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Dentistry Section

Comparison of Two Different Continuous Wave Compaction Gutta-percha Obturation Techniques for Filling Oval-shaped Root Canals: An In-vitro Study

SUMANTHINI V MARGASAHAYAM[1], GAURAV U CHAUDHARI[2], VANITHA U SHENOY[3], SHREYAL N DESHMUKH[4], TANVI SATPUTE[5], JAYEETA VERMA[6]

ABSTRACT

Introduction: The quality of Gutta-percha (GP) filling techniques depends on canal dimensions and anatomy. Thermoplasticised GP obturation techniques need to be modified in accordance to the root canal space anatomy.

Aim: To evaluate the efficacy of continuous wave and modified continuous-wave compaction GP techniques in obturating ovoid canals.

Materials and Methods: The present in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics in MGMDCH, Navi Mumbai, Maharashtra, India, from October 2019 to December 2019 on 45 single rooted human teeth were selected and mounted in Eppendorf tubes. The canals were cleaned and shaped using the Protaper Next rotary system. The specimens were divided into three groups based on the obturation technique: Group 1-Lateral Compaction (LC), Group 2-Continuous Wave Compaction (CWC), and Group 3-modified continuous-wave compaction. After obturation, the specimens were radiographed in labial and distal views. Subsequently, the specimens were removed from the Eppendorf tubes, and the extrusion of filling materials was assessed. The radiographic images were analysed using image analysis software, and the void area was measured. The obtained data was tabulated and statistically analysed using the Kruskal-Wallis test, followed by Post-hoc Dunn's test.

Results: The warm compaction techniques showed denser obturations compared to LC and were statistically significant ($p<0.0001$) by the Kruskal-Wallis test in the distal view. Post-Hoc analysis using Dunn's test for the density of obturation in the distal view showed a statistically significant difference between Group 1 compared to Group 2 ($p=0.000002$*) and Group 3 ($p=0.000204$*). Extrusion in Group 3 was comparable to Group 1, while the highest extrusion was observed in Group 2.

Conclusion: The modified continuous warm compaction technique showed dense and homogenous obturation comparable to the continuous wave technique and outperformed the LC technique. Additionally, the modified continuous warm compaction technique exhibited less extrusion compared to the continuous warm compaction technique.

Keywords: Cold lateral compaction, Hot temperature, Oval root canals, Root canal preparation, Root canal obturations, Warm vertical compaction

INTRODUCTION

Complete obturation of the root canal system with an adequate apical and coronal seal is a prerequisite for successful endodontic therapy. Incomplete and inadequately filled canals encourage microorganisms to thrive, culminating in persistent post-treatment disease when the periapical or coronal seal is compromised [1]. Gutta-percha (GP), combined with a root canal sealer, is the most commonly used obturation material. It is utilised in various obturation techniques, including Lateral Condensation (LC), Warm Vertical Compaction (WVC), continuous wave, injectable GP techniques, and others [2]. The root canal is considered well-obturated if a continuous radiopaque mass is observed in the radiograph within the canal space. It should be free from voids and properly adapted to the outline of the root canal, ending 0-2 mm short of the apex [3].

The LC technique has been the most popular obturating method. It provides a plausibly good apical seal by compacting GP points with a spreader from the apical to coronal direction. However, a major drawback of the LC obturation technique is the inability of the cold GP cones to adapt to the canal walls and adequately fill the canal space, especially in the presence of canal irregularities [4].

To overcome the deficiencies of LC, warm GP obturation techniques such as Continuous Wave Condensation (CWC) and thermoplasticised GP methods were developed. When heated above 60°C, GP becomes more plastic and easier to adapt to the irregularities in the root canal space, resulting in denser and more homogeneous obturation [5,6]. Several thermoplasticised GP techniques have been used in the past, including thermomechanical compaction, CWC, and core carrier techniques, particularly in oval-shaped canals [7]. However, these techniques may have a lower filling ability in the apical third, probably because the GP may not have undergone any plasticising due to inadequate heat transmission [8]. Furthermore, in thermoplasticised techniques, a definitive apical matrix is crucial to prevent extrusion of the obturating material, which could compromise the healing of periapical tissues. When an existing periradicular lesion is present, overextended root canal filled teeth have a worse prognosis [3]. Though warm GP filling techniques have proven to give clinically successful results when compared to the LC technique, the quality of obturation depends on factors such as canal dimensions, apical constriction, and shape of the root canal. Despite the promising performance of thermoplasticised GP obturation techniques, achieving complete and homogeneous filling of oval-shaped canals remains a difficult task [7]. These canals are often flattened in the mesiodistal direction, wider mesiodistally, and

