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The effect of coronal preflaring on the accuracy of two electronic apex locators

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Abstract. One of the main factors that determines the success of root canal treatment is the instrumentation confined to the root canal; specific methods are available for measuring its working length. This study aims to compare the accuracy of two types of apex locators and evaluate the influence of coronal preflaring on their use. The working lengths of sixteen first mandibular bicuspid were measured visually, using two types of apex locators before and after coronal preflaring. The result showed that there is a statistically significant difference between the two types of apex locators before coronal preflaring, but no statistically significant difference after coronal preflaring. The study concludes that coronal preflaring increases the accuracy of apex locators in locating the apical foramen.

1. Introduction

Root canal treatment should be limited only to the root canal. The dentin-cementum junction is the terminal point of root canal preparation and obturation. Determination of the working length of the root canal is important as a discrepancy in the working length during root canal treatment will decrease the success rate [1]. According to Chugal (2003), in in vivo studies, a loss of 1 mm of working length can increase the failure of root canal treatment as much as 14% [2]. This is because a short working length will result in areas that are not completely disinfected in the apical third, as in the 3 mm apical part, there are many lateral canals, and this could lead to ramifications. If instrumentation and irrigation are not done 2-3 mm shorter than the apical constriction, the total lateral length of the undisinfected main root canal will be about 6-7 mm [3]. Root canal treatments that exceed the working length will result in debris extrusions in the form of dentin flakes, pulp fragments, necrotic tissue, microorganisms, and intra-canal irrigation fluids. Attention needs to be paid to this matter as it will trigger inter-visit flare ups, post-instrumentation pain, acute inflammation responses, and retard periapical healing [4].

The most common method used to measure the working length is radiography, but the level of precision depends on the recording technique. Several disadvantages of this technique include radiation exposure, a long work process, and it is less representative of the three dimensional tooth structure [5,6]. Therefore, an electronic root canal length measurement device (ERCLMD) was developed to overcome the deficiencies of radiographic techniques. Another advantage of this device is that it is applicable during pregnancy [7], however, its use should be carefully considered in patients with pacemakers [8]. The ERCLMD, or so-called apex locator, works by electrical conductivity. The tissue surrounding the apex is larger than the inside of the root canal, both in dry and wet conditions, and is non-conductive [8]. Research by Suzuki showed that the electrical resistance between



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instrument electrodes inside the root canal and electrodes placed in the oral mucosa have specific values [8]. Based on this finding, Sunada indicated that the electrical resistance between them is constant [9]. In principle, the resistance of the electrode that is inserted into the root canal will increase and then drastically decrease when the file touches periapical mucous tissue, and can be read as beeps, buzzes, light flashes, digital readings, or signal needles [8].

Each working length measurement method has a varying degree of accuracy; there is no perfect method for determining the exact location of the apical constriction, and the available methods must be used in combination [10-14]. Meanwhile, developments in electronic technology have influenced the development of apex locators. Several electrical systems are currently available for determining root canal working length. These methods include measuring root canal resistance, and measuring impedance using high frequencies, low frequencies, or multiple frequencies. All of these apex locators will show the location of the file in the apical foramen through a numerical reading on the screen [8]. The apex locator that is often used as a benchmark is the Root ZX[®]. This apex locator measures the ratio of two frequencies (0.4 and 8 kHz) whose calculations will determine the location of the file tip relative to the apical foramen. A calculated ratio of 0.67 is a sign that the file tip has reached the apical foramen; this calculation is constant for every tooth and in every root canal condition [15].

