Direct Linear Measurement of Root Dentin Thickness and Dentin Volume Changes with Post Space Preparation: A Cone-Beam Computed Tomography Study

Abstract

Aim: The purpose of the present study was direct linear measurement of dentin thickness and dentin volume changes for post space preparation with cone-beam computed tomography (CBCT). **Materials and Methods:** Ten maxillary central incisors were scanned, before and after root canal and post space preparation, with Orthophos XG three-dimensional hybrid unit. Thirteen axial section scans of each tooth from orifice to apex and dentin thickness for buccal, lingual, mesial, and distal were measured using proprietary measuring tool and thereafter subjected to statistical analysis. Furthermore, dentin volume was evaluated using ITK-SNAP software. **Results:** There was statistically significant difference between the dentin thickness in pre- and postinstrumentation (paired *t*-test) and also between different groups (one-way ANOVA). In the shortest post length of 4.5mm the post space preparation resulted in 2.17% loss of hard tissue volume, where as 11mm longest post length post space preparation resulted in >40% loss of hard tissue volume. **Conclusion:** CBCT axial section scan for direct measurements of root dentin thickness can be guideline before and after post space preparation for selection of drill length and diameter.

Keywords: *Cone-beam computed tomography, dentin thickness, linear measurement*

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Introduction

A nonvital tooth, which has lost substantial amount of coronal tooth structure as a result of dental caries, trauma, fracture, and previous restoration or due to access cavity preparation for endodontic treatment[1] for such teeth, post core, and final crown restoration, has become routine postendodontic-restorative procedure.[2]

Recently, it has been found by many studies that increasing the post length does not necessarily increase the strength of the root.[3-5] Post space preparation is accomplished with the removal of root dentin. The apical seal of 4–5 mm of gutta-percha is maintained at the root apex; similarly, one-third of the root width is recommended for post space preparation as it will allow at least 1 mm of dentin around the post.[6] Therefore, the post diameter is approximately one-fourth of the root diameter measured at root face;[7] thus, the narrow post fails under occlusal loading without affecting root whereas the large diameter post will tolerate the occlusal load but will result in root fracture.

Dentin thickness after root canal treatment possesses <1 mm of root dentin dictating cases; a custom-made post should be used to fit the existing root canal morphology. A study by Pilo and Tamse[8] stated that maxillary and mandibular canines, maxillary central and lateral incisors, and maxillary first molar palatal roots possessed adequate 1 mm or more root dentin after normal and appropriate root canal cleaning and shaping. All other teeth have <1 mm of remaining dentin following root canal treatment. For the single canal in maxillary first premolars 0.7 mm or less in diameter, a post that preserves 1 mm of dentin lateral to the post was recommended.[9] However, the mandibular premolars with oval- or ribbon-shaped canals should not be undertaken for post space preparation because it will result in <1 mm of remaining root dentin around the post.[8] Based on the measurements of remaining dentin thickness for mesial root canals in mandibular molars, canal preparation can result in perforation or very thin areas of remaining dentin. Hence, it is recommended to avoid any post in these roots.[10]

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Among the various imaging modalities available, cone-beam computed tomography (CBCT) has been shown to be more accurate than digital radiographs in assessing root canal morphology.[11-13] A study concluded that CBCT was reliable for the evaluation of linear measurements between anatomic structures within soft tissues.[14]

The purpose of this study was to obtain three-dimensional (3D) CBCT scan images for linear measurement of dentin thickness and dentin volume changes in maxillary central incisor teeth, before and after (root canal prepared and post space prepared) instrumentation.

Clinical implications

Dentin thickness measurements from CBCT provides clinically appropriate guidelines for optimal post diameter and post length. Selection of suitable post should be such that 1 mm dentin thickness remains around the post, to avoid root perforations or extremely thin weak dentin.

Materials and Methods

Ten extracted intact human mature maxillary central incisors with single straight roots were used for the study. The specimens were mounted on rubber base mold with elastomeric impression material, Aquasil Soft Putty (DENTSPLY, Konstanz, Germany) as sample holder, to ensure that the vertical orientation of the teeth and teeth specimen was repositioned in the same position reproducibly and was consistent for CBCT imaging. Teeth were decoronated using 0.25 mm diamond disk with high-speed handpiece with water spray (NSK, Japan) at cementoenamel junction (CEJ). The length of teeth was standardized and only teeth with similar root length of 13 mm for each specimen were selected and root diameter was measured and only teeth with similar root dimensions were selected. Teeth were handheld for root canal procedure according to standard protocol for access opening, irrigation with sodium hypochlorite, canal instrumentation K-file size 25–80 (Mani, Japan) with reciprocating endo-express handpiece (NSK, ER10, Japan), and obturation with root canal sealer and gutta-percha.

