Volumetric Analysis of Root Filling with Cold Lateral Compaction, Obtura II, Thermafil, and Calamus using Spiral Computerized Tomography: An In Vitro Study

Abstract
Aim: The aim of the present study is volumetric analysis of root canal filling with cold lateral compaction, Obtura II, Thermafil, and Calamus using spiral computerized tomography (SCT).

Materials and Methods: Root canals of eighty mandibular premolars were instrumented using rotary ProTaper, and the volume of the canal space was measured using spiral computerized tomography (SCT). The teeth were divided into four groups of twenty teeth each, and root canals filled by lateral compaction technique, Thermafil carriers, Obtura II, and Calamus techniques, respectively. AH Plus was used as a sealer with all techniques. The filled volume in each canal was measured using SCT, and the percentage of obturated volume (POV) was calculated. The data were statistically analyzed using ANOVA, Kruskal–Wallis test, and Mann–Whitney U-test. Results: The four groups were comparable in canal volume. The overall POV was 78.11%, 85.72%, 82.50%, and 87.89% for lateral compaction, Thermafil, Obtura II, and Calamus, respectively (P < 0.05). Conclusion: The greatest POV was obtained with Calamus and Thermafil. Voids were seen in all root fillings.

Keywords: Obtura II, obturation, percentage of obturated volume, spiral computerized tomography, three-dimensional, volumetric analysis

Introduction
Root canal obturation involves the three-dimensional (3D) filling of the entire root canal system and is a critical step in endodontic therapy. There are two purposes of obturation that is elimination of all avenues of leakage from the oral cavity or the periradicular tissues into the root canal system and sealing within the root canal system of any irritants that remain after appropriate shaping and cleaning of the canals, thereby isolating these irritants. The introduction of thermoplastic gutta-percha (GP) to dentistry in the mid-19th century was a turning point in endodontic treatment. Plasticity combined with physical durability made it possible for the material to move into the recesses of the root canal system and to adapt to the canal walls.[1]

Quality of root fillings can be assessed by various experimental methods such as radioisotope, dye penetration, fluid filtration, bacterial leakage, microscopic analysis, clearing techniques, and Micro computerized tomography. It has been reported that spiral computerized tomography (SCT) has been a useful tool in various in vivo and laboratory studies. It was stated that with SCT, 3D volume measurements are possible without sectioning specimens, thus avoiding loss of material.[2]

Hence, the aim of this study was to assess and compare the total percentage of volume (POV) of the root canal filled with GP, as well as POV at three different levels – coronal, middle, and apical third of root canals, obturated with cold lateral condensation, Thermafil, Obtura II, and Calamus techniques using SCT.

Materials and Methods
Specimen preparation
This study sample comprised eighty extracted, permanent single-rooted human teeth, which were selected, cleaned of extraneous tissue and calculus, and then disinfected by 5.25% sodium hypochlorite for 2 weeks. Subsequently, the teeth were
decoronated at the cementoenamel junction (CEJ) and stored in deionized water before instrumentation.

**Tooth preparation**

Access cavity preparation was carried out using #2, #4 round carbide burs to establish an initial outline form. The remaining pulp was removed, and the working length was determined by introducing a size 10 K-file (Dentsply Maillefer) into the canal until it could be seen at the apical foramen.

The canals were prepared using ProTaper nickel–titanium rotary files (Dentsply Maillefer Ballaigues, Switzerland). The canals were irrigated between each file with 2 ml of 5.25% NaOCl. A size 15 K-file was introduced to maintain patency of the apical constriction. The canals were all prepared to a F2 ProTaper file. In between, recapitulation was carried out using #15 K-file. After completion of the preparation, all specimens were irrigated with 5 ml of 5.25% NaOCl for 60 s and dried with paper points (Dentsply/Maillefer). Teeth were then randomly distributed into four groups of twenty each and were mounted on wax.

Specimens were scanned using SCT (Siemens). They were then viewed under high resolution, both cross-sectionally and longitudinally with a constant thickness of 0.5 mm/slice and a constant spiral or table speed of 0.5 and 140 kVp [Figures 1 and 2]. The scanned data were then transferred to Syngo (Siemens) image analysis and evaluated. The area of prepared root canal in each slice was measured from CEJ to the apex of the root. The volume of root canal in each slice was calculated by multiplying the root canal area by the slice thickness (0.5 mm). Finally, the volume of each canal was calculated. The root length was divided into three equal parts; coronal, middle, and apical thirds, and the volume of each segment was calculated separately. AH Plus was used as the sealer.

**Group I: Cold lateral compaction**

The process included first checking the size F2 cone fitted with tugback. Sealer (AH Plus) was introduced into the canal with a lentulospiral. The master apical cone tip was dipped in sealer and then seated apically. The accessory cones were compacted 1 mm short of working length. No vertical compaction was performed.

