Research Article

Accuracy of apex locators in determining working length in single-rooted teeth – A histologic analysis

L. Sri Varsha*, S. Pradeep

ABSTRACT

Aim: This study aims to determine the accuracy of apex locators in determining the working length using histologic methods. **Materials and Methods:** A total of 45 extracted single-rooted teeth were collected. Access opening and coronal enlargement of the teeth were done. The working length was determined using Root ZX and Propexpixi apex locators. The orifice was closed using glass ionomer cement along with the file and was given for decalcification process to check the position of the file. **Results:** There was a significant difference between the pre-operative working length and working length determined by Propexpixi ($P = 0.049$) and between Propexpixi and Root ZX ($P = 0.047$). There was no significant difference between the pre-operative working length and working length determined by Root ZX ($P = 1.000$). **Conclusion:** The working length determined by Root ZX apex locator was more accurate when compared with the working length determined by Propexpixi apex locator.

KEY WORDS: Decalcification, Histologic methods, Propexpixi, Root ZX, Working length

INTRODUCTION

Working length is the distance between the reference point coronal to the point at which the canal preparation and obturation should terminate.[1] Working length determination is important to determine the instrument length in the canal, to confine the instrumentation to the canal system, to create and maintain an apical stop or seat at the minor constriction, to prevent underinstrumentation that could leave tissue and debris in the apical segment, and to prevent over instrumentation which could cause patient discomfort, damage periapical tissue, or potentially cause an infection or cyst development from the placement of irritating materials beyond the apex. The cementodentinal junction (CDJ) is the anatomical and histological landmark where the periodontal ligament begins and the pulp ends.[2] The apical constriction (AC) is recommended as the point up to which all instrumentation and obturation must terminate. The AC (minor foramen) is 0.524–0.659 mm above the anatomic apex of the tooth (apical foramen and major foramen).[3] One of the major problems in endodontic treatment is the identification and maintenance of the biological length of the root canal system. Proper healing with minimal contact between the obturation material and the apical tissue is achieved when root canal treatment terminates at the CDJ. Working length can be determined by radiographic and non-radiographic methods. The radiographic methods are Ingle's method, Grossman's formula, Bregman's method, Kutler's method, and Weine's method. The non-radiographic methods include digital tactile sense, apical periodontal sensitivity, paper points, and electronic apex locators. The accurate determination or even estimation of the apical canal constriction is not possible with radiography due to anatomical variations or errors in projection.[4]

An electronic apex locator is an electronic device used to determine the working length of the canal. With the original specification of apex locators (using one measuring frequency), it was difficult to determine working length, as they only gave precise results in dry root canals. Modern apex locators using impedance quotient measurements are able to determine an area between the minor and major foramen by measuring the impedance between the file tip and the canal fluid with different frequencies. The principle of measurement of these devices is based on the electrical resistance

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of dentine.[5] The first generation of apex locators used the resistance and alternating current as a 150 Hz sine wave. Pain was often felt due to high currents in the original machine, thus modifications were made and released as the Endodontic Meter and the Endodontic Meter S II which used a current of <5 lA.[6]

The second-generation apex locators were of the single-frequency impedance type which used impedance instead of resistance to measure the location within the canal. Impedance is comprised both resistance and capacitance and has a sinusoidal amplitude trace.[7] The third-generation apex locators use multiple frequencies to determine the working length. The Endex/Apit apex locators detect the AC by calculating the difference between two direct potentials picked up by filters when a 1 kHz rectilinear wave is applied to the canal.[8] The disadvantages of early apex locators (error readings with electrolytes) were overcome with the introduction of the ratio method and the subsequent development of the self-calibrating Root ZX.

The ratio method works are based on the principle of two electric currents with different sine wave frequencies will have measurable impedances that can be measured and compared as a ratio regardless of the type of electrolyte in the canal. The capacitance of a root canal increases at the AC and the quotient of the impedances reduces rapidly at the AC. The change in electrical capacitance at the AC is the basis for the operation of the Root ZX.[9,10] The fourth-generation apex locators use two separate frequencies 400 Hz and 8 kHz similar to the current third-generation units. The combination of using only a single frequency at a time and basing measurements on the root-mean-square values of the signals increases the measurement accuracy and the reliability of the device.[11]

Many literature studies show the efficiency of apex locators and comparison of various apex locators. However, there are very deficient studies on verifying the accuracy of apex locators using histological methods. Hence, this study aims to determine the changes in working length in enlarged canals using various apex locators.

