ORIGINAL RESEARCH

# Effectiveness of Four Different Gutta-percha Techniques in Filling Experimental Internal Resorptive Lesions Using Stereomicroscope: An *In Vitro* Study

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## Abstract

**Aim:** The aim of this study was to evaluate and compare the effectiveness of four different gutta-percha (GP) obturation techniques cold lateral condensation (CLC), warm lateral condensation (WLC), thermoplasticized GP, and thermomechanical compaction (TMC) in achieving optimal filling of simulated internal resorptive defects.

**Materials and methods:** Eighty extracted maxillary central incisors were divided into four groups ($n = 20$) based on the obturation techniques: CLC, WLC, thermoplasticized GP, and TMC. The samples were sectioned at the defect level, and stereomicroscopic analysis was conducted to assess the percentage of GP, sealer, and voids. Data were statistically analyzed using ANOVA and Tukey's *post hoc* test.

**Results:** Thermoplasticized GP showed the highest GP percentage (89.4 ± 4.52%) and the least voids (2.07 ± 1.26%). Thermomechanical compaction followed with 73.71 ± 9.35% GP and 7.64 ± 6.90% voids. WLC exhibited 51.52 ± 10.58% GP and 29.27 ± 9.87% voids, while CLC had the lowest GP percentage (34.57 ± 14.26%) and the highest void percentage (42.34 ± 11.47%). Significant differences ($p < 0.01$) were noted among the groups.

**Conclusion:** The thermoplasticized GP technique is the most effective for obturating internal resorptive defects, offering optimal sealing with minimal voids compared to other methods.

**Clinical significance:** Choosing the appropriate obturation technique is critical in managing internal resorptive defects, which present unique anatomical challenges. Techniques like thermoplasticized GP ensure optimal adaptability and sealing, thereby minimizing voids and reducing the risk of treatment failure, ultimately enhancing long-term clinical outcomes.

**Keywords:** Gutta-percha, Internal resorption, Obturation techniques, Root canal therapy, Stereomicroscope analysis, Thermoplasticized obturation.

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## Introduction

Internal resorption is a pathological condition characterized by the progressive loss of dentin and pulpal walls due to clastic activity. Although relatively rare, it presents significant clinical challenges in endodontic treatment because of its irregular and unpredictable morphology. The etiology of internal resorption is not completely understood but is believed to be triggered by factors such as trauma, chronic inflammation, orthodontic treatment, or viral infections, all of which expose dentin to odontoclastic activity.[1] These defects within the root canal system can complicate cleaning, shaping, and obturation, increasing the risk of treatment failure if inadequately managed.

The primary goal of root canal therapy in cases of internal resorption is to eliminate infection and completely seal the root canal system to prevent reinfection. Gutta-percha remains the gold standard material for obturation due to its biocompatibility, dimensional stability, and adaptability. However, the irregularities in resorptive defects necessitate advanced techniques that provide better flow and adaptation of the filling material to the complex anatomy of the root canal.

Various obturation techniques have been developed to address these challenges. Cold lateral condensation (CLC), the most commonly used method, is simple and effective in many cases but often fails to adequately fill irregular spaces, leaving voids. Advanced techniques like warm lateral condensation (WLC), thermoplasticized GP, and thermomechanical compaction (TMC) have been introduced to overcome these limitations.

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These techniques improve material flow, achieve better adaptation, and enhance the density of the obturation material within irregular and resorptive defects.[2,3]

Several studies have demonstrated the superiority of advanced obturation techniques in filling resorptive defects.[4,5] The thermoplasticized techniques provide better adaptation in resorptive lesions compared to traditional methods. The effectiveness of warm GP techniques has been well-documented, showing a higher percentage of GP fill and a reduction in voids within artificial resorptive cavities.[6,7] These findings emphasize the importance of selecting an appropriate technique to achieve optimal clinical outcomes.[7,8] To enhance material flow and density, WLC, and TGP techniques were introduced, allowing for better adaptation to irregularities. Additionally, TMC combines the advantages of TGP with mechanical spreading, offering a promising solution for filling internal resorptive defects. Several studies have reinforced the significance of selecting the appropriate obturation technique, with Goldberg demonstrating that thermoplasticized methods provide superior adaptation in resorptive defects compared to traditional approaches.[9,10]

