

Comparative evaluation of newer obturating systems using cone beam computed tomography and direct digital radiography

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Abstract

Introduction: Many techniques were developed to achieve proper obturation of root canal system by completely obliterating the canal space with a stable, nontoxic material to prevent the movement of bacteria or its by-products and tissue fluids through the filled canal.

Methods: 40 mandibular premolars were collected. Access cavity preparation was done and working length determined. Biomechanical preparation was done using ProTaper NEXT rotary files. Samples were divided into 4 groups and the quality of obturation was analysed using cone beam computed tomography and direct digital radiography.

Results: According to cone beam computed tomography analysis no voids could be detected in the obturated teeth due to presence of artefacts whereas on using direct digital radiography, voids were detected, no statistical significant difference between the 4 groups of obturation with mesial shift of tooth by 90° and paralleling technique was seen. Statistical significant difference of 0.006 at the coronal third with mesial shift of tooth by 90° was seen between the 4 groups and statistical significant difference of 0.04 between the coronal, middle and apical third was seen in GuttaFlow.

Conclusion: The study concluded that cone beam computed tomography could not be used to evaluate voids present in any of the obturation techniques. Direct digital radiography was used to evaluate the quality of obturating techniques and assessment of voids. Calamus followed by Elements showed superior obturation at apical, middle and the coronal third.

Introduction

Successful Endodontic therapy depends upon a triad of proper diagnosis, thorough biomechanical preparation (BMP) and three-dimensional (3D) obturation of root canal system [1]. The purpose of a root canal filling is to obliterate and seal the root canal system with a stable, nontoxic material so as to prevent the microorganisms and tissue fluids from percolating into the root canal system [2,3]. The efficacy of an obturation technique is determined by its ability to provide a fluid impervious apical seal [4].

Various techniques have been developed for GP placement in the root canal but cold lateral compaction continues to be used with great frequency [5]. GuttaFlow is a silicone polymer (polydimethylsiloxane) with very finely ground GP and silver particles [6]. The Calamus Dual 3D obturation system and the Elements obturating unit offers a backfill handpiece and a downpack handpiece to dispense warm thermoplasticized GP [7,8].

In Endodontics, images are routinely used before, during and after root canal treatment. Conventional radiographic images provide a two-dimensional (2D) rendition of a 3D structure, which may result in interpretation errors [9]. Cone beam computed tomography (CBCT) is one of the latest and most advanced types of digital radiography.

Materials and Methods

40 Single rooted mandibular premolars with intact crowns were collected from the Department of Oral and Maxillofacial Surgery and were disinfected as per the recommendations and guidelines laid by OSHA (Occupational Safety and Health Administration) and CDC [10]. Exclusion criteria includes incompletely formed apex, evident root fracture, calcified teeth, curved canals, pretreated teeth and bifurcated or multiple root canals. Access cavity preparation was done using Endo-Access Bur and Endo-Z Bur. Working length was determined and BMP was done till size #25 after which rotary system was used. ProTaper NEXT X1(4%) and X2 (6%).

Recapitulation and irrigation of the canal was done simultaneously by using 3% sodium hypochlorite solution followed by 5ml of 17%

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EDTA aqueous solution. Canals were dried using absorbent paper points. Obturation systems were grouped into A, B, C and D as Lateral Compaction, GuttaFlow, Calamus and Elements respectively. The teeth were divided into four groups with 10 teeth per group.

In lateral compaction, the canal wall was coated with AH Plus sealer with the help of lentulo spiral after which master cone of 6% taper # 25 size coated with sealer was inserted in the canal, subsequently 2% taper accessory cones coated with sealer were inserted after which lateral compaction was done with the use of spreader.

In group B, the GuttaFlow paste was carried into the canal system with the help of a syringe provided by the manufacturer till the working length and the paste was extruded into the canal with the orifice of the syringe always within the extruded material and back pressure was felt, master cone of 6% taper # 25 coated with GuttaFlow was then inserted and placed under apical pressure for 3 seconds.

In groups of Calamus obturation system and Elements obturating unit, lentulo spiral was used to coat the canal walls with AH Plus sealer and then GP master cone of 6% taper #25 size coated with sealer was inserted, 3mm of GP was compacted vertically using electric heat plugger (EHP) in Calamus and system B plugger in Elements till the working length. Cartridge of thermoplasticized GP was inserted in the back fill systems where the tip was placed into the canal 3mm short of working length and the hand piece was activated to pack thermoplasticized GP with the tip of the cartridge always within the extruded material and back pressure is felt till the orifice.

