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ORIGINAL RESEARCH

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

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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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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

patients and their parents were informed about the research project. After obtaining the consent, local anesthesia was administered. The teeth were isolated by a rubber dam, followed immediately by opening of the pulp cavity using high-speed air-rotor handpiece and endodontic access cavity preparation bur. After irrigation with 2.5% solution of sodium hypochlorite, pulp was extirpated and a file of adequate dimensions was inserted into the root canal. A coronal reference point was identified for every canal.

The working length was then evaluated for each canal by the following techniques:

- *Digital tactile sensation:* A file of suitable size was selected according to the width of the canal as observed on the preoperative radiograph. The stopper on the file was adjusted so that the tip of the file would reach approximately 1.00 mm short of the radiographic apex. Then the file was advanced in the canal till the stopper approached the coronal reference point on the tooth and at the same time a tactile sensation of the file bending at the constriction was felt. Resistance to retrieve the file from the canal was also noted. The instrument was then removed from the canal and the length obtained was measured using the ENDO-BLOC and was recorded for statistical analysis.
- *EAL (Root ZX):* The Root ZX was used according to the manufacturer's instructions.[5] The clip was applied to the patients lip and the electrode was connected to the file. The file insertion was advanced until the display indicated the minor diameter had been reached. After identifying the apical limit, the rubber stop was adjusted on the file shaft so that it touched the reference point. The instrument was carefully withdrawn and the distance from the tip of the instrument to the rubber stop was measured and value was recorded.
- *Digital radiography: (Kodak RVG 5000):* A file of adequate dimension with the rubber stop was placed in the root canal with the length reaching the radiographic terminus as noted from the preoperative radiograph. The sensor was protected against salivary contamination by disposable polythene sleeves when placed against the tooth and the patient was exposed to radiation. The file length was observed on the digitized image on the monitor, making sure that the tip of the file reaches radiographic terminus (RT) (Fig. 1). The instrument was carefully withdrawn and the distance from the tip of the instrument to the rubber stop was measured. This value was also confirmed on the digital image with RVG linear length measuring scale. The final length was calculated by subtracting 1 mm from the value obtained at RT and was recorded.

After determining the length of all canals by these methods, the rubber dam was removed and the teeth were extracted and immersed in 2.5% NaOCl, for 30 minutes, to remove all organic residues from the external root surface. After a short rinse in tap water, the teeth were stored in normal saline.

To observe the apical constriction directly, a window of about 4 to 5 mm was carefully made in each apex using a diamond disk at a very low speed (Fig. 2).[6,7] The apical constriction was studied under a plane-polarized microscope, Nikon ECLIPSE E 600 POL, at 4× magnification. Then the file used to perform the measurements, before extraction, was inserted into the canal and the distance from the coronal reference point to the file tip at the apical constriction was obtained (Fig. 3). The length was measured and recorded for statistical analysis.

RESULTS

The present, *in vivo*, study was undertaken to evaluate the accuracy of different methods of working length determination.

The accuracy of the three methods was evaluated by comparing the readings with the actual length. The values

Fig. 1: Digital image of the tooth with file to determine the working length

Fig. 2: An apical window sectioned

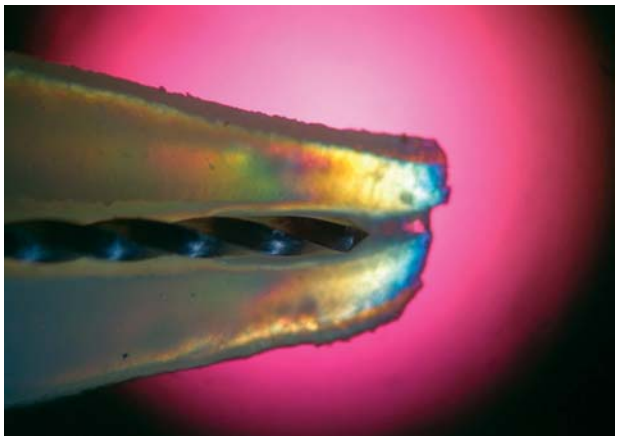

Fig. 3: The file reaching up to the apical constriction (considered as actual working length)

obtained were analyzed statistically by ANOVA test to compare the four groups and by z-test to check the difference pair wise. Table 1 indicates the mean values and standard deviation of the working length obtained with all the tested methods.