Radiographic tools, especially cone-beam computed tomography (CBCT), have revolutionized the diagnosis and management of internal resorption.[11] CBCT provides precise three-dimensional imaging of the lesion's extent and morphology, enabling clinicians to tailor their treatment approaches and select the most appropriate obturation technique. Clinically, internal resorption often remains asymptomatic until detected radiographically, presenting as a progressive enlargement of the root canal system.[12] Once diagnosed, the treatment involves removing necrotic tissue and bacteria, halting the resorptive process, and achieving complete obturation of the canal system.[13] Internal resorption poses a significant endodontic challenge due to its irregular morphology, making effective obturation difficult. Despite various techniques available, there is no clear consensus on the most effective method for sealing resorptive defects and preventing reinfection. Advanced obturation techniques aim to improve material flow and adaptation to these irregularities, but comparative studies are limited.

Therefore, the present *in vitro* study aimed to assess the effectiveness of four obturation techniques in obturating simulated internal resorptive defects. The study focused on comparing the sealing ability, GP adaptation, and the presence of voids in these techniques, aiming to identify the most effective method for managing internal resorptive lesions.

## Materials and Methods

This study was conducted at the Department of Conservative Dentistry and Endodontics, YMT Dental College and Hospital, Navi Mumbai, India, from 2013 to 2015. Ethical clearance was obtained from the institutional ethical committee. A total of 80 extracted maxillary central incisors with fully formed apices and single, straight root canals were selected for the study. The teeth were extracted due to periodontal reasons and only those without any carious lesions were included. To ensure uniformity in sample selection, teeth with calcified canals or pulp stones were excluded from the study (Fig. 1).

The samples were cleaned and stored in 10% formalin to maintain sterility and prevent tissue degradation. Cylindrical molds (20 cm height × cm in diameter) were made using 5 mL syringes. Modeling wax (Hindustan Dental Products) was used to provide base for each of the mold. Vaseline was coated on the inner surface of the entire mold and clear acrylic resin was used to fill the molds and the teeth were mounted at 1 mm level apical to the cementoenamel junction. To simulate internal resorptive defects, the crowns were decoronated at the cementoenamel junction using a diamond disk under copious water cooling to achieve a standardized root length of 16 mm. Access preparation, the working length was established by inserting a size 10 K-file (Mani, Inc., Japan) into the canal until the tip was visible at the apex and subtracting 1 mm from this length. The canals were then shaped

