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Reliability of CBCT in working length determination for successful endodontic treatment- an in vitro study

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Abstract
Aim: To evaluate and compare the accuracy of working length determination using radiovisiography, Cone Beam Computed Tomography and Actual working length of the tooth.
Material and Methods: After the access cavity preparation in seventy- two extracted human single rooted teeth, the working length was measured, using radiovisiography and Cone beam Computed Tomography and its accuracy was compared with the actual working length of the teeth using surgical loupes. Unpaired 't' test was used to test the significance of difference observed in mean working length measurements
Results: The difference in distribution of readings was found insignificant ($p<0.75$) by Chi square analysis. The result showed that cone beam computed tomography working length had high percentage of accurate readings as compared to radiographic working length readings. The results also showed high Karl Pearson's correlation coefficient between the actual working length, radiographic and CBCT working length.
Conclusions: Cone beam computed tomography (CBCT) imaging is as accurate and valuable adjunct as the actual working length in determining working length.
Clinical Significance: Considering the availability of CBCT and its wide implication in endodontics, there is a need to explore if CBCT can be used as a tool at par with the actual working length determination in endodontics.

KEYWORDS
Cone Beam Computed Tomography; dental radiovisiography; Root canal preparation

1 | INTRODUCTION

The success of endodontic treatment depends on the proper access cavity preparation, accurate working length determination, root canal preparation and obturation.[1] Working length determination is rewarded to be one of the most important of all these procedures.[2,3] Faulty working length determination usually leads to various mishaps like apical perforation, over filling, under filling, and postoperative pain due to resid-

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ual infection.[4] Most endodontists depend on apical constriction or apical foramen as reliable anatomic landmark for determination of apical end of the root canal. Traditionally, radiographs are most widely used for working length determination. However, it is challenging to determine location of the apical foramen or the apical constriction in the canal in radiographs. It poses difficulties due to anatomic variations or presence of curvatures in either buccal or lingual direction.[5] Unavoidable exposure of the radiations, two-dimensional characteristic of the image and superimposition of the structures makes the working length determination difficult.[6] Similarly, Direct Digital Radiography (RadioVisioGraphy-RVG) an intraoral imaging system,7 despite advantages such as enhanced visualization, lower radiation dose and patient exposure, digital format, and use of chemicals, have same disadvantages as conventional radiography.[8] Cone beam computed tomography (CBCT), which has been introduced in the year 1996 is considered as a diagnostic imaging mode which provides high quality, distinguished, accurate three-dimensional (3-D) illustration of the osseous elements of the maxillofacial skeleton. CBCT have advantages of capturing images at low radiation doses, which provides small field of view and adequate spatial resolution for applications in endodontic diagnosis, treatment planning, and post-treatment evaluation.[9] The Axial slice sections in CBCT can identify the angulations in the root canals and help in the location of the apical foramen with increased accuracy, which is not possible with intraoral radiographs. Considering the availability of CBCT and its widespread application in endodontics, it is necessary to investigate whether CBCT can be utilized as a tool on par with actual working length assessment in endodontics. Hence, the present study was designed to investigate the accuracy of root canal working length measurement by Cone Beam Computed Tomography and direct digital radiography in comparison with the actual working length calculated through anatomic measurement.

2 | METHOD

This study was an in vitro study carried out on extracted teeth. Study approval was obtained from Ethics committee(No. CDCRI/DEAN/ETHICS/CONS/03/2016 dated 19 Dec 2016). 72 freshly extracted fully developed single rooted and single canal human permanent incisors and or single rooted premolar teeth extracted for periodontal or orthodontic purposes were considered for the study.[10] After extraction, all the samples were disinfected and stored as per the recommendation and the guidelines laid down by CDC (Centre for Disease Control and Prevention).[11] Pre- operative diagnostic radiographs were taken with parallel technique for all teeth. The access cavities for opening the pulp chamber were made with a high-speed air rotor hand-piece (NSK, Japan) using Endo Access Kit (Dentsply/ Maillefer, Switzerland). After recommended access cavity preparation, canal orifices were enlarged with #3 Gate Glidden drills (Mani, Inc. Japan). The patency of the canal was verified with insertion of a size #10 or #15 K-file (Dentsply, Maillefer, Switzerland) until the apex had reached. The root canals were irrigated with 5 ml of 3% sodium hypochlorite solution (Neelkanth Health Care P. LTD. India) using a 30-gauge root canal irrigation needle (Vishal Dentocare PVT. LTD, India). The procedure of working length determination by three methods was performed on 72 teeth by single operator.