From the Table 2, we can observe that there is statistically significant difference between the groups in the determination of working length with F-value of 4.66 (p-value < 0.05). Hence we checked the difference pair wise using the z-test.

Table 3 reveals that there is significant difference between Tactile and DDR lengths and also between DDR and actual lengths. The Tactile and EAL, Tactile and Actual, EAL and DDR and EAL and Actual groups produced results where the differences were not significant.

Percentage accuracy (Table 4) indicates that EAL method shows maximum accuracy, i.e. 99.85% followed by tactile method with 98.20% accuracy and DDR being the last one in accuracy with a value of 97.90%.

DISCUSSION

Correct working length determination is one of the vital initial steps in endodontic therapy. However, locating the appropriate apical position has always been a challenge in clinical endodontics. The literature recommends two valid positions for working length; at the dentinocemental junction, as suggested by Kuttler,[8] or at the apical foramen.[9]

The dentinocemental junction is the ideal physiologic apical limit of working length.[1] However, the dentinocemental junction is a histological entity, with varying extensions of the cementum into the root canal.[2] Hence, the other anatomical landmark for limiting instrumentation is the apical constriction (AC). The significance of the AC in endodontic therapy is well recognized and the reliance on the dictum that canal preparation should terminate 1 mm short of RT is becoming increasingly unacceptable.[3] The invasion of this point, in an apical direction with instrumentation and/or filling material could affect apical healing.[2]

Table 1: Summary statistics

Groups	*Means*	*SD*
Digital Tactile (mm)	19.60	0.89
EAL, Root ZX (mm)	19.99	1.04
DDR (mm)	20.38	1.05
Actual (mm)	19.96	0.96

Table 4: Showing % age accuracy

Groups	*Accuracy %*
Tactile	98.20
EAL	99.85
DDR	97.90

Table 2: Comparison of four groups by ANOVA test

SV	*SS*	*Df*	*Ms*	*F*	*p-value*	*Significance*
Between groups	13.63972	3	4.546572	4.660694	0.003703	S
Within groups	167.7884	172	0.975514			
Total	181.4281	175				

S: Significant

Table 3: Comparison of pairs of groups by z-test

Groups	*Mean*	*SD*	*z-value*	*p-value*	*Significance*
Tactile (mm)	19.60	0.89	–1.88019	>0.05	NS
EAL (mm)	19.99	1.04			
Tactile (mm)	19.60	0.89	–3.79429	<0.05	S
DDR (mm)	20.38	1.05			
Tactile (mm)	19.60	0.89	–1.81679	>0.05	NS
Actual (mm)	19.96	0.96			
EAL (mm)	19.99	1.04	–1.78564	>0.05	NS
DDR (mm)	20.38	1.05			
EAL (mm)	19.99	1.04	0.138249	>0.05	NS
Actual (mm)	19.96	0.96			
DDR (mm)	20.38	1.05	1.993204	<0.05	S
Actual (mm)	19.96	0.96			

NS: Nonsignificant; S: Significant

There are various methods for determination of working length (Radiographic, Apex locators, Tactile), but none of these are perfect. The radiographic method is the most common method (and remains so) of measuring working length in root canal therapy. It is simple but also has certain disadvantages like radiation exposure, in most cases the dentinocemental junction (DC). Junction does not coincide with the radiographic apex and it gives a two-dimensional image and simply provides reliable information on the location of the radiographic apex.[9] Considering, that the apical foramen frequently does not coincide with the radiological apex, positioning of the file at the radiological apex will often lead to over instrumentation. Digital radiographic method is the recent and promising method of measuring working length. The advantages of RVG overconventional radiographs are the speed of image acquisition, reduced patient radiation dosage and the possibility of image editing.[10,11]

In recent years, electrical devices have been developed for determining the length of the tooth. This is one of the breakthroughs that brought electronic science into the traditionally empirical endodontic practice. Here the working length is determined by comparing the electrical resistance of the periodontal ligament with that of the gingiva surrounding the tooth, both of which should be similar. By measuring the depth of insertion of the file one may determine the exact working length of the root canal.[12] This helps reduce the treatment time and the radiation dose.