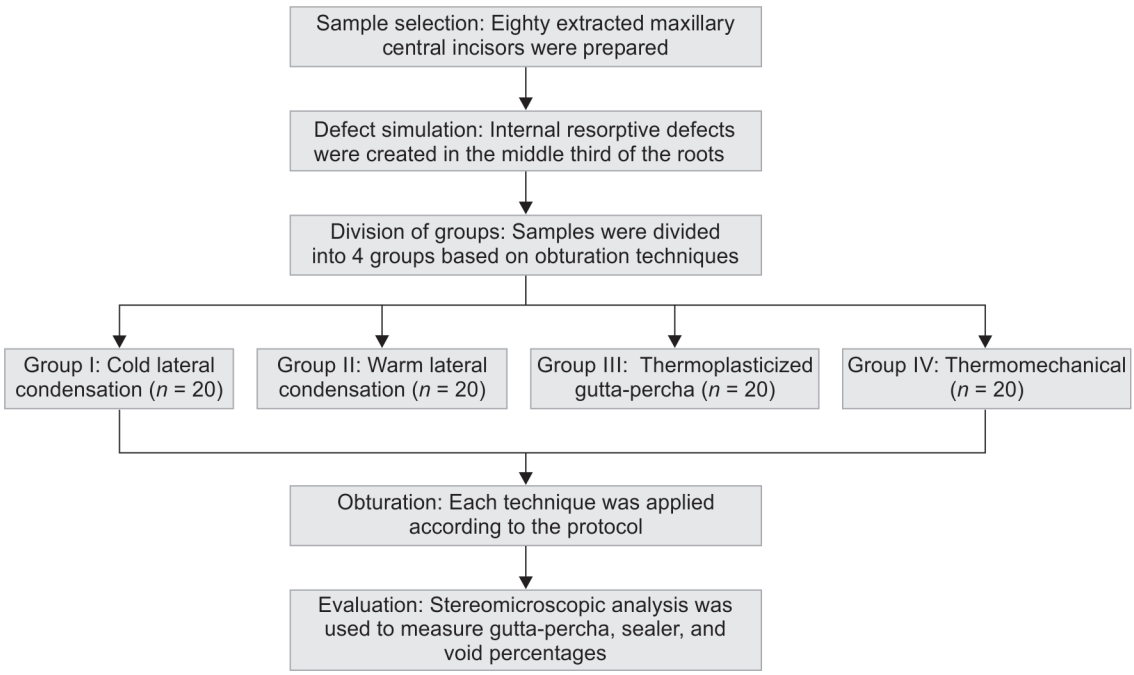



**Fig. 1:** Flowchart for methodology

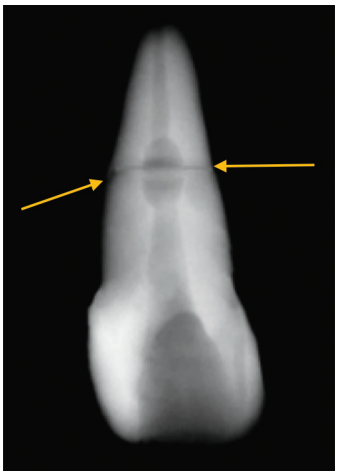


**Fig. 2:** Periapical radiograph of a right maxillary central incisor confirming the presence of an internal resorptive defect

using a ProTaper system (Dentsply, Maillefer) up to an F3 size, and irrigation was performed using 5.25% sodium hypochlorite (NaOCl) and saline throughout the procedure.

The roots were horizontally sectioned at 7 mm from the apex, and semicircular cavities were created in the canal walls using a #6 round bur to simulate internal resorptive defects. Semicircular cavities were created approximately 3 mm in diameter and 1 mm deep. The sections were reassembled using cyanoacrylate (Superglue) adhesive to restore the root's original structure. Radiographic images taken to confirm the presence, location, and uniformity of the artificially created internal resorptive defects before the obturation procedure. The radiographs ensure standardization of defect size and shape across all samples, allowing for an accurate comparison of the obturation techniques. Proper confirmation of defect formation is essential for evaluating the sealing ability and adaptability of different GP techniques in filling resorptive cavities (Fig. 2). To ensure uniformity across all groups, the same operator performed all procedures, including canal preparation, obturation, and sectioning. The obturation materials and instruments were used according to the manufacturers' instructions to eliminate variability.

## Experimental Groups

The samples were randomly divided into four groups ($n = 20$) based on the obturation technique:

- Group I: Cold lateral condensation—A GP master cone was fitted 0.5 mm short of the working length. AH-Plus sealer was applied to the canal, and the master cone was coated with sealer before placement. Lateral compaction was achieved using a 2% finger spreader (Dentsply, Maillefer) with accessory cones until resistance was noted in the coronal third. Excess GP was removed with a heated instrument.
- Group II: Warm lateral condensation—A GP master cone was fitted 0.5 mm short of the working length and coated with AH-Plus sealer (Dentsply, Maillefer). Lateral compaction was achieved using a heated 2% finger spreader and accessory cones until spreader penetration was restricted in the coronal third. Excess GP was removed with a heated instrument.
- Group III: Thermoplasticized gutta-percha (TPG)—A matched taper (0.06) GP cone (tip size 30) was trimmed 0.5 mm short of the working length and positioned. An activated E and Q Plus pen (200°C) was introduced 4 mm short of the working length for 3 s, with constant pressure maintained for 8–10 s. The plasticized GP was vertically condensed using a hand plugger, followed by backfilling with the E and Q gun (Meta Biomed, Chungju, Korea).
- Group IV: Thermomechanical compaction—A sealer-coated master cone was placed short of the prepared length. A McSpadden compactor (1200 rpm) Ransom and Randolph, Toledo, Ohio, softened and compacted the GP apically and laterally. The process was repeated with additional cones to fill the canal completely.

