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Comparison of volumetric analysis of lateral compaction & three different vertically compacted thermoplasticized obturation techniques using spiral CT – An *in vitro* study



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ABSTRACT

The objective of endodontic obturation is to provide a complete seal along the length of root canal system. This study was conducted to compare volumetrically, the laterally compressed gutta percha with three different vertically compacted thermoplasticized obturating systems using spiral CT, an *in vitro* study. Materials and methods included preparation of access cavities in 20 single rooted mandibular first premolars, followed by cleaning and shaping. Obturation was done with different thermoplasticized obturation systems: Group A – cold lateral; Group B – Calamus dual; Group C – E & Q Plus; Group D – Obtura II. Volume analysis was done using spiral computed tomography (CT). The percentage difference was calculated & statistically analyzed using one-way ANOVA and multiple comparisons between groups using Tukey's HSD test. The results of study has shown the statistical significance between all the groups with the p-value <0.0001. Multiple comparisons between different groups show statistical significance in all groups except Group C and Group D. With this significance in results, it can be concluded that Calamus dual showed the highest volume of obturation, followed by Obtura II and E & Q Plus. The least volume of obturation was observed in cold lateral condensation technique.

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1. Introduction

Success in endodontic treatment was originally based on the triad of the debridement, through disinfection and obturation with all aspects equally important. In an early radiographic study of success and failure, Ingle and colleagues indicated that 58% of treatment failure was due to incomplete obturation. The objective of obturation is to fill the root canal space and eliminate all portals of entry between the canal and the periodontium.[1] Gutta percha is the most commonly used root canal obturation material which is compressible, inert, dimensionally stable, tissue tolerant, radio-opaque & becomes plastic when heated.

Cold lateral condensation as an obturation technique is widely applied because of its advantages of controlled placement of gutta percha in the root canal and low cost.[2]

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However, its ability to replicate the internal surface of root canal has been questioned. The final filling is composed of a large number of GP cones tightly pressed together and joined by frictional grip and cementing substance, rather than a homogenous mass of GP. Voids because of spaces between individual GP cones and the root canal walls can be seen with poor root canal preparation, curved canals, inadequate lateral pressure during condensation, or mismatches between GP cones and the prepared root canal. The resulting fill in such cases would lack homogeneity and have to rely on sealer to fill the voids which may have questionable prognosis.[3]

Warm vertical condensation of GP can provide a high-density filling and better sealing at all portals of entry between the root canal and the periodontium. This technique was introduced to improve the homogenicity & surface adaptation of GP. Hence it can be more effective in filling lateral canals than cold lateral compaction.[4] With improvement in technology, several thermoplasticized gutta percha delivery systems, such as Obtura II, E & Q Plus, and Calamus dual have been introduced by different manufacturer. These instruments are designed to use differently formulated gutta percha at several temperature and extrusion rate to maximize gutta percha flow into irregularities of the canal system without any voids.[5,6] The significance of this study is to compare the efficacy of three different warm condensation equipment which are commercially available.

In a previous study of volumetric shrinkage, the teeth were sectioned longitudinally and photos were taken, which were analyzed with digital image processing to measure the surface area covered with obturation material. With spiral CT, three dimensional volume measurements are possible. Volume analysis with spiral CT gives more accurate measure than surface area measurement.[7–10]

The aims and objectives of study is to compare volumetrically the laterally condensed GP with vertically compacted thermoplasticized GP using three different system like E & Q Plus, Calamus dual and Obtura II using spiral CT (an *in vitro* study).

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Cold lateral condensation as an obturation technique is widely applied because of its advantages of controlled placement of gutta percha in the root canal and low cost.[2] However, its ability to replicate the internal surface of root canal has been questioned. The final filling is composed of a large number of GP cones tightly pressed together and joined by frictional grip and cementing substance, rather than a homogeneous mass of GP. Voids because of spaces between individual GP cones and the root canal walls can be seen with poor root canal preparation, curved canals, inadequate lateral pressure during condensation, or mismatches between GP cones and the prepared root canal. The resulting fill in such cases would lack homogeneity and have to rely on sealer to fill the voids which may have questionable prognosis.[3]

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2. Materials & methods

Twenty extracted single rooted mandibular premolars, which were planned for orthodontic extraction were selected. Teeth with fracture, cracks or any other defect were excluded from study. All the selected teeth were mounted on wax sheet (Fig. 1) & subjected to radiographic evaluation (Fig. 2) to eliminate the teeth with any variation. Access cavity was prepared and working length was determined radiographically. Those teeth having apical diameter of equivalent to 15 k-file were subjected to chemo-mechanical preparation with crown down technique using rotary ProTaper system. Master apical file was standardized up to F2 (8%) preparation of



Fig. 1 – Teeth mounted on wax sheet.