In 1991, Kobayashi et al suggested the ratio method for measuring root canal length, which was the basic working mechanism of the Root ZX. This device, simultaneously measures the impedances of 0.4 and 8 KHz, calculates the quotient of the impedances, and expresses this quotient in terms of the position of the file inside the canal. In a study by Kobayashi and Suda[4] the apex locator showed a similar precision as other methods. If working lengths were determined electronically before obtaining X-rays, the number of radiographic exposures would be reduced and would result in improved length of obturation.[13,14]

In the present study, the methods that were used to determine working length were apex locator, digital radiography and digital tactile sensation method. The EAL readings were very close to the actual readings, followed by digital tactile method. The digital radiographic method showed comparatively longer readings than actual and tactile methods. No statistically significant differences are noted between EAL and actual; tactile and actual and tactile and EAL methods. The results of the present study compared with those of many other previous studies.[15-21]

Seidberg et al (1975),[15] in a clinical study compared the sonoexplorer with digital tactile senses in determining the working length of the root canals, and found that the digital tactile sense was more satisfactory than the sonoexplorer. The investigators were able to establish the radiographic working length accurately with digital tactile means in 64% of the teeth compared with 48% accuracy when the sonoexplorer was used. Vachey et al (1989)[16] conducted a statistical study in order to evaluate the benefit afforded by tactile sense in endodontometry. The results showed no statistically significant difference between the electronic measurements and tactile measurements both being controlled radiographically.

In our study, we found no significant difference between digital tactile calculations and actual readings. Also, there is no significant difference between the digital tactile calculations and EAL calculations. However, a statistically significant difference is seen between digital tactile calculations and digital radiographic measurements (p-value = < 0.05). From these results we can conclude that if an excellent preoperative radiograph is made available and the operator has experience and good knowledge of anatomy and tactile sense, the digital tactile method has potential to produce an accurate measurement of length of the root canals.

Martinez Lozano MA et al[19] compared radiovisiography, conventional radiography and electronic system for working length determination on extracted human mandibular teeth. Later the actual working length was determined by selective grinding of roots and they found no significant difference between the three techniques. In this study, digital radiographic readings were longer than actual, postextraction measurements. Ashraf EIAyouti et al[20] in a study, concluded that complementing radiographic working length determination with electronic apex locator measurements might help to avoid overinstrumentation.

In our study, the digital radiographic measurements gave comparatively overestimated readings. An explanation may be that the apical foramen in most of our cases was located laterally rather than being apicocentral. An apical foramen that is located short of the radiographic apex of the root makes it difficult to identify its position on the radiographic film or digital radiographic image. The root canals in most of the cases did not end close to RT, leading to overestimation of the working length.

Another reason for the longer digital radiographic readings may be the magnification. Radiographic magnification increases as the OFD (Object-Film Distance) or OScD increases. Because it is physically impossible to place sensor directly against the tooth being imaged, due to hard and soft tissue constraints, a certain degree of magnification is expected. Even in an *in vitro* study conducted by Burger CL et al (1999)[18] the RVG method resulted in overestimated canal lengths that were significantly different from the true canal length.

Several studies are conducted to evaluate the accuracy of Root ZX *in vivo* and *in vitro* and found Root ZX to be most accurate.[22-24] The results of our study are in agreement

of these studies. In our study, the accuracy obtained with Root ZX for working length is 99.85% as compared to control group.

CONCLUSION

Within the constraints of this *in vivo* study, it was seen that: the digital tactile sensation method of working length determination produced comparable results with actual readings with 98.20% accuracy. The digital radiographic method showed statistically significant difference of mean value with mean value of actual reading with 97.90% accuracy. The EAL method (Root ZX) produced most reliable results when compared to actual readings with 99.85% accuracy.

Hence, we can conclude that though all the methods give satisfactory results, digital radiographic method overestimates the working length and the EAL shows the least discrepancy from actual length.

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