generation of electronic apex locators have reported accuracy of up to 93.4% (7). To achieve this degree of accuracy, however, the operator must have a good working knowledge of root canal anatomy as well as being aware of possible variations in morphology (2). Experience with electronic apex locators is also essential for good and consistent results (2).

The relative accuracy of electronic apex locators compared with radiographic methods to reliably locate the apical foramen has also been investigated (8). It was concluded that the apex locator was marginally more reliable than the radiographic method when locating apical foramina. Indeed, it has been shown that when electronic apex locators are used the probability of being within 0.76 mm of the cementodentinal junction, and therefore the apical foramen, is 68% (9). As a consequence it has been suggested, that when electronic apex locators are used radiographs need not be taken for working length determination. It is still recommended, however, that a radiograph be taken at this stage so as to exclude the possibility that a lateral canal has been negotiated in error (3).

During endodontic treatment a number of radiographs are required (10):

1. Preoperative assessment supplemented with parallax views if required
2. Working length determination at different angles in the case of teeth with multiple roots
3. Post obturation
4. For review and monitoring purposes

It is at the working length determination stage where the greatest potential variation in X-ray exposure to patients occurs. This is mostly due to repeat radiographs being taken, particularly by inexperienced practitioners, which potentially leads to increased X-ray exposure to the patient. The aim of this study was to investigate whether the use of an electronic apex locator as an adjunct to the radiographic determination of working length could potentially result in a reduction of X-ray exposure to patients during endodontic therapy.

MATERIALS AND METHODS

Fifty, sound, extracted, single-rooted canine and incisor teeth were selected and randomly divided into two groups (A and B) of

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Histomorphometric Study of the Root Apex of Mandibular Premolar Teeth: An Attempt to Correlate Working Length Measured with Electronic and Radiograph Methods to Various Anatomic Positions in the Apical Portion of the Canal

Ehab E. Hassanien, PhD, Abeer Hashem, PhD,* and Henry Chalfin, DDS†*

Abstract

One aim of this study was to attempt to relate the position of the cementodentinal junction (CDJ) and the apical constriction to that of the apical foramen in mandibular premolars, as well as to measure the canal diameter at these various points. Another aim was to evaluate how electronic working length determination by Root ZX and radiographic method of working length determination correlated to the location of these various positions. The results showed that CDJ was detected at average distance of 0.3 mm from apical foramen with average canal diameter of 0.32 mm, whereas the apical constriction was detected at average distance from apical foramen of 1.2 mm with canal diameter of 0.22 mm. There was a statistically significant difference between file-tip position from apical foramen in group I working length measured by Root ZX and group II working length measured radiographically. Also this significant difference was found between file-tip position in both groups and CDJ and apical constriction. The average canal diameter at 0.5, 1, and 1.5 mm from apical foramen was 0.33 ± 0.11, 0.28 ± 0.06, and 25 ± 0.05 mm, respectively. *(J Endod 2008;34:408–412)*

Key Words

Apex locator, apical constrictor, radiographic length

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Accurate working length determination is one of the main factors leading to success in root canal treatment. Recent studies have shown the histologic results of endodontic treatment to be superior when instrumentation and obturation are limited to the apical constriction (1). Neither the radiographic method nor the manual approach (tactile sensation) used for working length determination allowed for the precise location of the apical constriction (2). The manual technique is highly dependent on the tactile sense of the operator and is therefore subjective and hardly reproducible (3, 4). With radiographic determination (5), the working length is generally measured either to or a half-millimeter short of the radiographic apex, a point at which the apical constriction has been generally thought to be located. In reality, however, this point might be well beyond the apical foramen (2). Williams et al (6) mentioned that 2 trends should be considered when radiographic working length is determined. When a file is long radiographically, it is actually longer than it appears by an average of 1.2 mm, whereas when a file is short radiographically, it is closer to the apical foramen than it appears by an average of 0.46 mm, because 2-dimensional image will often give no indication of an apical foramen that is located well short of the root terminus (1).

Radiographic determination might also be influenced by a number of other factors, such as tooth inclination, film position, length of the cone, vertical and horizontal cone angulations, and film processing issues (7). In addition, radiographs expose patients to ionizing radiation, so it is advisable to keep their use to a minimum as an adjunct to electronic methods. Traditionally, it has been largely accepted that endodontic working length should be measured to the cementodentinal junction (CDJ) (8, 9), a point that was considered analogous to the apical constriction. In a recent study, Lee et al (10) reported that most commonly; file tips ended at the major foramen, regardless of the existence of a detectable CDJ, suggesting that the major foramen was a more reproducible position than the CDJ, which is merely a histologic landmark and not a clinical position in root canal system (11). Also, D'Assunção et al (12) found that measurements from the major foramen were more consistent than from the CDJ, whereas Shabahang et al (13) showed that the Root ZX (J Morita Co, Tokyo, Japan) was able to locate the foramen within a range of ±0.5 mm in 96.2% of cases. On the contrary, in 98% of the electronic measurements made by Satio and Yamashita (14) and Herrera et al (15), the Root ZX locator was able to detect the point at which the file tip entered the apical constriction area; even in the absence of this area, this locator was able to establish the narrowest point in the root canal.

The aim of this study was to attempt to relate the position of CDJ and the apical constriction to that of the apical foramen, as well as to measure the canal diameter at these various points. Furthermore, we attempted to evaluate how electronic and radiograph methods of working length determination correlated to the location of these various positions.

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International Endodontic Journal (1984) 17, 192–198

The position and topography of the apical canal constriction and apical foramen

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Abstract. Two hundred and seventy extracted human teeth of unknown age were evaluated for apex to foramen and apex to constriction distances, in addition the topography of the apical portion of the root canal was studied under ×20 magnification. The mean A–F distance was 0.38 mm and the mean A–C distance 0.89 mm, although it must be stressed that a wide range of values was observed. Four distinct types of apical constriction were routinely found, whilst a proportion of canals were apparently blocked. The study confirms the view that it is impossible, with complete certainty, to establish the position of the apical canal constriction during root canal therapy, but indicates that a combination of methods might be more successful than reliance on one.

Introduction

The significance of the apical canal constriction in endodontic therapy is well recognized (Ingle 1965, Chanoch 1966, Harty 1982), and all modern canal preparation techniques attempt to make use of its potential to act as a natural barrier between the contents of the canal and the apical tissues (Schilder 1967, Christie & Peikoff 1980a, b, Weine 1982). Although some of the complexities of the apical portion of the root canal have been reported in the past (Kuttler 1955, Green 1956, 1960, Chapman 1969), very little prominence has recently been given to the detailed anatomy of this region and, in particular, to the position and topography of the apical canal constriction.

This lack of emphasis is unfortunate, for it is only with a greater understanding of the anatomy of the root canal that operators will be able to make intelligent assessments of the end point of preparation for each tooth being treated. This is especially relevant today, as it is apparent that reliance on the dictum that canal preparation should terminate 1 mm short of the radiographic apex is becoming increasingly unacceptable (Levy & Glatt 1970, Palmer *et al.* 1971, Kerekes & Tronstad 1977a, b).

The present study was, therefore, carried out in order to obtain further information about the topography of the apical portion of root canals of human teeth, and to see whether the shape or form of the apical constriction could influence root canal therapy procedures.

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Materials and methods

A total of 270 extracted human teeth of unknown age, but with completely formed apices, were included in the study (Table I).

The position of the apical foramen was determined after briefly dipping the apices of the roots into molten blue inlay wax, and then immediately removing the excess with a paper tissue. This always left a small quantity of wax in the foramen. The distance from the apex of the root to the centre of the foramen was then measured at ×20 magnification using a dissecting microscope and a graduated scale. A reference mark on the microscope stage was used to ensure that all measurements were taken in an identical position in order to eliminate any possible error due to parallax. By these means it was possible to work to an accuracy of 0.01 mm.

The root canal and apical constrictions were then exposed by carefully sectioning the root apices in a longitudinal direction using a diamond disc in a straight handpiece against the hand-held teeth. The area was then stained

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ORIGINAL RESEARCH

An *in vivo* comparative evaluation to determine the accuracy of working length between radiographic and electronic apex locators

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ABSTRACT

Background: An *in vivo* comparative evaluation to determine the accuracy of working length between radiographic and electronic apex locators.

Aim: The study was aimed at evaluating the accuracy of electronic apex locator, to determine the working length of root canal, and to compare it with the radiographic method of working length determination.

Materials and Methods: A total of 20 teeth selected for the study had to go for extraction because of periodontal or orthodontic reasons. Access cavity was prepared and the clinical estimated working length (CEWL) was determined with 10–25 no. K-file. A radiograph was then taken for determining the radiographic estimated working length (REWL). For electronic measurement of root canal, a 10 no. K-file was advanced toward the apex until it reached a 0.5 mm short of apex as shown by the apex locator. After fixing the file with a light cured composite, the tooth was extracted, the tooth surface was then longitudinally grounded using straight fissure diamond bur until the root canal and the tip of the file were visible. The distance of file from the minor constriction was measured with help of stereomicroscope.

Statistical analysis: The chi-square test was used for statistical analysis for this study.

Results: The chi-square test where $\chi^2 = 21.034$ with $P = 0.000$ indicated that a significant difference exists among the groups. The electronic method showed highest number of cases with the working length at the minor constrictor.

Conclusion: The electronic method for determining the working length of root canal was found to be more accurate than the radiographic method.

Key words: Electronic apex locator, radiographic method, working length

One of the most important steps of endodontic therapy is the determination of accurate working length, which is the distance from the coronal reference point to the point at which the canal preparation and obturation should terminate. Proper cleaning, shaping, and obturation of root canal are possible once the accurate working length is determined.

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Various investigators have concluded that the most favorable prognosis was obtained when the procedure were terminated at the minor constriction and the worst prognosis when it extends beyond the minor constriction.[1-3]

It is impossible on the radiograph to detect the major and minor foramina or cemento-dentinal junction.[4-6] Although radiograph is routinely used to determine the working length, it has limitations as the apical foramen and apical constriction are usually not visualized in the radiograph;,[7] moreover, the position of the major apical foramen does not coincide with the root apex and may be located up to 2 mm away.[8-10] Various other studies have also stated that the distance between the apical foramen and apical constriction may vary by 1 mm or more.[11,12]

New instruments and equipment have since been developed to overcome the problem of determining accurate working length. Suzuki, in 1942, reported that the electric resistance between the periodontal ligament and oral mucosa was a

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Endodontics

A STEREOMICROSCOPIC STUDY OF THE ROOT APICES OF 400 MAXILLARY AND MANDIBULAR ANTERIOR TEETH

DAVID GREEN, D.D.S., BROOKLYN, N. Y.*

THE object of this study is to increase our knowledge in the field of endodontics through critical examination of tooth apices and to organize the findings in a definite statistical form.

This study of 400 anterior teeth is a continuation of my previous research dealing with the root apices of 100 mandibular molars. It was extended to anterior teeth as a result of the great interest exhibited in the original investigation. A study of the apical areas of teeth is of major importance, inasmuch as it involves the gateway of the circulatory and nervous systems of teeth.

The use of the stereomicroscope allowed precise visualization of the many variations in the morphology of the apex and foramina.

As in the previous study, the Bausch and Lomb senior model BKT-5, a stereoscopic wide-field microscope, was used; illumination was provided by a Nicholas illuminator. This instrument, adjustable for various positions, gives a most intense spotlight effect. Its easily adjustable condenser system efficiently concentrates brilliant intense light on a small area, or evenly distributes it over large fields of view. A blue daylight filter, the nearest approximation to daylight, was used. The intensity of light is adjusted by a transformer.

Measurements were made with a calibrated micrometer disk, inserted into a specific receptacle in the eyepiece. These calibrations were viewed superimposed on the magnified specimen. A millimeter ruler was placed on the stage. The number of calibrations in the eyepiece superimposed on 1 mm. of the ruler was noted. For example, if there were twenty divisions on the eyepiece to 1 mm. on the stage ruler, we recognized that each division was equal to 1/20 or 0.05 mm. on the specimen.

Presented at a meeting of the American Association of Endodontists, Chicago, Illinois, Feb. 5, 1956.

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Research Paper

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Clinical Evaluation of the Accuracy of an Electronic Tooth Apex Locator

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Clinical evaluation of the accuracy of an electronic apex locator, Ray-Pex 5, was carried out in 85 single-rooted teeth with vital pulp tissue. The normal procedure was followed, which included a standard endodontic access opening, pulp removal and irrigation of the root canal with 5.25% NaOCl. The working length of the selected teeth was estimated with Ray-Pex 5, using a size 15 K-file. The files were cemented at the measured working length and the teeth were extracted. It is thought that absolute comparisons could be made only with the actual working length directly measured after extraction of the teeth. For the teeth where the tip of the file was not visible at the apical foramen, the Berman-Fleischman technique was used. In locating the apical foramen Ray Pex 5 was 95% accurate, with clinically acceptable estimation within±0.5 mm. Ray Pex 5 was accurate 97.5% of the time to±1 mm. The significance of the difference between the electronically and microscopically assessed sample was found at the level of $p<0.01$ when paired t-test performed (95% CI for the difference -0.496, -0.204). The electronic device used for this study was found reliable in estimating the real length of the tooth root minimizing the need for multiple periapical x-rays during endodontic treatment.

Key words: Root canal length, electronic apex locator, accuracy, Ray-Pex 5

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Accuracy of two electronic apex locators in locating root perforations in curved canals in dry and wet conditions: A comparative *in vitro* study

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Abstract

Background:

The aim of the study was to evaluate the accuracy of iPex and Vdw gold apex locators in detecting simulated root perforations in curved canals in the presence of 3% sodium hypochlorite (NaOCl) and 2% chlorhexidine (CHX).

Materials and Methods:

In this comparative *in vitro* study Twenty mandibular molars with curved mesial roots were selected and perforation was made in the danger zone 4 mm from the furcation area. The actual length of the perforation site was measured using stereomicroscope software using a #15 K file, following which the teeth were embedded in alginate molds. The perforation site was electronically measured using two apex locators, iPex and Vdw gold in dry condition and in the presence of 3% NaOCl and 2% CHX. The values obtained were compared using the Friedman and Wilcoxon signed-rank test with level of statistical significance set at $P \leq 0.05$.

Results:

In dry condition, Vdw gold showed near accurate values, i.e., 0.25 mm from the manual value whereas iPex showed a significant difference ($P < 0.05$) of 0.76 mm from the manual value. In the presence of 3% NaOCl, both the apex locators showed a significant difference ($P < 0.05$) from the manual value with iPex

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Marroquín et al. Head & Face Medicine (2014) 10:57
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HEAD & FACE MEDICINE

RESEARCH Open Access

Accuracy of electronic apex locators to detect root canal perforations with inserted metallic posts: an ex vivo study

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Abstract

Introduction: The detection of possible root canal perforations caused during a metal post placement is frequently difficult to diagnose. The aim of this study was to investigate the accuracy of apex locators to diagnose such perforations.