According to El Ayouti *et al.*, several factors, such as the apical constriction diameter, instrument size, and the irrigation solution used during root canal preparation, can affect working lengths measured using apex locators [11]. Some researchers, however, reveal that the working length measurement is also influenced by coronal preflaring. A study conducted by Camargo *et al.* showed that the accuracy of apex locator measurements increases after coronal preflaring [16]. This study was similar to a study by Ibarrola *et al.* that examined the apex locator's (Root ZX[®]) accuracy in the presence of coronal preflaring. The results showed that coronal preflaring makes the file's path to the root canal more consistent in reaching the apical foramen, thereby increasing the accuracy of the apex locator's measurements [17]. Novel research by Morgental *et al.* showed that there is a significant difference in working length measurements after coronal preflaring [18]. Among the many studies on apex locators, few have discussed the effect of coronal preflaring on the apex locator's accuracy, particularly those using double and multiple frequencies. Therefore, the present study aims to compare the measurements for the location of the apical foramen using two types of apex locators before and after coronal preflaring is performed.

2. Materials and Methods

Sixteen teeth with single root canals were cleared from the soft tissue and calculus with a scaler, rinsed under running water, then stored in a saline solution before treatment. The occlusal parts of the teeth were flattened to stabilize the stopper placement during the measurement process. The location of the apical foramen from the crown was visually measured by inserting a no. 08 file into the root canal until the file was visible in the apical foramen. The axial surface of the tooth was placed perpendicular to the line of view, then the file tip was positioned in contact with the apical foramen. After obtaining the location, the stopper was fixed and the file was removed from the root canal after which it was measured using a caliper.

Before taking measurements using the apex locators, the prepared teeth were placed into tubes containing saline solution. Two types of apex locators were used to measure the location of the apical foramen from the crown. For each measurement a no. 08 file was placed into the root canal flooded with saline solution. The file was inserted until the number appearing on the screen showed 00 for 15 seconds, indicating that the file tip was located correctly in the apical foramen. Measurements were performed in triplicate until the stopper was in the right place. The file was fixed, then the distance between the stopper and file tip was measured using a caliper. After cavity access preparation and the straight path to the orifice was obtained, coronal preflaring was performed using an engine-driven Sx Protaper file along two-thirds of the working length of the root canal, which had been determined visually.

3. Results and Discussion

3.1 Results

Statistical analysis using a paired t-test for each apex locator measurement before and after coronal preflaring (Table 1) showed that there was a significant difference between measuring the location of the apical foramen using a multiple frequency apex locator before and after coronal preflaring ($p < 0.01$). Therefore, the accuracy level for determination of the location of the apical foramen using a multiple frequency apex locator after coronal preflaring was better than before coronal preflaring. Table 2 also shows that there was a significant difference between the measurement data locating the apical foramen using the double frequency apex locator before and after coronal preflaring ($p < 0.01$). Therefore, the accuracy level for determination of the apical foramen location using the double frequency apex locator after coronal preflaring was better than before coronal preflaring.

Table 1. Analysis of the measurements obtained using the two types of apex locators before and after coronal preflaring

Groups	N	Mean±SD	99% CI		p-value*
			Minimum	Maximum	
MF1 x MF 2	16	-0.2813±0.3146	-0.5130	-0.0495	0.003
FG1 x FG2	16	-0.2813±0.2562	-0.4700	-0.0925	0.001

* paired t-test $p < 0.01$

MF1 = measurement using the multiple frequency apex locator before coronal preflaring

MF2 = measurement using the multiple frequency apex locator after coronal preflaring FG 1

= measurement using the double frequency apex locator before coronal preflaring FG 2 =

measurement using the double frequency apex locator after coronal preflaring

Table 2 shows that there was no significant difference between the measurements for the location of the apical foramen using multiple frequency and double frequency apex locators after coronal preflaring ($p > 0.01$); thus, we accept the hypothesis that the accuracy level for determination of the location of the apical foramen using the multiple frequency apex locator was equal to the accuracy of the double frequency apex locator after coronal preflaring.

Table 2. Analysis of the measurements obtained using the two types of apex locators after coronal preflaring

Groups	N	Mean difference	99% CI		p-value*
			Minimum	Maximum	
MF2 x FG2	16	0.0313	-0.9383	0.8758	0.925

*unpaired t-test $p < 0.01$.

