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Comparison between apex locater and conventional radiography in working length determination of maxillary first molars: a clinical study

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Abstract

Aim of the study: The purpose of this study is to compare the working length (WL) measurement results of conventional periapical radiographies and electronic apex locater (EAL).

Materials and method: This study was conducted during sessions of root canal treatment of 10 patients diagnosed with acute pulpitis. A total 30 root canals measurement (ten 1st upper molars, each with 1 palatal canal and 2 buccal canals) were included in the data analysis. A linear correlation and linear regression tests were utilized to check for a linear association between apex locator and X-ray measurements. Measurements of all roots were first included in the linear correlation test, and then measurements of each type of roots (palatal, mesio-buccal and disto- buccal) were tested separately. Significant linear correlations were then tested with linear regression test to formulate an equation which can predict X-ray measurements from corresponding apex locator measurements.

Results: Generally, apex locator shows a linear correlation with X-ray in terms of measuring working length of the root ($P < 0.001$). The accuracy of apex locator varies according to the site of the tooth root under investigation, with being most accurate at disto-buccal (Pearson's $r = 0.98$, $P < 0.001$) and least accurate at palatal roots (Pearson's $r = 0.57$, $P = 0.084$).

Conclusion: Working length measurement of mesio-buccal and disto-buccal roots using electronic apex locater was precise when compared to radiographic method. While in palatal roots, WL measurements using apex locator were inaccurate when compared to radiographic method.

Keywords: Apex locater, conventional radiograph, palatal canal, mesio-buccal canal, disto-buccal canal, apical foramen.

Introduction

Perfect results of root canal treatment can be achieved with

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adequate cleaning, conservative shaping, disinfection and good obturation of the root canal system. This can be achieved if the length of the tooth and the root canal is determined with accuracy. 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. [1]

The proper point to which root canals should be filled is the junction of the dentin and the cementum (CDJ) which is the anatomical and histological landmark where the periodontal ligament begins and the pulp ends and it is 1mm shorter than the radiographic apex. Root canal preparation techniques aim to make use of this potential natural barrier between the contents of the canal and the apical tissues. It is generally accepted that the preparation and obturation of the root canal should be at or short of the apical constriction. [2]

Radiographic technique has been reported to be considered as the most successful method of WL determination compared to the other techniques available. Although the radiographic technique is considered the traditional technique and is still used for determining the WL, but it has several limitations. It provides only a two-dimensional image of a three-dimensional object. It is also technique sensitive and relies entirely on the experience of the operator. Variables such as radiographic technique, angulations, inadequate radiographic exposure, will result in distorted or completely useless radiographic images. It is some time necessary to take several radiographs that will expose the patient to unnecessary radiation levels. [3]

Some anatomical landmarks could be superimposed on each other, for example, the superimposition of the zygomatic arch over the roots of maxillary molars or mandibular torus over the roots of mandibular premolars which impede the proper location of the radiographic apex on those teeth. The zygomatic arch has been reported to be superimposed in approximately 20% and 42% on the apices of the first and second maxillary molars, respectively. [4]

Custer first investigated an electronic method for root length determination. [5] The idea was revisited by Suzuki in 1942 who studied the flow of direct current through the teeth of dogs. He registered consistent values in electrical resistance between an instrument in a root canal and an electrode on the oral mucous membrane and speculated that this would measure the canal length. [6]

Based on these basic principles, the first apex locators were introduced. In reality, these devices operate using the human body as one of the components to complete the electric circuit. One of the electrodes of the apex locator is connected to an endodontic file while the other is connected through a clip to the labial mucosa of the patient. Once the file is inserted into the root canal, the circuit is partially complete, and as the file reaches to the apex, then the electric circuit is completed, and the exact position of the apical foramen is located [7]

There are several advantages reported using EALs. First, they are beneficial in reducing the number of radiographs required to determine WL [8]. Some dentists determine the WL only by using the apex locators; others use only one radiograph to confirm the initial measurement. Another

advantage is by providing a greater precision in locating the apical foramen compared to the radiographic method. Apex locators can be used at any stage and if required for several times during the instrumentation to verify whether the WL remains stable or not and can be adjusted accordingly. The endodontic procedure may be shorter in time when EALs are used instead of conventional radiographs, with previous studies suggesting a 54% reduction in time compared to traditional radiographic technique. [3]

Based on a study on extracted teeth using Root ZX apex locator, it was reported that Radiographic WL determination alone resulted in overestimation in 51% of the root canals, while the percentage of overestimation was reduced to 21% by using EAL. The authors concluded that complementing radiographic WL determination with EAL may help to avoid overestimation beyond apical foramen. [9]

In multi-rooted posterior teeth and in patients with an acute gag reflex, the radiograph method can be complicated for WL measurement (as in maxillary molars). Electronic WL can provide an invaluable assistance in these situations. Therefore, the aim of this study is to compare the accuracy of the apex locater in WL determination of the upper first molars roots with that of conventional radiograph.