Materials and methods: Thirty mesiolingual root canals of extracted mandibular molars were instrumented (30/.04) and a post space was prepared. A root canal perforation was intentionally made at the bi-furcation (n = 15). Metal posts were cemented in 15 perforated and 15 non-perforated root canals. The teeth roots were embedded in an agar-agar solution. The resulting measurements ("short" or "beyond" the apex) disclosed if a perforation could be identified with five different apex locators (ProPex II, Elements Apex Locator, Apex NRG, Raypex 5 and Raypex 6). The sensitivity and specificity (95% interval confidence) were calculated.

Results: All devices excluded the absence of perforations (100% with 95% confidence interval [78%; 100%] specificity). The Apex NRG and Raypex 6 detected all perforations (100% with 95% confidence interval [78%; 100%] sensitivity). The ProPex II, Elements Apex Locator, and Raypex 5 detected 14 out of 15 perforations (93% with 95% confidence interval [68%; 100%] sensitivity).

Conclusions: All devices determined root canal perforations, due to metallic posts, within clinical acceptable ranges.

Keywords: Root perforation, Metal post, Diagnosis, Apex locators

Introduction

Despite technological advancements in endodontic techniques, endodontic mishaps such as root perforations during access preparation, root canal instrumentation, or preparation for post space are not unusual [1,2]. Root perforations compromise the success of endodontic therapy and have been regarded as, and probably are still, one of the most unpleasant accidents to deal with during re-treatment [3,4]. Occasionally, a clinician will be challenged with the fact that a radiological diagnose of patient with non-acute clinical symptomatology shows that the tooth has been previously endodontically treated, a post has been placed and the crown restored without evidence of a root perforation caused during the post insertion. A root perforation is defined as an artificial opening in the tooth crown or root area creating a communication between the root canal system with the periodontal tissues or oral cavity [5]. Iatrogenic root perforations are frequently caused by inappropriate post space preparation and have been classified as one of the most common types of root perforations [6] occurring approximately between 2 to 12% of the endodontically treated teeth [2,7]. The time elapsed between perforation and treatment [3,8,9], perforation size and location [10,11] play an important role when treating the affected site [3]. The treatment possibilities [4,5,11] as well as the post-treatment outcome of a root perforation [12] are

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30.

Research article

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RDE
Restorative Dentistry & Endodontics

Accuracy of Root ZX in teeth with simulated root perforation in the presence of gel or liquid type endodontic irrigant

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Objectives: To evaluate the accuracy of the Root ZX in teeth with simulated root perforation in the presence of gel or liquid type endodontic irrigants, such as saline, 5.25% sodium hypochlorite (NaOCl), 2% chlorhexidine liquid, 2% chlorhexidine gel, and RC-Prep, and also to determine the electrical conductivities of these endodontic irrigants. ***Materials and Methods:*** A root perforation was simulated on twenty freshly extracted teeth by means of a small perforation made on the proximal surface of the root at 4 mm from the anatomic apex. Root ZX was used to locate root perforation and measure the electronic working lengths. The results obtained were compared with the actual working length (AWL) and the actual location of perforations (AP), allowing tolerances of 0.5 or 1.0 mm. Measurements within these limits were considered as acceptable. Chi-square test or the Fisher's exact test was used to evaluate significance. Electrical conductivities of each irrigant were also measured with an electrical conductivity tester. ***Results:*** The accuracies of the Root ZX in perforated teeth were significantly different between liquid types (saline, NaOCl) and gel types (chlorhexidine gel, RC-Prep). The accuracies of electronic working lengths in perforated teeth were higher in gel types than in liquid types. The accuracy in locating root perforation was higher in liquid types than gel types. 5.25% NaOCl had the highest electrical conductivity, whereas 2% chlorhexidine gel and RC-Prep gel had the lowest electrical conductivities among the five irrigants. ***Conclusions:*** Different canal irrigants with different electrical conductivities may affect the accuracy of the Root ZX in perforated teeth. (*Restor Dent Endod* 2012;37(3):149-154)

Key words: Electrical conductivity; Root canal irrigants; Root perforation; Root ZX

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Introduction

Root perforations that result in a communication of the root space with the periodontal tissues occasionally occur during endodontic procedures. They may be induced iatrogenically, by resorptive process, or by caries.[1] Identification of root perforations is possible by direct observation of bleeding, indirect bleeding assessment using a paper point, radiography, and an electronic apex locator (EAL).[2] The EAL's principle was initially introduced to clinical practice by Sunada.[3] The EALs are considered as accurate tools for determining canal working lengths, and are valuable aids in clinical endodontics.[4] EALs may detect root fracture that reaches the pulpal chamber and should detect the fracture as an 'apex' from the beginning of the periodontal communication at the fracture site.[5] The accuracies of EALs in fractured or resorpted root cases have been evaluated in a few studies, but confusing results have been reported.[6-8] In case of per-

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International Endodontic Journal

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In vivo evaluation of the iPex and Root ZX electronic apex locators using various irrigants

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Abstract

Duran-Sindreu F, Gomes S, Stöber E, Mercadé M, Jané L, Roig M. *In vivo* evaluation of the iPex and Root ZX electronic apex locators using various irrigants. *International Endodontic Journal*, **46**, 769–774, 2013.

Aim To evaluate *in vivo* the performance of the iPex and Root ZX electronic apex locators (EALs) in the presence of several irrigant solutions: 2.5% sodium hypochlorite (NaOCl) and 2% chlorhexidine (CHX).

Methodology Thirty-two single-rooted human teeth that were scheduled for extraction were selected. Teeth with metallic restorations, fractures, root resorption, pulp necrosis or open apices were not included The working length (WL) was determined electronically for the root canals with the iPex and Root ZX EALs in the presence of two different irrigant solutions, 2.5% NaOCl and 2% CHX. After the teeth had been extracted, a size 10 K-file was used to determine the reference working length (RWL), which was established at 0.5 mm short of the major foramen. In each case, the RWL was subtracted from the electronic measurements. Positive values indicated electronic measurements that exceeded the RWL (long measurements), whereas negative values indicated measurements that were short of the RWL. The values obtained with the different irrigants and EALs were compared using the paired *t*-test. Significance was set at $P < 0.05$.

Results The accuracy of the iPex nor Root ZX EAL was not affected by 2.5% NaOCl or 2% CHX ($P > 0.05$). However, significant differences were observed between the readings of the iPex and Root ZX, irrespective of whether 2.5% NaOCl or 2% CHX was used as the irrigant ($P < 0.05$). The iPex was less accurate than the Root ZX in determining the RWL.

Conclusions The accuracy of neither the iPex nor Root ZX EAL was affected by the irrigant used. However, the iPex was less accurate than the Root ZX in determining the RWL both for 2.5% NaOCl and for 2% CHX.

Keywords: electronic apex locator, iPex, Root ZX, working length.

Received 31 August 2012; accepted 6 December 2012

Introduction

During root canal treatment, it is critical to determine and maintain the working length (WL) (Ricucci 1998, Ricucci & Langeland 1998). The WL is defined as the distance from a coronal reference point to the point at which canal preparation and filling should terminate (American Association of Endodontists 2003). The traditional method used to determine WL is based on the radiographic visualization of an instrument placed in the root canal. The most obvious drawback to this method is that it is impossible to determine accurately the position of the apical constriction and the apical foramen on the basis of conventional radiographs alone (ElAyouti *et al.* 2001, 2002, Tselnik *et al.* 2005). The foramen of the main root canal may be located to one side of the anatomical apex, sometimes at distances of 3 mm (Gordon & Chandler 2004). Furthermore, radiographs provide a two-dimensional image of a three-dimensional structure; they are subject to distortion and magnification

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ORIGINAL ARTICLE
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Efficiency of 2 electronic apex locators on working length determination: A clinical study

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Abstract

Aims: The aim of this clinical study was to evaluate the clinical accuracy of two electronic apex locators (EALs). **Materials and Methods:** A total of 120 patients with 283 roots were randomized into three groups including, traditional radiographic method, EAL (Root ZX mini), and apex locating endodontic motor (VDW Gold) for working length (WL) determination. Root canals were instrumented to a size ProTaper F3 nickel titanium file. The obturation quality of matched tapered master cone (ProTaper F3) was determined for the accuracy of WL. **Statistical Analysis Used:** Descriptive statistics were expressed as numbers and percentages. Pearson Chi-square test was used to determine for differences between groups. $P < 0.05$ was considered statistically significant for all tests. **Results:** There was no statistically significant difference between the three tested groups ($P = 0.894$). **Conclusions:** The success of both apex locators was similar to the radiographic WL determination technique.

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Full Text

Introduction

A correct working length (WL) is one of the critical factors for the success of endodontic treatment. [1] Short measurements may leave parts of the root canal uninstrumented. [2] On the other hand, over instrumentation with enlargement of the apical constriction may result in damage to periradicular tissues. Consequently, 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. [3]

Traditionally, conventional radiographs are used to determine the WL. However, radiographs are subject to distortion, magnification, interpretation variability, and lack of a two-dimensional representation of a three-dimensional object. [4] Radiograph is a technique that provides information about the canal anatomy and surrounding tissues, but superimposition and anatomy interferences can be problematic and affect correct interpretation of the images. [5] The results of a microscopic study showed that the major foramen may be located up to 3.5 mm from the radiographic apex. [6] In such teeth, if the canal terminates in the plane of the film, the radiographic appearance will be "short," and any adjustment will result in the WL being overextended. Other shortcoming of radiography is the danger of ionizing radiation.

Recently, the use of electronic devices became popular and numerous devices have been introduced to the market. The advantages of electronic apex locators (EALs) include reduction in radiation dosage and procedure time, both of which aid in maintaining patient cooperation. [7] The EALs are used to locate the minor constriction. [1] Microscopic studies have shown the apical constriction to be located 0.5-1.0 mm from the major foramen. [8] Root ZX mini (J. Morita Corp., Kyoto, Japan) is a modified version EAL based on the same technology of the Root ZX. [9] The Root ZX mini has a compact size and conveniently portable design. Besides the Root ZX mini offers 3 programmable memory settings, shock resistance and automatic calibration. However, there is a lack of information in the literature about the in vivo accuracy of Root ZX mini in determining the correct WL. VDW Gold is an endodontic motor integrated apex locator device. The continuous monitoring of WL is important during canal preparation as the WL may vary during the procedure, especially in curved canals. [10] The combinations of EAL and low-speed endodontic hand-pieces have been introduced to achieve the accuracy of conventional EALs during canal shaping. [11]

The purpose of this randomized clinical study was to evaluate the clinical accuracy of traditional radiographic method, EAL and apex locating endodontic motor.

Materials and Methods

A total of 120 patients with 283 root canals that referred for endodontic treatment were selected. Informed written consent in full accordance with ethical principles was obtained from each patient before the treatment was initiated. Patients that used heart pacemakers were excluded. The teeth with no apical patency or with the radiographic signs of resorption were excluded. The selected patients were aged 20-65 years old. The patients were informed about routine endodontic procedures. The teeth were randomly allocated to each group. All clinicians involved in this study had at least 5 year of experience with apex locators. In case of the disability of determination of proper WL with the selected method, such teeth were excluded from the study.

Under local anesthesia (Ultracain D-S, Sanofi Aventis, Turkey) and isolation with rubber dam, caries, and existing restorations were removed. Standard access cavity was carried out using high-speed diamond round bur (Dentsply Maillefer, Ballaigues, Switzerland) under water coolant for each tooth and a straight-line access to the root canals was achieved. The entrances of the root canals were irrigated with 2.5% sodium hypochlorite solution and excess sodium hypochlorite was removed from the pulp chamber by using cotton pellets, no attempt was made to clean debris or pulp tissue remnants prior to introducing a size 15 k-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canals.

Following the preparation of adequate access cavity, the steps followed for each group were as follows:

Group 1 (Conventional radiographic length determination)

The preoperative periapical radiography was taken using paralleling technique.A size 15 k-file was placed to the estimated length and WL radiograph was taken. The primary WL was determined to be 0.5 mm short of radiographic apex. The initial WL was recorded.Canal preparation was carried out with ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) nickel

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An In Vivo Evaluation of Root ZX Electronic Apex Locator

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The Root ZX has been introduced recently as a device capable of performing accurately in the presence of sodium hypochlorite, blood, water, local anesthetic, and pulpal tissues. The Root ZX was used to locate the apical foramen in 26 root canals of vital teeth. After extraction of the teeth, a stereomicroscope was used to confirm visually the relationship of the tip of the endodontic file to the apical foramen. The Root ZX located exactly the apical foramen in 17 canals (65.4%), was short in 1 canal (3.8%), and was overextended in 8 canals (30.8%). When a potential error of ±0.5 mm from the foramen is accepted as a tolerable range for the clinical application of an electronic apex locator, the Root ZX was able to locate the foramen within this range in 25 teeth for a clinical accuracy rate of 96.2%.

Numerous electronic apex locating devices have been introduced since the 1960's. They operate under different electronic principles and circuitry. In 1962, Sunada (1) demonstrated that the electrical resistance between the periodontal ligament and oral mucosa has a constant value that can be measured. As a result, a number of devices were developed for use as clinical aids in apex location. However, many devices often performed unpredictably from patient to patient.

Wet contaminants in the canal were recognized as factors adverse to reliable performance (2, 3). Consequently, one manufacturer placed plastic insulation over the electronic probe to prevent electrical conductance through moist canal contents. However, the thickness of the insulating material prevented entry of the probe into tight and tortuous canals, especially at midroot and the apical level (3).

Several manufacturers have introduced devices that use more advanced technology that measures the ratio of two electrical impedances emitted from the probing instrument. The Root ZX instrument (J. Morita Corp., Tustin, CA) is one such device.

The promotional material for the Root ZX states that it can perform with high accuracy in the presence of sodium hypochlorite solution, blood, water, local anesthetic, and pulpal tissues (4). The manufacturer further states that fine endodontic files can be used without the need to precalibrate the circuitry before locating the apical foramen.

The purpose of this in vivo study was to determine the ability of the Root ZX to locate the apical foramen in unprepared root canals of vital teeth.

MATERIALS AND METHODS

Seven healthy patients with a total of 26 teeth treatment planned for extraction participated in this study. An informed written consent meeting the criteria of the Institutional Review Board of the University of the Pacific School of Dentistry and the California Pacific Medical Center was obtained from each patient before treatment was initiated. The teeth were tested to confirm vitality of the pulp, and all demonstrated intact periapical tissues on radiographic examination.

Two clinicians from the Department of Endodontics, School of Dentistry, University of the Pacific, participated in the clinical trial of this device.

Under local anesthesia, each tooth was accessed with a high-speed handpiece. The contents of each canal were not removed. The apical foramen was located with the Root ZX device by advancing a fine endodontic file toward the apex. File insertion was stopped when the meter flashed and an audible signal indicated that the foramen had been reached. For this particular device, the 0.5 marking just before the "apex" was selected for termination. Self-curing glass-ionomer material (Ketac-Silver, ESP-Premier, Norristown, PA) was mixed to the manufacturer's direction, injected into the access cavity to surround the shaft of the file, and allowed to set completely. Locked in place, the file handle and exposed shaft were separated using a high-speed handpiece. The Root ZX electrode was again placed against the residual shaft of the file to verify that the meter reading had not changed. The tooth was then extracted and stored in 10% formalin.

