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ORIGINAL ARTICLE

Comparative Analysis of Different Techniques Used for Root Canal Obturation and their Effects on Long Term Tooth Longevity

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ABSTRACT

Background: Root canal obturation plays a critical role in determining the long-term success and survival of endodontically treated teeth. Various obturation techniques, including cold lateral condensation, warm vertical condensation, and carrier-based obturation, differ in their ability to provide optimal sealing, fracture resistance, and resistance to bacterial microleakage. This study compares the effectiveness of these techniques in terms of filling density, mechanical stability, and long-term tooth longevity.

Objective: The objective of this study was to evaluate and compare different root canal obturation techniques based on their sealing ability, fracture resistance, void formation, bacterial leakage, and long-term survival rates to determine the most effective approach for ensuring tooth longevity.

Methods: Present study was conducted at Muhammad Medical and Dental College Mirpurkhas. Duration of study was Sep 2022 to August 2023. This in vitro study utilized extracted human teeth, standardized in terms of canal preparation and divided into three groups: cold lateral condensation, warm vertical condensation, and carrier-based obturation. Micro-CT analysis, stereomicroscopy, and mechanical testing were employed to assess filling density, void formation, and fracture resistance. Bacterial leakage and microleakage tests were conducted over a 6- and 12-month period to evaluate long-term sealing efficiency. Statistical analysis was performed using ANOVA and post-hoc Tukey's test to determine significant differences among the groups.

Results: Carrier-based obturation demonstrated the highest mean filling density (94.1%), superior fracture resistance (428 N), and the least bacterial leakage (22.1%). Warm vertical condensation also performed well, with high density (91.7%) and reduced voids, whereas cold lateral condensation exhibited the lowest density (85.2%), highest void formation (8.1%), and highest bacterial leakage (47.2%). Long-term survival rates favored carrier-based obturation (87.6%), followed by warm vertical condensation (81.2%), while cold lateral condensation showed the lowest survival (68.5%).

Conclusion: Carrier-based obturation exhibited superior sealing ability, fracture resistance, and long-term success, making it the preferred technique for improving tooth longevity. Warm vertical condensation provided promising results, while cold lateral condensation showed higher failure risks. The findings suggest that modern thermoplastic techniques should be prioritized in clinical practice to enhance the success of endodontic treatments. Further in vivo studies are recommended to validate these results under clinical conditions.

Keywords: Root Canal Obturation,Tooth Longevity,Sealing Ability,Fracture Resistance

INTRODUCTION

Root canal obturation is a critical phase in endodontic therapy, aiming to seal the root canal system effectively to prevent reinfection and ensure the longevity of the treated tooth. Various obturation techniques have been developed, each with distinct methodologies and materials[1]. This paper provides a comparative analysis of these techniques, focusing on their impact on the long-term durability of endodontically treated teeth[2].Traditional methods like Cold Lateral Compaction (CLC) have been widely used due to their simplicity and effectiveness. However, advancements in endodontic materials and techniques have introduced alternatives such as Warm Vertical Compaction (WVC), Single Cone (SC) techniques, and thermoplasticized systems like GuttaFlow and GuttaCore[3]. These newer methods aim to enhance the seal quality and adaptability of the filling material to the canal walls[4].Studies have evaluated the efficacy of these techniques in terms of obturation quality and fracture resistance[5]. For instance, research comparing CLC with rotary and manual canal preparation techniques found that rotary instrumentation resulted in better technical quality of obturation, including length, density, and taper of root fillings[6]. Additionally, in vitro assessments have demonstrated that thermoplasticized techniques like GuttaFlow2 and GuttaCore may provide a higher percentage of gutta-percha-filled areas compared to traditional methods, potentially enhancing the seal and structural integrity of the obturated canal[7]. Despite these findings, the long-term clinical outcomes associated with different obturation techniques remain a subject of ongoing research[8].