**Group II: Thermafil obturation technique**

Thermafil obturator of the same size as the size verifier that fitted passively at working length was selected. A rubber stop was adjusted to coincide with the working length taken from the root. A thin layer of sealer was placed at the coronal orifice; the Thermafil obturators were heated in the ThermaPrep oven as per manufacturer’s instructions, and the thermoplasticized GP was delivered into the canals. The carrier was stabilized with the index finger, and after GP was cooled, the carrier was cut using a round bur.

**Group III: Obtura obturation system**

A 20-gauge Obtura (Obtura Spartan, Fenton, MI, USA) needle tip was selected. The tip was inserted into the canal 3–5 mm short of the working length. The temperature was set at 200°C, the trigger was pressed so that the molten GP flowed, and the tip was withdrawn slowly out of the canal. The apical segment was compacted using appropriate Obtura Pluggers. Backfilling was achieved by the application of thermoplasticized GP in 4–5 increments, followed by uniform compaction with pluggers.

**Group IV: Calamus obturation system**

The master cone was lubricated lightly with sealer and gently inserted to length. The Calamus Electric Heat Plugger was activated and utilized to sear off the master cone at the CEJ. This plugger was used with short, firm
vertical strokes to scrape warm GP off the canal walls and flatten the material coronally. The working end of
the plunger was used to vertically press on this flattened
platform of warm GP for 5 s. Calamus backfill was
performed by positioning the tip of the warm cannula
against the previously packed GP material for 5 s. For
backfill, the flow handpiece was activated, and 3–4 mm
segment of warm GP was dispensed into the canal. The
backfill technique was continued in the manner described
until the canal was completely filled.

A second SCT scan was performed to determine the volume
of GP and sealer. POV in each tooth was calculated. POV
in the coronal, middle, and apical thirds for each tooth was
calculated separately.

Statistical analysis
Statistical analysis was performed with nonparametric tests
(ANOVA, Kruskal–Wallis, and Mann–Whitney U-test). The
level of significance was set at $P < 0.05$.

Results
The volume (mean and standard deviation) of root
canals after cleaning and shaping for each group is given
in Table 1. The four groups were statistically comparable
in respect of canal volume ($P > 0.05$). All POV values
are summarized in Table 1. The Calamus and Thermafil
gave the highest POV values and were significantly
different in comparison with Obtura II and lateral
compaction ($P < 0.05$).

An intragroup comparison of POV at apical, middle, and
coronal third of the root canal as shown in Graph I also
showed statistically significant difference.

Discussion
Successful root canal treatment depends critically on
controlling pulp space infection.$^{[3]}$ The final objective of
endodontic procedures should be the total obturation of
the root canal space.$^{[4]}$ Biologic necessity requires the
elimination of the protein degradation products, bacteria,
and bacterial toxins which emanate from necrotic and
gangrenous root canals. While these irritants may be
eliminated by extraction of the tooth, the health of the
dentin is secured more soundly if they are eliminated by
the cleaning and shaping and total obturation of the root
canal system. In the final analysis, it is the sealing off of the
complex root canal system from the periodontal ligament
and bone which insures the health of the attachment
apparatus against breakdown of endodontic origin.$^{[5]}$

Traditional methods of evaluating root fillings have
disadvantages. On sectioning the root, there could be a loss
of material which might mimic voids. Radiographs give
only two-dimensional interpretations. The time taken for
fluid filtration and clearing techniques may be a concern.
Dye penetration studies do not correlate clinically, whereas
dye extraction studies evaluate only the apical third of the
tooth.$^{[6]}$ Bacterial leakage studies do not simulate exact
clinical conditions, need long periods of observation, and
do not allow quantification of the number of penetrating
bacteria.$^{[7,8]}$ A literature search revealed that only sectioning
studies have been undertaken to assess thermoplasticized
root fillings at various levels.$^{[2]}$ SCT, a noninvasive
technique, gives a 3D interpretation at various levels,
avoids loss of material, yields reproducible results, and
the specimens can be used for further research. The specific
location of voids can be determined accurately.$^{[9,10]}$

In this study, Calamus and Thermafil gave the highest overall
POV. The reason could be that the use of heat-softened GP
had created a better homogeneous mass with less voids and
better adaptation of the GP to the canal wall, whereas cold
lateral compaction gave the least POV.$^{[11]}$

Overfilling is the most common concern expressed about
using the Obtura system [Figure 3]. Pressure should be
applied only on the softened GP but not on canal walls
during condensation. The tapered preparation enhances the
flow of the plasticized material, whereas the Coke bottle
preparation negates the flow. While attempting to provide
a hermetic seal, we have to keep in mind that when heated
GP cools, always there is contraction.$^{[12]}$

Lateral compaction had 78.1% of overall filling, the lowest
value of all the fillings [Figure 4]. This was mainly because
this technique does not produce a homogeneous mass and
may leave spaces between the GP and the dentinal walls
or accessory cones. The accessory and master cones are
laminated and remain separate from each other. Sometimes,

![Graph 1: Comparison of % volume filled for all techniques](image-url)
Jindal, et al.: Volumetric analysis of different obturation techniques

The sealer fills the space between the cones, often depicting a denser root fill. Sequential injection and then multiple compactions of warm GP compensate for the contraction of GP that takes place on cooling and hence creates a dense obturation.