The teeth were soaked in 5.25% sodium hypochlorite for 24 h. The teeth were then subjected to decalcification in 5% nitric acid for 3 days, with daily changes of the solution. After a short rinse in tap water, the teeth were dehydrated by immersing them in 80% ethyl alcohol for 24 h, followed by a 90% and 100% alcohol immersion for 1-h periods. A final immersion in methyl salicylate (Sigma Chemical Co., St. Louis, MO) for 4 h rendered the teeth transparent.

The apex of each tooth was inspected independently by three examiners under an Olympus SZ-STB1 stereomicroscope. The

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An In Vivo Evaluation of an Electronic Apex Locator that Uses the Ratio Method in Vital and Necrotic Canals

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The purpose of this study was to compare the canal length determined by an apex locator to the apical constriction in both vital and necrotic canals.

Informed consent was obtained from patients waiting to have teeth extracted. The teeth were anesthetized, isolated, and accessed. The pulp was considered vital if bleeding was present in the pulp chamber. The Root ZX was used to measure the root canal length. The file was cemented into place, and the tooth was extracted. Twenty-nine teeth containing 34 cemented files were studied, and the distance from the apical constriction was measured.

The Root ZX was 82.3% accurate to within 0.5 mm of the apical constriction. The mean distance from the apical constriction was 0.21 mm in vital cases versus 0.49 mm for necrotic cases. There was no statistical difference between the ability of the Root ZX to determine the apical constriction in vital canals versus necrotic canals.

Determining the proper length of the root canal system is essential for successful endodontic treatment (1). Virtually all elements of root canal therapy demand strict length control to ensure that neither the root canal system itself nor the periodontal ligament are damaged. Correct canal length measurements are also necessary to minimize the extrusion of potentially infected dentinal debris into the periapical area. However, determining the accurate length of the root canal system is complicated by significant length variance from reported average canal lengths (2), and the end point of the root canal system, the cementodentinal junction (CDJ), is a histological landmark, not a morphological landmark (2, 3).

Traditionally, the periapical radiograph has been the primary method of canal length determination (4), but there are many technical limitations associated with this approach. Radiographs necessitate exposing the patient to ionizing radiation and are merely two-dimensional images of a three-dimensional object that do not consistently reveal the root canal portal(s) of exit (3, 7). Furthermore, obtaining quality radiographs requires precise film placement, X-ray beam angulation, and film processing (5, 6).

Alternate methods of determining root canal system lengths have been developed that help minimize the inherent problems previously described. Suzuki (8) determined that the electrical resistances between the periodontal ligament and the oral mucosa were constant at ~6.5 kΩ. This constant was then used by Sunada (9) to build the first electronic apex locator, but this apex locator gave inaccurate readings in the presence of electrolytes or vital pulp tissue in the canal (6, 10).

Multiple advances in apex locators have been made such that accurate readings can now be made in the presence of electrolytes and so that standard K-type files can be used. Recently, Kobayashi and Suda (10) have developed an apex locator, the Root ZX (J. Morita Co., Tustin, CA), which simultaneously calculates the ratio of two impedances in the same canal using two different frequencies, and which is able to determine canal length in the presence of an electrolyte or vital pulp tissue.

Because a canal with a necrotic pulp may have a different impedance than a canal with a vital pulp due to the destruction of the periodontal ligament and bone associated with a periapical radiolucency (11), the purpose of this investigation was to compare the canal lengths determined by the apex locator in vivo to the actual apical constriction in both vital and necrotic canals.

MATERIALS AND METHODS

Fifteen healthy adult patients who were having teeth extracted for periodontal or prosthodontic conditions at the University of Illinois Oral Surgery Clinic participated in this study. All experimental teeth had adequate remaining tooth structure for rubber dam isolation, radiographically visible canal(s), and fully formed root apices. Twenty-nine teeth containing 35 canals were used as materials for this study.

Informed consent was obtained, and the age, sex, and tooth number(s) were recorded. Local anesthetic was appropriately administered, and the experimental teeth were isolated with a rubber dam. The remaining cusps were then flattened with a sterile tapered fissured bur (Caulk, Milford, DE).

Using ×3.5 magnification (Designs for Vision, Ronkonkoma,

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In Vitro Comparison of Three Electronic Apex Locators

George M. Guise, DMD, MS, Gary G. Goodell, DDS, MS, MA, and Glen M. Imamura, DDS, MS

Abstract

Introduction: The purpose of this study was to compare the accuracy of the Root ZX II Apex Locator (RZX), the Elements Apex Locator (ELE), and the Precision Apex Locator (PAL). **Methods:** Forty single-rooted extracted teeth were decoronated and the root canals coronally flared. Actual canal lengths were determined by inserting a #10 file until the tip was visualized (12.8× magnification) just within the apical foramina. Teeth were mounted in gelatin conducting medium and randomly tested with each electronic apex locator (EAL) to determine the electronic canal length. Differences between the electronic and actual canal lengths were calculated. **Results:** The mean differences were −0.02 mm, 0.13 mm, and 0.15 mm for the RZX, PAL, and ELE, respectively. One-way analysis of variance showed a highly significant difference among EALs ($p = 0.003$). Student-Newman-Keuls post hoc analysis found significant differences between the RZX and the PAL and between the RZX and the ELE at $p < 0.05$. No significant difference was noted between the PAL and the ELE. The proportion of electronic canal length measurements falling within ±0.5 mm of the actual canal lengths for the EALs was as follows: 97.5% for the RZX, 95% for the PAL, and 90% for the ELE. **Conclusion:** The RZX was the most accurate at locating the apical foramen compared with the ELE and the PAL. *(J Endod 2010;36:279–281)*

Key Words

Electronic Apex Locator, Elements, Precision Apex Locator, Root ZX II

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The opinions or assertions expressed in this article are those of the authors and are not to be construed as official policy or position of the Department of the Navy, Department of Defense or the U.S. Government. Certain commercial materials and equipment are identified in this paper to specify the experimental procedure. In no instance does such identification imply recommendation or endorsement by the U.S. Navy, or that the material or the equipment identified is necessarily the best available for the purpose.

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Accurate determination of the root canal length from the coronal orifice to the apical foramen is critical in the endodontic management of the root canal space. At the apical foramen, the cementodentinal junction (CDJ) or minor constriction is the landmark that anatomically and histologically determines where the pulp ends and the periodontal ligament begins (1).

Root canal preparation techniques attempt to use this natural barrier as the endpoint for canal preparation (2). However, Lee et al. (3) found that almost 50% of teeth evaluated had no distinguishable CDJ. Therefore, the CDJ should be thought of as a histologic and not a morphologic landmark (4).

Instrumenting and obturating the root canal short of the CDJ may leave undebrided bacteria in this critical space. These bacteria have the potential to contribute to subsequent failure of endodontic treatment. On the contrary, a long measurement causing instrumentation past the CDJ will damage the natural anatomy of the root end, making it difficult to obtain an apical seal and maintain the root canal filling within the tooth.

Electronic apex location began in 1942 with studies by Suzuki (5). He discovered that a constant electrical resistance of approximately 6.5 kΩ existed between the periodontium and oral mucous membrane *in vivo*. In 1962, Sunada (6) formulated his principle of "biological characteristic theory," stating that electrical resistance values between the periodontal ligament and the oral mucosa can be determined by electronic means.

As many as four generations of electronic apex locators (EALs) have been developed since their inception. A third-generation EAL, Root ZX (J. Morita Mfg Corp, Kyoto, Japan) has a reported accuracy ranging from 82% (7) to 100% (8). A study by Shabahang et al. (9) found Root ZX to be 96.2% effective in determining the location of the apical foramen to within ±0.5 mm when used according to manufacturer's recommendations. Ounsi and Naaman (10) found that Root ZX was 84.72% accurate to within ±0.5 mm of the apical foramen when using the "apex" reading as an apical determination. Root ZX II (RZX) is J. Morita's updated version of the original Root ZX with original electronic components being used with the addition of a new external casing.

The Elements Apex Locator (ELE) (SybronEndo, Sybron Dental Specialties, Anaheim, CA) is a manufacturer-claimed fourth-generation EAL with a reported accuracy of 94.28% by Plotino et al. (11). The Precision Apex Locator (PAL) (Brasseler USA, Savannah, GA) is a new EAL whose accuracy has not been tested and reported in the literature to date. The purpose of this study was to compare the accuracy of the RZX, the ELE, and the PAL.

Materials and Methods

The study design used was similar to that of Cunha D' Assunção et al. (12). Forty single-rooted extracted teeth were obtained and stored in a 0.2% sodium azide solution until use. Gross debris was removed from the root surfaces with a 10-minute soak in 6% NaOCl (The Clorox Company, Oakland, CA). The root surface and apical portion of each tooth were examined for the absence of fractures and the presence of a mature apex under a dental operating microscope (Global Surgical Corp, St Louis, MO) at 12.8× magnification. All samples met these inclusion criteria. The crown of each tooth was then sectioned at the cement-enamel junction with a diamond disk to provide unrestricted access to the canal space and to provide a constant reference point for all measurements. The coronal portion of each canal was flared by using sequential Gates Glidden drills #4, #3, and #2 in a crown-down fashion. Irrigation was then performed with 3 mL 6% NaOCl followed by 3 mL sterile saline to remove gross debris from the canal space. A #10 FlexoFile (Dentsply Maillefer, Johnson City, TN) was then used to verify patency of the canal space and the apical foramen under the dental operating microscope.

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CLINICAL ARTICLES

In Vitro Evaluation of the Reliability of the Endex Electronic Apex Locator

Hani F. Ounsi, DCD, DESE, and Gaby Haddad, DCD, DESE

A new generation of electronic apex locators (Endex) that operates in moistened canals has been developed lately. An experimental comparison of this apparatus with the real, tactile, and radiographic measurements of the root canal length has been conducted. Results show that tactile determination is highly inaccurate and that the Endex is as accurate as radiographic measurements. It also demonstrates that the nonreproducibility of radiographic measurements is statistically significant, whereas that of the Endex is not significant.

Using electronic measurement (EM) devices has always been controversial because the presence of conductive liquids in the canal yields unreliable results. According to manufacturers, new devices (Endex EMS3, Root ZX) can accurately measure root canal length even in highly conductive conditions (i.e. blood, pus, sodium hypochlorite, etc.). In 1983, Aurelio et al. (1) presented a model to measure in vitro canal length Huang (2) modified this model and showed that the constant value of impedance of the tooth is a purely physical phenomenon, and that in vitro models can be used to evaluate electronic measuring devices.

Several studies assessed the accuracy of the Endex: Saito and Yamashita (3) showed that it gives a precise measure whatever the irrigant ($n = 15$), Fouad et al. (4) indicated that Endex produced 73 to 90% acceptable results ($n = 30$), and according to Felippe and Soares (5) who evaluated the precision of Endex on 350 extracted teeth, accuracy in locating the apical foramen reaches 96.5% (±0.5 mm). Unlike other studies, they had no readings that were long beyond the foramen.

This proves the precision but not the reliability of the instrument. To be reliable, a technique must give *reproducible* precise results. The aim of this study is to compare precision and reliability of the Endex to that of tactile sense and radiography. The reference value will be the real length of the canal.

MATERIALS AND METHODS

Thirty-seven extracted, single-rooted mature teeth were numbered and kept in an isotonic sodium chloride solution (Solu-Pac, Serum products SARL, Choueifat, Lebanon).

The teeth were cut at the cementoenamel junction to simplify endodontic access and obtain a reliable occlusal landmark. Tactile measurement was then completed using a precurved #10 K-file (Zipperer UDM, West Palm Beach, FL) with a directional stopper. All instruments used were brand new, and two stoppers were used to eliminate accidental stop movements during work. Tactile measurements were the first to be conducted to avoid possible loss of apical structures due to repetitive passage of instruments. EMs were done next using Endex EAL (Osada Electronics Co., Ltd., Tokyo, Japan). Teeth were then put in contact with a conductive gel simulating the periodontium. This gel is the one described by Donnelly (6) (i.e. Jell-O (Kraft General Foods, Inc., White Plains, NY)) with 0.9% sodium chloride solution instead of water. Measurements were taken after a 2-ml irrigation of 5.25% sodium hypochlorite (Clorox, Clorox Co., Oakland, CA), and length was

TABLE 1. Distribution of values for each type of measurement

	Real Length	Tactile	EM	Radiography
−1.25	0	5	2	0
−1.00	1	7	8	0
−0.75	0	1	3	1
−0.50	2	6	11	3
−0.25	15	11	13	17
0.00	72	18	49	41
+0.25	39	11	29	33
+0.50	7	13	13	38
+0.75	0	5	5	3
+1.00	0	15	3	0
+1.25	0	8	0	0
>1.25	0	36	0	0
Total	136	136	136	136

TABLE 2. Values of Z ($\alpha = 0.05$)

	Intraoperator		Interoperator
	$A_1 - A_2$	$B_1 - B_2$	$A_{ext} - B_{ext}$
Measurement	1.16	1.58	1.55
Real length	0.41	0.15	1.04
Radiography	1.5	0.47	2.07

A and *B* are the operators. A_{ext} and B_{ext} are the extreme values obtained by the two operators. A_1 and A_2 are the two different measurements by operator A.

37.