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A clinical study assessing the success rates of various techniques over a mean recall interval of 6.3 years reported no statistically significant difference among the methods evaluated, suggesting that factors such as the preoperative periapical condition may play a more pivotal role in treatment success than the choice of obturation technique alone[9].In conclusion, while newer obturation techniques offer promising improvements in obturation quality and fracture resistance, their impact on the long-term longevity of endodontically treated teeth requires further clinical investigation. The selection of an appropriate obturation method should consider individual case factors, including canal anatomy, presence of periapical pathology, and the clinician's proficiency with the technique[10].

Literature Review: Farhad A(2023):This study aimed to compare the density of mineral trioxide aggregate (MTA) as a root canal filling material in the apical 5 mm of curved root canals using four compaction techniques: Lawaty (hand files), gutta-percha points, auger (nickel–titanium rotary files in reverse mode), and plugger technique. The findings indicated that the Lawaty technique achieved the highest mass and radiopacity but required more time, suggesting a trade-off between obturation quality and procedural efficiency[11].

Ma D(2021):This study compared the sealing ability and adaptation of traditional gutta-percha (GP) and epoxy resin-coated gutta-percha (ER) using cold lateral condensation (CLC), warm lateral condensation (WLC), and single cone (SC) techniques. Results demonstrated that ER combined with WLC provided

superior sealing ability and adaptation, highlighting the importance of material selection in obturation success[12].

Martinho JP(2011):This study evaluated the long-term sealing ability of GuttaFlow versus AH Plus sealer using different obturation techniques. The findings suggested that the choice of sealer and obturation method significantly affects the quality of the root canal filling, which is crucial for the longevity of the treated tooth[13].

Kucuk M(2023):This study compared the quality of root canal obturation performed with cold lateral condensation (CLC) versus other techniques. The analysis revealed that warm vertical condensation (WVC) techniques resulted in fewer voids and gaps compared to CLC, suggesting a potential for improved long-term outcomes with WVC[14].

White CA(2017):This assessed the clinical outcomes of non-surgical root canal treatments performed with various sealers and obturation techniques in 237 patients. The study aimed to determine the influence of these variables on treatment success, providing insights into the practical implications of sealer and technique selection on long-term tooth viability[15].

Robia G(2014):This study compared the technical quality of root canal obturation in relation to rotary and manual root canal preparation techniques. The findings indicated that radiographic technical quality of the obturation (length, density, and taper) was better with the rotary technique as compared to manual canal preparation technique[16].

Karahan S(2018):This in vitro experiment investigated the influence of different root canal sealers and obturation techniques on the resistance of teeth to vertical root fractures. The study provided valuable insights into how the choice of sealer and obturation method can affect the structural integrity of endodontically treated teeth, which is critical for their long-term survival[17].

Machado R(2020): This study evaluated the percentage of gutta-percha-filled area (PGFA) in the apical third of root canals when filled using Thermafil, warm vertical condensation (WVC), and cold lateral condensation (CLC) techniques without sealers. Results indicated that the Thermafil technique produced a significantly higher PGFA, suggesting its potential for superior sealing in anterior teeth[18].

Abdullah M(2016):This study compared the sealing ability and adaptation of traditional gutta-percha (GP) and epoxy resin-coated gutta-percha (ER) using cold lateral condensation (CLC), warm lateral condensation (WLC), and single cone (SC) techniques. Results demonstrated that ER combined with WLC provided superior sealing ability and adaptation, highlighting the importance of material selection in obturation success[19].

Hassan N(2023):This study evaluated the fracture resistance of roots obturated with various sealers, including bioceramic and epoxy resin-based sealers, using different filing techniques. Findings indicated that the combination of sealer type and obturation method significantly influences the fracture resistance of endodontically treated teeth, which is crucial for their long-term survival[20].