narrower in the labial or buccal aspect. They present challenges in chemo-mechanical disinfection as well as obturation [8,9]. Previous reports have indicated that hand and rotary instrumentation of oval-shaped canals may leave untouched canal extensions or recesses, which can retain remnants of necrotic pulp tissue, dentin debris, and bacterial biofilms. The presence of residual biofilms and infected debris can be a potential source of persistent infection and treatment failure [10,11].

In the current study, a modified CWC technique was employed to assess the quality of obturation in teeth with oval canal morphology. This procedure involves using an initial LC technique with GP cones, followed by a down-pack with the CWC technique. This modified CWC (MCWC) technique was previously applied by Guess GM et al., to obturate mesiobuccal roots of mandibular molars [4]. However, there are no existing studies in the literature where the MCWC technique has been used to assess the obturation of oval canals. Therefore, the primary objective of present study was to evaluate the radiographic quality of obturation in ovoid canals when obturated with LC, CWC, and MCWC GP obturation techniques. The density was evaluated from both labial as well as distal views. The secondary objective was to observe the presence of sealer and/or GP extrusion from the apical foramen of the root canal when obturated using the aforementioned techniques. The null hypothesis tested was that there would be no difference in the quality of obturation when oval root canals are obturated with two different CWC GP obturation techniques.

MATERIALS AND METHODS

The present in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics at MGMDCH in Kamothe, Navi Mumbai, Maharashtra, India, from October 2019 to December 2019. The study was conducted after obtaining approval from the Institutional Ethics Committee (MGM/DCH/IEC/NO32/19) and in accordance with the Declaration of Helsinki.

Inclusion and Exclusion criteria: The inclusion criteria involved selecting extracted human permanent teeth with intact, mature, single oval roots and a single canal. Each tooth was radiographed in buccolingual and mesiodistal projections to categorise them and detect possible obstructions. Canals were classified as flat-oval when the coronal and middle third of the buccolingual diameter were four times larger than the mesiodistal diameter [12]. Teeth with more than one canal, bifurcation or trifurcation, apical delta, isthmus, lateral or accessory canals, apical curvature, previous endodontic treatment, immature or resorbed apex, and canal obstructions or calcifications were excluded from the study. The teeth were cleaned of calculus and periodontal tissue using an ultrasonic scaler and decoronated to obtain a standardised tooth length of 18 mm.

Sample size calculation: The sample size was estimated using the Cochran formula, based on the findings of a previous study by Guess GM et al., [4,13]. For a significance level of 0.05 and a power of 80%, the sample size was determined to be 15 per group. A total of 45 extracted human single-rooted teeth were selected after applying the inclusion and exclusion criteria.

Study Procedure

The parameters studied were the density of obturation radiographically in the labial and distal proximal views. The extrusion of root canal filling material was assessed by visualisation of the root apex post-obturation.

Root canal preparation involved exploring the root canal for patency using a number 10 K file (Mani INC, Japan), and completing the access opening with a number four round bur (Mani INC, Japan). The coronal two-thirds were enlarged with the X1 Protaper Next rotary system (Dentsply Maillefer, Ballaigues, Switzerland), followed by working length determination. The working length was established by subtracting 1 mm from the length at which the file's tip was visualised from the apical foramen, resulting in a length of 17 mm. The specimens were mounted in Eppendorf tubes (Eppendorf India Private Limited, Cidco Industrial Estate, Ambattur Chennai, India) covered with an opaque film [Table/Fig-1].

[Table/Fig-1]: The specimens mounted in Eppendorf tubes covered with an opaque film.