Post space preparation

The post space was prepared with 1.5 mm (0.060”) para post drill (Coltene/Whaledent AG, Switzerland). The post space preparation was done as per the recommendation guidelines[10] as follows: (i) post space preparation length (PSPL) of 10 mm for post length should be equal to crown length; crown length was taken as 10 mm. (ii) PSPL of 11 mm for the post length should be longer than crown length. (iii) PSPL of 4.3 for post length should be one-third of the crown length. (iv) PSPL length of 6.5 mm for post length should be one-half of the root length; the root length was 13 mm. (v) PSPL at 8.6 mm for post length should be two-third of the root length. (vi) PSPL of 10 mm for post length should be four-fifth of the root length. (vii) PSPL of 7 mm for post length should be terminated one-half between the crestal bone and the root apex; 7 mm was taken as the length between crestal bone and root apex. (viii) PSPL of 9 mm for post length should be as long as possible without disturbing the gutta-percha apical root seal; gutta-percha apical seal was 4 mm. The post length was calculated accordingly. The post drill and post length sizes are given in Table 1. For the objective of this study, the only purpose of this procedure was to measure dentin thickness by linear measurement at various levels before and after instrumentation.

The mounted root samples were imaged using CBCT, Orthophos XG-3D hybrid unit (Sirona, Bensheim, Germany). The scanner unit for the high definition mode (HD) and metal artifact reduction software (MARS) provides brilliant 3D images which in the small volume, for endodontics, can also be reconstructed with high resolution of 100 µm. The CBCT unit has the ability to instantly view digital images required for endodontic procedures combined with the crisp well-defined 3D volumetric images, as well as precise measurement of canal length, widths, and apicoectomy procedures (Manufacturer Brochure, Sirona, Germany). The scan parameters for CBCT unit were 85 kV, 7 mA, exposure time 14.2 s and radiation dose of 561 $mGycm^2$. Voxel size was 0.3 mm^3, field of view (FOV) was 8 cm × 8 cm resulted in scan volume of 8 cm × 8 cm × 8 cm, and the reconstructed 3D data were saved in a proprietary data format file. The software allows various aspects of imaging. The teeth were inspected in sagittal, coronal, and axial sections. Using proprietary measurement tool, the tooth being measured can be depicted independently. The tooth could be rotated by the operator to find a suitable plane for measurement. For linear measurement, maxillary central incisor was scanned in a CBCT unit before and after instrumentation (root canal treated and post space prepared). During both scans, root alignment was standardized. Starting at canal orifice, 13 axial-sectional CBCT images were obtained at 1 mm interval in root apex direction for all ten root specimen. At each level in the axial plane, the measurements were done, and root dentin thickness was measured at four sites, mesial, distal, buccal, and lingual. A straight line was drawn from inner root dentin (canal outline) to the outer dentin (root periphery), mesial dentin thickness (M), distal dentin thickness (D), buccal dentin thickness (B), and lingual dentin thickness (L) [Figure 1]. To eliminate inter-examiner variability, all measurements were done by a senior qualified oral radiologist and repeated again after 2 weeks [Figure 2].

Table 1: Different sizes of post length and post drill

	Tooth number									
	1	2	3	4	5	6	7	8	9	10
Para post drill size (mm)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Post space preparation length (mm)	11	10	10.4	9	8.6	7	6.5	4.5	7.5	8

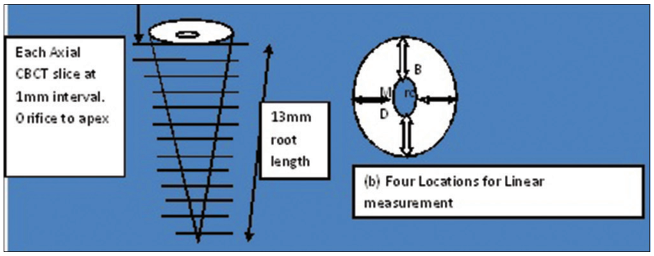

Figure 1: Schematic presentation: Cone-beam computed tomography axial section at 1 mm sequential from canal orifice to root apex and the linear measurement for dentin thickness, locations at four sites, M-mesial, D-distal, B-buccal and L-lingual (rc-root canal outline)