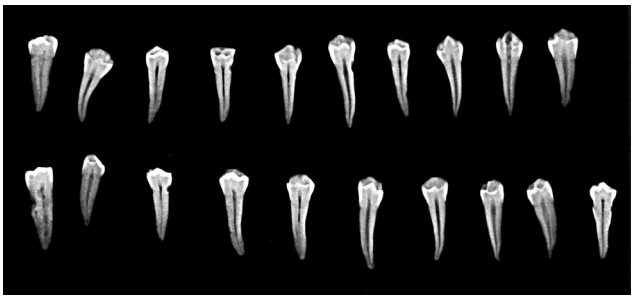


Fig. 2 – Radiographic examination of samples.

ProTaper system. 5.25% sodium hypochlorite was used for irrigation after each instrumentation. After chemo-mechanical preparation, corresponding F2 (8%) master cone of GP was selected. Teeth were divided into four groups of 5 teeth each and mounted on plastic stand using modeling wax to take spiral CT (Fig. 3). After CT imaging, the volume of root canal in each tooth was estimated (Table 1) using Siemens Emotion Duo model of spiral CT with aid of Syngo software.

Group **A – Cold lateral compaction technique:** A standardized GP master cone was fitted with tugback 0.5 mm from the apical foramen. AH plus sealer was applied to the root canal wall using finger spreader with counter-clockwise rotation. The apical part of master cone was coated with sealer & introduced slowly into the root canal until the working length was reached. Lateral compaction was done using standardized finger spreaders and medium fine accessory GP cones coated with sealer were used.

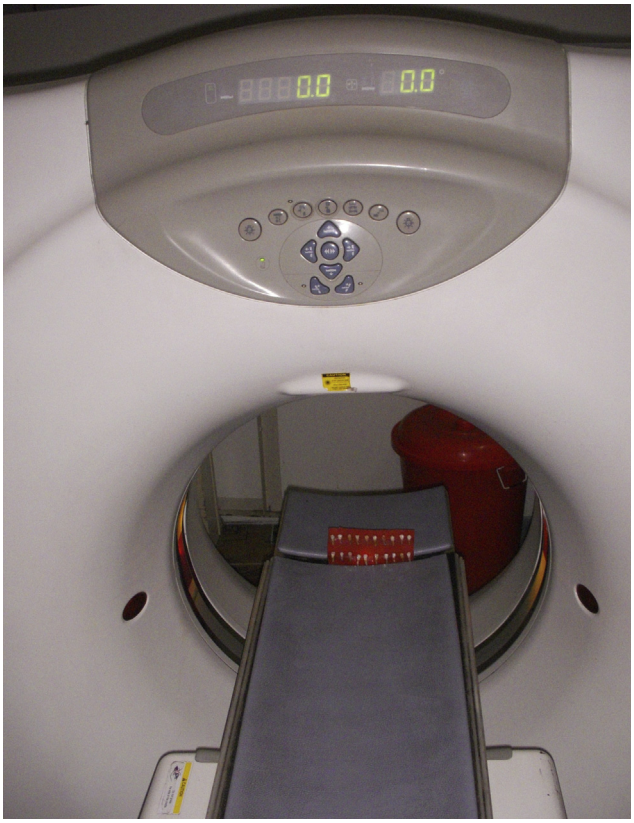


Fig. 3 – Spiral CT scan of samples.

Group **B** – Canals were filled using CALAMUS DUAL. A heating tip in the pen grip hand piece was selected to fit in the root canal without binding 4 mm short of working length. A standardized GP cone exhibiting a "short crisp" tugback sensation at 0.5 mm from working length was chosen. A thin coat of sealer was applied to the root canal walls to approximate depth of master cone using finger spreader. Then the master cone was lightly coated with a sealer at apical third and placed into the canal. The heating tip was activated to 200 °C and coronal excess of GP was removed till the orifice. The activated tip was inserted in a slow, steady motion into the canal depth 4 mm short of working length & was maintained there for 3–4 s. The tip was then allowed to cool for 10 s and removed after a single burst of heat applied for about 1 s. The backfilling of canals were done using 23 gauge injection needles with thermo-plasticized GP as a singular one step obturation. The system was used at 180 °C and 60% flow rate. The needle was placed short of binding and the GP was injected into the canal. As the GP was extruded into the canal, the needle was displaced coronally until GP was visualized at CEJ. The back pressure from the GP was resisted initially and then allowed to back the needle out of the canal. A prefit plugger was directed apically to compact the GP & prevent shrinkage during cooling.