MATERIALS AND METHODS

A total of 45 extracted single-rooted teeth with completely formed roots were collected. Scaling was done to remove debris and calculus from the extracted teeth. Pre-operative radiographs were taken. Standard access preparation was carried out. Initial working length was determined using radiograph. The teeth were then mounted in alginate. K-files (Mani, Dentsply) were used in this study. All the teeth were orifice enlarged using Protaper S1 (Dentsply, Tulsa, Swiss). Working length was determined used Propexpixi apex locators (Dentsply) and the working length was noted from the file using a Vernier caliper. Working length was again determined using Root ZX (Morita) apex locator for all the teeth.

Recording of Working Length using Root ZX and Propexpixi

The working length was recorded with Root ZX using 15 K-file. Root ZX was switched on, the contrary electrode was placed into the corner of the mouth and then the file holder was clipped onto the file. The file was then progressed until "00" appeared on the screen as per the manufacturer's instructions. The silicone stop on the file was set to the reference point and the readings were recorded. A similar procedure was repeated for Propexpixi and the readings were measured as the file progressed to "00" on the screen. The coronal portion of the teeth was sealed with glass ionomer cement (Shofu). The file was then cut and given for decalcification.

The values of pre-operative radiographic working length, working length of the file after access preparation, working length determination using Propexpixi apex locators, and Root ZX apex locators were all entered into an Excel sheet and statistical data were analyzed.

RESULTS

The mean value of the pre-operative working length, Propexpixi, and Root ZX was found to be 18.10, 17.57, and 18.08 [Table 1]. *P* value of pre-operative working length and Propexpixi was $P = 0.049$. *P* value of Propexpixi and Root ZX was 0.047 and *P* value of Root ZX and pre-operative working length was 1.000 [Table 2].

DISCUSSION

In this study, there was a significant difference between the pre-operative working length and Propexpixi ($P = 0.049$). There was a significant difference between Propexpixi and Root ZX ($P = 0.047$). There was

Table 1: Mean value of the working length determined by three methods

Groups	Mean±SD
Pre-operative working length	18.10±1.17
Propexpixi	17.57±1.28
Root ZX	18.08±1.47

SD: Standard deviation

Table 2: Significance between the three groups

Post hoc Tukey HSD tests	
Groups	**(*P*<0.05)**
I versus II	0.049*
II versus III	0.047*
I versus III	1.000

no significant difference between the pre-operative working length and Root ZX ($P = 1.000$). Thus, Root ZX was more accurate than Propexpixi.

Root ZX is considered as the gold standard to which the newer apex locators are being compared. According to the previous studies, its accuracy varies from 50% to 100%. Root ZX mini is accurate even in the presence of electrolytes such as sodium hypochlorite, saline, tap water, or hydrogen peroxide.[9,12,13]

In enlarged canals, the Root ZX identified the narrowest canal diameter even in the absence of the anatomic AC, and the lengths obtained with small and large size files were comparable (use the largest file that fits passively within the canal, i.e., the file should not be able to move up or down without intervention from the operator).[14]

In vitro study, Root ZX was 96% accurate to within ±0.5 mm of the apical foramen.[15] In another study, accuracy of the Root ZX *in vitro* in the presence of a variety of endodontic irrigants was tested. The irrigants were saline, 2% lidocaine with 1:100,000 epi., 5.25% NaOCl, RC Prep, liquid ethylenediaminetetraacetic acid (EDTA), 3% hydrogen peroxide, and Peridex. The Root ZX was able to consistently determine the location of the apical foramen (within approximately ±0.4 mm) in the presence of any of the tested irrigants.[16]

An *in vivo* study compared the accuracies of working length of two different generations of electronic apex locators. The two different electronic apex locators used were as follows: Root ZX – a third-generation apex locator that uses the ratio method to measure the root canal length and iPex – a fourth-generation apex locator which measures capacitance and resistance simultaneously to determine the location of file tip in the canal. The values obtained were of 72% accuracy for Root ZX when compared to 57.8% accuracy for iPex, and the observed difference was not statistically significant.[17]

In another study, the accuracy of two apex locators with cone-beam computed tomography (CBCT) was done where there was a significant difference between CBCT and Propexpixi ($P = 0.03$), and Propexpixi and Root ZX mini ($P = 0.02$), where Root ZX mini was found to be better in accuracy in determining the working length when compared with Propexpixi. No statistically significant difference was seen between Root ZX mini and CBCT ($P = 1.00$).[18]

A study compared the accuracy of three apex locators: Root ZX (RZX), Precision Apex Locator (PAL), and Elements Apex Locator. Mean differences between electronic and actual lengths were found to be 0.02 mm, 0.13 mm, and 0.15 mm for the Root ZX, the PAL, and the ELE. There was a highly significant difference among electronic apex locators at $P = 0.003$. Student–Newman–Keuls *post hoc* analysis found significant differences between the RZX and the PAL and between the RZX and the EAL at $P < 0.05$. No significant difference was noted between the PAL and the EAL.[19]