Actual Working Length Measurement(AWL)

A K-file of size #10 or#15 was inserted into the root canal until the tip of the file was appreciably seen from a tangential angle at the apical exit using 3.5X magnification loupe (Surgiwel, India), at the level of the most coronal boundary of the major foramen. When the file tip was visible at the apical foramen, the silicon stopper was adjusted to the coronal reference point. If the position of the apical foramen was not at the tip of the apex, the lower border of the foramen was considered as the exit of the canal. The distance between the file tip and silicon stopper was measured with a vernier calliper under 3.5X magnification and recorded in mm. The actual working length was established by subtracting 0.5 mm from the true canal length(Fig. 1).[12] This method was taken reference from previous studies.[13]

Radiographic Working Length (RWL) Measurement using RVG

The tooth samples were mounted on the mandible cast. For all teeth samples, the radiographs were taken two times using the parallel angle technique. Size 1 sensor was used to record images and was set at 19 micron pixel size, 12 bits gray scale and 16 lp/mm spatial resolutions The digital periapical images were recorded using a RVG(RVG 5200, Carestream Health, Inc, USA) and Dental Imaging Software- 6.13.3.3 (Carestream Health, Inc, 2014). First time the radiograph was taken to determine the radiographic tooth length. Radiographic tooth length is described as the distance between the most coronal point of reference and the radiographic apex (Fig. 2a). The second radiograph was taken to determine the RWL (Fig. 2b) . For radiographic working length determination, a size # 10 or # 15 K-file was inserted into the canal, and then 0.5 mm was subtracted from the gauging, which was recorded as the radiographic working length (Fig. 2c).

Cone Beam Computed Tomography Working Length Measurement (CBCT WL)

The CBCT images were acquired by oral radiologist, with a CS 9300 Select (Carestream Health, Inc, USA) operating at 80 kVp, 4.0 mA and an exposure time of 8 seconds at field of view (FOV) 10 x 10 cm and voxel size 180. The tooth samples were mounted on the wax block model. The working model was placed on the dental impression holder onto the 3D bite block support in the chin rest base, to standardize the imaging. The image was examined with the 3D Object Acquisition Interface (Carestream Health, Inc, USA). A reference point was taken from the occlusal plane, following the visible canal curvature in the respective cone beam computed tomography slice. CBCT records were placed in parallel alignment to the long axis of the root measured and a scrolling tool was used to locate the maximum length of each root in both the coronal and sagittal sections of the CBCT image. The measurements of the different canals were taken through use of the software measurement tool(Fig 3). The lengths were determined by measuring from the cusp tips to the radiographic apex after scrolling through to find this maximum length.

Statistical methods

The statistical analysis was done using SPSS (Statistical packages for Social Sciences) Version 16.0 software. Mean, standard deviation, mean difference, standard error (SE), and accuracy (Accuracy = 100 - error%) was measured at 95% confidence interval. Unpaired 't' test was used to test the significance of difference observed in mean working length measurements. The difference was analysed by Chi square analysis. Level of significance was set at 0.05.

3 | RESULTS

Mean for AWL was 22.14±1.41, for RWL was 21.99±1.39 and for CBCT working length was 22.01±1.39 (Table 1). Accuracy in RWL determination was 99.33% and for CBCT WL determination was 99.43%. On applying unpaired t test, it showed insignificant difference in mean working length between the AWL versus RWL (0.147) and AWL versus CBCT WL groups (0.125). The difference between CBCT WL and AWL was however less that of RWL and AWL. 30.56% of CBCT WL readings were equal to AWL when whereas only 25% RWL readings were equal to cone bean working length. The difference was found to have the p value <0.75 by Chi square analysis. The working length measurements by the actual and CBCT methods were comparable and no significant differences existed between their means. The difference was found to be insignificant (p<0.75) by Chi square analysis. The CBCT WL is as accurate as AWL in determining working length. High correlations were found between the AWL versus RWL (0.99) and AWL versus CBCT WL (0.99).