Accuracy of Three Electronic Apex Locators Compared with Digital Radiography: An *Ex Vivo* Study

Luigi Cianconi, MD, DDS, Vincenzo Angotti, DDS, Roberto Felici, DDS, Gabriele Conte, DDS, and Manuele Mancini, DDS

Abstract

Introduction: This study compared (1) the accuracy of three different electronic apex locators (EALs) in detecting the apical foramen *ex vivo* under clinical conditions; (2) the accuracy of digital radiography and EALs in determining the working length (WL) with visible control under a microscope; and (3) the precision of #10, #15, and #20 K-files in electronic measurements. **Methods:** The length of 101 extracted human teeth was measured with three different EALs (Endex [Osada Electric Co, Tokyo, Japan], ProPex II [Dentsply-Maillefer, Ballaigues, Switzerland], and Root ZX [J. Morita Co, Tustin, CA]), with radio videography (RVG) and compared with the actual length. An endodontic training kit (Pro-Train; Simit Dental, Mantova, Italy) was used during the experimental procedures. **Results:** Statistical analysis showed that Endex and ProPex II were more accurate than Root ZX in determining the WL. The paired sample *t* test showed no statistically significant difference between the accuracy of the two radiographic planes examined. The *t* test showed no significant difference between the three different K-file sizes measurements. **Conclusions:** Endex and ProPex II were more accurate than Root ZX in determining the actual WL. Instrument sizes of hand files did not affect the accuracy of EALs. EALs showed to be more accurate in determining the WL than RVG. *(J Endod 2010;36:2003–2007)*

Key Words

Electronic apex locator, Endex, ProPex II, radio videography, Root ZX, working length

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Working length (WL) has been defined as "the distance from a coronal reference point to the point at which canal preparation and obturation should terminate" (1). It has been stated that the WL for instrumentation and obturation of the root canal system should be established at the apical constriction (2). The apical constriction, also referred to as a minor diameter, represents the transition between the pulpal and the periodontal tissue at the cement-dentinal junction. The cement-dentinal junction has been suggested as the position of termination of the canal filling (3). Anatomic studies have shown the apical constriction to be located 0.5 to 1.0 mm from the external or major foramen (2). Historically, methods of determining WL include the use of radiographs, tactile sensation, and electronic apex locators (EALs). However, radiographs are subject to distortion, magnification, interpretation variability, and lack of three-dimensional representation. The magnification error has been found to be 5.4% with a paralleling technique (4). As a result, WL determined from radiographs is generally measured about 0.5 to 1 mm short of the radiographic apex. Pratten and McDonald (5) showed that the assumption of the apical constriction being 1 mm short of the radiographic apex will result in an underestimation of WL. Vertical and horizontal cone angulations, film processing issues, tooth inclination, and film position will influence WL determination from radiographs (6). In some teeth, the major foramen may be located up to 3.5 mm from the radiographic apex (7). In such teeth, if the canal terminates in the plane of the film, the radiographic appearance will be "short," and any adjustment will result in the WL being overextended. A WL 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 WL established short of the minor diameter may lead to inadequate debridement and underfilling of the canal. However, tactile sense is quite variable, and accuracy is questionable (8). Root canals with excessive curvature, an immature apex, or calcified canals will hinder the tactile sensation of the apical constriction. Custer (9) was the first to introduce an electrical method of locating the apical foramen. Suzuki's (10) discovery that electrical resistances between the periodontal ligament and oral mucosa registered constant values of 6.5 kΩ led to the development of the first EAL (Sunada) (11). The accuracy of EALs was poor because of the influence of fluids or pulp tissue in the canal. Advances in EAL technology have led to the development of EALs that make accurate readings in the presence of electrolytes. Manufacturers suggest that canals be moist rather than dry if more accurate WL readings are to be achieved. Özsezer et al (12) found that the WL measurements with the Propex (Dentsply-Maillefer, Ballaigues, Switzerland) were more accurate after extirpation of the pulp than after the use of irrigation solutions, among which the accuracy of WL determination was highest with chlorhexidine gluconate followed by sodium hypochlorite and saline. Endex (Osada Electric Co, Tokyo, Japan) was created in 1984 by Yamaoka based on studies by Ushyama (13). It is based on the difference in impedance between two wavelengths (1 and 5 kHz). The Endex can measure WL more precisely in wet root canals (14) than in dry root canals (15). Moreover, Endex must be calibrated for each canal. Many studies (16–18) have shown precision measurements ±0.5 mm from the WL in 59%, 100%, and 68% of the specimens treated. Advances in technology have led to the development of EALs such as the Root ZX (J. Morita Co, Tustin, CA) that determine the minor diameter position using the "ratio method," which allows for the simultaneous measurement of impedance at two frequencies; a quotient of impedance is then calculated and expressed as a position of the file in the canal. The Root ZX works in the presence of electrolytes

38.

Methodological considerations in the determination of working length

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Abstract

Martínez-Lozano MA, Forner-Navarro L, Sánchez-Cortés JL, Llena-Puy C. Methodological considerations in the determination of working length. *International Endodontic Journal*, **34**, 371–376, 2001.

Aim The aim of this study was to evaluate the diagnostic efficacy of an electronic system for the determination of working length, in comparison with two radiological methods (conventional film and digital radiography).

Methodology The study sample consisted of 28 root canals belonging to 20 human mandibular teeth. A comparison was made between the working length measurements obtained by two radiological methods (conventional film and digital radiography) and an apex locator, using as gold standard the observation of the file position within the root following selective grinding of the root tissue.

Results The electronic method was satisfactory in 67.8% of cases, versus 50.6% and 61.4% for the conventional and digital radiological methods, respectively. No statistically significant differences occurred between the techniques according to the chi-squared and Kruskal–Wallis nonparametric tests.

Conclusions None of the techniques was totally satisfactory in establishing the true working length. There were no differences between the techniques investigated.

Keywords: digital radiography, electronic apex locator, working length.

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Introduction

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. In theory, the apical extent of endodontic instrumentation should be the dentinocemental junction (Kuttler 1955). However, the literature suggests two valid positions for terminating obturation: at the dentinocemental junction (Burch & Hulen 1972), or at the apical foramen (Altman *et al.* 1970). Unfortunately, no method has been developed that is capable of reliably locating either of these two anatomical points (Hedrick *et al.* 1994). Although radiography is the most commonly used diagnostic aid in endodontics, it is only able to provide a two-dimensional image. In this context, it is used routinely to determine working length, but is only able to provide reliable information on the location of the radiographic apex (Kuttler 1955). The anatomical apex may or may not coincide with the apical foramen. In most cases (50–98% of all roots), the foramen deviates from the greater axis of the tooth, the mean distance between the anatomical apex and the foramen being 0.5–1.0 mm (Palmer *et al.* 1971, Chunn *et al.* 1981, McDonald & Hovland 1990). Thus, considering that the apical foramen frequently does not coincide with the radiographical apex, positioning of the file within the latter will often lead to under- or overinstrumentation.

Electronic determination of the working length in root canal treatment is an alternative approach that has generated considerable interest. Most electronic measuring devices are based on the theory of Sunada (1958). Huang (1987) pointed out that the basis of electrical measurement of the root canals was not related to biological differences amongst tissues, but rather to an electrical principle. A second generation of

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39.

Influence of Instrument Size on the Accuracy of Different Apex Locators: An *In Vitro* Study

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Abstract

The aim of this *in vitro* investigation was to determine the accuracy of 4 different electronic apex locators (EALs) with 3 different instrument sizes. For this study 146 roots were embedded in an agar solution. Electronic measurements were made to the physiologic foramen (apical constriction) with the Elements Apex Locator, Justy II, Raypex 5, and ProPex II and K-type files sizes 08, 10, and 15. Statistical significances were calculated with the sign test ($P < .001$). Exact measurements to the physiologic foramen were made with the Elements Apex Locator, 36.99%, 39.04%, and 44.93%; Justy II, 38.62%, 32.41%, and 43.41%; Raypex 5, 42.76%, 39.31%, and 39.06%; and ProPex II, 38.62%, 43.45%, and 40.63% of the time with instrument sizes 08, 10, and 15, respectively. No significant differences were found between the actual working length and EALs/instrument size. A nonsignificant higher number of unstable measurements were observed in all EALs with instrument size 15. *(J Endod 2008;34:698–702)*

Key Words

Apex locators, instrument size, working length

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Success or failure of endodontic treatment depends, among other parameters, on an accurate determination of the working length. Electronic apex locators (EALs) are a routinely used procedure in endodontic practice (1); yet their accuracy has been reported to vary from 35% (2) to 100% (3). The operating systems of the EALs (frequency or impedance quotient) and different investigative methodologies explain the higher accuracy obtained with the current generation of devices. It is difficult to draw conclusions on the basis of the results obtained with the new generation EALs because of research variables that can influence the results such as the lack of an accurate terminology used in the different investigations. For example, the working length landmark has been described as apical foramen, constriction, apical region or terminus, major and minor diameter or foramen, actual length, apical constriction, anatomic apex or end, apex, or foramen. Furthermore, it has been determined under direct or microscopic visualization and subtracting 0.5–1 mm as soon as the measuring instrument was "apically" visible (3–11). Yet some manufacturers claim that the working length determination is made when the instrument tip is between the anatomic (major) and physiologic (minor constriction) foramina, allowing the operator to decide which is the right point on the basis of his own clinical experience. It is widely accepted that the apical constriction or physiologic foramen is the point to which the cleaning and shaping procedures and root canal filling materials should terminate (12–15). Thus, independent of the capability of an EAL to localize a certain morphologic landmark or area, the physiologic foramen is the landmark that an operator is attempting to determine before the endodontic procedures in the root canal. Although it is morphologically difficult to determine the exact location of the physiologic foramen, there is a need in this type of research to define an exact landmark to which the working length can be determined.

The aim of this study was to investigate whether the size/diameter of the measuring instrument had an influence on the accuracy of 4 different EALs.

Materials and Methods

The crowns of 146 teeth were removed through separation at the cementoenamel junction level. In case of teeth with 2 or more roots, the roots were then separated at the furcation level. Only roots that showed under magnification (30×) completely formed apices, a well-defined physiologic foramen (apical constriction), no signs of resorption, and were patent with a 06 size K-type file (Dentsply Maillefer, Ballaigues, Switzerland) were included in the study. The root canals were immersed in sodium hypochlorite during 24 hours and dried with paper points to reduce moisture excess and make sure that they did not contain any tissue remnants. No distinction was made concerning the root type, origin, length, curvature degree, or internal anatomic characteristics, but these variables were recorded. Each root was fixed in a plastic tube (44 mm height, 14 mm diameter), which contained a buffered agar-agar solution with a constant pH of 7.3. A stainless steel rod (30 mm length, 1.5 mm diameter) was fixed 5 mm from the bottom plane of each tube. The stainless steel rod was connected to the negative pole of the EALs.

The EALs investigated were Justy II (Hager & Werke GmbH, Duisburg, Germany), Raypex 5 (VDW, Munich, Germany), Elements Apex Locator (SybronEndo, Glendora, CA), and ProPex II (Dentsply Maillefer). They were used according to the manufacturers' recommendations.

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Influence of Preflaring on the Accuracy of Length Determination With Four Electronic Apex Locators

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Abstract

Introduction: The aim of this study was to compare the influence of preflaring on the accuracy of 4 electronic apex locators (EALs): Root ZX, Elements Diagnostic Unit and Apex Locator, Mini Apex Locator, and Apex DSP. **Methods:** Forty extracted teeth were preflared by using S1 and SX ProTaper instruments. The working length was established by reducing 1mm from the total length (TL). The ability of the EALs to detect precise (–1mm from TL) and acceptable (–1±0.5mm from TL) measurements in unflared and preflared canals was determined. **Results:** The precise and acceptable (P/A) readings in unflared canals for Root ZX, Elements Diagnostic Unit and Apex Locator, Mini Apex ,and Apex DSP were 50%/97.5%, 47.5%/95%, 50%/97.5%, and 45%/67.5%, respectively. For preflared canals, the readings were 75%/97.5%, 55%/95%, 75%/97.5%, and 60%/87.5%, respectively. For precise criteria, the preflared procedure increased the percentage of accurate electronic readings for the Root ZX and the Mini Apex Locator ($P < .05$). For acceptable criteria, no differences were found among Root ZX, Elements Diagnostic Unit and Apex Locator, and Mini Apex Locator ($P > .05$). Fisher test indicated the lower accuracy for Apex DSP ($P < .05$). **Conclusions:** The Root ZX and the Mini Apex Locator devices increased significantly the precision to determine the real working length after the preflaring procedure. All the EALs showed an acceptable determination of the working length between the ranges of±0.5mm except for the Apex DSP device, which had the lowest accuracy. *(J Endod 2009;35:1300–1302)*

Keywords

Electronic apex locator, Root ZX, working length

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The establishment and maintenance of working length are a critical step during endodontic therapy (1). An appropriate microbial disinfection, correct cleaning and shaping, and hermetic sealing of the root canal depend on the correct determination of working length. The apical constriction is also referred to as the minor constriction diameter and marks the transition between the pulpal and periodontal tissue (2). This anatomic landmark might be located at 0.5–1mm from the major foramen (2, 3), and it has been stated that it is an ideal point to end the instrumentation and obturation of the root canal system (3).

Traditionally, the working length has been determined by radiographs and electronic apex locators (EALs) (1). The evolution of EALs made the assessment of the working length more accurate and predictable (4–6). First, Sunada (4) introduced the principle of EAL applied for clinical purposes. Then many other appliances were developed, passing through the first generation of electrical resistance–based EALs (4) to the second generation impedance-based EALs and the third generation frequency-based EALs such as the Root ZX (7, 8). In recent years multi-frequency–based apex locator has also been entered into the market (6). A few of these appliances become more compact devices, which could be easier to operate in many clinical situations, such as the Mini Apex locator (9, 10). The Root ZX measures the impedance of 2 frequencies simultaneously (0.4 and 8kHz) (6) and expresses this quotient in terms of the position of the file inside the canal. On the other hand, other appliances such as the Elements Diagnostic Unit and Apex Locator (11) and Apex NRG (Medical NRG, Afikim, Israel and Septodont, France) are multi-frequency–based devices (12). Gordon and Chandler (1) classified multi-frequency devices as the fourth generation of EALs.

The coronal flaring of the root canals gives many advantages during the contemporary cleaning and shaping procedures, such as to facilitate the insertion of manual and rotary instruments into the apical portion of the root canals (13, 14). To date, only 1 study suggested better accuracy with an EAL when the root canals were preflared before the instrumentation (14). It is unknown whether new apex locators might improve their performance after preflaring the root canals before the working length determination.

The purpose of this in vitro investigation was to evaluate the influence of preflaring on performance of 4 EALs: Root ZX (J. Morita Corp, Tokyo, Japan), Elements Diagnostic Unit and Apex Locator (Sybron Endo, Sybron Dental, Anaheim, CA), Mini Apex Locator (Sybron Endo, Sybron Dental), and Apex DSP (Septodont, Saint-Maur des Fossés, Cedex, France).

Material and Methods

Selection of Sample

Forty mandibular incisor single-rooted teeth were used in this study. Teeth were radiographed in both mesiodistal and buccolingual views to verify the absence of root resorption or canal curvatures. Only root canals with Vertucci's type I canal configuration were used (15). After coronal access, debris and remnants of pulp tissue were removed with a size 15K-file (Dentsply-Maillefer, Ballaigues, Switzerland). The root canals were irrigated by using 1% sodium hypochlorite (NaOCl) solution with a 23-gauge needle. For measurement of the tooth length, the incisal edges were planed (flattened) by using a polishing machine under refrigeration (APL-4; Arotec, Cotia, SP,

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Accuracy of three electronic apex locators in the presence of different irrigating solutions

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Abstract: The present study compared the accuracy of three electronic apex locators (EALs) – Elements Diagnostic®, Root ZX® and Apex DSP® – in the presence of different irrigating solutions (0.9% saline solution and 1% sodium hypochlorite). The electronic measurements were carried out by three examiners, using twenty extracted human permanent maxillary central incisors. A size 10 K file was introduced into the root canals until reaching the 0.0 mark, and was subsequently retracted to the 1.0 mark. The gold standard (GS) measurement was obtained by combining visual and radiographic methods, and was set 1 mm short of the apical foramen. Electronic length values closer to the GS (± 0.5 mm) were considered as accurate measures. Intraclass correlation coefficients (ICCs) were used to verify inter-examiner agreement. The comparison among the EALs was performed using the McNemar and Kruskal–Wallis tests ($p < 0.05$). The ICCs were generally high, ranging from 0.8859 to 0.9657. Similar results were observed for the percentage of electronic measurements closer to the GS obtained with the Elements Diagnostic® and the Root ZX® EALs ($p > 0.05$), independent of the irrigating solutions used. The measurements taken with these two EALs were more accurate than those taken with Apex DSP®, regardless of the irrigating solution used ($p < 0.05$). It was concluded that Elements Diagnostic® and Root ZX® apex locators are able to locate the cementum-dentine junction more precisely than Apex DSP®. The presence of irrigating solutions does not interfere with the performance of the EALs.