Many studies reported that pulpal vitality or canal irrigants do not affect the third-generation apex locators accuracy. Various diameters of glass tubules were used in their study to mimic root canals. When they filled the canals with less conductive electrolytes such as 3% hydrogen peroxide, the accuracy of the real length ±1.0 mm was 75–100% despite the increase in tubule diameter. When they filled the canals with strong electrolytes such as 0.9% saline solution, 2.5% sodium hypochlorite solution, and 17% EDTA, the accuracy of the Root ZX decreased as the tubule diameter increased.[20-22]

A radiographic evaluation has always been the primary technique to determine the vertical limit of instrumentation, irrigation, and obturation in endodontic therapy. Radiographs are useful for diagnosis, treatment planning, and determining the curvatures in the root canal system. However, radiography may lead to problems associated with the working length assessment as it is difficult to locate the AC on a two-dimensional radiographic image. There are other limitations of radiography such as superposition of the apex on surrounding structures and insufficient resolution and magnification. Thus, it was concluded that radiographic evaluation was not accurate enough and causes over instrumentation, especially in 56% of premolars and 33% of molars. Radiographic assessment of small areas of resorption is difficult, particularly in cases, where resorption occurs on buccal or lingual aspects of the root. This will often not be visible radiographically, resulting in an increased risk of over instrumentation and/or overfilling.[23,24]

A clinical study compared two methods of working length determination and its effect on radiographic extent of root canal fillings. The comparison was done between an electronic apex locator used alone and also in combination with a conventional radiograph. The observed differences were not statistically significant, and the authors concluded that the correct use of an apex locator alone could prevent the need for further diagnostic radiographs for the determination of working length.

Extracted human teeth are used histopathological study of dental pulp. In the histological preparations, rapid fixation of tissue elements is important. It is indicated that fixation of dental pulp is achieved by

immediate grinding from one side of the teeth until the coronal portion of the pulp is exposed. The grinding is done using low-speed saw (IsoMet) with formalin fixative as a lubricant.

Decalcification of bone and teeth often obscures the structures. Teeth, in particular, are damaged due to the tooth enamel, being about 96% mineral substance is usually completely destroyed by ordinary methods of decalcification. Undecalcified teeth may be studied by making thin ground sections of the specimens. The equipment used for making ground sections includes a laboratory lathe, a coarse and a fine-abrasive lathe wheel, a stream of water directed onto the rotating wheel and a pan beneath to catch the water, a wooden block (about 25 mm cube), 13 mm adhesive rape, a camel's hairbrush, ether, mounting medium, microscopic slides, and cover glasses. For the preparation of thin ground sections of a mandibular molar, the tooth is cut longitudinally in a mesiodistal plane. The coarse abrasive lathe wheel is attached to the lathe, water is directed onto the wheel, the tooth is held securely in the fingers, and its buccal surface is applied firmly to that flat surface of the rapidly rotating wheel. The tooth is ground down nearly to the level of desired section. A piece of adhesive tape is wrapped around the wooden block in such a way that the sticky side of the tape is directed outward. The ground surface of the tooth is wiped dry and then pressed onto the adhesive tape on one side of the wooden block. With the block held securely in the fingers, the lingual surface of the tooth is applied on the coarse abrasive lathe wheel, and the tooth is ground down to a thickness of about 0.5 mm. The finished ground section is soaked off of the adhesive tape with ether and then dried for several minutes. Drying for too long will result in cracking. It is then mounted on a microscope slide by placing a drop mounting medium and then lifting the section with a camel's hairbrush and then placing on the drop. Another drop is added on top of the section and a cover glass is affixed for microscopic study. The teeth used for ground section should not be allowed to dry out after extraction as drying will make the hard tissues brittle and cause chipping of enamel. The extracted teeth should be preserved in 10% formalin. Precision equipment (hard tissue microtome) which are used for ground sectioning are of greater accuracy.[25]

The performance of electronic apex locators has been affording some acceptable error in locating the apex. Thus, radiographic positions within the 0.5 mm range to the apex are considered as acceptable.[26,27] Measurements attained within this value are considered highly accurate. Root canals always do not end with an AC, a well-delineated minor or major apical diameter, or an apical foramen within the base of the cemental cone.[28] Lacking such demarcations, an error tolerance of 1.0 mm is deemed clinically acceptable.

CONCLUSION

In this study, Root ZX apex locator was more accurate in determining the working length when compared with Propexpixi apex locator. The use of apex locator does not exclude the need for radiographs for determining the working length. Apex locators are useful alternatives in situations where the apices are superimposed by anatomic structures or if the use of radiographs is contraindicated, in case, if the patient is pregnant, handicapped, and sedated or has an extreme gag reflex. Electronic apex locators should be used in caution on patients with pacemakers, and consultation with the patient's cardiologist is well advised.[29]

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