The dentin volume before and after instrumentation was measured using ITK-SNAP www.itksnap.org. (Free Software, USA). The software applications are used to segment structures in 3D medical images that allow the user to navigate manually delineate anatomical regions of interest and perform automatic image segmentation.[15]

Results

The pre- and post-instrumentation changes in dentin thickness within each group were statistically analyzed using paired *t*-test at (P = 0.05). One-way ANOVA and Tukey's honestly significant difference were used to compare pre- and post-instrumentation differences between the groups (P = 0.05) in SPSSversion 11.5 for windows, (Chicago, IL, USA). According to the measurements, the root length was divided into three parts as: from CEJ, the slices from 1 to 5 mm were designated as coronal one-third (C), from 5 to 9 mm middle one-third (M), and from 19 to 13 mm apical one-third (A). The mean, standard deviation, standard error, and 95% confidence interval for coronal one-third (C); middle one-third (M), and apical one-third (A) on all the four sides (buccal, lingual, mesial, distal) and in both pre- and post-instrumentation are shown in Table 2.

The paired *t*-test showed a significant correlation ($P < 0.05$) in all the groups pre- and post-instrumentation. There was a significant correlation ($P < 0.05$) between pre- and post-instrumentation dentin thickness in between the groups.

Discussion

In the present study, CBCT produced slice thickness of 0.3 mm; therefore, reconstruction of teeth in three dimensions was achieved because of this precision. A study[16] had reported that the radiographs can lead to an underestimation of root dentin thickness, and sectioning of tooth is invasive and destructive method. That problem can be extremely minimized to <1 mm, if not eliminated, by CBCT for direct measurement evaluation method.

The standard guidelines for preparation of post placement are as follows:[17] i) The post length is two-third of the canal length.ii) Intraradicular post length at least same as the coronal core length or half of the bone-supported length of the root.[18] But for iii) fiber post with adhesive Luting cement, maximum length of post be one-third or one-half the length of the canal or iv) radicular post extension be equal to the coronal length of the core.[19,20] Proper length of the post for root canal-treated teeth has guidelines with wide range of recommendations. This is because of varied root canal anatomy, root length, and remaining coronal tooth structure.[10] Therefore, the post length is dictated and determined by the crown length, root length, bone support for root, and the apical gutta-percha seal. These recommendation are as follows: the post length should be equal to crown length, post length should be longer than crown length, post length should be one-third of the crown length, post length should be one-half of the root length, post length should be two-third of the root length, post length should be four-fifth of the root length, post length should be terminated one-half between the crestal bone and the root apex, and post length should be as long as possible without disturbing the gutta-percha apical root seal.

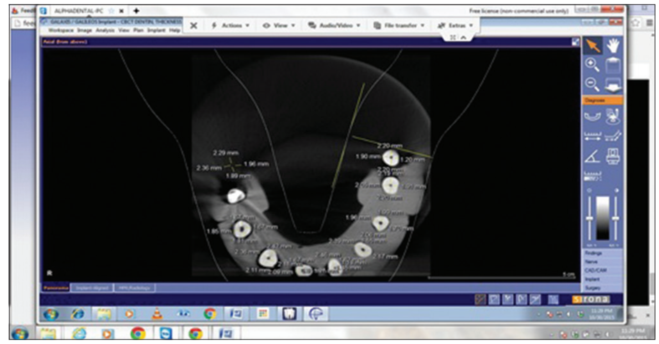

Figure 2: Cone-beam computed tomography scan axial section image for measuring buccal, lingual, mesial, distal dentin thickness for each tooth sample

The results of the present study initiated a thought of dividing and designating zones for post space preparation depth as follows: safest zone (coronal third of root), encounter zone (middle third), and the prohibited zone (apical third of root) [Figure 3].