Group C – E & Q Plus samples were obturated in the similar ways of Group B.

Group D – OBTURA II samples were obturated in the similar ways of Group B.

A second spiral CT was done and the volume of obturation in each tooth was estimated (Table 1) as before. The percentage volume of obturation was calculated as $\{(a - b) \times 100/a\}$, where 'a' was volume of root canal after biomechanical preparation and 'b' was the volume of root canal (voids) after obturation with the four different techniques.[7,8] Post BMP volumes (Table 1) were calculated using Syngo software from orifice of canal to its apex. Similarly, post obturation voids were calculated by identifying the void within the obturated teeth samples which appears to be radiolucent shadow on spiral CT scan.

2.1. *Statistical analysis*

The data was analyzed using SPSS version 12.0 software. The statistical significance of difference in the mean obturation fraction was evaluated using one-way ANOVA (Chart 1). The pair-wise significance of difference was studied using Tukey's HSD. The significance was tested at 5% level.

3. Result

One-way ANOVA indicated statistically significant difference of mean obturation fraction across the group with p-value <0.0001 (Chart 1). Pair-wise significance analysis was carried out using Tukey's HSD. The results are shown in following Table 2. It is evident from the table that except the comparison between E & Q Plus and Obtura II, all indicated significant difference in the mean obturation with $p < 0.05$ (Table 2).

Table 1 – Data collection.

Groups	Tooth no.	Working length	Post BMP volume (in cc)	Post obturation – volume of voids (in cc)	Post obturation volume (in cc)	% Of obturation	Average % of obturation
Group A Lateral compaction	1	19 mm	0.0360	0.0022	0.0338	93.88%	93.34%
	2	19.5 mm	0.0270	0.0019	0.0251	92.96%	
	3	20.5 mm	0.0360	0.0021	0.0339	94.16%	
	4	19 mm	0.0350	0.0023	0.0327	93.42%	
	5	21 mm	0.0260	0.0020	0.0240	92.30%	
Group B Calamus dual	6	23 mm	0.0300	0.0012	0.0288	96.00%	96.21%
	7	19.5 mm	0.0380	0.0013	0.0367	96.58%	
	8	22 mm	0.0370	0.0014	0.0356	96.22%	
	9	21.5 mm	0.0340	0.0014	0.0326	95.88%	
	10	20.5 mm	0.0360	0.0013	0.0347	96.39%	
Group C E & Q plus	11	21.5 mm	0.0370	0.0016	0.0354	95.68%	95.17%
	12	18 mm	0.0280	0.0013	0.0267	95.36%	
	13	18 mm	0.0300	0.0014	0.0286	95.33%	
	14	21.5 mm	0.0410	0.0021	0.0389	94.88%	
	15	22.5 mm	0.0390	0.0021	0.0369	94.61%	
Group D Obtura II	16	23 mm	0.0300	0.0015	0.0285	95.00%	95.22%
	17	20.5 mm	0.0280	0.0013	0.0267	95.36%	
	18	21 mm	0.0290	0.0012	0.0278	95.86%	
	19	20 mm	0.0280	0.0016	0.0264	94.29%	
	20	20 mm	0.0340	0.0015	0.0325	95.59%	

4. Discussion

The root canal is a complex system with many surface irregularities, fins, accessory and lateral canals and isthmuses. To seal this system, the filling material must adapt to all portions of root canal. Incomplete obturation of the canal system may result in failure of the endodontic treatment. Root canal filling materials are intended to prevent micro-organism and toxins in the canal from passing along the root canal space into the peri-radicular tissues.[1,8]