Materials and method

The sample of this clinical study composed of ten patients (20-40years old) diagnosed with acute pulpitis and undergoing endodontic treatment for their maxillary 1st molar teeth in a specialized endodontic center. All the teeth are vital, free of periapical pathosis. Therefore, a total of thirty canals were included in the data analysis (each tooth has one palatal canal and two buccal canals. The fourth canals were neglected).

The work began with routine and regular endodontic therapy procedures, usually start with anesthetizing the region and rubber dam isolation. Then an access cavity is prepared, the pulp tissue is removed from the chamber, the canal orifices are located, and then the chamber and the canals are irrigated with hypochlorite solution. A suitable size K-file was chosen with a rubber stopper (No 10 or 15 for buccal canals and No1 20 or 25 for palatal canals) according to the canals width and introduced until it reaches the estimated working length (EWL) based on the pre-determined WL, using a table showing the average length of each tooth and diagnostic radiograph [10] following pre-flaring of the canal. It is suggested that pre-flaring of the root canals prior to WL measurement using EAL is always helpful to remove calcifications and dentinal shavings which may have negative impact on the accuracy of EALs.[11,12]

At first, the working length was determined by X-ray film. Next, the file was removed and after processing of the radiograph film, the working length was calculated by evaluating the position of the end of the file in the canal on the radiograph (The distance from the reference point to the radiographic apex minus 1mm, based on the suggestion that the apical constriction located at 1mm short of radiographic apex) [13,14]. This reading was recorded as the radiographic WL for each root. After this, the WL of the same tooth (at the same time) was evaluated using electronic apex locater (ipexII) according to the device's manufacturer instructions: After calibrating and making sure that the lip clip is in stable contact with the

lip, the chosen endodontic (25-mm length) file is inserted into the canal (the pulp chamber should be dry). The second electrode is connected to the file. The file is provided with a clear path to dentin with no alloy contact, and then the file was advanced until an apex reading was obtained. The apical constriction should be approximately 0.5-1 mm shorter than this point (determined by introducing the file slightly beyond the foramen in order to make sure that the file has reached the PDL and then pulling the file back to adjust the WL at the apical construction) [3]. It's important to remember that EAL works on the basis of contact with the canal walls and periapex, with a better adaptation of the file to the canal walls results in a more accurate reading. Therefore, it is important to get a reasonably good file fit inside the canals; and should be fairly close to that of the foramen [15]. Finally, the file was removed and measured by the endodontic gauge. This procedure was repeated on the two buccal canals of the same tooth. After measurement the WL of the three canals, the readings were recorded as the apex locater readings. Hence, the length of each tooth root was measured with both X-ray and apex locator.

The total thirty roots were categorized as following: Group (p) which represents the palatal roots of our patients (n=10), group (mb) which represents the mesio buccal roots (n=10) and group (db) which represents the disto buccal roots (n=10).

A linear correlation and linear regression tests were utilized to check for a linear association between apex locator and X-ray measurements. Measurements of all roots were first included in the linear correlation test, and then measurements of each type of roots (palatal, mesio-buccal and disto-buccal) were tested separately. Significant linear correlations were then tested with linear regression test. The aim of linear regression test is to formulate an equation which can predict X-ray measurements from corresponding apex locator measurements. IBM SPSS 24.1 was utilized to conduct our study analysis. A P-value of <0.05 was considered statistically significant, so the risk of type I error is $<5\%$ for each individual correlation.