The linear measurement of dentin thickness for pre-instrumentation in the coronal third of root (CBCT axial sections of coronal 1–5 mm), the average buccal dentin thickness (DT) was 2.68 mm, lingual DT was 2.72 mm, mesial DT was 1.82 mm, and distal DT was 1.85mm. Postinstrumentation average, buccal DT was 1.99 mm, lingual DT was 2.00 mm, mesial DT was 1.75 mm, and distal DT was 1.50 mm. Adequate dentin thickness in coronal third of the root was present and it was designated as "safest zone." The linear measurement of dentin thickness for pre-instrumentation in the middle third of the root (CBCT axial section of Middle 6–9 mm),the average buccal DT was 2.06 mm, lingual DT was 2.15 mm, mesial DT was 1.3 mm and distal DT was 1.35 mm. Postinstrumentation, buccal DT was 1.34 mm, lingual DT

Table 2: Dentin thickness values of mean and standard deviation in coronal,middle and apical one-third on buccal, lingual, mesial,and distal sides in both pre- and post instrumentation

Location	Root portion	Mean	SD	SE	95% CI for mean	
					Lower bound	Upper bound
Buccal						
Pre	C	2.5700	0.26359	0.03728	2.4951	2.6449
	M	2.0215	0.31878	0.05040	1.9196	2.1234
	A	1.1430	0.37883	0.05990	1.0218	1.2642
	Total	1.9622	0.67295	0.05902	1.8454	2.0789
Post	C	2.027	0.2806	0.0397	1.947	2.107
	M	1.521	0.2638	0.0417	1.436	1.605
	A	0.748	0.2176	0.0344	0.678	0.818
	Total	1.478	0.5897	0.0517	1.375	1.580
Lingual						
Pre	C	2.5700	0.26359	0.03728	2.4951	2.6449
	M	2.0215	0.31878	0.05040	1.9196	2.1234
	A	1.1430	0.37883	0.05990	1.0218	1.2642
	Total	1.9622	0.67295	0.05902	1.8454	2.0789
Post	C	2.049	0.2645	0.0374	1.973	2.124
	M	1.5215	0.2687	0.0425	1.457	1.629
	A	0.815	0.2299	0.0363	0.741	0.888
	Total	1.513	0.5719	0.0502	1.414	1.613
Mesial						
Pre	C	2.11	0.247	0.035	2.04	2.18
	M	1.59	0.270	0.043	1.51	1.68
	A	0.84	0.351	0.056	0.73	0.96
	Total	1.56	0.600	0.053	1.46	1.67
Post	C	1.680	0.2066	0.0292	1.621	1.739
	M	1.167	0.2497	0.0395	1.088	1.247
	A	0.575	0.1615	0.0255	0.523	0.627
	Total	1.182	0.5034	0.0442	1.095	1.270
Distal						
Pre	C	2.12	0.244	0.035	2.05	2.19
	M	1.60	0.265	0.042	1.52	1.69
	A	0.87	0.330	0.052	0.76	0.97
	Total	1.58	0.590	0.052	1.47	1.68
Post	C	1.6484	0.18590	0.02629	1.5956	1.7012
	M	1.1348	0.26773	0.04233	1.0491	1.2204
	A	0.5668	0.16809	0.02658	0.5130	0.6205
	Total	1.1575	0.49509	0.04342	1.0716	1.2435

C: Coronal one-third; M: Middle one-third; A: Apical one-third; SD: Standard deviation; SE: Standard error; CI: Confidence interval

was 1.58 mm, mesial DT was 1.19 mm, and distal DT was 0.94 mm. The linear measurements of dentin thickness, for the post space preparation, the width, and depth, should be measured from CBCT scan images precisely before preparation procedure so that the operator can select the most suitable drill diameter and post space preparation depth such that at least 1 mm of dentin thickness will be available around the post, so that the chances of mishaps, such as perforation, weakening of dentin, and deviation, can be and should be avoided. Therefore, dentin thickness

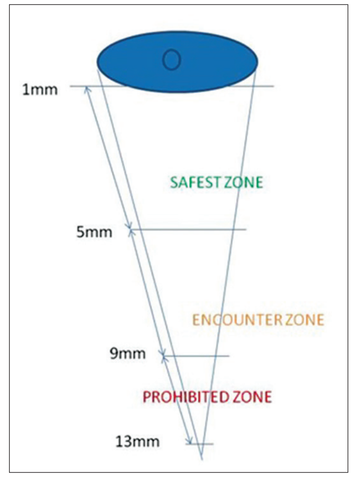

Figure 3: Schematic diagram representing the post space preparation zones in root canal