The focus of this study was to analyze volumetrically, the ability of three different thermoplasticized GP delivery systems to fill a prepared root canal to working length and then to compare it with cold lateral compacted GP. Capurro et al[11] had recommended the use of artificial root canals to prevent possible distortion of filling material during methodology. However, Goldberg et al[12] argued that using extracted teeth, instead of artificial canals, stimulate the clinical conditions more accurately. Mandibular first premolars were selected as it is single rooted and single canal tooth with ovoid coronal preparation which allows debridement of entire pulp chamber, funnels down to ovoid midcanal and is large enough buccolingually to allow passage of instrument used to enlarge and fill the canal space.[13] In this study, extracted human teeth were used to enhance the reliability of the investigation by correlating with clinical situation. The only restrictions imposed were that the teeth had to be single rooted & have only one root canal.[14] To reduce the variability all the canals were prepared by one operator using standard techniques. Rotary ProTaper were used to shape the canals. This permitted the 23 gauge needle (equal to size 60 K-file) to be placed, respectively, within 3.5–5 mm of working length in Group B, C, D. Resin based root canal sealer was used because it has been found in both clinical practice and in experimental research that adding a sealer improves the sealing property of GP as a root canal filling material regardless of technique used.[15–17] Percolation of periapical exudate into an incompletely filled root canal has been suggested as the primary

Table 2 – Inter group comparison using statistical analysis.

Comparison	*p*-value
One-way ANOVA	<0.0001
Tukey's HSD	
Lateral Compaction & Calamus dual	<0.0001
Lateral compaction & E & Q Plus	0.0003
Lateral compaction & Obtura II	0.0002
Calamus dual & E & Q Plus	0.0357
Calamus dual & Obtura II	0.0468
E & Q Plus & Obtura II	0.9989

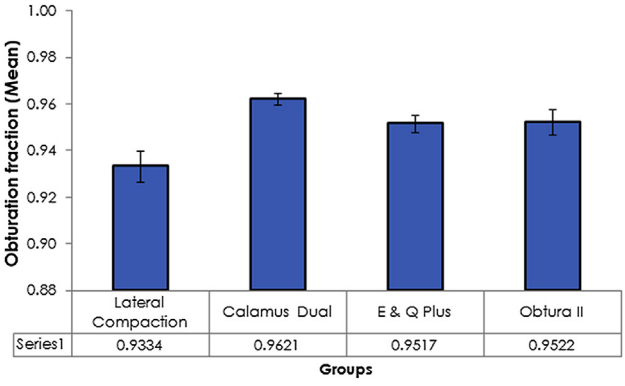


Chart 1 – Results of statistical analysis using one-way ANOVA.

cause of endodontic failure. Sealer alone is not efficient at prohibiting bacterial ingress. Therefore, it is important to minimize the amount of sealer and flow the GP into as many anatomical areas of the canal as possible.[14,18]

Numerous *in vitro* investigators have evaluated obturation techniques by comparing different variables such as length of fill,[19] defect replication,[20] and GP density[21] .In the current study, the focus was on the volume of obturation. Volume analysis was done with spiral CT. Three dimensional volume analysis is used in the field of medicine in a variety of applications (e.g. thoracic and abdominal aneurysm, intracranial aneurysm etc), which have proved that the accuracy is equal to that of conventional techniques like angiograms.[22] Volume analysis gives more accurate measure than surface area measurement.[7,8] With spiral CT, three dimensional volume measurements are possible without sectioning the specimens and thus avoiding the loss of material during sectioning. Nandini et al used volumetric analysis by spiral CT to determine the removal efficiency of calcium hydroxide intracanal medicament with two calcium chelators.[7] Kandaswamy et al used spiral CT for the volumetric analysis to assess the efficiency of laterally condensed, vertically compacted thermoplasticized and cold free flow GP obturation.[8]

Results of this study, revealed that the volume of obturation by all thermoplasticized obturation techniques were significantly better than cold lateral compaction technique (Chart 1). Among the three thermoplasticized techniques, Calamus dual had shown significantly better volume of obturation as compared to E & Q plus and Obtura II system (Table 2). Statistically results indicate that not much significant difference was present between E & Q Plus and Obtura II (Table 2). The Calamus obturation system is designed to extrude filling material with an adjustable flow rate. A motorized plunger maintains the steady flow rate when activated. In the present study, gutta percha cartridges with 23-G needles were used; the temperature (180 °C) and flow rate (60%) were adjusted according to the manufacturer's recommendations. The plunger in the E & Q Plus and Obtura II is not motorized, and the clinician can adjust the flow rate with a trigger.[3] It has been shown that the ability of gutta percha to flow is a reflection of the chemical formulation of gutta percha filling material and properties may vary with different brands.[23,24] Commercially available gutta percha is composed of an organic gutta percha polymer component and inorganic components (zinc oxide and barium sulfate). Gulgen-Filho et al[24] suggested that a low percentage of gutta percha polymer could result in reduced plasticity and a decreased flow rate of the filling material. Results from a study Karabucak et al[4] has confirmed that the different formulations of gutta percha filling material by different brand influence flow rate and root filling capacity.