Results

Our study reveals that the accuracy of apex locator varies according to the site of the tooth root under investigation, being more accurate at disto-buccal and less accurate at palatal roots. Generally, apex locator shows a linear correlation with X-ray in terms of measuring the work length of the root ($P <0.001$) (figure 1). The Pearson correlation coefficient (Pearson's r) for this association is +0.89 (on a scale of -1 to +1, with a value of 0 indicates there is no association. The stronger the association of the two variables, the closer the correlation coefficient would be to either +1 or -1, depending on whether the relationship is positive or negative). Apex locator and X-ray measurements show no significant linear correlation at palatal roots (Pearson's r=0.57, P=0.084) (figure 2). Apex locator and X-ray measurements show a significant linear correlation at med-buccal (Pearson's r=0.96, $p< 0.001$) and disto-buccal tooth roots (Pearson's r= 0.98, $P< 0.001$) (figure 3 and 4, respectively).

Linear regression shows that the linear correlation between Apex locator and corresponding X-ray measurements can be presented by an equation. This equation ($y=1.12x - 3.74$) can be utilized to predict X-ray results from apex locator

measurements, where (y) represents X-ray, and (x) represents apex locator measurement. However, this equation is statistically significant only when applied at disto-buccal tooth roots (P=0.044).

Discussion

Different strategies have been used to determine the position of the apical foramen to measure the WL of root canals. The most widely used method is taking periapical radiographies. However, although the accepted place for apical constriction is between 0.5 to 1.0 mm from the radiographic apex, there are variations in the relationship from that point of reference which result in errors of instrumentation, and that obviously influence the position of endodontic filling.

References of anatomical structures visualized on radiographies can be showed as hidden and some anatomical landmarks could be superimposed on each other, for example, the superimposition of the zygomatic arch over the roots of maxillary molars.

Electronic devices to detect the end of the root canal represent important innovations in endodontic treatment. The functionality of this equipment is based on the fact that the electrical conductivity of the tissues surrounding the root apex is greater than the conductivity inside the root canal system [16].

In this study, the 1st upper molar teeth were chosen, in which the radiographic method may be complicated for WL measurement. Then we checked the linear association between the radiographic and electronic apex locator (AL) in WL measurement.

We avoided all the factors which may influence the AL reading like dryness of the canal, preflaring of the access opening, type of the irrigant solution, the vitality of the teeth (all the teeth are vital, either for traumatic exposure or acute pulpitis). To reduce necrotic tissue as much as possible, all the roots were completely free of resorption and free of apical pathosis. [17,18]

The results show that the measurements of all types of roots (palatal, mesio-buccal and disto-buccal) show a significant linear correlation between these two methods. This results agree with many previous comparative studies using T test analysis which concluded that, there are no significant differences between these two methods [3.14, 15].

When this comparison had been done for each type of roots separately, the results show that there is no significant linear correlation between these two methods for the palatal canal, and a highly significant correlation at mesio-buccal and disto-buccal roots. These results agreed with Krajczar, K.etal 2008, based on an in vitro study on MB canals of upper first molars, which concluded that EAL was more accurate than using radiographic method alone [19].

These results can be explained by the fact that the palatal canal is wider than the two buccal canals, and the diameter of apical constriction may affect the accuracy of the EALs[20]. The size of the apical foramen also has an influence on electronic length determination. A study found that when the size of the major foramen was less than 0.2 mm, the measurements were not affected, even in the presence of conductive irrigants. However, as the size increases above 0.2 mm, measured distances from the foramen increase also; meaning that as the width of the major foramen increases, the distance between the file tip and foramen increases as well, which may affect the readings of AL. [2] These results can be explained also

by the fact that, the foramen of the main root canal may be located to one side of the anatomical apex so location of the apical constriction varies considerably from root to root and its relationship to the CDJ is also variable as the CDJ is highly irregular and can be up to 3 mm higher on one wall of the root compared with the opposite wall. When the apical foramen exits to the side of the root or in a buccal or lingual direction, it becomes difficult to view on the radiograph which lead to inaccurate measurement of WL with conventional X-ray. [2]. We need more histological studies to be conducted to know which of the two methods is more accurate.

The equation (y=1.12x -3.4) where y represents X-ray measurement and x represents apex locater measurements, was statistically significant only at disto-buccal (DB) roots, and not significant with (MB) roots. The can be explained by the more complex morphology of the (MB) roots in comparison to the (DB) roots. Sultan etal at 2017 found that about 55-60% of MB roots of upper 1st molars have 2 canals (MB2), and 33.3% are type IV (2-1-2) which ended with 2 apical foramens (which had been neglected in this study).[21] On the other hand, disto-buccal roots have only one canal in most cases. So, we believe that more studies are needed to evaluate the WL of the fourth canals.