The evaluation of the obturation was done using CBCT and the images were obtained using the Planmeca Romexis 4.3.0.R software with a flat panel sensor using low artefact reduction mode (Endo Mode). (Figure 1).

Evaluation of the obturation technique was continued using direct digital radiography. Since direct digital radiography is a 2D image of a 3D object, X-rays were taken at two different angulations that are by paralleling technique and mesial shift of tooth by 90° using Intraskandigi software. Standardization of focal distance and angulation of the cone, sensor and the teeth was done by a customized apparatus (Figures 2A and 2B).

A reference point was made on the cervical third on the buccal, mesial, distal and lingual surfaces using a radiopaque material. Keeping the reference point the measurement of buccolingual and mesiodistal width of the teeth at the cervical third was obtained using Vernier caliper and Motic software. There was a noted change in the dimension of the image of the teeth in the Motic software when compared to the dimension of the actual teeth using a Vernier caliper. Therefore, an error percentage was calculated of every teeth buccolingually and mesiodistally using the formula.

$$\frac{\text{Width of the tooth under motic software}}{\text{Actual width of the tooth using caliper}} = \text{Error percentage}$$

The area of the largest diameter of voids under Motic software in micrometres at the cervical, middle and apical third using paralleling technique and mesial shift of tooth by 90° was obtained.

The error was nullified by multiplying the error percentage obtained to the values obtained in Motic software. The values were converted into millimeters representing the area of the largest diameter of void

A scoring criteria to analyze the area of the largest diameter of void in mm² using Motic software was designed in the Department by Dr Waleed K. Mukadam and Prof. Dr. Mithra N. Hegde.

SCORE	PRESENCE OF VOID	
0	Absent	
>0	Present	
	SCORE	AREA OF VOID (mm ²)
	1	0-0.01
	2	0.011-0.02
	3	0.021-0.03
	4	0.031-0.04
	5	0.041-0.05
	6	>0.05

Scoring criteria was tabulated, where 0 is no voids and >0 is voids present.

The data obtained was statistically analysed by Kruskal Wallis test and Fisher's exact test. Significance level was set at p-value <0.05.

Results

According to CBCT analysis of the obturated teeth, no voids could be detected due to presence of artefacts like noise, making it difficult to differentiate between the radiopaque GP and the teeth. High attenuation substance like GP in field of view cause bright streaks which makes it difficult to visualize the voids present in the teeth after obturation.

In direct digital radiography more voids could be detected with mesial shift of tooth by 90° as compared to paralleling technique, hence the data obtained using paralleling technique was annulled and data obtained with mesial shift of tooth by 90° was statistically analysed. (Figures 3A and 3B).

Largest diameter of void was observed in Group B and Group C with mesial shift of tooth by 90° and paralleling technique. On statistically analyzing the data using Kruskal Wallis test, there was no statistical significance between the four groups with mesial shift of tooth by 90° and paralleling technique

Discussion

The main objectives of Endodontic therapy are cleaning and shaping, disinfection and obturation of the root-canal system in 3D. GP is the most widely used and accepted obturation material [11]. Due to improper obturation there could be post-operative complications resulting in failure of endodontic therapy. The quality of obturation may be influenced by various types of techniques [4].

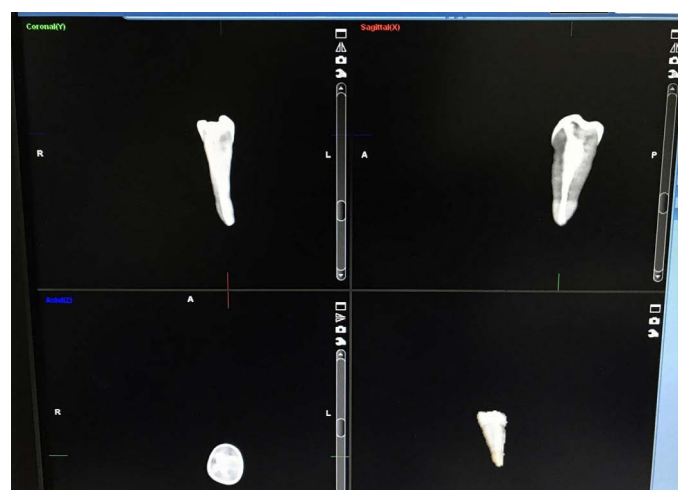


Figure 1. CBCT image of obturated teeth

The present study compares the quality of obturation and presence of voids using CBCT and RVG. According to the results, CBCT could not analyze voids in any of the obturating techniques.