Group IV (Calamus obturation system) Figure 5 showed the maximum POV. This comparatively newer 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. It utilizes different sizes manual pluggers with different working end diameters to compact GP efficiently to the canal walls.[13]

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 which technique is utilized.

Thermafil produces a homogeneous 3D obturation [Figure 6]. It allows simple, fast, and predictable fillings of root canals, especially useful for small curved canals. Thermafil technique requires minimal compaction only in coronal end, so it produces few strains during compaction of GP. It easily flows around curves and canal irregularities providing a greater density of GP at the apical portion of the filling. Thermafil technique leaves a plastic carrier in the canal which poses a problem if post is required or the case has to be retreated. Special oven (ThermaPrep plus oven) is required to heat thermofil cones. In curved canals, carrier usually gets stripped of GP in curvature.[14,15]

When comparing the POV of coronal, middle, and apical thirds of lateral compaction, Thermafil, Obtura, and Calamus techniques, there was a difference in the efficacy of fillings. It was seen that the POV of coronal third was slightly more than apical third [Figure 7]. Even though pluggers were used in case of Obtura for coronal compaction and lack of additional vertical condensation with pluggers in the Thermafil group, there was a decrease in efficacy. This could be due to the mismatch in taper of the instrument to that of the enlarged canal orifice.

Conclusion

The aim of obturating the root canal system is to perfectly seal the root canal space to prevent penetration of bacteria and their products into the periradicular tissues and create a favorable biological environment for healing of periapical tissues to take place. A hermetic 3D obturation of the root canal system is one of the conditions under which long-term successful root canal therapy can be achieved. Voids created by inadequate fusion of the GP cones; penetration of bacterial toxins and their flow into periapical tissue from oral cavity jeopardize the endodontic treatment success.

- Voids were seen in all the root fillings
- Calamus obturating technique showed the least spaces or voids
Jindal, et al.: Volumetric analysis of different obturation techniques

• Lateral compaction produced the maximum spaces or voids
• Warm vertical compaction exhibited least voids than cold lateral compaction.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References
1. Ørstavik D. Materials used for root canal obturation: Technical, biological and clinical testing. Endod Topics 2005;12:25-38.
2. Anbu R, Nandini S, Velmurugan N. Volumetric analysis of root fillings using spiral computed tomography: An in vitro study. Int Endod J 2010;43:64-8.
3. Whitworth J. Methods of filling root canal. Princ Pract Endod Topics 2005;12:2-24.
4. Endodontics: Colleagues for Excellence. Obtration of the Root Canal Systems. Available from: http://www.aae.org/uploadedfiles/publications_and_research/endodontics_colleagues_for_excellence_newsletter/fall09ecfe.pdf. [Last accessed on 2009].
5. Schilder H. Filling root canals in three dimensions 1967. J Endod 2006;32:281-90.
6. Camps J, Pashley D. Reliability of the dye penetration studies. J Endod 2003;29:592-4.
7. Siqueira JF Jr., Rôças IN, Favieri A, Abad EC, Castro AJ, Gabyva SM. Bacterial leakage in coronally unsealed root canals obturated with 3 different techniques. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:647-50.
8. Siqueira JF Jr., Rôças IN, Lopes HP, de Uzeda M. Coronal leakage of two root canal sealers containing calcium hydroxide after exposure to human saliva. J Endod 1999;25:14-6.
9. Nathani P, Naik S. Endodontic applications of spiral computed tomography. Peoples J Sci Res 2009;2:31.
10. Kandaswamy D, Venkateshbabu N, Krishna RG, Hannah R, Arathi G, Roohi R. Comparison of laterally condensed, vertically compacted thermoplasticized, cold free-flow GP obturations – A volumetric analysis using spiral CT. J Conserv Dent 2009;12:145-9.
11. Bhatt A, Rajkumar B. A comparative evaluation of volumetric analysis during lateral condensation technique, Gutta flow technique and thermo plasticized technique (System B and Thermafil) using spiral computed tomography: In-vitro study. Int J Sci Res 2015;4:299.

12. Tanikonda R, Sekhar S. Flowable Gutta-percha in endodontics – Review and few case reports. J Res Adv Dent 2013;2:86-90.

13. Ruddle CJ. Filling root canal systems: The Calamus 3-D obturation technique. Dent Today 2010;29:76, 78-81.

14. Cohen S, Burns RC. Obturation of the cleaned and shaped root canal system. Pathways of the Pulp. United States of America: John Schefer; 2010. p. 349-88.

15. Chu CH, Lo EC, Cheung GS. Outcome of root canal treatment using Thermafil and cold lateral condensation filling techniques. Int Endod J 2005;38:179-85.