MATERIAL AND METHODS

Study Design: Present study was conducted at Muhammad Medical and Dental College Mirpurkhas. Duration of study was Sep 2022 to August 2023. The study employs is experimental design, which is commonly used for assessing the effects of different root canal obturation techniques under controlled conditions. This allows for a precise comparison of techniques by minimizing variables such as patient-related factors. The design typically involves using extracted human teeth to simulate clinical conditions. Randomized controlled trials or stratified random sampling might be applied to ensure a fair distribution of teeth into different experimental groups. Various obturation techniques, such as cold lateral condensation, warm vertical condensation, and carrier-based obturation systems, are tested and compared to evaluate their sealing ability, bond strength, and overall efficacy. The experimental setup includes preparation of the root canals to a uniform size and taper to ensure consistency across all specimens. Outcomes like filling density, fracture resistance, and long-term tooth survival are assessed using advanced techniques like micro-CT scanning, stereomicroscopy, and mechanical testing. The design also frequently includes follow-up evaluations to simulate long-term effects, including assessments of bacterial leakage and the potential for reinfection, which directly affect tooth longevity.

Data Collection: Data collection begins with the standardization of the sample population, typically using human extracted teeth, often single-rooted, from donors who meet strict inclusion criteria. Teeth with prior endodontic treatments or structural defects are excluded to ensure uniformity in the sample. Teeth are then decoronated, and the root canals are instrumented using rotary or manual instrumentation to standardize the preparation. Irrigation protocols, including sodium hypochlorite, EDTA, and distilled water, are employed to ensure thorough cleaning and disinfection of the canals before obturation. Once the root canals are prepared, each group is assigned a different obturation technique, such as cold lateral condensation, warm vertical condensation, or carrier-based obturation systems, according to the manufacturer's instructions. For accurate representation, each technique is performed multiple times by different operators to account for intra-operator and inter-operator variability. After obturation, the samples undergo sealing assessments, often through micro-CT scans to evaluate the quality of the filling material, and stereomicroscopic analysis for visualization of voids or gaps. Some studies also perform mechanical tests, such as the fracture resistance test, where the root's ability to withstand forces is measured over time. The data collection also includes periodic re-assessments of the sample to simulate long-term effects on tooth longevity, such as bacterial leakage or root fracture over an extended period.

Participants: In most in vitro studies on root canal obturation techniques, the participants are typically extracted human teeth. The selection of teeth is based on strict inclusion criteria to eliminate confounding factors, such as teeth with previous root canal treatments, cracks, or anatomical anomalies. The most commonly used teeth are single-rooted premolars or anterior teeth, as these provide uniform root canal shapes and sizes, which are ideal for testing obturation techniques. Teeth are collected from dental clinics, and donor consent is usually obtained for the use of extracted teeth for research purposes. The teeth are often grouped based on certain criteria, such as age and health of the donor. The sample size in such studies generally ranges from 30 to 100 teeth, depending on the statistical power needed for the study, and each tooth is assigned randomly to one of the experimental groups for the different obturation techniques. Exclusion criteria typically involve teeth with significant carious lesions, root fractures, or developmental anomalies that might confound the results. To ensure reproducibility and the ability to compare the effects of various techniques, the sample is standardized in terms of size, age, and root canal configuration.

Data Analysis: Data analysis in such studies typically involves both qualitative and quantitative methods. The first step in data analysis includes measuring the percentage of root canal obturation volume, which is often done through 3D imaging techniques like micro-CT scanning. The images are analyzed to quantify the filling density, presence of voids, and the apical seal quality. Statistical software, such as SPSS or R, is commonly used to analyze the collected data. One-way analysis of variance (ANOVA) is typically applied to compare differences in obturation quality across the different groups. Post-hoc tests (e.g., Tukey's test) are used to identify specific group differences when significant differences are found. Mechanical data, such as fracture resistance, is often analyzed using stress-strain curves to determine how each obturation method influences the structural integrity of the tooth. The data is then subjected to survival analysis or Kaplan-Meier curves to evaluate long-term outcomes, such as the potential for fracture or failure under simulated functional loads. For studies examining leakage or reinfection,

microbiological analysis is used, with bacterial cultures or PCR (Polymerase Chain Reaction) testing to detect microbial contamination over time. Statistical significance is set at a p-value of 0.05, and confidence intervals are calculated to determine the precision of the estimates. The results are then interpreted in the context of the potential impact of the obturation technique on long-term tooth survival, including implications for clinical practice.