**Fig. 3:** Stereomicroscopic analysis of sectioned samples for obturation quality assessment

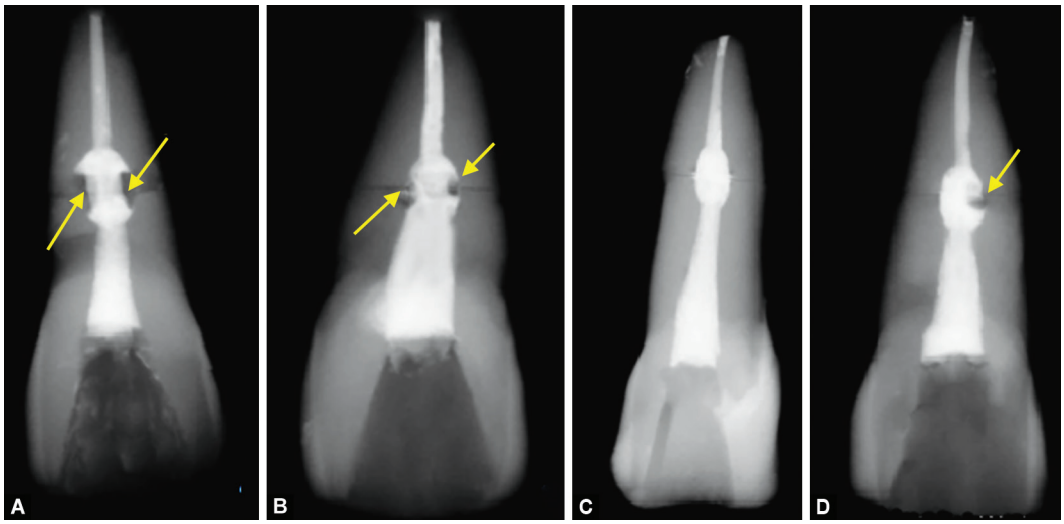
Before obturation, the canals were dried using paper points. A radiograph was taken after obturation to evaluate the quality of the fill. After obturation, the roots were sectioned horizontally at the level of the resorptive defect using a scalpel blade. The percentages of GP, sealer, and voids in the resorptive lesion were measured in standardized buccolingual and mesiodistal directions. Sectioned samples were examined under a stereomicroscope (SMZ-143 Series, Motic) at 4× magnification, and digital images were captured using a 3 CCD camera (Moticam). Image analysis was performed using Motic Images Plus 2.0 mL software to quantify the distribution of GP, sealer, and voids within the resorptive cavities. The evaluator, blinded to group assignments, meticulously assessed each sample to ensure accuracy in measuring the adaptation and completeness of obturation materials, independent of the software-based analysis (Fig. 3). The radiographic and stereomicroscopic evaluation of different obturation techniques used for filling internal resorptive defects. The images highlight variations in material adaptation, with differences in GP fill, sealer distribution, and the presence of voids across the techniques (Figs 4 and 5).

## Statistical Analysis

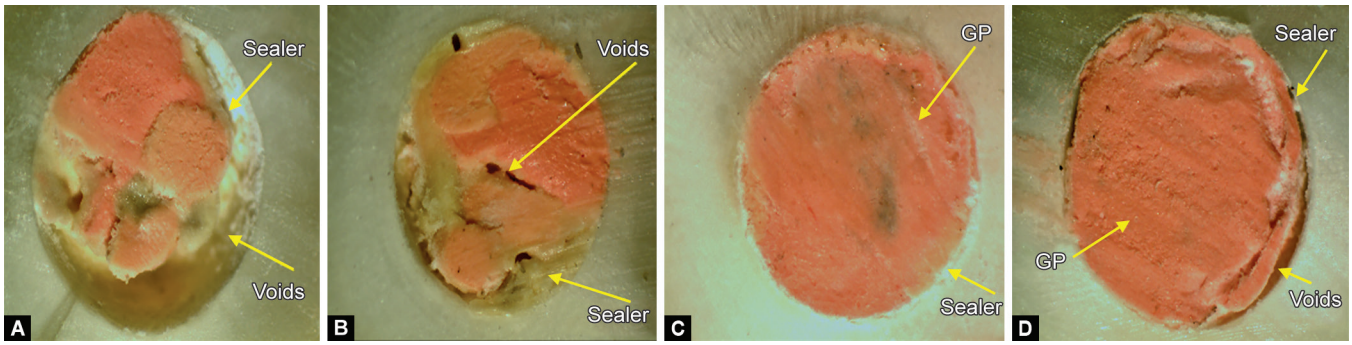
The data were recorded as the mean percentage of GP, sealer, and voids for each group. Statistical analysis was performed using one-way ANOVA to compare the groups, followed by Tukey's *post hoc* test for pairwise comparisons. A $p$-value of $< 0.05$ was considered statistically significant.