in this crucial region needs to be evaluated, before and after post space preparation, when planning for postendodontic restoration. Hence, the middle third of root was designed as "encounter zone" for probability of mishaps due to over preparation in width or depth. For apical third of the root (CBCT scan axial sections 9–13), preinstrumentation average, buccal DT was 0.90 mm, lingual DT was 0.96 mm, mesial DT was 0.55 mm, and distal DT was 0.58 mm. Postinstrumentation average, buccal DT was 0.62 mm, lingual DT was 0.79 mm, mesial DT was 0.44 mm, and distal DT was 0.50 mm. Only thin dentin is available in the apical third of root and should be reserved for 4–5 mm gutta-percha apical seal after root canal preparation. No post space preparation should be encroached upon the root canal apical seal, and hence, the apical third of root was designated as "prohibited zone."

A laboratory study had reported that increasing the post drill diameter resulted in more amount of dentin loss, for maxillary central and lateral incisors, at 5 mm and 7 mm from root apex. At 5 mm length from apex, there were more sample teeth with <1 mm of remaining dentin thickness than at 7 mm from apex.[3] In the present study, the post space preparation depth of 10, 10.4, and 11 mm from CEJ encroached the apical seal prohibition zone and hence was considered as null and void. Adequate dentin thickness ≥2 mm was present at the coronal third of root in the safest zone, and at the middle third of root, the dentin thickness was ≥1 mm in the encounter zone. Dentin thickness was more for buccal and lingual (2.06 and 2.15 mm) and less for mesial and distal (1.30 and 1.35 mm) comparatively, as shown by the linear measurement results on all CBCT axial sections.

Radiographs are essential for information on tooth anatomy, pulp morphology, root length, root curvatures, and periapical tissues. Linear measurements are made from the radiographic images and should have error <1 mm.[21] Few studies used cadaver mandibles

Table 3: Dentin volume: Pre- and postinstrumentation (root canal treatment, PSP) and dentin volume loss

Tooth number	Volume (mm^3) (preinstrumentation)	Volume (mm^3) (postinstrumentation)	Dentin volume loss (mm^3)
1	277.5	116.4	161.4
2	280.2	169	111.2
3	283.1	165.5	117.6
4	271.9	208	106.4
5	288.2	220.1	68
6	279.3	251.4	27.9
7	286.4	270.4	16
8	281.7	275.2	6.5
9	280.9	247.1	33.8
10	299.1	243.2	56

PSP: Post space preparation

and found that the measurement error was <1 mm in 94% of computed tomography samples, 39% of samples with conventional tomography, 53% of samples with intraoral radiography, and 17% of samples with panoramic radiography.[22,23] The innovative and new technology provides 3D cross-sectional images without superimposition or blurring.[24,25] The linear measurements of dentin thickness before and after the root canal treatment and post space preparation were done from the 3D axial sections of CBCT scan, using in-built software measurement tools. The dentin thickness decreased as the length for post space preparation depth increased from coronal to apical region.

Ikram *et al.*[26] in their study have shown that the hard tissue loss was 8.3%, largest loss, caused by caries removal, 4.4% second largest loss by access cavity preparation, 4.1% loss for cast post preparation, and 1.4% loss for fiber post preparation. Minimal hard tissue loss of 1% was shown for root canal preparation. In the present study, the longest 11mm post length preparation resulted in >40% loss of hard tissue, thereby significantly increasing the fracture risk of a restored tooth. Whereas for the shortest 4.5mm post length preparation resulted in only 2.17% loss of hard tissue, will comparatively decrease the fracture risk of the restored tooth. The inference from the dentin volume results is that the hard tissue loss will be directly proportional to the diameter and length of post preparation drill. The dentin volume, from CBCT-scanned images, before and after post space preparation was done as shown in Table 3.

Conclusion

CBCT is an important new technology tool with many applications for endodontics. The linear measurements of dentin thickness would be the guidelines in clinical situations for both, post preparation depth (length of drill) and selection of drill diameter (post preparation width), and also hard tissue volume loss can be estimated, beside other diagnostic and treatment evaluations. Based on the previous studies with CBCT unit and physical measurement and the present study with CBCT unit and linear measurements for dentin thickness, it can be concluded that CBCT is reliable for linear measurement of dentin thickness of teeth. Well-designed clinical *in vivo* studies are needed, with all possible CBCT specifications, for further future research.

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Conflicts of interest

There are no conflicts of interest.

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