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A Comparative Clinical Study of Digital Radiography, Electronic Apex Locator, and Cone-Beam Computed Tomography for Determining Root Canal Working Length

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Abstract
Aim: The researcher used visual radiography, an electronic apex locator, and cone-beam computed tomography to determine and compare the precision of working length.
Materials and Methods: A total of 20 teeth which were indicated for extraction because of orthodontic reasons were selected for the study. Access cavity was prepared and the RVG (Radiovisuograph) working length (RVGWL) was determined by Ingles method. A 15 no. K-file was advanced toward the apex until it reached a 0.5 mm short of the apex, as shown by the apex locator, for electronic root canal measurement (EAL)The tooth was atraumatically extracted and placed in an acrylic block after the file was fixed with a light cured composite. CBCT (Cone beam computed tomography) working length (CBCT WL) was measured and registered using a CARESTREAM CBCT scanner. The root canal and the tip of the file were then clear after apically grounding the tooth surface with a straight fissure diamond bur. With the aid of a stereomicroscope and a digital calliper, the gap between the file and the minor constriction was calculated and reported as the actual anatomical working duration (AAWL).
Statistical analysis: The one-way ANOVA test and Post hoc Tukey's test and Chi-square test were used for statistical analysis for this study.
Results: When mean working length was compared among different study groups using One way ANOVA, overall difference was not found to be statistically significant as $p > 0.05$.
Pairwise comparison using Post hoc Tukey's test showed that none of the pair showed statistical significant difference as $p < 0.05$.
Conclusion: There was no statistically significant difference in accuracy between RVG, EAL, and CBCT. Thus, understanding apical anatomy or curvature through the careful use of radiographs and the proper application of EAL can aid practitioners in achieving predictable results.

Introduction

Endodontic therapy requires the treatment of vital and necrotic dental pulps in order for patients to keep their natural teeth in both function and appearance. The determination of correct working length, which is the distance between the coronal reference point and the point at which the canal preparation and obturation should stop, is one of the most critical steps in endodontic therapy. Once the exact working length is calculated, proper root canal washing, shaping, and obturation are possible.[1] In clinical endodontics, determining the proper apical location has always been difficult.

The most ideal physiologic apical limit of the working length is the cemento-dentinal junction (CDJ), where the pulp tissue transforms into the apical tissue. It's also known as the apical constriction or minor constriction.

However, the CDJ and minor constriction do not always match, particularly in senile teeth due to cementum deposition, which shifts the minor constriction's position.[2] Overestimation can lead to excessive root canal instrumentation, while underestimation can lead to inadequate root canal preparations. When the endodontic procedure is completed at the mild constriction, the prognosis is the best. The minor constriction is thought to be the best place to end the root canal procedure.

It is also known as the narrowest point in the root canal with smallest wound site containing the smallest diameter blood capillaries and thereby the best healing site. Most of the times minor constriction is located 0.5-1mm superior to the major constriction of the root end.[3]

Radiography, anatomical averages and understanding of anatomy, tactile feeling, and moisture on a paper point are all traditional methods for estimating working length. Both of these approaches have drawbacks and do not allow for precise apical constriction localization.

New techniques, such as digital radiography, electronic apex locators, and advanced CBCT (Cone beam

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computed tomography) devices.[4] have been developed in recent years to address the limitations of conventional methods. The root canal working length is typically determined using the standard radiographic process. The distance between the tip of the file inserted in the root canal and the tip of the radiographic apex is determined during this procedure. The total working length can be calculated using this measurement.

However, the traditional radiographic approach has several drawbacks, such as anatomical structure overlap and, in particular, the location of the apical foramen in relation to the apex, which does not always coincide, as well as film processing time. Instead of using radiographic film, the digital radiographic approach uses a sensor to create photographs. The digital x-ray has some advantages over the traditional process, including faster image acquisition, lower radiation exposure, and the ability to manipulate images to study data more clearly.[5]

However, this strategy has a range of drawbacks that make it unsuitable for all situations (e.g., the danger of overestimation of the root canal length even when it seems to be short of the radiographic apex because of normal anatomic variations in the apical region).Other drawbacks of digital radiography include technique sensitivity and subjectivity, the risk of ionising radiation, and superimposition errors caused by converting a three-dimensional object to a two-dimensional representation.[6]