Canal cleaning and shaping were accomplished using the Protaper Next 6% rotary file system, up to size 30, and circumferential filing with a 2% number 30 hand K-file by crown-down technique. The root canal was copiously irrigated with 5% Sodium Hypochlorite (NaOCl) (Trifarma, Thane). Passive Ultrasonic Irrigation (PUI) was performed using an Irrisafe tip (Satelec, Acteon, France). The smear layer was removed by irrigating with 2 mL of 17% Ethylenediaminetetraacetic Acid (EDTA) (Prime dental products Pvt. Ltd., India), followed by rinsing with Normal Saline (NS) and 2 mL of 5% NaOCl. Finally, the canals were irrigated with 2 mL of NS. The specimens were divided into three groups of 15 roots each, based on the obturation technique:

- Group 1: Lateral Compaction (LC)
- Group 2: Continuous Wave Compaction (CWC)
- Group 3: Modified CWC obturation (MCWC)

The specimens in Group-1 were obturated using the LC technique. A master GP cone (Dentsply Maillefer instruments holding SAR Switzerland) of size 30 with a 06% taper was selected and inserted into the root canal until full working length, checked for tug back. Digital Intraoral Periapical (IOPA) radiographs were taken to confirm the adaptation of the master cone. All radiographs were captured using a Carestream 60 KVp dental x-ray unit (Carestream Health, Inc. 150 Verona Street Rochester, NY 14 608, USA) with Radio VisioGraphy (RVG) 5200 (Carestream Health, Inc. 150 Verona Street Rochester, NY 14 608, USA) at an exposure time of 0.150 seconds. The canal was dried with absorbent paper points (Dentsply Maillefer, Ballaigues, Switzerland), and AH Plus (Dentsply detrey GmbH, Germany) root canal sealer was mixed according to the manufacturer's instructions and applied to the root canal wall using the Master Apical File (MAF) number 30 K-file. The master GP point was coated with sealer and placed to full working length. The canal was obturated using the LC technique. The protruding GP points were seared off at 1 mm below the level of the cementoenamel junction of the tooth using heated hand pluggers (GDC Fine Crafted Dental Pvt., Ltd., Hoshiarpur). The access cavity was restored with intermediate restorative material, IRM (Dentsply, Tulsa Dental, Switzerland).

Specimens in Group-2 were obturated using the CWC technique. After selecting an appropriate master cone as described in Group-1,

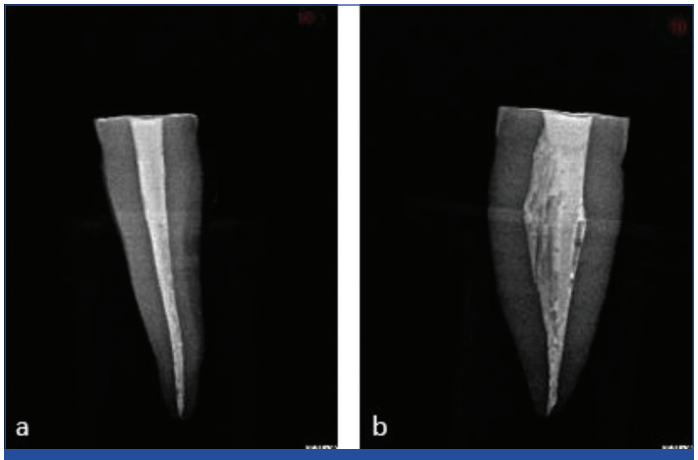
a hand plugger was pre-fitted to within 5 mm from the calculated working length. Sealer application was done as in Group-1. A rubber stopper was placed 5 mm short of the working length on the 0.5 mm M plugger of the Denjoy Freefill unit (Denjoy dental Co, Ltd., China), and the temperature was set to 200°C in the touch mode.

The premeasured master GP point was cut 0.5 mm at the tip to compensate for the vertical movement of GP, coated with root canal sealer, and slowly placed into the canal. The preselected plugger tip was inserted into the canal with gentle but firm pressure while activating the device. When the rubber stopper reached the reference point, the heat was deactivated while firm pressure was maintained on the plugger for 5 to 10 seconds. Afterward, the tip was activated for 1 second to facilitate plugger removal. Compaction was completed using a preselected cold hand plugger against the GP.