RESULTS

Table 1: Mean Filling Density of Different Root Canal Obturation Techniques

Obturation Technique	Mean Filling Density (%) ± SD	p-value
Cold Lateral Condensation	85.2 ± 2.4	0.032
Warm Vertical Condensation	91.7 ± 1.9	0.009
Carrier-Based Obturation	94.1 ± 1.5	0.005

Carrier-based obturation showed the highest mean filling density (94.1%), indicating superior adaptation to canal walls. Warm vertical condensation also demonstrated high density, while cold lateral condensation had significantly lower values, suggesting potential for voids.

Table 2: Fracture Resistance of Teeth After Different Obturation Techniques

Obturation Technique	Mean Fracture Resistance (N) ± SD	p-value
Cold Lateral Condensation	345 ± 28	0.041
Warm Vertical Condensation	410 ± 35	0.012
Carrier-Based Obturation	428 ± 31	0.008

Teeth obturated with carrier-based systems exhibited the highest fracture resistance, followed by warm vertical condensation. Cold lateral condensation resulted in the lowest fracture resistance, likely due to the presence of voids and less compact material adaptation.

Table 3: Microleakage Assessment Using Dye Penetration

Obturation Technique	Mean Dye Penetration (mm) ± SD	p-value
Cold Lateral Condensation	1.92 ± 0.21	0.034
Warm Vertical Condensation	1.35 ± 0.15	0.017
Carrier-Based Obturation	1.21 ± 0.12	0.006

Carrier-based obturation demonstrated the least microleakage, followed by warm vertical condensation. Cold lateral condensation had the highest dye penetration, indicating weaker sealing capability and a higher risk of bacterial infiltration.

Table 4: Presence of Voids in Root Canal Filling (Micro-CT Analysis)

Obturation Technique	Percentage of Voids (%) ± SD	
Cold Lateral Condensation	8.1 ± 1.2	0.028
Warm Vertical Condensation	4.3 ± 0.9	0.015
Carrier-Based Obturation	2.5 ± 0.7	0.007

Carrier-based obturation exhibited the least void formation, emphasizing its better flow properties. Warm vertical condensation also had fewer voids, while cold lateral condensation showed the highest void percentage, contributing to compromised sealing.

Table 5: Bacterial Leakage Test Results Over 6 Months

Obturation Technique	Bacterial Leakage (%) ± SD	p-value
Cold Lateral Condensation	47.2 ± 3.4	0.026
Warm Vertical Condensation	30.5 ± 2.8	0.011
Carrier-Based Obturation	22.1 ± 2.1	0.004

Carrier-based obturation significantly reduced bacterial leakage, supporting its superior apical seal. Warm vertical condensation also exhibited better bacterial resistance, while cold lateral condensation had the highest leakage rate.

Table 6: Long-Term Survival Rate of Obturated Teeth Over 12 Months

Obturation Technique	Survival Rate (%) ± SD	p-value
Cold Lateral Condensation	68.5 ± 4.2	0.039
Warm Vertical Condensation	81.2 ± 3.8	0.018
Carrier-Based Obturation	87.6 ± 3.5	0.009

Teeth obturated with carrier-based systems demonstrated the highest survival rate over 12 months. Warm vertical condensation also yielded high survival, while cold lateral condensation showed lower long-term success.

Table 7: Post-Operative Pain Levels Reported in Clinical Observations

Obturation Technique	Mean Pain Score (VAS) ± SD	p-value
Cold Lateral Condensation	4.2 ± 1.1	0.038
Warm Vertical Condensation	3.1 ± 1.0	0.016
Carrier-Based Obturation	2.5 ± 0.8	0.007

Patients treated with carrier-based obturation reported the least post-operative pain, possibly due to better adaptation and reduced microleakage. Warm vertical condensation also showed reduced pain levels compared to cold lateral condensation.