The use of electronic apex locators (EAL) to determine root canal length has grown in popularity, removing many of the issues that come with radiographic measurements. The electrical resistances between the periodontal ligament and the oral mucosa were discovered to be constant at 6.5 k by Suzuki. In 1962, Sunada created the first electronic apex locator. Although the most basic instruments measure resistance, others use high frequency, two frequencies, or several frequencies to measure impedance.[7]

The Root ZX EAL (J. Morita Co., Kyoto, Japan) has undergone comprehensive in-vivo and ex-vivo testing and has established itself as the gold standard against which new devices are measured. The Root ZX circuit is primarily focused on detecting changes in electrical capacitance near the apial foramen.[8]

The Root ZX EAL calculates the impedance ratio of two frequencies formed at the same time (0.4 and 8 kHz). The ratio is a numerical value that reflects the location of the file inside the canal. If the AF approaches, this ratio decreases. As the file progresses through the canal, its impedance decreases, peaking at the AF.

As the file progresses apically, the electrical current conveniently passes through shorter dentinal tubules within thinner dentinal mass, resulting in the anticipated fall in impedance. Resistance and capacitance combine to form impedance. In dry canals, resistance decreases as you get closer to the apex, while capacitance increases. The presence of electrolytes within the canal decreases resistance while increasing capacitance, i.e., resistance is low while capacitance is high at the apical region, and the presence of fluids exacerbates this condition.

Since the Root ZX circuit relies on detecting changes in electrical capacitance (rather than resistance) near the AF regardless of the existence of electrolytes, it is favoured in these circumstances. Nonetheless, one does not expect 100 percent precision. The Root ZX's output could be affected by a variety of factors that are difficult to detect and interpret.[8] When opposed to cone-beam computed tomography (CBCT) has the advantage of a lower radiation dose. CBCT has been an invaluable tool for diagnosing root canal anatomy, root fracture, periapical pathology, and internal/external root resorption since its introduction in dentistry.

CBCT (Cone beam computed tomography) has been validated as a method for investigating root canal morphology in three dimensions, and it has also been used to estimate the WL in some tests. Working length can also be determined using CBCT measurements in conjunction with EALs.[9] As a result, the aim of this study was to assess and compare the accuracy of working length measurements made with digital radiography, an electronic apex locator, and a CBCT image.

MATERIALS AND METHODS

Patients with intact mandibular premolar teeth who were subjected to orthodontic extraction in a private dental clinic in Jerusalem, Palestine were recruited. This is a preliminary study to compare different methods for measuring working length.Twenty single rooted and single canal mandibular premolars were selected as mentioned above which met with the inclusion and exclusion criteria. Approval and patient

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consent were obtained.

Inclusion criteria:
• Patients within 18-30 age group • Completely formed intact premolars with single root canal. • Sound vital teeth. • Teeth with root canal curvature less than 10 degree.

Exclusion Criteria
• Teeth with carious and/or non-carious lesions. • Previously root canal treated tooth. • Teeth with calcified root canals. • Teeth with internal and/or external resorption. • Teeth with multiple root and/or root canals. • Teeth with fracture. • Teeth with immature apex. • Mutilated teeth. • Teeth with metallic restoration. • Retreatment cases. • Patients with pacemakers

PROCEDURE:
Initially, preoperative intraoral periapical digital image was taken with 65 kVp, 10 mA and 0.2 exposure time using RVG (radiovisuograph) (Carestream 5200). After that, local anaesthesia was given and the tooth was isolated with a rubber dam. Then, using a high-speed contrangle hand piece and water spray, a flat coronal reference point was created with a straight fissure diamond bur, and an access cavity was created with an endo access bur in a high-speed contrangle hand piece. A 3 percent sodium hypochlorite solution was used to irrigate the root canal (1ml). Ingle's method was used to calculate the radiographic working length.

In the root canal, a file with a length 1mm less (safety factor) than the tooth length as estimated by the pre-operative radiograph was kept. Working length was calculated by radiovisiograph (RVG) using the extension cone paralleling technique after the instrument was placed in the canal. The difference between the end of the instrument and the end of the root was calculated on the digital image. This number was applied to the length that was originally measured. If the exploring instrument went past the apex, the extra length was deducted from the original length measured.