Descriptors: Dental Instruments; Odontometry; Root Canal Therapy; Endodontics.

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Introduction

Correct determination of working length is a key factor that can influence the outcome of root canal treatment.[1-5]

The cementum-dentine junction (CDJ) is thought of as the ideal limit for endodontic instrumentation because of the small diameter of the root canal at that point. Moreover, it has been established that endodontic procedures should take place inside the root canal and should not affect the cementum, thereby preserving the remaining apical periodontal tissue.[6-9]

Establishing the exact limit of the CDJ is not simple, as shown in the classic study by Kuttler.[10] Using 268 extracted teeth, it was observed that

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Better success rate for root canal therapy when treatment includes obturation short of the apex

What is the optimal obturation length of a root canal to achieve the best prognosis?

Schaeffer MA, White RR, Walton RE. ***Determining the optimal obturation length: a meta-analysis of literature. J Endod 2005; 31:271–274***

Data sources Medline and reference lists of identified articles in English only.

Study selection Initial screening identified studies on humans with radiographic information on the terminal point of obturation. Subsequently studies with (a) a minimum follow-up of at least 2 years; (b) data on termination of obturation/instrumentation; (c) failures of treatment defined adequately (with a minimum radiographic evaluation for failure outlined and defined); (d) data available on success/failure of root canal therapy in relationship to the obturation/instrumentation length; and (e) presence or absence of rarefaction included.

Data extraction and synthesis This meta-analysis considered three categories of obturation length from the radiographic apex: (a) 0–1 mm (group A), (b) >1 mm but <3 mm (group B), (c) obturated past the radiographic apex, including sealer (group C). The studies were independently assessed for quality with readers blinded to the names of the authors and their institutions, names of the journals, sources of funding, and acknowledgments. Statistical analyses were done using the DerSimonian and Laird estimates.

Results Four studies met the inclusion criteria. In terms of percentage rates of success, the meta-analysis showed that obturation 0–1 mm short of the apex (group A) was better than obturation 1–3 mm short of the apex (group B); both were superior to obturation beyond the apex (group C). The success rate in group A was 28.9% better than group C and 5.9% better than group B (95% CI = −3.8%, 61.5%), $P = 0.08$ and (95% CI = −1.3%, 13.1%), $P = 0.11$, respectively. After adjustment for quality, the results remained unchanged.

Conclusions The results demonstrate that obturating materials extruding beyond the radiographic apex correlated with a poorer prognosis. In addition, we realised that standardised protocols are necessary in endodontic procedures and in dental research. If studies are to be compared and the information used clinically, the design of the studies must be similar and repeatable. The results of prospective studies will then be comparable and the data can be combined statistically, thereby creating a more powerful, clinically useful meta-analysis.

Commentary

It is important to investigate the factors influencing prognosis following root canal therapy. This systematic review focused on the position of termination of root canal filling, among many of the factors potentially influencing the outcome of root canal therapy.

Success rate of obturation beyond the apex was inferior both 0–1 mm short of the apex and 1 to 3 mm short of the apex, statistically. However, while obturation 0–1 mm short of the apex was better than 1–3 mm short of the apex this was not significant. The overall conclusions provided by the authors are not surprising, as it has been widely accepted that obturating materials are an irritant.

Only four reports were used for the meta-analysis, after 60 papers were initially screened. The inclusion criteria of at least 2 years of follow-up and the performance of radiographic evaluation was a reasonable choice. The authors categorised the obturation length into three groups; 0–1 mm short of the apex, 1–3 mm short of the apex, and obturation beyond the apex. While this seems a pragmatic approach greater discussion of this choice would be helpful. It may also have been useful to raise the limitations of conventional radiographs because of the nature of two-dimensional imaging, and that the root apex is not always located at the apical end of the root.

This study has important implications for clinicians and researchers. From a clinical perspective, obturating materials beyond the radiographic apex during lateral condensation technique clearly decreased the success rate of endodontic treatment. From a research perspective, there is a lack of agreement of definition of success, standardised clinical procedure and evaluation of radiographs. Accumulation of further high quality studies will be required.

Practice point

- Having root canal obturating materials extruding beyond the radiographic apex decreases the success rates of root canal therapy.

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In Vivo Measurement Accuracy in Vital and Necrotic Canals with the Endex Apex Locator

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Currently apex locators are being used to determine working length. This study was undertaken to see what is actually being measured and if the pulp status, i.e. vital or necrotic, makes a difference in the determination. In this in vivo study, 33 teeth, both vital and necrotic, were measured by the Endex apex locator and then radiographed. After the length determination, the file was cemented to place, the tooth extracted, and then shaved back until the file and the apex were exposed. The position of the file was measured in relation to the apical foramen. Results indicate that all measurements were within a narrow range (−0.86 mm to 0.50 mm). There was no statistical difference in measurements between vital and necrotic canals.

Several in vivo studies have been conducted on various electronic apex locators (EALs) to determine their accuracy and consistency. These studies examined the relationship of the measurement file to the apical constriction (minor diameter), the foramen, radiographic apex, and/or anatomical apex. They measured their consistency without regard to vital or necrotic conditions. Chunn et al. (1) in a 1981 study found the Forameter to be inaccurate 65% of the time and radiographs to be inaccurate 40% of the time. These authors defined accuracy as any measurement 0.5 mm to 1.0 mm short of the foramen opening (major diameter). Any measurement beyond these parameters was considered inaccurate.

In another study Fouad et al. in 1990 found the five EALs they investigated in vivo to vary in accuracy from 55 to 75% within ± 0.5 mm of the apical foramen. After the measurements were taken with the various EALs, the file or probe was withdrawn from the tooth and the length was measured ± 0.25 mm. After extraction, a #10 file was placed and advanced to a point "just" inside the apical foramen and this was determined to be the true length. The measurements derived from the EALs were compared with this true length and any measurement within ± 0.5 mm was deemed to be acceptable. In their study they did not label the true length as the measurement to the major diameter (foramen), although just inside the apical foramen and the illustrations included in the study would indicate this to be the case.

Stein and Corcoran in 1991 (3) and 1990 (4) found that EALs seemed to consistently measure within a narrow band (SD = 0.76 mm) near the apical constriction (where the mean value was 0.24 mm coronal to the cementodentinal junction). The electronic device Berman and Fleischman (5), tested, measured consistently within a small range near the apical foramen (−0.48 mm from the apical foramen with a SD of 0.44 mm). This study was done on mature vital teeth that were destined for orthodontic extraction.

Numerous other authors (6–8) have investigated and evaluated commercially available EALs. Although some of these studies identified vital and necrotic teeth, no study specifically examined the accuracy of the EALs in vital versus necrotic cases. In the necrotic cases where there is inflammatory root resorption, the apical constriction may be altered and even nonexistent. In teeth with periapical lesions, no periodontal ligament may remain to respond to the "apex locator." The purpose of the present study was to evaluate, in vivo, the measurement accuracy in vital and necrotic canals by means of the Endex (Osada Electric Co., Los Angeles, CA) apex locator.

MATERIALS AND METHODS

Thirty-three teeth destined for extraction in 19 patients were selected. All were single-rooted maxillary or mandibular teeth with mature apices. Radiographs were taken to determine whether or not a periapical radiolucency and/or resorption could be detected. The teeth were tested using an Analytic Technology pulp tester, a carbon dioxide ice pencil, percussion, and palpation. Seventeen teeth were determined to be vital and 16 were necrotic. The patient was anesthetized and the tooth was isolated using a rubber dam. The majority of the coronal portion of the tooth was removed using a 557 carbide bur or a bullet-shaped diamond in the high-speed handpiece. Once access was gained, the canal orifice was widened using Gates Glidden drills to facilitate placement of the file. The canals were irrigated using 5.25% sodium hypochlorite and, as recommended by the manufacturer, were *not* dried prior to insertion of the measurement file.

A file was then inserted within 2 to 3 mm of the radiographic apex. The Endex probe and lip clip were then placed and the instrument turned on and reset. The size of the measurement file was between a #15 and a #35, depending on the size of the canal initially.

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A SEM Study of In Vivo Accuracy of the Root ZX Electronic Apex Locator

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Twenty-nine unprepared, vital teeth were used to evaluate the accuracy of the Root ZX in locating the root canal foramen. After extraction of the teeth, a scanning electron microscope analyzed the relation of the file tip to the foramen. The sample was divided into two groups (Group A and Group B) according to the presence of a normal apical foramen (along the root main axis) or of a lateral foramen (deviating from the root main axis). With a tolerance level of ± 0.5 mm, a clinical accuracy rate of 82.75% was recorded in the total sample. With a ± 1.0-mm tolerance level, an accuracy of 100% was found. The error in locating the apex was significantly smaller in cases with a normal apical foramen (Group A) than in cases with a lateral foramen (Group B) ($p < 0.001$). An accuracy of 100% at the ± 0.5-mm tolerance level was registered in Group A.

More than 50 years ago, Suzuki (1) discovered that the electrical resistance between a root canal instrument inserted in a root canal and an electrode applied to the oral mucosa registered consistent values in any portion of the periodontium. Sunada (2) first developed an electronic method that could measure the length of the canal according to these principles in 1962. In the following years, however, studies (3, 4) have questioned the possibility of obtaining an accurate apex location in the presence of electrolytes such as sodium hypochlorite, exudate, or excessive hemorrhage.

In 1984 Yamashita (5) proposed a method that calculates the difference between two potentials of the root canal with composite sine wave current sources of two frequencies, which has been commercialized as the Endex (Osada Electric Co., Tokyo, Japan). This device is able to make an accurate measurement of the root canal length, even if a strong electrolyte is in the canal (6). The Endex must be calibrated (zero adjustment) at several millimeters from the apical foramen in each individual root canal. This adjustment is not accurate in dry root canals (7).

Finally, in 1991 Kobayashi et al. (8) reported the "ratio method" for measuring the root canal length, then commercialized as the Root ZX (J. Morita Corp., Tustin, CA). The ratio method simultaneously measures the impedance of two different frequencies, calculates the quotient of the impedances, and expresses this quotient as a position of the electrode (file) inside the root canal. The measurement is supposed to be hardly affected by the electrical condition inside the canal and can be performed in dry canals without any calibration (8). In a stereomicroscopic study, Shabahang et al. (9) assessed the clinical accuracy rate to be 96.2% in apex location with the Root ZX.

The purpose of this study was to assess the accuracy in root canal length measuring of the Root ZX in the presence of vital tissue by means of scanning electrone microscopy (SEM). Specifically evaluated were the effects of the variation in the position of the foramen (apical versus lateral).

MATERIALS AND METHODS

Thirty-five single-rooted teeth were selected for this study in 19 patients scheduled for dental extractions. An informed written consent was obtained from each patient before treatment. All selected teeth presented with a completely formed apex and with vital pulp tissue. The response of each tooth to electric pulp testing (Analytic Technology Vitality Scanner 2006, Analytic Technology Corp., Redmond, WA) was recorded, and a standardized periapical radiograph was undertaken.

After administration of local anesthesia (2% mepivacaine hydrochloride with adrenaline 1:100,000, Parke-Davis, Milan, Italy), the teeth were isolated under a rubber dam. The major part of the clinical crown of the teeth was removed with a high-speed handpiece under abundant irrigation to obtain easy access to the radicular portion of the teeth. The entrance to the root canal was enlarged by means of a Gates-Glidden bur, and undercuts were placed in the pulp chamber for later stabilization of the file during extraction. After irrigation of the canal entrance with a 2.5% solution of sodium hypochlorite, the excess of fluid was aspirated, and a file of adequate dimensions (ranging from #08 to #15) was inserted into the root canal.

The Root ZX was then used according to the manufacturer's instructions. The clip was applied to the patient's lip, and the electrode was connected to the file. The file insertion was stopped when the inscription "APEX" on the display flashed and the audible continuous signal indicated that the anatomical foramen had been reached. The 0 marking at "APEX" was selected for termination. After identification of the apical limit according to the Root ZX, the file was locked in place using the undercuts and light-curing composite material (Heliomolar, Vivadent, Schaan,

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Accuracy of electronic apex locators in comparison to actual length—an in vivo study

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KEYWORDS
Working length;
Endodontic;
Measurement precision;
Determination;
Apical foramen

Summary *Objectives*: The measurement precision of four electronic apex locators (Root ZX, Morita, Tokyo, Japan; Endy, Loser, Leverkusen, Germany; Justy II, Hager-Werken, Duisburg, Germany; Endox Lysis, Milan, Italy) was examined in the present in vivo study.
Methods: The root canal length of 40 single-rooted and multi-rooted teeth was determined with the four devices prior to tooth extraction. To determine the actual root canal length, the apical third was longitudinally sectioned, the root canal instrument was positioned and the apex was examined using a microscope.
Results: The average measurement deviation (±SD) in relation to the apical constriction was 0.3 mm (±0.6) for the Root ZX, 0.7 mm (±1.0) for the Endy, 0.2 mm (±0.7) for the Justy II and 1.3 mm (±1.7) for the Endox. The limit of ±0.5 mm from the apical constriction was attained by the Root ZX in 78%, by the Endy in 67%, by the Justy II in 80% and by Endox in 31% of all measurements.
Conclusions: The latest generation of apex locaters provide the clinician with an accurate and useful adjunct for the determination of root canal length.

Introduction

In endodontic treatment the determination of the working length comprises one of the most critical steps and is still difficult to achieve under clinical circumstances.[1,2] Radiography is the traditional method of obtaining information on the anatomy of the root canal and its surrounding tissue.[3,4] The exact determination is achieved using hand instruments and the subsequent translation with the assistance of gauges.[5] However, radiography is sensitive both in its exposure and interpretation. Goldman, Pearson and Darzenta[6] examined 253 cases and found agreement among observers in less than half, with the most disagreement being found in maxillary molars.