A study done by Sogur et al, evaluation of homogeneity and length of the obturation was done using 3 different imaging methods. SPP and

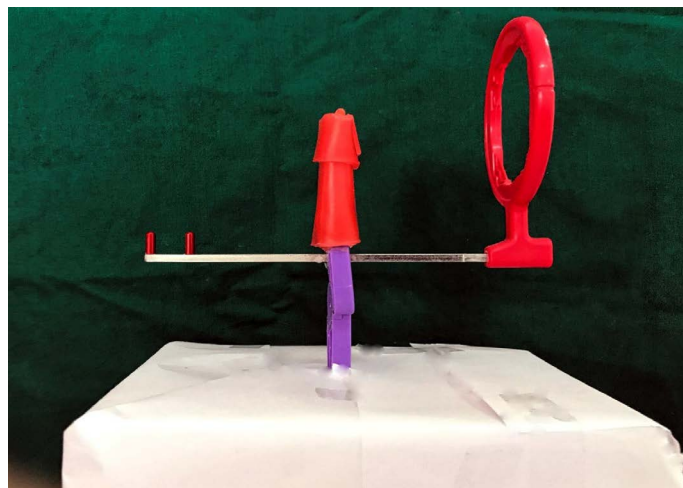


Figure 2a. Customized Apparatus used to standardize the distance and agulation of the teeth

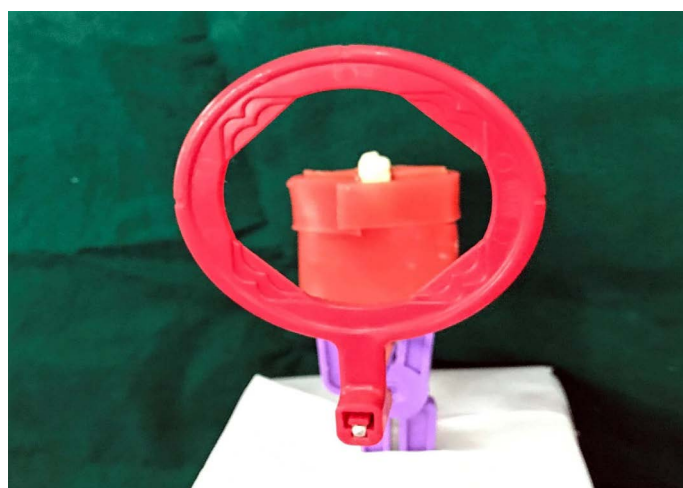


Figure 2b. Customized Apparatus used to standardize the distance and angulation of the teeth

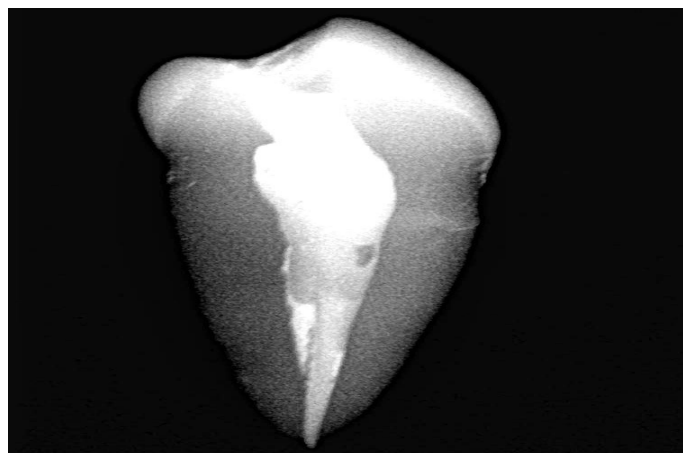


Figure 3a. Mesial shift angulation in RVG



Figure 3b. Paralleling technique in RVG

F-speed analogue film image exhibited superior images of obturation than LCBCT due to the presence of streaking artefacts from the sealer and GP, compromising the quality of image [12].

According to the study done by Rosen E. et al, in certain clinical situations, a more contemporary 3D imaging modality (such as CBCT imaging) may be ineffective, whereas a conventional 2D imaging modality (such as periapical radiography) may be of significant value [13].