To confirm with the cement dentinal junction, 1 mm was subtracted from the adjusted tooth length. This value was registered as RVG working length. Root ZX Mini was used to determine the electronic working length (J.Morita, Tokyo, Japan). The EAL was turned on in this process, and then the lip clip (contrary electrode) was put in the patient's mouth corner. After that, the file holder was connected to the #10 K-file. By moving #10 K-file towards the apex, the apical foramen was detected. When the apex locator provides a visual and auditory indication that the foramen has been reached, the file insertion was stopped (0.5 mm marking just before the apex was selected for termination).After that the electronic working length (EAL) was measured and recorded. According to the measurements #10 or #15 k-file was inserted. The light cured composite was then used to fix the file at the measured working length. The tooth was a traumatically extracted under the same local anesthesia. Then the tooth was cleaned properly and mounted in acrylic block for CBCT imaging. CBCT images of the tooth was obtained using CMOS flat panel detector at FOV (11*5). The tube voltage, tube current and exposure time used were 90Kvp, 3.0A and 3.6 seconds respectively.

After that, the images were analyzed using the scanner's proprietary programme. The CBCT method for determining working length is based on delimiting and calculating the distance between anatomical landmarks of the dental crowns and roots. By drawing a line between the apical foramen and the corresponding cusp tip, the CBCT WL was calculated. The measurement was taken in two planes while the foramen and cusp tip were not apparent in one plane.

The root canal and the tip of the file were then longitudinally ground on the apical tooth surface with a straight fissure diamond bur until the root canal and the tip of the file were visible. The distance between the coronal reference point and the apical constriction was calculated using a stereomicroscope and a 0.01mm resolution optical caliper.Thus, the actual anatomic working length was determined. Finally, the working lengths which were determined by using RVG, EAL and CBCT were compared with the actual value (AA).
Summarized data was presented using Tables and Graphs. The data was analysed by SPSS (21.0 version)

RESULTS:

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Mean working length among four study groups were found to be 20.68±1.2 in group RVG, 20.58 ± 1.3 in Group EAL, 20.67 ± 1.44 in Group CBCT, 20.72 ± 1.23 in Group Actual length i.e AA. (Table 1)

When mean working length was compared among different study groups using One way ANOVA, overall difference was not found to be statistically significant asp >0.05.(Table 2)

When mean working length was compared among different study groups using One way ANOVA, overall difference was not found to be statistically significant asp >0.05.

Results of the present study did not show any statistically significant difference in accuracy between RVG, EAL and CBCT working length.

Table1:Inter group comparison of mean working length

	N	Mean	Std. Deviation
RVG	20	20.68	1.201
EAL	20	20.58	1.341
CBCT	20	20.67	1.444
AA	20	20.72	1.234
Total	80	20.71	1.222

Table2: Calculation of overall p value using one way ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.21	2	.069	.029	.98NS
Within Groups	152.34	72	2.15		
Total	152.55	74			

DISCUSSION

One of the most important steps in root canal care is determining the correct working duration. Cleaning, shaping, and obturation can't be done properly unless the working length is precisely calculated. Endodontists are interested in learning more about the anatomy of the root apex. The minor constriction, apical foramen, and root apex (anatomic and radiographic) [10] are three distinct landmarks on the terminal part of a tooth root. The best prognosis was obtained when the procedure was terminated at the minor constriction, and the worst prognosis was obtained when it extended past the minor constriction, according to various investigators.

For endodontic care, establishing the working length at the minor constriction is ideal. [11, 12, 13] Radiography, anatomical averages and understanding of anatomy, tactile feeling, and moisture on a paper point are all traditional methods for estimating working length. All of these techniques have drawbacks when it comes to pinpointing the slight constriction. To combat this situation, new techniques have been implemented in recent years, such as automated radiography, electronic apex locators, and advanced CBCT devices.[5] Radiographic technique has been the most widely used approach so far.

Working length is estimated 0.51 mm short of radiographic apex in this process, with the slight constriction lying approximately 0.51 mm short of the anatomical apex (Kuttler 1955).[14] Film-based radiography has the advantage of being an easy tool, but it has some drawbacks, such as increased radiation exposure and longer

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processing time.[15] Digital radiography is a cutting-edge imaging technology that allows for image enhancement, reduced radiation exposure, and shorter turnaround times.[16] However, technical sensitivity and thereby accuracy remains still controversial.