4 | DISCUSSION

Different methods have been used to determine the position of the apical foramen and thus to measure the working length of root canal. Traditional methods for establishing working length have been (a) by applying the knowledge of the tooth anatomy, (b) tactile sensation, (c) use of paper point, (d) periapical radiography and (e) electronic apex locator. Now in clinical practice, new imaging modalities have been included such as digital radiography; densitometry, computed tomography, magnetic resonance imaging and ultrasound technique.[14] There are few consensuses in the past studies regarding the accuracy of CBCT working length measurement and its use in determining working length when compared with traditional methods. This study was undertaken to compare and evaluate the accuracy of cone beam computed tomography and direct digital radiography in determining the working length by comparing them with the AWL calculated through anatomic measurement. The results of this study showed that there was insignificant difference in mean working length between AWL and CBC WL which is in accordance with previous reports.[15,16] Yu-Hong Liang et al.[17] in his study also concluded that working length measurements based on CBCT were more reliable and accurate when compared with actual working length. Tchorz et al. in their study using molar teeth found a 0.32 mm difference between CBCT and actual working length measurements.[18] In the present study, the mean difference was very less (0.14 mm) as compared to the previous studies. Connert T.[19] in their study, found that the mean of values of absolute differences between CBCT and actual working length was 0.41 mm (99% CI 0.31–0.52 mm) and concluded that the use of CBCT in determining the working length can be encouraged. The results of the above-mentioned studies were in accordance with the present study. The result of the present study showed that in comparison to percentage of radiographic working length readings (25%), higher percentage (30.56%) of cone beam computed tomography (CBCT) working length readings were equal to the actual working length amplifying the accuracy of CBCT. Similar results were found in previous studies. [14,20] They found no statistical difference between them and concluded that pre-existing CBCT scans were reliable for working length determination. This could be attributed to the high-quality image scanning details in CBCT as compared to Radiography. The 3 Dimension property of CBCT makes the detection of the anatomical landmarks easier and more precise. The more the similarity of the experimental techniques with the actual working length, the higher its accuracy. In the present study the accuracy of radiographic working length determination was 99.33% and for CBCT was 99.43%. This could be attributed to the sensitivity and 3D property of CBCT. The present study showed high Karl Pearson's correlation coefficient between the AWL versus RWL (0.99) and AWL versus CBCT W (0.99). This result was in accordance with the previous study (r=0.094).[21] Based on the possibility that cone beam computed tomography images may be advised for teeth with apical periodontitis as a diagnostic aid, it may also favour the working length measurements.

5 | CONCLUSION

The result of this study proved that the measurement of working length determination through CBCT was as accurate as actual working length determination. If the CBCT is already being advised for any diagnostic purpose, it can also be reliably utilised for the working length determination of the root canals for that patient if needed.

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Conflict of interest

The authors have no conflicts of interest to declare.

Supporting Information

Additional supporting information may be found at the journal's website.

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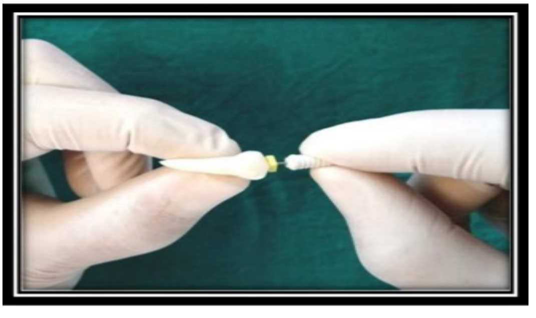

FIGURE 1 Actual Working Length determination using the extracted tooth

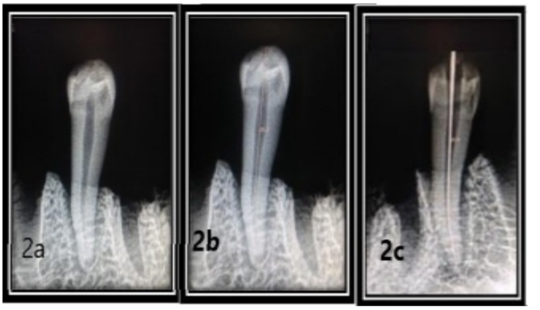

FIGURE 2 Radiovisiography images (2a) Pre-operative, (2b) Actual Working Length (AWL), (2c) Radiographic Working Length (RWL)

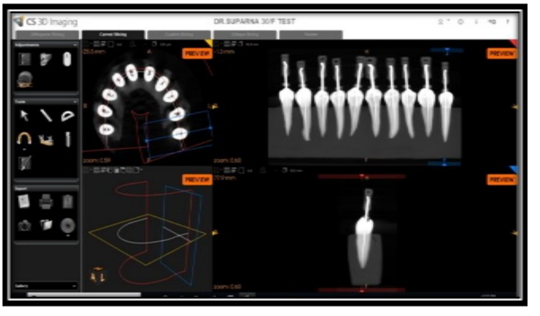

FIGURE 3 CBCT images in coronal, sagittal and transverse sections.)

TABLE 1 Working length determination methods

Working length determination methods	Mean± SD
Actual Working Length (AWL)	22.14 ± 1.41
Radiographic Working Length (RWL)	21.99 ± 1.39
CBCT Working Length (CBCT WL)	22.01 ± 1.39