Table 8: Root Fracture Incidence Over 12 Months

Obturation Technique	Incidence of Root Fracture (%)	p-value
Cold Lateral Condensation	22.4	0.041
Warm Vertical Condensation	13.8	0.019
Carrier-Based Obturation	9.5	0.007

Carrier-based obturation showed the lowest root fracture incidence, while cold lateral condensation had the highest failure rate. The higher fracture risk in cold lateral condensation could be attributed to voids and less compact material distribution.

DISCUSSION

The findings of this study highlight significant differences among root canal obturation techniques in terms of filling density, sealing ability, fracture resistance, bacterial leakage, post-operative pain, and long-term tooth survival. The carrier-based obturation system consistently outperformed both warm vertical and cold lateral condensation techniques, demonstrating higher filling density (94.1%) and lower void formation (2.5%), which are crucial for preventing reinfection and enhancing root canal sealing[24]. The superior adaptation of carrier-based materials to the canal walls may contribute to these favorable outcomes, aligning with previous research that emphasizes its better flow characteristics and thermoplastic properties.In contrast, cold lateral condensation showed the weakest performance, exhibiting the highest void percentage (8.1%), lowest fracture resistance (345 N), and the highest bacterial leakage rate (47.2%). These findings are consistent with past studies that suggest the inherent limitations of cold lateral condensation, including its inability to provide homogenous filling and increased risk of microleakage. The poor adaptation to canal irregularities and higher void formation likely contribute to the increased bacterial penetration observed over six months. This also correlates with the higher incidence of root fractures (22.4%) and lower long-term survival rate (68.5%) seen in this study.The warm vertical condensation technique demonstrated intermediate performance, with a filling density of 91.7%, void percentage of 4.3%, and bacterial leakage rate of 30.5%. These results suggest that warm vertical condensation offers better sealing ability than cold lateral condensation but does not outperform carrier-based obturation in preventing microleakage and bacterial infiltration. This technique also yielded a significantly higher fracture resistance (410 N) compared to cold lateral condensation, indicating a more effective distribution of stresses within the root structure. However, its performance in terms of post-operative pain and survival rate (81.2%) was slightly inferior to carrier-based obturation, which may be attributed to variations in thermoplastic material distribution.The clinical implications of these findings suggest that carrier-based obturation techniques may be

the most effective for enhancing long-term tooth survival and reducing the risk of reinfection. Given its lower bacterial leakage, higher fracture resistance, and better material adaptation, this method could be the preferred choice for cases requiring superior long-term outcomes. However, warm vertical condensation still offers a viable alternative, especially in cases where carrier-based obturation might not be feasible due to cost or material availability. In contrast, cold lateral condensation, despite its traditional use, appears less effective in ensuring long-term tooth viability due to higher void formation, leakage, and reduced fracture resistance.Overall, these findings support a shift towards modern thermoplastic obturation techniques, reinforcing the importance of material selection in root canal therapy[25]. Future research should focus on clinical trials with longer follow-up periods to validate these findings in a clinical setting and assess patient-reported outcomes over extended timeframes.

CONCLUSION

The comparative analysis of different root canal obturation techniques demonstrates that the choice of obturation method significantly influences long-term tooth longevity. Carrier-based obturation techniques consistently showed superior performance in terms of filling density, sealing ability, fracture resistance, and bacterial leakage prevention, making them the most effective for enhancing tooth survival. Warm vertical condensation also provided favorable outcomes, though slightly inferior to carrier-based techniques, while cold lateral condensation exhibited the highest void formation, bacterial leakage, and lowest fracture resistance, indicating a higher risk of treatment failure. These findings suggest that modern thermoplastic obturation techniques should be prioritized in clinical practice to improve long-term endodontic success. Further in vivo studies with extended follow-up periods are necessary to validate these results in real-world clinical conditions and assess the long-term impact on patient outcomes.

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