MF2 = measurement using the multiple frequency apex locator after coronal preflaring FG

2 = measurement using the double frequency apex locator after coronal preflaring

3.2 Discussion

Coronal preflaring provides many advantages during cleaning and shaping in root canal procedures. The study conducted by Stabholtz *et al.*, showed that coronal preflaring increases the tactile sensitivity of the operator in determining the location of the apical constriction. It also showed that the largest resistance when inserting the file into the root canal is the first one-third of the coronal end of the canal. Coronal preflaring decreases file resistance, thus, it is easier to insert the file into the root canal toward the apex of the tooth [19]. The results of the Stabholtz study were used by Ibarolla *et al.*, to assess the effect of coronal preflaring in improving the accuracy of apex locator measurements. The results show that coronal preflaring allows for better apex locator measurements, as the measurements are more consistent than those without it [17]. Other advantages of performing root canal preparation with coronal preflaring include improved irrigation circulation within the root canal, reducing the risk

of bacteria being pushed into the periapical tissue and decreasing the risk of debris and irrigation fluid extrusion during root canal preparation procedures, as well as reducing errors in determining the working length during root canal preparation [20].

The results of this study indicate significant differences between measurements for the location of the apical foramen using two apex locator systems before and after coronal preflaring. This means that the measurements performed after coronal preflaring had better values than those performed without coronal preflaring [16]. In vitro experiments were conducted in the present research in order to obtain a decent level of accuracy with controlled results. The advantages of this research model included the simplicity of the equipment used during the study and the strict control over each test. The disadvantage of using an in vitro method was that the experiments could not entirely simulate in vivo conditions. However, Huang's study evaluating apex locator measurements with an in vitro method reported that when the file tip was passed through the narrow apical foramen, there was a gradual decrease in electrical resistance resulting from the physical properties of the foramen [21], not from the biologic characteristics of the periodontium tissue, as reported by Sunada [9].

The apex locators applied in this study utilized measurements based on double frequency and multiple frequency ratios. Root ZX[®] was used to represent a double frequency apex locator system. Root ZX[®] has the highest degree of accuracy in determining the location of the apical foramen, as presented in several previous studies. Thus, this device was used as the benchmark for other apex locators. Supporting research for Root ZX[®] was obtained from Welk *et al.* [15], Shabang *et al.* [22], Dunlap *et al.* [23], and Plotino *et al.* [24] who reported that its accuracy levels were 90.7%, 96.2%, 82.3%, and 97.37%, respectively. Apex locator measurements based on frequency ratios are not affected by dielectric material inside the root canal, resulting in better measurements [8]. Root ZX[®] measures double frequency impedance (0.4 and 8 kHz) and calculates the impedance ratio for each frequency, indicating the location of the file in the root canal. The ratio measurement of the double frequency impedance value of 0.67 indicates the exact file position in the apical foramen; this value is constant and does not require calibration before measurement. This feature is exclusive to the Root ZX[®] [15]. In this study, Woodpex I[®] represented the multiple frequency apex locator.

Lee *et al.*, examined the most consistent locations for taking measurements with apex locators, comparing the apical foramen and the dentinal cementum junction. They found that the apical foramen was more stable, reproducible, and accurate than the dentin-cementum junction [25]. In current study, the measurements were taken up to the apical foramen in order to prevent morphological differences in the dentinal cementum junction among the examined teeth. There were some limitations to the present study which indicate the need for more advanced research. The disadvantages of this study were that it was an in vitro study and measured the apical point only for the location of the apical foramen. The study did not include radiographic views as measurement references for the apical foramen location; the working systems of these apex locators are still based on impedance of the measurement ratios for double and multiple frequencies.

4. Conclusion

We conclude from this study that coronal preflaring improves the accuracy of measurements for locating the apical foramen using apex locators. The accuracy level in determining the location of the apical foramen using a multiple frequency apex locator after coronal preflaring was better than before coronal preflaring. The accuracy level in determining the location of the apical foramen using a multiple frequency locator was equal to that obtained using a double frequency locator after coronal preflaring.

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