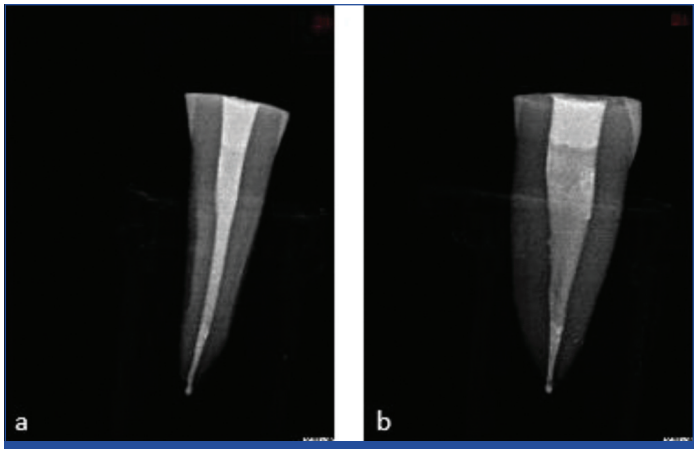
The remaining coronal canal space was backfilled using injectable thermoplasticised GP (Denjoy Freefill, Denjoy Dental Co, Ltd., China). A 0.6 mm diameter injection needle was selected, and a rubber stopper was placed at 12 mm or at the level that coincided with the remaining coronal space of the root canals. The unit was set to 200°C, and GP was injected into the canal, ensuring the needle tip was entirely immersed within the extruding GP as the canal was filled to 1 mm short of the Cementoenamel Junction (CEJ). The softened GP was compacted with a large-sized hand plugger, maintaining constant pressure while the GP hardened. The access cavities were later restored with IRM.

Specimens from Group-3 were obturated using the modified CWC technique [4]. In Group-3, the apical 5 mm of the canal was obturated using LC, similar to Group-1. Next, a preselected plugger tip (as described in Group-2) was inserted into the canal and activated to remove excess coronal GP, followed by vertical compaction with a cold hand plugger, as in Group-2. The remaining coronal canal space was backfilled with injectable GP, and the access cavities were restored with IRM.

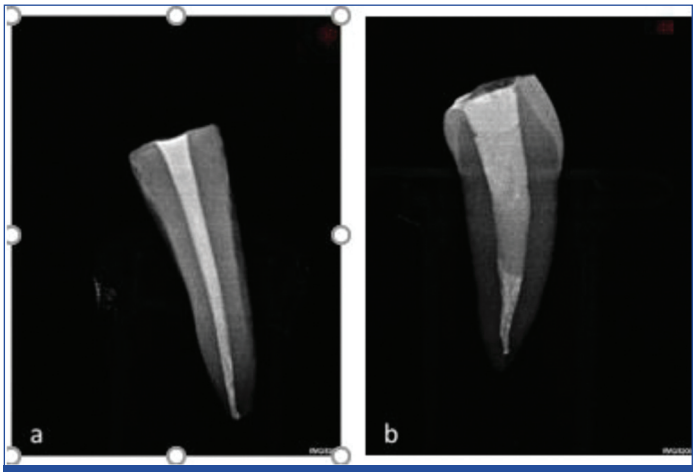
Assessment of obturation: Digital Intraoral Periapical (IOPA) images were taken for all the specimens using a customised prop at an exposure time of 0.150 seconds. The radiographs were evaluated for the quality of obturation from both the labial and distal views for the LC technique [Table/Fig-2a,b], CWC technique [Table/Fig-3a,b], and MCWC technique [Table/Fig-4a,b]. All the specimens were coded, and an observer blinded to the procedure assessed the radiographs. The Image J 1.52a software (Wayne Rasband National Institutes of Health, USA) was used to measure the complete area of filled canal space and the void area.



[Table/Fig-2]: Radiograph showing obturation with lateral compaction technique in: a) Labial view; b) Distal view.



[Table/Fig-3]: Radiograph showing obturation with CWC technique in: a) Labial view; b) Distal view.