According to Barrett J. F. et al, the main difficulty of CBCT imaging as compared to periapical radiographic images is the production of artefacts, which can be defined as “a systematic discrepancy [14].

Schulze R. et al (2011) identified the misconception that CBCT data contains fewer artefacts than their CT counterparts. CBCT imaging actually involves additional artefacts such as scatter and a generally higher noise level when a high-density material is present in the scanned volume, adversely affecting its diagnostic efficacy as proposed by Neves F. S. et al. (2014). The type of material used for root filling and its relative radiopacity as well as the CBCT acquisition parameters such as the voxel size and the field of view may sometimes influence the presence of artefacts observed in CBCT images [15,16]. In the present study also, CBCT could not be of any diagnostic value for evaluating the quality of obturation because of artefacts like noise which camouflage the voids and the obturation appears to be a dense opaque image.

The results of the current study are in contrast with Gupta et al (2015), Singh R et al (2015), Gambarini G et al (2016), B Huybrechts et al(2009) and Arora S et al (2014), where the evaluation of voids in the obturation could be assessed [4,17-19]. This could be due to the difference in CBCT hardware and software operated to visualize the voids in the obturation techniques or the voids could be calculated by evaluating the percentage of volume of root canal space before BMP and after obturation [20,21].

According to the present study area of the largest diameter of void were observed with mesial shift of tooth by 90° than the paralleling technique. According to Shetty et al (2014), for accurate reproduction the image receptor (X-ray film or digital sensor) must be parallel to the long axis of the tooth and the X-ray beam should be perpendicular to the image receptor and the tooth being assessed. For better radiographic

image acquisition two or three radiographs at different angles should be taken [22].

All obturations performed in the split-tooth model in the study done by Zielinski T et al (2008) also had voids; however, no quantification of the area or frequency of voids were made [23]. In this study we were able to determine the size of the void using Motic software.

In the present in vitro study, paralleling technique was done for complete analysis of voids present in the obturation followed by mesial shift of tooth by 90°. Area of the largest diameter of void was observed in GuttaFlow and Calamus obturating technique (Table 1). There was no statistical significant difference ($p>0.05$) with presence of void between the four obturating techniques. Comparing the area of the largest diameter of void present in the coronal, middle and apical third, the four groups showed statistical significant difference ($p>0.05$) in the coronal third (Table 2).

GuttaFlow showed few area of the largest diameter of void at the apical third, 30%, whereas, more area of the largest diameter of void was seen in the middle third, 90% (Table 3). This could be due to the lack of density in cold compaction technique over thermoplasticized obturation and lateral compaction. GuttaFlow expands slightly while setting and exhibit voids and gaps because of the filling technique (Hammad M et al., 2008).[24] 3D compaction techniques are considered to be superior over single-cone filling technique, because the volume of sealer is high relative to the volume of the cone, which promotes void formation and reduces the quality of the seal. The manufacturers of GuttaFlow recommend that it should be dispensed first in the apical part of the root canal and then a master GP cone is placed. This ensures the least amount of voids and gaps in the apical third [25].

Lateral compaction showed area of the largest diameter of void of 80% in the coronal third followed by GuttaFlow, Elements and Calamus (Table 2). A study conducted by Torabinejad et al, Goldman et al and Kersten et al, it was reported that “in lateral compaction pattern of voids was frequently where the fillings adapted reasonably well at the apical and coronal parts and showed longitudinal voids in the midroot section and excessive amounts of root canal sealer and open spaces between the GP cones” were observed [26, 27].

In the present study, Calamus showed the least number of area of the largest diameter of void at the coronal third 10% followed by the apical third 30% and middle third 40%. Similarly, Elements obturation technique exhibited least number of area of the largest diameter of void in the coronal third 20%, apical third 30% and middle third 50%. Calamus and Elements showed superiority in obturation at the apical, middle and coronal third when compared to lateral compaction (Table 3). Calamus obturation system showed the maximum percentage of obturated volume. This system is based on the principle of warm vertical compaction where the objective is to continuously and progressively carry a wave of warm GP along the length of the master cone, starting coronally and ending in apical corkage. This method advantageously serves to initially thermosoften the master cone, maximizes the volume of GP, and effectively increases hydraulics during obturation [28]. It utilizes different sizes manual pluggers with different working end diameters to compact GP efficiently to the canal walls [7]. The consistent flow of the Calamus unit does make the obturation of curve quicker and easier. The warm GP needs to be compacted as it cools to overcome any shrinkage that will normally occur. Since the softness of the GP is mass dependent, the GP at the orifice level has the greatest mass and will stay softest for the longest time in the canal, regardless of

Table 1. Mean, median and standard deviation values of area of the largest diameter of void present in the groups using paralleling technique and mesial shift of tooth by 90°.