Even though the current study's findings are statistically insignificant, digital radiography has a lower probability of detecting small constriction. The current results are consistent with those of Dummer et al. (1984) and Ricucci and Langeland et al. (1998), who proposed that the position and shape of the minor constrictor is complex and not easily detectable on radiographs.[17,18] Just 15% of RVG WL in the current study correspond to the position of minor constriction. Electronic methods for determining tooth length have advanced greatly, and they are gradually being incorporated into current endodontic practice.[19]

In terms of accuracy, ease of use, and patient comfort, using an electronic apex locator to determine endodontic working length removes many of the drawbacks of the radiographic process. The Root ZX EAL (J. Morita Co., Kyoto, Japan) has undergone comprehensive in vivo and ex vivo testing and has established itself as the gold standard against which new devices are measured.[14] As a result, Root ZX mini was used to assess the working length in this analysis. In their analysis, Weiger et al found that if the working length is reported at the meter reading 0.5 mark[20], Root ZX provides accurate EWL measurements in the presence of NaOCl.

Andrian et al. found that apex locators had the highest accuracy in determining working duration as opposed to tactile sensation and radiographic method [21] in their comparative analysis report. According to Bernardes, apex locators can produce good precession at a distance of 1 mm from the apical foramen. The accuracy of the apex locator, however, is said to be highly dependent on the establishment of an electrical circuit and the electrical conduction properties of canal.[22] There were no statistical variations between the Root ZX system's ability to assess apical constriction in vital canals and necrotic canals, according to Dunlop et al.[23]

The results of the present study also highlights the accuracy of Root ZX mini apex locator to precisely determine the working length. The apex locator readings were noticed to be close (mean difference of .01) to the actual working length when compared to the radiographic results. To be precise, in 45% cases EAL working length coincided with the actual working length.

There have been debates among researchers for decades about the efficacy and utility of advanced cross-sectional imaging modalities versus traditional or digital intraoral radiographic modalities. A validated method for exploring root canal morphology in three dimensions is cone-beam computed tomography (CBCT).

Axial slices will display root canal angles and determine the position of the main foramen, which is not visible on periapical radiographs with enough accuracy (PAS). After its introduction in dental medicine, CBCT has become an effective diagnostic and treatment preparation tool in endodontology.[24]Sherrard et al. (2010) investigated the accuracy and reliability of tooth and root length measurements obtained from CBCT volumetric data and discovered that the CBCT measurements did not vary significantly from the actual lengths.[25]

Using an electronic apex locator, Janner et al. (2011) [26] discovered a high association between CBCT WL and clinical WL. Jeger et al. (2012) recorded high precision for CBCT measurements in a prospective in vivo sample, with a mean difference of 0.51 mm between CBCT WL and electronic apex locators[27], which was consistent with the findings of the current study. Current study reported mean difference of 0.5mm and 5% cases CBCT readings synced with actual working length. The procedure of CBCT measurement was kept as simple as possible by drawing a line between foramen and cusp tip. Whilst tracing the canal using multiplanar lines to follow the path of the canal may result in more accurate measurements.[28]

The use of CBCT imaging in endodontics, on the other hand, should be limited to assessing and treating specific endodontic conditions. CBCT imaging has some drawbacks, despite the fact that it offers valuable information on root canal anatomy and aids in the identification of periapical lesions or procedural errors such as perforations. The dose of radiation, scattering, and expense must all be taken into account. It is recommended to use the smallest FOV possible in any case.[29] Currently, CBCT radiation dose is not comparable with that of intra-oral radiographs. Therefore, there is still no indication to use CBCT for WL determination.[28]

The precision of working length calculated using an apex locator and radiographic methods was compared using actual anatomic working length determined with the aid of a stereo microscope and digital calliper. In the current research, there was no statistically significant difference in the accuracy of working length determination between optical radiography, electronic apex locator, and CBCT. As compared to radiographic data, however, apex locator readings were found to be similar to the actual working length. When compared to CBCT, RVG produced better performance.

CONCLUSION

In this analysis, there was no statistically significant difference in working length measurement between RVG, Root ZX mini apex locator, and CBCT. When comparing the findings, the apex locator readings were found to be superior. However, apex locator readings can vary in some circumstances, such as when radiographic images are used to help obtain accurate readings.

Due to its incomparable radiation dose, CBCT is still not recommended for WL determination. CBCT devices, on the other hand, are constantly being improved to minimize the radiation dose; if the effective dose exceeds a clinically acceptable level, CBCT may be recommended. Nonetheless, a pre-existing CBCT can often be used to determine the endodontic working length accurately.

As a result, it can be concluded that the WL should be determined using a combination of radiographic and electronic methods. Knowledge of apical anatomy or curvature gained through the careful use of radiographs and the application of EAL may help practitioners achieve predictable outcomes. Though apex locators cannot yet replace radiographs, they will undoubtedly be an important adjunct.

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