[Table/Fig-4]: Radiograph showing obturation with MCWC technique in: a) Labial view; b) Distal view.

The adequacy of obturation was determined by calculating the percentage void area present in the distal and labial views using the following formula [14]:

$$\text{Percentage area of canal with void} = \frac{\text{Area of canal with voids}}{\text{Total canal area}} \times 100$$

The extrusion of sealer and/or GP through the apical foramen was recorded using a yes/no scheme.

STATISTICAL ANALYSIS

The data obtained were tabulated, and statistical analysis was performed using MedCalc Statistical Software version 19.1.1 (MedCalc Software bvba, Ostend, Belgium). Normality testing was conducted using the Shapiro-Wilk test. The data for the % void area in the distal and labial views did not follow a normal distribution. Therefore, a non parametric test (Kruskal-Wallis test) was used to compare the three obturation methods for '% of area with void'. Subsequently, Post-hoc Dunn's test was applied for individual pairwise comparisons. The Chi-square test was used to compare discrete data for 'sealer extrusion' among the three obturation techniques. The statistical analysis was performed using two-tailed tests with an alpha error of 0.05. Thus, the criterion for rejecting the null hypothesis was a p-value <0.05.

RESULTS

The specimens obturated with LC showed the highest number of voids (5.6533) compared to the warm compaction techniques in the distal view [Table/Fig-5]. In the labial view, LC and MCWC exhibited similar mean values of void presence [Table/Fig-6]. The Kruskal-Wallis test revealed a statistically significant difference ($p<0.0001$) among the obturation techniques when analysed in the

distal view [Table/Fig-7], while there was no statistically significant difference (p=0.99) in the labial view [Table/Fig-8]. Post-hoc analysis using Dunn's test demonstrated a statistically significant difference between Group-1 (LC) and Groups 2 (CWC) (p=0.000002) and Group-3 (MCWC) (p=0.000204), as shown in [Table/Fig-7]. The LC method exhibited less homogeneity and density [Table/Fig-2a,b], while both CWC and MCWC were observed to have denser obturation [Table/Fig-3a,b,4a,b].

Group	Lowest value	Highest value	Mean	95% CI for mean	Median	95% CI for median	SD
Group-1	0.2000	13.9000	5.6533	3.5822-7.7244	4.3000	3.4060-7.5940	3.7399
Group-2	0.0000	8.5000	0.8867	-0.3066-2.0799	0.2000	0.0000-0.6470	2.1547
Group-3	0.0000	2.5000	0.3667	-0.05801-0.7913	0.0000	0.0000-0.2735	0.7669

[Table/Fig-5]: Descriptive statistical data depicting percentage void area in the distal view.
SD: Standard deviation

Group	Lowest value	Highest value	Mean	95% CI for mean	Median	95% CI for median	SD
Group-1	0.0000	4.9000	0.4600	-0.2310-1.1510	0.0000	0.0000-0.3000	1.2477
Group-2	0.0000	1.3000	0.2467	0.03130-0.4620	0.0000	0.0000-0.4735	0.3889
Group-3	0.0000	3.3000	0.4600	-0.03832-0.9583	0.0000	0.0000-0.7675	0.8998

[Table/Fig-6]: Descriptive statistical data depicting percentage void area in labial view.

Variables				Values	
Kruskal-Wallis test					
Test statistic				23.9312	
Corrected for ties Ht				24.6942	
Degrees of Freedom (DF)				2	
Significance level				p<0.0001 (Significant)	
Post-hoc analysis (Dunn's test)					
Groups	**n**	**Average rank**	**Test statistic**	**Std. Test statistic**	**p-value**
Group-1 (LC) Vs Group-2 (CWC)	15	36.27	4.733	1.003	0.000* (0.000002)
Group-2 (CWC) LC Vs Group-3 (MCWC)	15	18.73	22.267	4.716	0.316
Group-3 (MCWC) Vs Group-1 (LC)	15	14.00	17.533	3.714	0.000* (0.000204)

[Table/Fig-7]: Summary of Kruskal-Wallis test and post-hoc analysis for percentage of void area in distal view.
*Statistically significant

Kruskal-Wallis test	Values
Test statistic	0.005990
Corrected for ties Ht	0.007894
Degrees of Freedom (DF)	2
Significance level	p=0.996061 (N.S.)