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Effect of pre-flaring and file size on the accuracy of two electronic apex locators

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ABSTRACT

Objective: This *ex vivo* study evaluated the effect of pre-flaring and file size on the accuracy of the Root ZX and Novapex electronic apex locators (EALs). Material and methods: The actual working length (WL) was set 1 mm short of the apical foramen in the palatal root canals of 24 extracted maxillary molars. The teeth were embedded in an alginate mold, and two examiners performed the electronic measurements using #10, #15, and #20 K-files. The files were inserted into the root canals until the "0.0" or "APEX" signals were observed on the LED or display screens for the Novapex and Root ZX, respectively, retracting to the 1.0 mark. The measurements were repeated after the pre-flaring using the S1 and SX Pro-Taper instruments. Two measurements were performed for each condition and the means were used. Intra-class correlation coefficients (ICCs) were calculated to verify the intra- and inter-examiner agreement. The mean differences between the WL and electronic length values were analyzed by the three-way ANOVA test ($p<0.05$). Results: ICCs were high (>0.8) and the results demonstrated a similar accuracy for both EALs ($p>0.05$). Statistically significant accurate measurements were verified in the pre-flared canals, except for the Novapex using a #20 K-file. Conclusions: The tested EALs showed acceptable accuracy, whereas the pre-flaring procedure revealed a more significant effect than the used file size .

Key words: Endodontics. Odontometry. Root canal preparation. Tooth apex.

INTRODUCTION

The correct determination of the working length is an essential step during endodontic therapy. Although the radiographic method plays an important role in achieving acceptable root canal measurements, electronic apex locators (EALs) have been widely used for this purpose as well[14]. Several studies[19,30,34] compared the accuracy of different models of EALs with radiographic root canal length determination and showed that the electronic methods provided the best results. In addition, the EALs have the advantage of reducing the number of radiographs required to establish the apical limit of root canal instrumentation in clinical practice[11,23].

However, although the use of EALs is well established, predictable and reproducible electronic readings were only possible with the development of last generation devices[14]. Root ZX (J. Morita CO., Tokyo, Japan) and Novapex (Forum Engineering Technologies Ltd., Rishon Lezion, Israel) are commercially available modern EALs that measure the impedance between the file tip and the root canal at different frequencies[8,14]. These EALs present satisfactory performance in the presence of blood, fluids, or irrigating solutions[4,5,8,26,27] as well as during retreatment procedures[1,13]. A high accuracy rate of measurements that are 0.5-1 mm closer to the actual length are possible using these devices[8,26].

Several factors may influence the accuracy of

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SYSTEMATIC REVIEW

Electronic apex locator: A comprehensive literature review — Part II: Effect of different clinical and technical conditions on electronic apex locator's accuracy

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ABSTRACT

Introduction: To investigate the effects of different clinical and technical conditions on the accuracy of electronic apex locators (EALs). **Materials and Methods:** "Tooth apex," "dental instrument," "odontometry," "electronic medical," and "electronic apex locator" were searched as primary identifiers via Medline/PubMed, Cochrane library, and Scopus data base up to 30 July 2013. Original articles that fulfilled the inclusion criteria were selected and reviewed. **Results:** Out of 402 relevant studies, 183 were selected based on the inclusion criteria. In this part, 75 studies are presented. Pulp vitality conditions and root resorption, types of files and irrigating materials do not affect an EAL's accuracy; however, the file size and foramen diameter can affect its accuracy. **Conclusions:** Various clinical conditions such as the file size and foramen diameter may affect EALs' accuracy. However, more randomized clinical trials are needed for definitive conclusion.

Key words: Dental instrument, electronic apex locator, electronic medical, odontometry, tooth apex

Introduction

Exact determination of the canal length is a necessary factor for the long-term success of root treatment.[1] The use of the electronic apex locators (EALs) as an aid to measure canal length has increased recently.[2]

In the first part, different generations, comparison with other techniques and different usages of EALs have been reviewed and discussed. The aim of this part is to evaluate the effects of different clinical and technical conditions on the accuracy of EALs.

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Materials and Methods

Search strategy

Electronic searches were performed, using "tooth apex," "dental instrument," "odontometry," "electronic medical," and "electronic apex locator" as keywords. The searching protocol used in this literature review was identical to that used for Part I of the review.[2]

Inclusion and exclusion criteria

The inclusion and exclusion criteria for this review were set as Part I of the review.[2] In this part, 75 studies were selected.

Data extraction

Extraction of data from studies, assessment of validity, and designed check list was based on the first part.[2]

Result

Out of 402 articles, 183 studies were reviewed, and 75 studies were selected for this part. The studies were categorized as follows.

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Accuracy of Root Length Determination Using Tri Auto ZX and ProTaper Instruments: An *In Vitro* Study

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Abstract

The accuracy of the electronic apex locator feature of Tri Auto ZX was assessed. Twenty distobuccal roots were selected and, after endodontic access, placed in plastic cylinders filled with 2% agar until completely covered. The roots were divided in two groups according to the calibration of the automatic apical reverse mechanism of Tri Auto ZX, at 1 and 2 mm from the apical foramen. Preparation was performed with ProTaper instruments connected to the device. Afterwards, the last file used was introduced into the canal and fixed in place with acrylic resin. The roots were removed from the agar and ground until exposure of the file. The distances between file tip and apical foramen were submitted to statistical analysis. The distances reached were actually shorter than the preset distances in every case, however, they were considered clinically acceptable. Setting the reverse mechanism at 1 mm was more reliable than at 2 mm. *(J Endod 2006;32: 142–144)*

Key Words

Apex locator, root canal length, Tri Auto ZX

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The correct biomechanical preparation of the root canal system is an important step for a successful endodontic therapy and establishing a precise apical limit accounts for great part of the success. This apical limit is generally set near the apical constriction of the canal, which is the narrowest part with the smallest diameter of blood supply in the canal, thus creating the smallest wound site possible and best healing condition (1).

A precise working length prevents transportation of the apical foramen and possible overfilling of the root canal system; and also inadequate debridement, which in turn could lead to retained pulp tissue and lack of healing (2). Custer (3) was the first to introduce the electrical method of locating the apical foramen. Suzuki's (4) discovery that the values for the electrical resistances between the periodontal ligament and oral mucosa were always constant allowed the development of the first apex locator by Sunada (5).

Several devices for identification of the apical foramen have been developed in the last years and successfully employed. Tri Auto ZX (J. Morita, Kyoto, Japan) is also an instrumentation system that features an electronic apex locator. Its apical automatic reverse function reverses the rotation when the instrument tip reaches the length previously set by the professional. This measurement may be at 0.5, 1, 1.5, or 2 mm from the apical foramen. According to the manufacturer, setting the measurement at 0.5 mm would correspond to the apical constriction.

The purpose of this study was to assess the accuracy of Tri Auto ZX as an apex locator and its automatic apical reverse mechanism while in use with engine-driven nickel-titanium files.

Materials and Methods

Twenty distobuccal roots with no dilacerations of maxillary molars were selected for the study. The teeth had been stored in 10% buffered formalin after extraction and then washed in a saline solution. Endodontic access was performed with a #4 carbide bur (KGSorensen, RJ, Brazil) and the pulp chamber copiously irrigated with 1% sodium hypochlorite solution. A #10 K file was used to verify the presence of possible obstructions and assure a direct access to the apical foramen.

Each root was placed in a plastic cylinder (4.5 cm height and 4.5 cm diameter), through a central hole that had been previously performed on top of the container and fixed with acrylic resin to avoid any movement during instrumentation. The cylinders were filled with 2% agar covering the root to simulate clinical conditions. A tiny hole was made on the top of the container to hold the electrode (lip-clip). The cylinders containing the roots were then divided in two groups accordingly: Group 1, 10 roots prepared using the automatic apical reverse mechanism set at 1 mm; and group 2, 10 roots prepared using the automatic apical reverse mechanism set at 2 mm.

Biomechanical preparation was performed in a crown-down technique, with ProTaper instruments (Dentsply-Maillefer, Ballaigues, Switzerland), ending with a Finishing 3 (F3) file in every root.

Once the preset distance was reached, the device emitted a sound and activated the reverse function. After preparation, the last F3 file used was carefully introduced into the canal by hand to verify if the preset distance had been reached and fixed in place using acrylic resin.

The roots were carefully removed from the cylinders and viewed under a dissecting microscope (Nikon, Tokyo, Japan) at ×30 original magnification. The position of the apical

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The Accuracy of the Root ZX Electronic Apex Locator Using Stainless-Steel and Nickel-Titanium Files

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Numerous apex locator studies have been performed. Generally, they use only stainless-steel hand files for testing purposes. Today many clinicians use both stainless-steel and nickel-titanium files during the treatment of a case. Given the widespread use of nickel-titanium files, a comparison of the accuracy in determining length with an apex locator using stainless-steel and nickel-titanium files seems clinically relevant. Campbell et al. (1) published a study where only nickel-titanium files were used. A literature search failed to reveal any studies that directly compared stainless-steel and nickel-titanium files when used with an apex locator to determine length measurements in the same tooth. The purpose of this study was to determine if there is a measurable difference in accuracy of length determination when stainless-steel and nickel-titanium files were used for this purpose in the same tooth.

MATERIALS AND METHODS

A group of 20, single-rooted, single-canal, extracted, maxillary anterior teeth with mature root apices and patent root canals were used. Tooth suitability was determined by visual inspection using a dental operating microscope, radiographs, and finally, after decoronation, placement of a file into the root canal to determine patency. Each tooth was decoronated at approximately the CEJ to provide a flat horizontal surface. A #10 stainless-steel Flexofile (Dentsply/Maillefer, Tulsa, OK) was placed into the root canal until the tip of the file reached the plane of the major diameter of the foramen as defined by Kuttler (2). Proper positioning was verified using a dental operating microscope (Global, St. Louis, MO) at the 0.8 step (×6.4 magnification) setting to view the file tip. The file length was determined by placing the file's measurement stopper flush to the flat horizontal coronal surface of the root when the file tip was placed to the level of the major foramen. The length of the file was then read using a traveling microscope (Gartner Scientific Instruments, Chicago, IL) with a measurement accuracy of 0.01 mm. The Endo-M-Block (Dentsply/Maillefer) was used to hold the file in a horizontal position when it was being measured with the traveling microscope.

Canal measurements were made to the nearest 0.01 mm. All experimental measurements were repeated three times. An individual tooth's true length was taken to be the average of these measurements. Each tooth was mounted in an alginate model (3) so that an electronic apex locator could be used to measure canal length. The manufacturer's recommended operating procedures for the Root ZX (J Morita USA, Inc., Irvine, CA) apex locator were used.

Before taking electronic apex measurements, the root canals required instrumentation to an ISO size #20 file to allow the measurement files to fit to length. All measurements of canal length were to the apex designation on the Root ZX or the apex location as visualized with the dental operating microscope. The four file types tested were stainless-steel hand Flexofiles (FO) (Dentsply/Maillefer), nickel-titanium hand Sureflex (SF) files (Dentsply/Caulk, Milford, DE), nickel-titanium rotary Lightspeed files (LS) (Lightspeed Technologies Inc., San Antonio, TX) and nickel-titanium rotary Profile .04 taper (PF) files (Dentsply/Tulsa Dental, Tulsa, OK). To avoid bias, the measurements were taken by randomizing the order of the file types, with the exception that the Profile rotary was always used last because it incorporated the greatest amount of taper and therefore required additional removal of dentin to be placed to the apex for all measurements. Files with apical sizes of #20, #25, and #30 were used for all file groups.

The instrumentation technique consisted of a simple crown-down technique as described by Stabholtz et al. (4), when Gates Glidden rotary instruments were used for preflaring the coronal ⅓ of canal followed by stainless-steel files #20, #25, and #30 to the apex. Data for each tooth, file type, and file size were recorded along with the true length (TL) and electronically measured length (EL). One operator performed the TL and EL measurements and all the canal instrumentation. A random-effects, repeated-measures ANOVA was used to assess whether there is a different accuracy according to: file type (FO, SF, PF, LS) and file size (#20, #25, and #30). Accuracy was defined as the difference between the TL and the EL.

RESULTS

As the tooth-to-tooth variability accounted for 99.83% of all variability, measurement of the TL accounts for less than 0.17% of error. The ANOVA results showed significant difference between the 12 groups of file types and file sizes ($F(30, 689) = 39.6$, $p < 0.0001$). Statistically significant differences occurred between file types and sizes but the largest of these differences (0.11 mm) was not clinically significant. Overall variability between electronic measurements and true length was approximately 6% regardless of

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ORIGINAL ARTICLE

Tooth anatomy risk factors influencing root canal working length accessibility

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The aim of this study was to analyze the specific influence of root canal anatomy on the accessibility of working length during root canal therapy. Four hundred seventy-six root canal therapy cases (amounting to a total of 1 005 root canals) were examined. The anatomy risk factors assessed in each case included: tooth type (tooth location), root canal curvature, and root canal calcification, as well as endodontic retreatment. The investigation examined the correlation between each of these anatomic factors and the working length, with statistical analysis consisting of Chi-square tests and multiple logistic regression analysis. In an independent factor analysis, tooth type (tooth location), root canal curvature, canal calcification, and endodontic retreatment were determined to be the primary risk factors. In a multiple-factor regression model, root curvature and canal calcification were found to most significantly influence root canal working length accessibility ($P<0.05$). Root canal anatomy increases the difficulty of root canal preparation. Appropriate consideration of tooth anatomy will assist in accurate determination of preparation difficulty before instrumentation. This study alerts clinical therapists to anatomical factors influencing the working length accessibility, and allows for a direct estimate of success rate given in situ measurements of tooth factors during the root canal treatment procedure.

Keywords: root canal anatomy; root canal preparation; root canal treatment; working length

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Introduction

Endodontic disease is associated with multiple-bacterial infection, where root canal therapy serves as a significantly effective treatment method [1-2]. Although successful therapy depends on many factors, one of the most important steps in any root canal treatment is canal preparation [3]. Canal preparation determines the degree of control over the complete elimination of root canal contents, which is crucial to debridement infection [4-5]. A number of studies have indicated that the ability of the dental instrument to access the full root canal length (called the working length accessibility) significantly affects the success of the root canal treatment. Negishi reported that inaccessibility of the apical anatomy significantly impairs the success of root canal treatment [6]. Consistently, researchers [7] showed that an instrument that reaches to the apical constriction gives the best prognosis. These results suggest that establishing and maintaining adequate working lengths is critical for root canal treatment.