# Results

The TGP group achieved the highest mean percentage of GP fill (89.4 ± 4.52%) and the lowest void percentage (2.07 ± 1.26%), indicating superior sealing and adaptability. The TMC group also performed well, with a GP fill of 73.71 ± 9.35% and voids




**Figs 4A to D:** Radiographic image demonstrating obturation using the (A) Cold lateral condensation technique; (B) Warm lateral condensation technique; (C) TGP technique; (D) Thermomechanical compaction technique. The yellow arrow indicates the presence of voids within the obturation




**Figs 5A to D:** Stereomicroscopic view of the sample under 4× magnification, highlighting the internal adaptation of the obturation in the (A) Cold lateral condensation technique; (B) Warm lateral condensation technique; (C) Thermoplasticized gutta-percha (TGP) technique; (D) Thermomechanical compaction technique. The yellow arrow indicates the presence of voids within the obturation

of 7.64 ± 6.90%, showcasing good efficacy but less consistent results compared to TGP. The WLC group demonstrated moderate performance, with a GP fill of 51.52 ± 10.58% and voids of 29.27 ± 9.87%, showing room for improvement in sealing efficiency. The CLC group had the lowest GP fill (34.57 ± 14.26%) and the highest void percentage (42.34 ± 11.47%), reflecting its limited ability to adapt to the irregularities of the internal resorptive lesion. Overall, the TGP technique outperformed the others, with statistically significant differences observed between the groups (Table 1 and Fig. 6).

The results for the GP percentage across the four obturation techniques. The sum of squares shows that the variability between the groups (34,985.028) is much larger than the variability within the groups (8,038.603), indicating substantial differences among the techniques. The degrees of freedom are 3 for between-group variability and 76 for within-group variability, leading to a total *df* of 79. The mean square, calculated as the sum of squares divided by the degrees of freedom, is significantly higher for between groups (11,661.676) compared to within groups (105.771). This results in a large *F*-ratio (110.254), suggesting that the observed differences between the techniques are not due to chance. The *p*-value (< 0.001) confirms that the differences in GP percentages across the groups are statistically significant. These results underscore the impact of the obturation technique on the quality of the fill, with TGP likely outperforming the other methods (Table 2), mean wise comparison of the percentages (Fig. 7).

**Table 1:** Mean and standard deviation (SD) of percentages for all groups

| *Technique* | *Gutta-percha (%)* | *Sealer (%)* | *Voids (%)* |
|---|---|---|---|
| Cold lateral condensation | 34.57 ± 14.26 | 23.09 ± 8.94 | 42.34 ± 11.47 |
| Warm lateral condensation | 51.52 ± 10.58 | 19.21 ± 8.05 | 29.27 ± 9.87 |
| Thermoplasticized gutta-percha | 89.4 ± 4.52 | 8.53 ± 2.66 | 2.07 ± 1.26 |
| Thermomechanical compaction | 73.71 ± 9.35 | 18.65 ± 7.32 | 7.64 ± 6.90 |

The results for the sealer percentage across the four obturation techniques. The sum of squares for between-group variability is 2,314.292, reflecting notable differences among the groups, while the within-group variability is 4,200.125. The degrees of freedom are 3 for between groups and 76 for within groups, resulting in a total *df* of 79. The mean square for between groups (771.431) is significantly higher than the within-group mean square (55.265), leading to an *F*-ratio of 13.959, which is substantial. The *p*-value

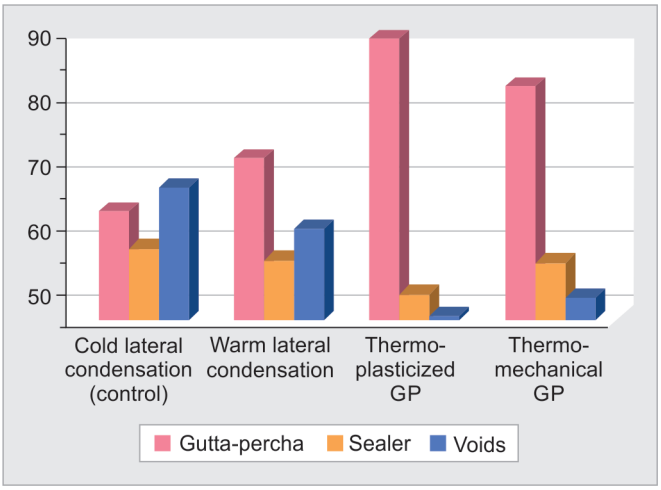



**Fig. 6:** Mean and SD of percentages for all group

**Table 2:** Descriptive statistical data for gutta-percha percentage across all groups

| *Group distribution* | *Sum of squares* | *df* | *Mean square* | *F* | *p-value* |
|---|---|---|---|---|---|
| Between groups | 2314.292 | 3 | 771.431 | 13.959 | 0.000 |
| Within groups | 4200.125 | 76 | 55.265 | | |
| Total | 6514.417 | 79 | | | |