[Table/Fig-8]: Summary of Kruskal-Wallis test for percentage of void area in labial view.
N.S: Non significant

Root canal sealer extrusion was observed in all the groups. Differentiation between the canal sealer and GP was not made. The teeth obturated with the LC method exhibited the least extrusion (26.7% of the specimens), followed by the MCWC (33.3%) and CWC groups (53.3%), as presented in [Table/Fig-9]. The chi-square test indicated that it was not statistically significant [Table/Fig-9].

Group	Present	Total (N)
LC	4 (26.7%)	15
CWC	8 (53.3%)	15
MCWC	5 (33.3%)	15
Total	17 (37.8%)	45
Chi-square test	**Values**	
Chi-squared	2.458	
Degrees of Freedom (DF)	2	
Significance level	p=0.2926 (N.S.)	
Contingency coefficient	0.228	

[Table/Fig-9]: Number of specimens with extrusion of root canal filling material and the Chi-square test.

DISCUSSION

In the present study, oval-shaped root canals were evaluated because obturating oval-shaped canals presents a significant challenge due to their wider faciolingual/palatal dimensions [8]. The results of the study indicate that warm GP techniques had significantly fewer voids compared to LC techniques. There was a statistically significant difference in obturation quality when using a CWC or modified CWC technique, leading to the rejection of the null hypothesis.

The most commonly employed obturation method is the cold LC technique, which is considered the benchmark against which all other obturation techniques are compared. However, the LC technique has been found to leave void spaces, result in a nonhomogeneous mass of filling materials, and fail to adequately fill canal irregularities [9,15]. To overcome these limitations, warm GP techniques are often used. WVC methods have shown to provide dense obturation, better canal replicability, and improved filling of irregularities compared to the LC technique [16,17]. Additionally, warm GP techniques have been reported to offer more favourable clinical outcomes than the LC technique [18]. The CWC technique, which is a warm GP technique, involves transmitting heat at a constant temperature and pressure through a pre-fitted plugger to a single master cone matching the MAF [19]. This technique has been shown to provide an effective apical seal and obturate lateral canals [20].

For the continuous-wave obturation technique, it is recommended to set the plugger depth within 3 to 5 mm of the working length [4]. Inadequate heat transmission to the apical extent of the GP can result in a single, uncondensed, and poorly adapted cone in the apical region [4,21]. The quality of obturation in thermoplastic GP techniques also depends on the shape of the root canals, particularly in oval-shaped canals where hydraulic forces applied to a single cone might be insufficient [1]. Therefore, the CWC technique was modified by incorporating an initial step of LC. The CWC and modified CWC techniques were then compared with the conventionally used LC method.

The modified CWC technique of obturation, as described in present study, takes advantage of the length control and adaptive ability of LC. The GP points are mostly round in cross-section, which may leave spaces in the root canal where the cross-section is ovoid. This can result in inadequate adaptation of the master GP cone in the apical third. The CWC method relies on a well-adapted apical GP point, but achieving this may be challenging due to the ovoid canal shape. It can lead to an ill-adapted single uncondensed cone in the apical third. In LC, the master GP is laterally compacted with a spreader one or two sizes smaller than the MAF. In present study, the specimens of Group-3 (MCWC) canal were filled with LC up to 5 mm, followed by the downpack. The plugger penetration was maintained at 5 mm to allow heat transmission to soften the GP

mass beyond the plugger tip, typically to a depth of 3-4 mm [22]. The specimens obturated by the modified CWC (Group-3) showed the least mean % void area among all three groups, followed by the CWC (Group-2) and LC (Group-1). These findings are consistent with a study by Farias AB et al., where the CWC technique was compared with mechanically plasticised GP and thermoplasticised GP techniques [11].