Unfortunately, canal preparation is adversely affected by the highly variable nature of root canal anatomy [8-9]. Many problems that occur during root canal preparation, such as missed canals, perforation of the pulp floor, or canal transportation, result from poor knowledge of the

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Investigation of Apex Locators and Related Morphological Factors

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Abstract

Introduction: The purpose of this study was to investigate the ability of three electronic apex locators (EALs) to detect the minor foramen and morphological influencing factors relative to working length determination. **Methods:** Three hundred fifty-six extracted teeth were decoronated, and the coronal portion of the canal was flared. The distance between the major foramen and the file tips (DMFF) was determined by different EALs. The relationship between the DMFFs determined by the EAL and the morphological features of the root apex was analyzed by linear regression analysis. **Results:** The average DMFFs were 0.261mm, 0.376 mm, and 0.383 mm for the Root ZX (J. Morita, Kyoto, Japan), Raypex 5 (VDW, Munich, Germany), and Elements Apex Locator (SybronEndo, Anaheim, CA), respectively. The file tips determined by EALs were much closer to the major foramen in teeth with a "lateral major foramen" ($p < 0.001$). The area and diameters of the minor foramen were significantly related to the variation of the DMFFs determined by EALs. **Conclusion:** When the "minor foramen" reading was given, the file tip connected to the Root ZX was much closer to the major foramen than the other two EALs. The minor foramen's morphology and the major foramen's location were both important influencing factors on the performance of EALs. *(J Endod 2010;36:1399–1403)*

Key Words

Electronic apex locator, Root ZX, Raypex 5, Elements Apex Locator, morphological factor

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Proper root canal therapy procedures exhibit the following features: complete removal of infected pulp tissues, thorough canal cleaning, shaping, disinfection, and three-dimensional obturation. These purposes can be achieved only when the termination of root canal is determined accurately (1, 2). During this process, the minor foramen or physiological foramen is the desirable endpoint for the procedures within the root canal (3, 4) . Traditionally, tactile and radiographic methods have been used to determine the minor foramen; however, tactile sense is empirical and the radiograph can only provide a two-dimensional image of a three-dimensional object (1, 2).

Electronic apex locators (EALs) are now widely used for locating the minor foramen. The latest generation of EALs detects the minor foramen through calculating the subtle variation of impedance values between the file tip within the root canal generated by electrical impedances with different frequencies. Because of the development and advances in electronic engineering technology in the past several decades, the precision and stability of EALs have been greatly improved (5, 6). The accuracy of various EALs has been reported to be from 31% to 97.37% (7–12). In previous studies, accurate measurements were usually defined as measuring file tips within ± 0.50 or ± 1.00 mm around the preset endpoint of the root canal (1, 2). However, it remains questionable if the major foramen was set as the endpoint. In an *ex vivo* study conducted by Ounsi and Naaman (13), part of file tips, which were considered accurately determined by the Root ZX to the apical constriction, had actually gone beyond the root canal when the accuracy was defined as ± 0.5 mm around the major foramen. Correspondingly, the measured working length was actually unacceptable for root canal treatment. Therefore, it might be more objective to evaluate EALs by the distribution of measuring file tips in relation to the major foramen.

The file tip's location determined by EALs has been observed using radiographic (14, 15), histologic (7, 8), and direct file length measuring methods (11, 12, 16). Radiographic interpretation can be compromised by image distortions, whereas the histologic examination is destructive to the specimens. In both in and *ex vivo* studies, the conventional method is to represent the file tip's location by calculating the difference between the measuring file and the actual root canal length (1, 2, 11, 12, 16). However, the unexpected movement of the rubber stop and the lack of parallelism between the measuring file and gauge might result in procedural errors that would influence the study results (17). ElAyouti and Löst developed a mounting and measuring unit (MMU) to assist locating file tips. They found that the MMU was superior to the conventional method in repeatability and produced less measurement errors (17). Preferably, it would be more appropriate to use MMU instead of other methods to study the performance of EALs in laboratory studies.

The diameter of apical foramen has been thought to be a major factor that influences the performance of EALs (6, 18). Stein et al (19) reported that the accuracy of EAL was associated with the major foramen's diameter but was not affected by the minor foramen's diameter, whereas other researchers found that the measurements of EALs varied with the minor foramen's diameter (10, 20, 21). Moreover, Pagavino et al (10) reported that the measuring error of EAL was significantly different in teeth with different major foramen locations. The purpose of this study was to investigate the ability of three EALs, Root ZX (J. Morita, Kyoto, Japan), Raypex 5 (VDW, Munich, Germany), and Elements Apex Locator (SybronEndo, Anaheim, CA), to detect the minor foramen and related morphological influencing factors during working length determination.

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Effects of Simulated Lateral Canals on the Accuracy of Measurements by an Electronic Apex Locator

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Abstract

Background: Accurate determination of the apical terminus plays a significant role in the success of root canal therapy, but accuracy may be affected by the presence of accessory canals.

Objective: To evaluate the accuracy of a ratio-based electronic apex locator for roots with simulated lateral canals.

Methods: Forty-two single-rooted human teeth were randomly divided into 2 groups. For each tooth, the root canal was prepared to the visually determined working length, and the working length was then measured with the Justy II electronic apex locator. Simulated lateral canals (of 2 different diameters) were then prepared at 3 mm (group A) or 6 mm (group B), and the working lengths were measured again with the same instrument. The measurements were analyzed by one-way analysis of variance.

Results: For both groups, there were no significant changes in working length after the creation of simulated canals ($p > 0.05$).

Conclusion: Measurements obtained with the ratio-based electronic apex locator were not affected by the preparation of simulated lateral canals, and the instrument was able to accurately determine the location of the tooth apex.

Accurate determination of the apical terminus (major foramen or apex) plays a significant role in the success of root canal therapy, specifically in calculating the working length. Working length is defined as "the distance from a coronal reference point to the point at which canal preparation and filling should terminate."[1] Several techniques, including electronic methods, have been used to determine the position of the apex.[2] Electronic apex locators detect the canal terminus using certain characteristics of human tissues that can be modelled by a combination of electrical components.[2] However, in some cases, the device incorrectly indicates that the apex has been reached before the instrument tip reaches the apical terminus.[3,4] Such inaccuracies may be caused by extensive carious lesions or

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Critical Diameter of Apical Foramen and of File Size Using the Root ZX Apex Locator: An *In Vitro* Study

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Abstract

Introduction: An evaluation was made of the accuracy of the Root ZX apex locator (J. Morita Corp, Tokyo, Japan) in widened foramina, considering the existing controversy over this issue in the literature. **Methods:** Ten single-root teeth were embedded in an alginate mold. The foramina were widened from 0.6 mm to 1.0 mm. The measurements were taken with all possible file sizes ≥#10. The statistical accuracy of the Root ZX was calculated for the different diameters and for the influence of file size. **Results:** The accuracy of the Root ZX apex locator with a range of error of ±0.5 mm was 87% in an apical foramen size of 0.6 mm and 84% using files size 45 or larger in an apical foramen size of 0.7 mm. With a tolerance of ±1 mm, the accuracy was 99% in an apical foramen size of 0.6 mm, 98% using files size 45 or larger in an apical foramen size of 0.7 mm, and 95% using files size 70 or larger in an apical foramen size of 0.8 mm. In the rest, accuracy was not certain. The measurements taken with smaller files were shorter. There were no cases of overestimation of the working length. **Conclusions:** The Root ZX apex locator was accurate for an apical size of 0.6 mm, independently of the file size; between 0.7 to 0.8 mm, we should adjust the files to the foramen, whereas above size 0.9 mm the locator is not accurate. The results show that the accuracy of this electronic apex locator is gradually lost as the foramen widens. Considering the stable conditions of *in vitro* studies, our findings advise caution in clinical application of the locator. *(J Endod 2011;37:1306–1309)*

Key Words

Apical widening, electronic apex locator, file size, root length determination, Root ZX

The apical constriction is widely accepted as the landmark for ending endodontic instrumentation and obturation (1, 2). The accuracy of canal length measurement using electronic apex locators (EALs) is in the range of 80% to 100% as shown by *in vitro* (3–7) and clinical studies (6, 8–11). However, for decades, it has been reported that a number of factors may influence the accuracy of EALs, such as the size of the apical foramen (3, 4, 6, 12–15), the type and size of the measuring file (15–17), the irrigation solution used, and electroconductivity of the pulp (3, 4, 12, 16, 18). In 1994, the Root ZX (J. Morita Corp, Tokyo, Japan) was introduced to overcome the problem of moist canals or vital pulp tissue (19). Nevertheless, the size of the apical foramen and the file characteristics remain controversial topics.

Previous reports indicate that the critical diameter of the foramen is 0.3 mm (ie, file size #30) (4) or 0.6 mm (ie, file size #60) (3, 20). In glass tubes that simulate canals (12) or when the apical constriction is destroyed (21), a terminal opening of 0.4 mm (ie, file size #40) or larger decreases the accuracy of measurement. For other investigators, the critical diameter is greater, and accurate measurements are obtained for diameters of 0.8 mm (18) and even 0.9 mm (7). Additionally, according to some authors (6, 15, 17), these measurements can change depending on the discrepancy between the caliber of the measuring file and the size of the apical foramen although others studies have failed to confirm this (3, 14, 18, 20–22).

The apparent discrepancy can be explained by the different research methods used. Nevertheless, considering the methodologic aspects involved, the following coincidences can be observed in those studies that have used these instruments:

1. EALs were used with values measured at two frequencies (8 and 0.4 kHz), calculating an impedances ratio (19).
2. The conical shape of the canal was still maintained, even in the absence of the anatomic apical constriction (16, 18, 21).
3. Irrigation was performed with sodium hypochlorite solution with or without EDTA (16, 18, 20).

The results of these investigations show that in diameters smaller than 0.6 mm of the apical constriction the measurements are accurate regardless of the size of the file and the apical diameter (14, 16, 18, 21). This finding coincides with a previous study by our group (20) in which the measurements proved accurate with a widening of 0.6 mm but not with a widening of 1.0 mm. It is also possible that there may be a critical diameter in the interval between sizes 0.6 and 1.0 mm.

Thus, the aim of this study was to determine whether the accuracy of the Root ZX apex locator is affected by widening of the apical foramen at 0.6 mm, 0.7 mm, 0.8 mm,

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Influence of Apical Constriction Diameter on Root ZX Apex Locator Precision

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Abstract

Small-diameter hand files are systematically used to determine the initial working length and to establish patency of the root canal. In wide canals, electronic apex locator accuracy might be influenced by file size. This article reports on a study to assess the influence of apical constriction diameter on the precision of the Root ZX apex locator by using files of varying diameter on teeth with 3 different degrees of apical widening: 0.37, 0.62, and 1.02 mm. Ten extracted single-root teeth, stored in saline solution at 37°C, were sectioned at the enamel-cement junction and embedded in an alginate mold. Initial working length (L_0) was determined with a #10 Kerr file, and canals were irrigated with either 50% citric acid or 5.25% sodium hypochlorite. To assess the ability of the locator to identify the narrowest area of the root canal as constriction diameter increased, the canal was progressively widened by insertion of files of increasing diameter (10–100) at a point L_0 + 1 mm. After each enlargement, the working length (L) was redetermined, with files from #10 (L_{10}) up to the file used for widening. Comparison of statistical results was based on the difference between final working length and initial length (L_{10}) for each apical width. Statistical analysis was carried out with analysis of variance test for comparison of means. Results showed that at apical constriction widths of 0.37 and 0.62 mm, there was no significant difference between initial working lengths as determined by a Kerr #10 file and final working lengths after widening with files of up to #60. In those teeth whose apical width had been increased to 1.02 mm, there was no statistically significant difference between initial and final working lengths as measured by files from #10–#25; however, significant differences were apparent between #10 and #30, #35, or #40 ($P < .05$), and the degree of significance increased considerably ($P < .001$) for files #45 or greater. These results suggest that Root ZX apex locator precision varies as a function of apical constriction diameter. *(J Endod 2007;33:995–998)*

Key Words

Apex locator, apical constriction, apical widening

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Proper endodontic treatment involves thorough cleaning and hermetic sealing of the root canal. These procedures have to be confined to the canal to prevent damage and iatrogenic irritation of periapical tissue and to minimize the extrusion of filling materials into the periapex.

The apical constriction is widely considered to be the ideal anatomic limit for root canal instrumentation and obturation (1–4); locating the apical constriction is therefore a key stage in endodontic treatment.

Radiography has traditionally been used to establish the apical limit; unfortunately, however, the apical constriction varies considerably in shape and is not detectable by radiography.

In 1962 Sunada (5) reported a new method for measuring the length of the root canal, giving rise to the development and marketing of the first electronic apex locators (EALs), on the basis of the electrical resistance theories of Suzuki (6). These first-generation locators provided rather inaccurate measurements as a result of the presence of vital pulp tissue, excessive blood, exudates, or moisture within the canal. Other devices based on electrical impedance were subsequently developed to overcome these drawbacks (7).

In the 1990s a new dual-frequency technique was designed to locate the apical constriction by measuring the maximum difference in the impedance generated by a dual-frequency alternating current (8). The major advantage of this apparatus is that it provides precise measurements even in the presence of blood, pus, or pulp tissue, with a reliability ranging between 80%–95% (9–16).

Although they are largely reliable, dual-frequency locators might yield erroneous measurements in certain clinical situations, including subgingival caries, root fracture (17), and teeth with a widened apical foramen or an immature apex (12, 18–20). A number of studies reported that as apical foramen diameter increases, EAL accuracy decreases (12, 21, 22).

Small-diameter hand files are systematically used to determine the initial working length and to establish patency of the root canal. In wide canals, EAL accuracy might be influenced by file size, because a slim file is likely to leave space within the canal, whereas a larger-diameter file will yield a tighter fit.

This article reports on a study to assess the influence of apical constriction diameter on the precision of the Root ZX (J. Morita USA, Irvine, CA) apex locator by using files of varying diameter on teeth with varying degrees of apical width.

Material and Methods

Ten single-root teeth were extracted and stored in saline solution at 37°C until use. Crowns were sectioned at the enamel-cement junction to gain standard root canal access and obtain a fixed, stable point of reference, with a view to minimizing errors in working length measurements caused by variations in the coronal reference point.

Teeth were then embedded in an alginate mold that was kept moistened in saline solution throughout the study to model a locator operation in a clinical context (23–25). Initial working length (L_0) was routinely determined with the Root ZX apex locator by using a #10 Kerr file, following manufacturer's instructions. The file was advanced into the canal until the reading on the apex locator dial flashed "apex." The file was then retracted until the device signaled that the constriction was reached. This procedure was repeated as necessary for each measurement. Three measurements were made for

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Original Article

Accuracy of an Electronic Apex Locator for Working Length Determination in Primary Anterior Teeth

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Abstract

Objectives: Correct determination of working length is an important step for success of endodontic therapy. Conventional radiography has limitations in providing the accurate location of apical foramen. For this reason, electronic apex locators (EALs) were developed to shorten the treatment time and decrease the radiation dose. The aim of this study was to evaluate the accuracy of Root ZX EAL for working length determination in primary anterior teeth.

Materials and Methods: In this in-vitro study, 50 extracted primary anterior teeth with root resorption were selected with no obstructed canals or history of previous root canal therapy. Working lengths were measured by direct observation of actual length (AL), radiography and Root ZX EAL. A variation of ±0.5 mm from the AL was considered acceptable. The results were analyzed statistically using paired t-test and interclass correlation coefficient (ICC) at 0.05 level of significance.

Results: Considering an acceptable 0.5 mm margin from AL (direct measurement), the accuracy of Root ZX EAL and radiography was found to be 86% and 76%, respectively. Absolute value of error from AL was significantly lower for ZX compared to radiography ($P<0.001$). Interclass correlation comparing both radiography and Root ZX with AL showed strong correlations.

Conclusion: Root ZX EAL can be used as a reliable tool for obtaining root canal length in primary anterior teeth with resorption.