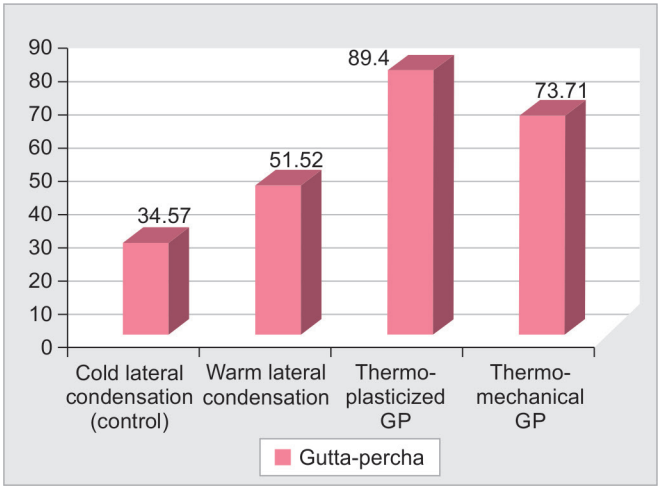



**Fig. 7:** Mean-wise comparison of the percentage of gutta-percha for all groups

(< 0.001) confirms statistically significant differences in sealer percentages among the obturation techniques (Table 3), mean-wise comparison of the percentages (Fig. 8).

These results highlight the variation in sealer distribution across the groups, with TGP likely exhibiting better sealer adaptation due to its higher flow and adaptability. The data underline the importance of technique selection to optimize sealer distribution and minimize voids in obturation procedures.

The void percentages across the four obturation techniques. The sum of squares shows a significant amount of variability between groups (21,181.977) compared to within groups (5,284.831), indicating substantial differences in void formation among the techniques. The degrees of freedom are 3 for between groups and 76 for within groups, with a total *df* of 79. The mean square for between groups (7,060.659) is much higher than that for within groups (69.537), resulting in a highly significant F-ratio (101.538). The *p*-value (< 0.001) confirms that these differences are statistically significant (Table 4). Mean-wise comparison of the percentages (Fig. 9).

The findings demonstrate that the void percentages vary significantly depending on the obturation technique.

**Table 3:** Descriptive statistical data for percentage sealer all groups

| *Group distribution* | *Sum of squares* | *df* | *Mean square* | *F* | *p-value* |
|---|---|---|---|---|---|
| Between groups | 2314.292 | 3 | 771.431 | 13.959 | 0.000 |
| Within groups | 4200.125 | 76 | 55.265 | | |
| Total | 6514.417 | 79 | | | |

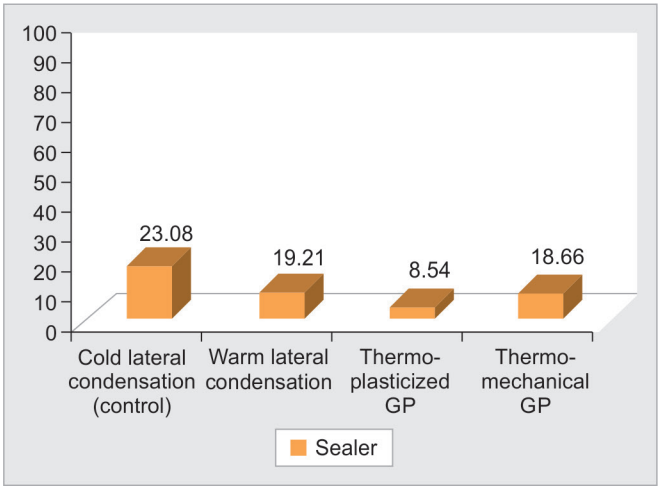



**Fig. 8:** Mean-wise comparison of the percentage of sealer for all groups

**Table 4:** Descriptive statistical data for percentage voids all groups

| *Group distribution* | *Sum of squares* | *df* | *Mean square* | *F* | *p-value* |
|---|---|---|---|---|---|
| Between groups | 21181.977 | 3 | 7060.659 | 101.538 | 0.000 |
| Within groups | 5284.831 | 76 | 69.537 | | |
| Total | 26466.808 | 79 | | | |