Using thermoplasticized GP delivery systems as a singular obturation modality is technique sensitive and prone to potential GP extrusion because of lack of material control. However in current study, none of the study sample showed any extrusion of GP from apical foramen. Meticulous instrumenting techniques contributing to the formation of an apical plug can help prevent apical extrusion of material with low temperature TPI GP. When extrusions occur, peri-radicular tissues tolerate GP quite well, provided the canal system has been properly cleaned and sealed and there was no preoperative periapical lesion. However, it has been shown that the best results are obtained from root fillings within 0–2 mm from working length and that GP overfill has a negative effect on prognosis.[25]

In addition, excessive canal enlargement to accommodate the injection needles has been cited as a problem with thermoplasticized gutta percha delivery systems. The advent of increased taper rotary files has potentially helped circumvent this problem permitting the operator to achieve a desirable cone-shaped tapered canal without over instrumenting the apical portion.[20]

Lateral compaction offers the advantage of controlled placement of gutta percha into the root canal, but the obturation is time consuming,[26] lacks homogeneity with spaces formed between cones,[27] poorly adapts to the canal walls,[28] and may induce vertical root fractures.[29,30] The continuous wave of condensation technique, developed by Buchanan,[31] serves as a hybrid of the cold lateral and warm vertical techniques. The technique takes advantage of a well-fit master apical cone of lateral compaction to reduce apical extrusion of gutta percha and adds the benefits of warm vertical compaction to thoroughly obturate the root canal system. The continuous wave of condensation technique involves placing a single master cone and applying the heated pen tip at 200 °C[32,33] to a depth 3–4 mm short of working length.[34] The canal is then backfilled with warm gutta percha with an increment of up to 10 mm in depth.[35] The continuous wave of condensation is less time consuming, provides less microbial coronal leakage,[36] and better adapts to grooves and depressions of the canal walls and lateral canals than lateral compaction.[19,37]

In a similar by Kandaswamy et al,[8] volumetric analysis was done using spiral CT for comparison between cold lateral compaction, vertically compacted thermoplasticized gutta percha (E & Q Plus system) and cold free flow gutta percha (gutta-flow). Study concluded that cold free flow obturation technique showed highest volume of obturation followed by E & Q Plus system and lateral condensation technique. Lea et al[21] compared quantitatively the density of standard cold lateral gutta percha compaction & warm vertical compaction (Heated System-B) by using continuous wave of condensation technique and concluded that warm vertical condensation resulted greater gutta percha fill by weight and density compared with cold lateral compaction technique. Najla Al-Dewani et al[14] compared cold lateral condensation and low temperature thermoplasticized gutta percha root filling (Ultrafill) and concluded that later has better sealing ability than its counterpart. Collin et al[20] used a split tooth model with artificially created intracanal wall defect to compare cold lateral compaction with warm lateral and warm vertical compaction (Obtura II) of gutta percha. Statistically significant better results were seen with both warm techniques (Obtura II) compared to cold lateral obturation. Karabucak et al[4] evaluated the ability of two commercially available thermoplasticized system i.e. Obtura II and Calamus to fill artificially created lateral canals in stimulated plastic teeth using various type of commercially available GP. The result indicated that flow of filling material to lateral canal is function of viscoelastic properties of filling material rather than mechanical properties of delivery systems.

5. Conclusion

In this study, all the three thermoplasticized obturation techniques have shown greater percentage of obturation than conventional lateral compaction. Among the three thermoplasticized obturation technique, Calamus dual has significantly shown better volume of obturation than its counterparts. As laboratory testing cannot exactly stimulate *in vivo* conditions, the clinical relevance of this *in vitro* study should be interpreted with caution, but it would appear that the thermoplasticized obturation techniques is an alternative to lateral compaction of gutta percha for obturation of root canals.

Conflicts of interest

All authors have none to declare.

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PFA MISSION

PIERRE FAUCHARD ACADEMY

The purpose of the Academy as an honour society shall be the elevation of dentistry to the highest degree of professionalism attainable as made manifest by the practice of integrity and ethics. The academy shall position itself to accomplish this mission by publicly honouring in a significant and noteworthy manner those practitioners who exemplify these ideals. The Academy shall further expand the accomplishment of this stated purpose by creating a Fellowship, the selection to which in itself become an honour. The selection of Fellows commensurate with the honour-fellowship ideal shall be the practice of all sections. It is through this purpose in deed and action that the causes, aims and objective of the Academy for the benefit of dentistry and the society that it serves will be achieved