Although there was no statistically significant difference in the void area between Group-2 and Group-3, Group-1 exhibited a significantly higher void area compared to Group-2 and Group-3. Among the groups, specimens obturated with warm compaction techniques demonstrated fewer voids, resulting in denser obturation. This is consistent with various studies [23,24]. These findings align with a study by De Deus G et al., where the authors compared the percentage of GP filled area achieved in oval-shaped canals using three thermoplasticised and LC techniques [7]. Although the warm GP techniques had limited ability to fill oval canals, they performed better than the LC technique. These results differ from a study by Guess GM et al., where no significant difference was found between the CWC technique and the modified CWC method. However, it's worth noting that they did not evaluate oval canals in their study [4].

The percentage of void area observed in the labial view was lower for all three techniques and was found to be statistically insignificant. This was in contrast to the observations made in the distal proximal view, where the percentage of void area was higher in the LC Group than in the warm GP techniques and was statistically significant. The difference observed in the labial and proximal views can be attributed to the greater labiolingual dimension of the canal space, resulting in a larger canal space filled with GP. This finding is noteworthy because clinically, only the labial view is available in the periapical radiograph technique for evaluating obturation. The LC method resulted in more voids, especially in the proximal view, which are not visible in the labial aspect. The CWC and MCWC methods resulted in obturations with fewer voids in the proximal view.

One of the advantages of the LC technique is less extrusion of filling materials owing to better length control, as observed in present study and supported by other authors [25,26]. Moreover, extrusion seen in the MCWC Group was found to be less than the CWC group and comparable to the LC group. Apical extrusion of filling material was observed in 53.3% of the specimens in the CWC group, followed by 33.3% in the MCWC Group and 26.7% in the LC group. Studies have shown that periapical tissues can tolerate extrusions of GP and root canal sealers, provided that the canal system has been thoroughly cleaned and shaped [27,28]. However, in periapical lesions, the healing process might be affected by GP overfills and foreign body reactions caused by the extrusion of obturating materials into the apical tissues [26,29]. The apical third in the modified CWC was initially compacted by the LC technique, resulting in significantly less extrusion, thus taking advantage of the LC method while achieving a more homogeneous and denser obturation. The modified CWC technique outlined in the study should be further investigated in clinical studies for endodontic healing outcomes.

Limitation(s)

The present study has limitations due to its in-vitro study design and the failure to replicate intraoral conditions, such as temperature, humidity, and periapical tissues. Additionally, the evaluation of potential apical leakage was not evaluated, which could have provided better evidence of GP adaptation to the canal walls.

CONCLUSION(S)

Within the limitations of present in-vitro study, it was observed that the modified continuous-wave compaction technique showed fewer voids, comparable to the continuous-wave compaction technique, in addition to less extrusion of root filling materials. The warm GP technique demonstrated better obturation density with fewer voids than the LC technique. This could be appreciated in the distal view rather than in the labial view. All three obturation techniques showed extrusion of the apical filling material, with the least extrusion seen in the LC technique.

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PARTICULARS OF CONTRIBUTORS:
1. Professor and Head, Department of Conservative Dentistry and Endodontics, M.G.M Dental College and Hospital, Kamothe, Navi Mumbai, Mumbai, Maharashtra, India.
2. Postgraduate Student, Department of Conservative Dentistry and Endodontics, M.G.M Dental College and Hospital, Kamothe, Navi Mumbai, Mumbai, Maharashtra, India.
3. Former Head, Department of Conservative Dentistry and Endodontics, M.G.M Dental College and Hospital, Kamothe, Navi Mumbai, Mumbai, Maharashtra, India.
4. Postgraduate Student, Department of Conservative Dentistry and Endodontics, M.G.M Dental College and Hospital, Kamothe, Navi Mumbai, Mumbai, Maharashtra, India.
5. Assistant Professor, Department of Conservative Dentistry and Endodontics, M.G.M Dental College and Hospital, Kamothe, Navi Mumbai, Thane (W), Maharashtra, India.
6. Associate Professor, Department of Conservative Dentistry and Endodontics, M.G.M Dental college and Hospital, Kamothe, Navi Mumbai, Mumbai, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Sumanthini V Margasahayam,
Junction of NH 4 and Sion-Panvel Expressway, Sector 1, Kamothe, Navi Mumbai, Mumbai-410206, Maharashtra, India.
E-mail: margsuman@gmail.com

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