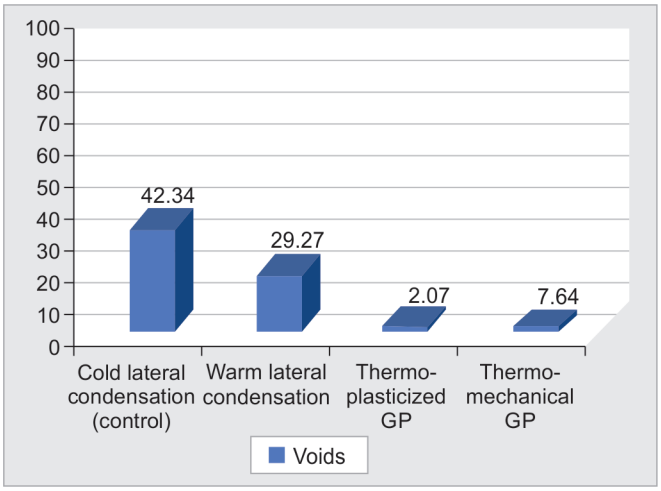



**Fig. 9:** Mean-wise comparison of the percentage of voids for all groups

**Table 5:** Tukey's multiple comparisons for GP percentage in all groups

| *(I) Major* | *(J) Major* | *Mean difference (I–J)* | *Std. error* | *Sig.* |
|---|---|---|---|---|
| Group-I Cold lateral condensation technique | Warm lateral condensation T. | −16.94750* | 3.25225 | 0.000 |
| | Thermoplasticized GP T. | −54.82300* | 3.25225 | 0.000 |
| | Thermomechanical T. | −39.13200* | 3.25225 | 0.000 |
| Group-II Warm lateral condensation technique | Cold lateral condensation T. | 16.94750* | 3.25225 | 0.000 |
| | Thermoplasticized GP T. | −37.87550* | 3.25225 | 0.000 |
| | Thermomechanical T. | −22.18450* | 3.25225 | 0.000 |
| Group-III Thermoplasticized GP technique | Cold lateral condensation T. | 54.82300* | 3.25225 | 0.000 |
| | Warm lateral condensation T. | 37.87550* | 3.25225 | 0.000 |
| | Thermomechanical T | 15.69100* | 3.25225 | 0.000 |
| Group-IV Thermomechanical compaction technique | Cold lateral condensation T. | 39.13200* | 3.25225 | 0.000 |
| | Warm lateral condensation T. | 22.18450* | 3.25225 | 0.000 |
| | Thermoplasticized GP T. | −15.69100* | 3.25225 | 0.000 |

*The mean difference is significant at the 0.05 level

Thermoplasticized gutta-percha likely produced the least voids, aligning with its superior adaptability and sealing properties, while techniques like CLC are expected to have the highest void percentages. This emphasizes the critical role of technique selection in minimizing voids and ensuring successful root canal therapy.

The Tukey's *post hoc* analysis demonstrated statistically significant differences ($p < 0.05$) in GP percentages among the four obturation techniques. The TGP technique significantly outperformed all other methods, with the largest mean differences observed against CLC (−54.82) and WLC (−37.88). The thermo-mechanical compaction technique also showed significantly higher values compared to CLC (−39.13) and WLC (−22.18), though it was less effective than TGP (−15.69). The WLC technique performed better than CLC (−16.95), but it was significantly less effective than the thermoplasticized and thermomechanical techniques. Finally, the CLC technique had the lowest performance among all groups, highlighting its limitations in achieving adequate GP adaptation. These findings confirm the superior performance of TGP in obturating internal resorptive defects (Table 5).

## Discussion

The present study aimed to evaluate the effectiveness of four different GP obturation techniques in filling simulated internal resorptive defects. The findings highlight the strengths and limitations of each technique in terms of GP adaptation, sealer distribution, and void formation. CLC, despite its widespread use due to simplicity and cost-effectiveness, exhibited the highest percentage of voids. This technique relies on lateral compaction of GP cones, which often results in poor adaptation to irregular canal walls, leading to an increased risk of micro leakage and reinfection.[14] These findings are consistent with previous studies that reported similar limitations with lateral condensation techniques.