Keywords: Tooth, Deciduous; Radiography; Tooth Apex

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INTRODUCTION

The main purpose of endodontic treatment is to preserve the teeth affected by dental caries, traumatic injuries or other causes and also their supporting tissues. In such cases, maintaining the vitality of the pulp tissue must be primarily attempted. However, a non-vital tooth is still able to function normally in the oral cavity [1]. In primary teeth, unlike the permanent teeth, it is not necessary to determine the exact length of the root canal, because of their open apices [2].

Root length determination is crucial for a successful treatment, because of the need for complete debridement and disinfection without traumatizing the periapical tissue [3].

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Influence of the Canal Contents on the Electrical Assisted Determination of the Length of Root Canals

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The purpose of this study was to compare the influence of the root canal status on the determination of the root canal length by an electronic apex locator in vital and necrotic canals and canals with root canal filling retrieval.

One hundred seven teeth with a total of 171 canals with various contents (105 vital pulp, 47 necrotic pulp, and 19 retrieval of root canal filling materials) were measured for root canal length in vivo with the AFA Apex Finder. The distance between the file tip and the radiographic apex was also determined on radiographs. In 86% of the evaluated roots, the file tip position as indicated by the Apex Finder was located within 0.5 mm of a point 1.0-mm short of the radiographic apex. The Apex Finder showed higher accuracy for determining the apical constriction in vital canals (93.9%) than in necrotic canals (76.6%), and this difference was statistically significant ($p \leq 0.05$).

The Apex Finder indicated the point −1 mm ± 0.5 mm in canals with retrieval of root canal filling materials in 68.4% of these cases, but because of the small number of retrieval cases, this is not comparable statistically with vital and necrotic cases. The authors concluded that the AFA Apex Finder is highly accurate in vital canals.

The accurate locating of the physiological apex of root canal is a prerequisite for a successful endodontic therapy (1). Traditionally, the generally accepted method for root canal length determination is the radiographic interpretation of an instrument placed in the canal. The most obvious disadvantage of this technique is that the position of the apical constriction cannot be accurately determined by radiographs. Several researchers have shown that the location of the apical constriction varies in relation to the anatomical apex, usually in a range of 0.5 to 3.0 mm from the radiographic apex (2, 3).

In 1918, Custer (4) was the first to develop the idea that root canal length could be estimated by the use of an electrical current. In 1962, Sunada (5) demonstrated that the electrical resistance between the periodontal ligament and oral mucosa has a constant value that can be measured. Inoue (6) developed a sonic readout system by using a transistor equalizer-amplifier feedback circuit and low frequency oscillation for root canal length measurement. Since then, different apex locators have been developed commercially, and for most of them, the clinical accuracy of their electronic root canal measurement has been evaluated either by radiographs (7) or on extracted teeth (8). The values for accuracy have varied from 15% (9) to 94% (10).

Previous studies have shown that apex locators often yield inaccurate results, particularly when fluids are present in root canals (6, 11).

To overcome this shortcoming, several manufacturers have introduced devices using advanced technology that measures the ratio of two or more electrical impedances emitted from the probing instrument. In 1983, Ushiyama (12) described the gradient impedance method to determine working length in the presence of electrolytes.

The AFA (all fluids allowed) Apex Finder, Model 7005 (Analytic Endodontics, Orange, CA) is a newly designed device that uses five different frequencies (0.5 kHz, 1, 2, 4, and 8 kHz) for measuring the root canal length. The device allows root canal length measurements in a canal filled with different electrolytes, such as purulent exudate, blood, and sodium hypochlorite.

It is assumed that a canal with a vital tissue may demonstrate a different impedance compared with a canal with a necrotic pulp. Moreover, it is conceivable that a preflared canal after retrieval of root filling material may also present a different higher impedance value due to inadvertent flaring of the apical foramen (13). The purpose of this in vivo investigation was to compare the root canal length determined by the Apex Finder Model 7005 in vital and necrotic canals and after retrieval of root canal filling material.

MATERIAL AND METHODS

In a total of 107 maxillary and mandibular teeth (49 incisors, 29 premolars, and 29 molars, 171 canals) the root canal length was determined by using the AFA Apex Finder Model 7005. The teeth

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Influence of pulp vitality on length determination by using the elements diagnostic unit and apex locator

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Objective. The aim of this study was to compare the influence of the pulp condition (vital or necrotic) on the determination of the root canal length by using a fourth generation electronic apex locator (EAL).
Study design. The Elements Diagnostic Unit and Apex Locator was used to measure 143 teeth, totaling 294 canals with different conditions (236 necrotic and 58 vital pulp), for root length. After assessing the root canal and ascertaining the tooth length by using the EAL, the position of the file was confirmed by radiograph. The distance between the file tip and the root end was measured radiographically and was compared with the electronic measurement.
Results. Under clinical conditions within an acceptable range lower than 0.5 mm, the concordance between the 2 measurements was 96.6%. This new EAL showed no significant difference ($P \leq .05$) on accuracy of root canal length determination between vital cases (94.8%) and necrotic cases (97%).
Conclusion. This device proved to be reliable regardless of the pulpal vitality. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:e129-e132)**

Establishing the root canal length is an important step for the success of endodontic therapy. The widely accepted working length during the instrumentation is the occlusal or incisal distance between 1 reference point occlusally or incisally on the tooth and the cementodentinal junction or apical constriction.[1-3]

Although dentists routinely use radiography to determine the working length, it is subject to distortions, and the apical foramen usually is not seen in radiographs. In cases where the apical foramen is eccentric to the root apex, radiographic methods are often inaccurate and result in overextension of root canal instrumentation.[1] Several studies have shown that the mean distance from the apex to apical constriction is around 0.5 mm to 1.0 mm.[4,5]

Electronic apex locators (EALs) have been developed to determine the working length during endodontic treatment. The principle of the electrical location was first studied by Suzuki[6] where he demonstrated that the electrical resistance between the periodontal ligament and the oral mucous membranes is constant and equal to 6.5 ohms. This led to development of the first EAL by Sunada[7] and brings this unit into the clinical practice, where it works by analyzing the decrease in impedance when the instrument reaches the apical constriction or apical foramen.

The first generation of apex locators used the principle of DC resistance, and the second generation, AC single-frequency impedance. A few years ago, the third generation was introduced and it was based on the ratio of dual-channel or multichannel impedance principle. Different than the other apex locators, the new apex locator studied here, the Elements Diagnostic Unit and Apex Locator (SybronEndo, Orange, CA), is classified as the fourth generation and works by breaking the impedance down into its primary components (resistance and capacitance) and measuring them directly and independently during use. This reading theoretically results in a more precise measurement. This device allows root canal length determination in a canal filled with different electrolytes, such as sodium hypochlorite, blood, and exudates.

A literature search revealed few ex vivo[8] and in vivo[9] studies evaluating the influence of the pulp condition on the length determination by using this fourth generation EAL. The objective of this study was to evaluate in vivo the root canal length measurement by the Elements Diagnostic Unit and Apex Locator in vital and necrotic pulp conditions.

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58.

Accuracy of Root ZX II in Locating Foramen in Teeth with Apical Periodontitis: An *In Vivo* Study

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Abstract

Introduction: This study was conducted *in vivo* to investigate the accuracy of Root ZX II in locating the apical foramen in teeth with apical periodontitis (AP). **Methods:** Twenty-seven single-root teeth scheduled for extractions were selected; in AP group, there were 12 teeth with pulp necrosis and radiographic evidence of apical lesions, and VT group consisted of 15 vital teeth. After endodontic access, the coronal portion of the canal was flared, and electronic measurement was performed by using a 15 K-file until the device level reading "APEX" was reached. The file was fixed in place, and the tooth was extracted. The apical third of the root was shaved until exposure of the file. The distance from the file tip to the most coronal border of the apical foramen was obtained. **Results:** The mean distance in AP group was +0.117 (standard deviation, 0.373) and in VT group was −0.105 (standard deviation, 0.218). The unpaired *t* test showed no difference between the groups when comparing the mean distances ($P > .05$). The apical foramen was accurately located within ±0.5 mm in 83% of the teeth in AP group and in 100% of VT group. Statistical analysis showed no difference between the groups ($P = .1092$). **Conclusions:** The Root ZX II device was accurate in locating the apical foramen regardless of the presence of AP. *(J Endod 2011;37:1213–1216)*

Key Words

Apical foramen, apical periodontitis, Root ZX II, working length

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Accurate working length determination has a profound effect on the ideal preparation, disinfection, and hermetic sealing of the root canal system (1). Sufficient evidence suggests that instrumentation either beyond or well short of the radiographic apex can adversely affect success (2). The apical constriction has been recommended as the ideal apical limit of working length, because it corresponds to the narrowest diameter of the root canal (3, 4).

Apical periodontitis (AP) is a consequence of root canal infection, which can involve progressive stages of inflammation, resulting in resorption identified as radiolucencies on radiographs (5). The resorption of the hard tissues of the tooth might also occur during this process, resulting in loss of cementum and dentin (6). Apical root resorption can cause some enlargement of the apical canal diameter, deviation of the foramen, and partial or even complete distortion of the apical constriction (6–8).

The structural alterations in the root apex should be considered during endodontic treatment, especially when establishing the working length (6, 8). Nevertheless, the resorption observed with the scanning electron microscope or in histologic studies is difficult to determine in clinical practice because radiographic assessment of small areas of resorption is complicated by several biological and technical factors (8–10). Moreover, the radiographic method to determine the canal length might prove inaccurate, depending on the direction of the root curvature, the position of the foramen, and the physiologic or pathologic factors that modify the root canal morphology (10–13). Therefore, in AP teeth, radiographic determination of working length might result in an increased risk of overinstrumentation and/or overfilling.

In 1962 Sunada (14) developed the first device for electronic canal length measurement on the basis of the assumption that there is a constant resistance between the periodontal membrane and oral mucosa. Since then, various electronic methods that use a variety of other principles have been developed to detect the canal terminus. Although these devices have been generally called electronic apex locators (15, 16), they do not assess the position of the root apex, but the apical foramen (17); thus it is suitable to use electronic apical foramen locator (EAFL) as a generic name (18).

The Root ZX II (J. Morita Corp, Kyoto, Japan) is an EAFL that measures the impedance of 2 frequencies simultaneously and expresses this quotient in terms of the position of the file inside the canal (16). This EAFL has proved capable of accurate readings in the presence of various intracanal contents and irrigants (15, 16, 19); however, it has also been reported to be influenced by factors such as the foramen's area, diameter, shape, and position (20–22).

The pathologically altered apex of a tooth with AP might influence the accuracy of the EAFL's (21, 23). Although different studies have evaluated EAFL's performance in teeth with altered apical anatomy (20–22, 24, 25), there is insufficient information concerning the clinical use of EAFLs in teeth with apical lesions or root resorption.

Methods

Fourteen healthy adult patients who were having teeth extracted for periodontal or prosthodontic reasons participated in the study. An informed written consent form was obtained from each patient before the study began. The principal investigator conducted all procedures, and the clinical protocol was similar to that of Jakobson et al (26).

Twenty-seven single-rooted teeth with mature apices were selected. Twelve teeth with clinical pulp necrosis and radiographic presence of an apical lesion were included

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ORIGINAL PAPERS

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MACIEJ KUŹMIŃSKI

The Influence of Apical Lesions on Electronic Tooth-Length Measurements – an *in vitro* Study

Wpływ obecności zmian okołowierzchołkowych na elektroniczny pomiar długości zęba – badania *in vitro*

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Abstract

Objectives. Investigating the influence of apical lesions on tooth-length measurements with the Root ZX apex locator (Morita, Japan) and checking a modified method of uncovering the apical part of the canal.
Material and Methods. Eighteen freshly extracted human teeth with attached apical lesions were investigated. Tooth lengths were measured with the Root ZX and a No. 10 K-file in an alginate mould according to the method of Katz et al. (1996) (group A). After removal of lesions, the teeth were embedded in freshly mixed alginate and measured again (group B). Then the file was secured in place with a composite material. The apical 4 mm of the canal of each tooth was exposed by grinding with a water-cooled high-speed diamond bur. Distances from the file tip to the dentino-cemental junction and to the apical foramen were measured with an endodontic microscope (Karr, Switzerland) under ×17 magnification.
Results. The tooth lengths measured in group A were longer than in group B in 9 cases (by 0.25 to 1.25 mm). In the presence of the apical lesions, the measurements were too long in 7 canals by 0.15 to 1.3 mm. The mean difference between group A and B was 0.36 mm, with a standard deviation of 0.3 mm. There was a statistically significant difference between both groups at the probability level of $p < 0.05$. The modified method of uncovering the apical part of the canal proved to be useful.
Conclusions. The presence of apical lesions negatively affects electronic tooth-length measurements (**Adv Clin Exp Med 2006, 15, 4, 607–611**).

Key words: apical lesions, electronic tooth measurement, Root ZX.

Streszczenie

Cel pracy. Ocena wpływu obecności zmian okołowierzchołkowych na elektroniczny pomiar długości zębów z użyciem endometru Root ZX (Morita, Japonia). Zbadano ponadto własną metodę szlifu odkrywającego przebieg kanału w okolicy wierzchołka korzenia zęba.
Materiał i metody. Badania przeprowadzono na 18 świeżo usuniętych zębach ze zmianami okołowierzchołkowymi, które pozostały na wierzchołkach korzenia zębów po ekstrakcji. Długość zębów zmierzono z użyciem pilniczka o rozmiarze 10 wg ISO w modelu alginatowym zgodnie z metodą Katza (grupa A). Po usunięciu zmian z wierzchołków korzeni zęby ponownie umieszczono w świeżo zarobionym alginacie i zmierzono długości (grupa B). Pilniczki używane do pomiarów unieruchomiono przez wypełnienie komory płynnym kompozytem. Wykonano szlif odsłaniający wierzchołkową część kanału z użyciem diamentowego wiertła na wiertarkę szybkoobrotową. Zmierzono odległości między końcem narzędzia a otworem anatomicznym pod 17-krotnym powiększeniem, używając mikroskopu endodontycznego (Karr, Szwajcaria).
Wyniki. Długości uzyskane podczas pomiarów w grupie A były dłuższe od tych z grupy B w 9 przypadkach (różnica wynosiła 0,25–1,25 mm). W zębach ze zmianami zmierzone długości były za długie w 7 kanałach (0,15–1,3 mm). Różnica średnich obu grup wyniosła 0,36, a odchylenie standardowe 0,3. Wystąpiła istotna statystycznie różnica między obiema grupami przy poziomie istotności 0,05. Zmodyfikowana metoda szlifu okolicy wierzchołkowej okazała się użyteczna.
Wnioski. Obecność zmian okołowierzchołkowych wpływa negatywnie na dokładność elektronicznego pomiaru długości zęba (**Adv Clin Exp Med 2006, 15, 4, 607–611**).

Słowa kluczowe: zmiany okołowierzchołkowe, elektroniczny pomiar długości zęba, Root ZX.