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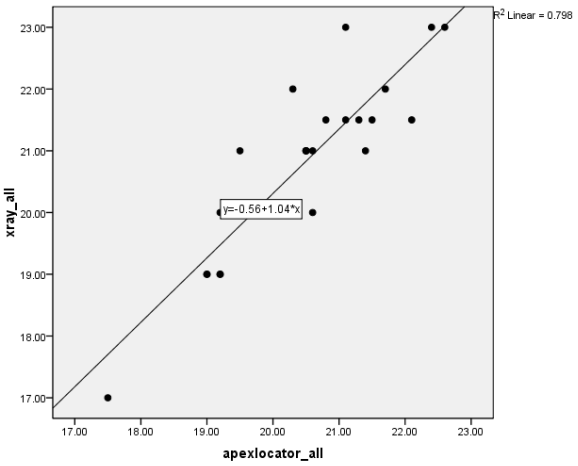
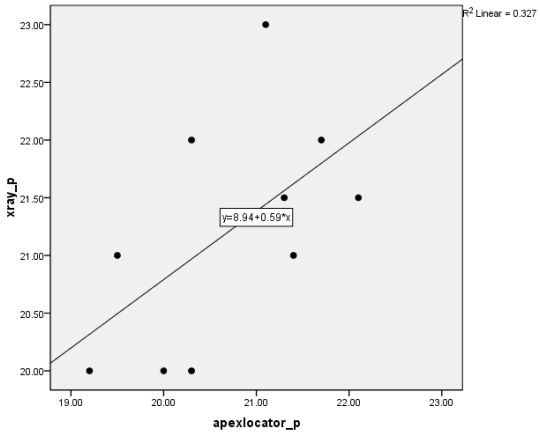


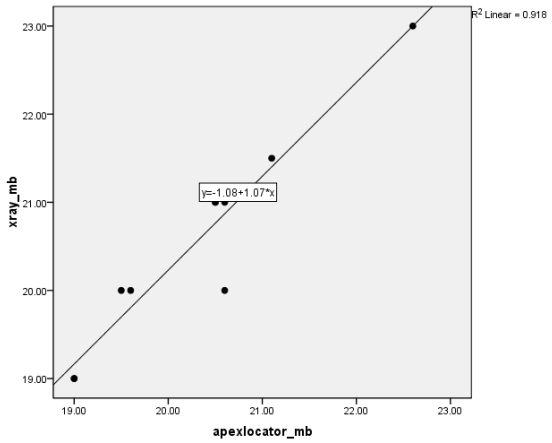
N	X-axis	Y-axis	Pearson's correlation	p-value
30	Apex locator	X-ray	0.894	<0.001

Figure 1. The linear correlation between apex locator and X-ray.



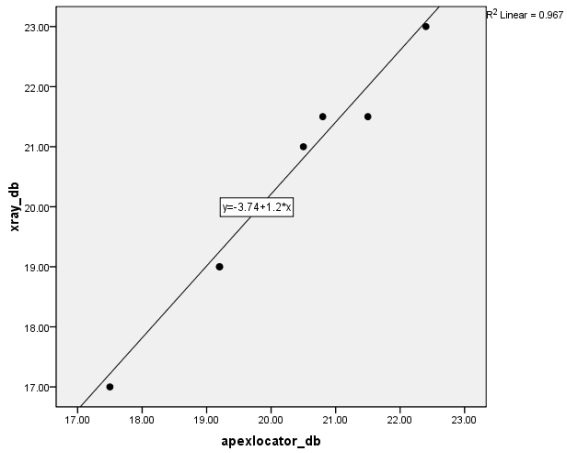
N	X-axis	Y-axis	Pearson's correlation	p-value
10	Apex locator	X-ray	0.572	0.084

Figure 2. The linear correlation between apex locator and X-ray at palatal roots.



N	X-axis	Y-axis	Pearson's correlation	p-value
10	Apex locator	X-ray	0.958	<0.001

Figure 3. The linear correlation between Apex locator and X-ray at mesio-buccal tooth roots.



N	X-axis	Y-axis	Pearson's correlation	p-value
10	Apex locator	X-ray	0.983	<0.001

Figure 4. The linear correlation between Apex locator and X-ray at disto-buccal tooth roots.