	Groups	N	Mean	Standard deviation	Median	Kruskal Wallis test	
						Chi square value	p-value
Mesial Shift of tooth by 90°	A	10	0.015	0.010	0.014	6.76	0.08(NS)
	B	10	0.032	0.017	0.028		
	C	10	0.038	0.070	0.020		
	D	10	0.020	0.019	0.016		
Paralleling Technique	A	10	0.006	0.009	0	1.68	0.64(NS)
	B	10	0.012	0.016	0.007		
	C	10	0.012	0.027	0		
	D	10	0.008	0.012	0		

* $p<0.05$ statistically significant,
 $p>0.05$ Non significant, NS

Table 2. Fisher's exact test comparison of area of the largest diameter of void present between the four obturating techniques at the coronal, middle and apical third

Mesial Shift of tooth by 90°		Group				Total	Fisher's exact test
		A	B	C	D		p-value
Coronal Third	0	2	5	9	8	24	0.006*
		20.0%	50.0%	90.0%	80.0%	60.0%	
	>0	8	5	1	2	16	
		80.0%	50.0%	10.0%	20.0%	40.0%	
Middle Third	0	3	1	6	5	15	0.11(NS)
		30.0%	10.0%	60.0%	50.0%	37.5%	
	>0	7	9	4	5	25	
		70.0%	90.0%	40.0%	50.0%	62.5%	
Apical Third	0	6	7	7	7	27	1.00(NS)
		60.0%	70.0%	70.0%	70.0%	67.5%	
	>0	4	3	3	3	13	
		40.0%	30.0%	30.0%	30.0%	32.5%	

* $p<0.05$ statistically significant,
 $p>0.05$ Non significant, NS

Table 3. Fisher's exact test comparison of area of the largest diameter of void present between apical, middle and coronal third of the four obturating techniques

Group	Mesial Shift of tooth by 90°	Groups			Total	Fisher's exact test
		Coronal Third	Middle Third	Apical Third		p-value
A	0	2	3	6	11	0.25(NS)
		20.0%	30.0%	60.0%	36.7%	
	>0	8	7	4	19	
		80.0%	70.0%	40.0%	63.3%	
B	0	5	1	7	13	0.04*
		50.0%	10.0%	70.0%	43.3%	
	>0	5	9	3	17	
		50.0%	90.0%	30.0%	56.7%	
C	0	9	6	7	22	0.45(NS)
		90.0%	60.0%	70.0%	73.3%	
	>0	1	4	3	8	
		10.0%	40.0%	30.0%	26.7%	
D	0	8	5	7	20	0.50(NS)
		80.0%	50.0%	70.0%	66.7%	
	>0	2	5	3	10	
		20.0%	50.0%	30.0%	33.3%	

*p<0.05 statistically significant,
p>0.05 Non significant, NS

which technique is utilized [28]. The Elements obturating System heats the GP, enabling it to flow well and allows more efficient and effective compaction as reported by Budd et al (1991) [29].

Elements obturation techniques have advantages similar to that of Calamus obturation technique. Thermoplasticized obturation techniques always have an advantage over cold compaction technique. However, for efficient and effective obturation one should master the technique for void free compaction. CBCT could not be used as a diagnostic tool for the evaluation of the quality of obturation.

Future studies with larger sample size should be conducted to evaluate the efficiency of obturation techniques.

Conclusion

The present study concluded that CBCT could not be used to evaluate voids present in any of the obturation techniques, due to presence of artefacts like noise and beam hardening. Owing to this result RVG was used to evaluate the quality of obturating techniques and assessments of voids in apical, middle and coronal third of the root canal system.

It was observed that there was no significant difference in any of the obturation techniques. Lateral compaction obturation showed the large diameter of voids in the apical and coronal third, whereas in the middle third GuttaFlow showed the large diameter of voids. On the other hand, Calamus followed by Elements showed superior obturation at apical, middle and the coronal third.

Future studies with larger sample size should be conducted to evaluate the efficiency of obturation techniques.

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