Warm lateral condensation demonstrated better adaptability than CLC, reducing void formation. However, its effectiveness was still limited, as complete elimination of voids was not achieved. Although this technique enhances GP flow and compaction, it does not provide the same level of homogeneity as thermoplasticized techniques. The TGP technique was the most effective in achieving a dense and homogenous fill. The superior adaptability of this technique can be attributed to the heat-softened GP, which allows better flow into canal irregularities. This resulted in minimal void formation, reducing the chances of coronal or apical leakage. The findings align with studies by Saeed and Salman, as well as Choudhary et al., who reported that injectable TGP techniques provide superior adaptation to internal resorptive defects compared to hybrid or ultrasonic compaction methods.[15,16] However, a potential drawback of this technique is the risk of overfilling and sealer extrusion, which can lead to postoperative complications.

Thermomechanical compaction also demonstrated promising results, performing significantly better than both cold and WLC but slightly less effectively than TGP. This technique generates frictional heat, allowing the GP to soften and flow into irregularities, ensuring improved adaptation. McSpadden introduced the thermo-mechanical compaction technique, emphasizing its ability to compact GP effectively, while Gencoglu et al. also noted that thermo-mechanical techniques such as JS Quick-Fill and Thermafil outperform traditional lateral condensation in terms of GP-to-sealer ratios.[6,17] However, the technique requires precise control to prevent overfilling and heat damage to surrounding structures.

Several studies have reported similar findings. Goldberg et al. and Basheer, noted that CLC was the least effective method for obturating internal resorptive defects due to its high percentage of voids and poor adaptability.[10,18] Collins et al. found that warm lateral and vertical condensation techniques achieved superior GP adaptation.[7] Saeed and Salman, along with Choudhary et al., demonstrated that TGP provided optimal adaptation to resorptive cavities, further supporting the present study's results.[15,16]

The TGP technique has several advantages, including its ability to flow and adapt well to irregularities within the root canal system, ensuring a dense and homogenous fill. This technique minimizes voids, improves sealing ability, and enhances the long-term success of root canal therapy. Additionally, warm vertical compaction using alpha-phase GP, as noted by Zhang et al., allows for better penetration into lateral canals and complex canal morphology, reducing the risk of reinfection.[19,20] However, a disadvantage of thermoplasticized techniques is the potential risk of overfilling and apical extrusion, which can cause postoperative discomfort or complications. Additionally, specialized equipment and operator expertise are required, making the technique less accessible in certain clinical settings.

In contrast, WLC techniques offer better adaptation compared to CLC but are still limited in their ability to completely fill resorptive defects. Although this technique improves GP flow and reduces void formation, it may not achieve the same level of three-dimensional sealing as TGP. On the other hand, CLC remains the most commonly used technique due to its simplicity, cost-effectiveness, and ease of application. However, its major drawback is the higher presence of voids and lack of adaptability to irregular canal shapes, making it less reliable in cases of internal resorption. Factors such as the percentage distribution of GP, sealer, and voids are critical in assessing the success of obturation techniques, as they directly influence the sealability and longevity of the treatment. Evaluating these factors helps determine the reliability of a technique, with studies also highlighting the importance of achieving an optimal GP-to-sealer ratio to prevent micro leakage and reinfection.

The use of stereomicroscopic analysis in this study provided an accurate evaluation of obturation quality, overcoming the limitations of radiographic assessment. Goldberg et al. highlighted that radiographs often fail to reveal voids and cannot reliably differentiate between GP and sealer, making stereomicroscopy a more reliable tool for assessing obturation quality.[10]

The strengths of this study include its comprehensive evaluation of obturation techniques using standardized methods and advanced analysis tools. The study offers valuable insights into the effectiveness of different techniques in managing internal resorptive defects. However, limitations include the *in vitro* nature of the study, which may not fully replicate clinical conditions. Additionally, operator variability and the influence of long-term outcomes were not assessed. Future studies should incorporate clinical trials and advanced imaging techniques, such as CBCT, to further validate these findings and optimize obturation strategies for internal resorptive defects.

## Conclusion

The TGP technique (E and Q plus system) demonstrated the highest percentage of GP fill and superior performance compared to CLC, WLC, and TMC techniques in filling internal resorptive lesions. CLC was the least effective, showing higher percentages of voids and sealer. Overall, the thermoplasticized technique proved significantly better for obturating resorptive defects, but further studies are needed to validate these findings.

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