EJPMR, 2026, 13(5), 219-226 **Research Article** **Impact Factor: 8.158**

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

ISSN (O): 2394-3211
ISSN (P): 3051-2573
Coden USA: EJPMAG

COMPARATIVE EVALUATION OF REMAINING DENTIN THICKNESS AND REMOVAL OF ROOT CANAL FILLING MATERIAL USING TWO OBTURATION TECHNIQUES AND TWO RETREATMENT FILE SYSTEMS– AN INVITRO STUDY

[1]*Dr. Ushma Sharma, [2]Dr. Sanjeev Kumar Tyagi, [3]Dr. Vartul Dwivedi, [4]Dr. Diya Gilla, [5]Dr. Varnita Yadav, [6]Dr. Harshita Karwatkar

[1,4,5,6]Post Graduate, Department of Conservative Dentistry and Endodontics, Peoples's Dental Academy, Bhopal, Madhya Pradesh, India.
[2]Dean, Professor and HOD, Department of Conservative Dentistry and Endodontics, Peoples's Dental Academy, Bhopal, Madhya Pradesh, India.
[3]Professor, Department of Conservative Dentistry and Endodontics, Peoples's Dental Academy, Bhopal, Madhya Pradesh, India.

***Corresponding Author: Dr. Ushma Sharma**

Post Graduate, Department of Conservative Dentistry and Endodontics, Peoples's Dental Academy, Bhopal, Madhya Pradesh, India.

DOI: https://doi.org/10.5281/zenodo.19885015

How to cite this Article: [1]*Dr. Ushma Sharma, [2]Dr. Sanjeev Kumar Tyagi, [3]Dr. Vartul Dwivedi, [4]Dr. Diya Gilla, [5]Dr. Varnita Yadav, [6]Dr. Harshita Karwatkar. (2026). Comparative Evaluation Of Remaining Dentin Thickness And Removal Of Root Canal Filling Material Using Two Obturation Techniques And Two Retreatment File Systems– An Invitro Study. European Journal of Biomedical and Pharmaceutical Sciences, 13(5), 219–226.

Article Received on 24/04/2026 **Article Revised on 13/04/2026** **Article Published on 01/05/2026**

ABSTRACT

Background: Successful endodontic retreatment requires effective removal of root canal filling material while preserving dentin integrity. Both obturation techniques and retreatment systems play a crucial role in determining these outcomes. **Aim:** To comparatively evaluate remaining dentin thickness (RDT) and removal of root canal filling material (RFM) using two obturation techniques and two retreatment file systems. **Materials and Methods:** Sixty extracted single-rooted mandibular premolar were divided into two groups based on obturation technique(n=30): lateral compaction and Obtura (C-Fill) system. Each group was subdivided based on retreatment file system: Hyflex Remover and Endostar REvision (n=15 each). All canals were obturated using gutta-percha with AH Plus sealer. Retreatment was performed using the respective systems. RDT was analyzed using CS 3D imaging software, and volumetric analysis of residual filling material was performed using 3D Slicer software (version 5.8.1). Data were analyzed using ANOVA and Tukey post hoc tests. **Results:** The least residual filling material (RFM) was observed in the Lateral Compaction + Hyflex group, while the highest was seen in the Obtura + REvision group. Hyflex demonstrated superior removal efficiency compared to Endostar REvision. Tukey analysis revealed that REvision caused greater dentin removal in coronal and middle thirds, whereas Hyflex resulted in increased dentin removal in the apical third. All intergroup differences were statistically significant ($p < 0.05$). **Conclusion:** Both obturation technique and retreatment system significantly influence retreatment outcomes. Hyflex showed superior cleaning efficiency, while dentin preservation varied across root levels between systems.

KEYWORDS: Retreatment, remaining dentin thickness, Hyflex Remover, Endostar REvision, lateral compaction, C-Fill obturating system.

INTRODUCTION

The primary goal of endodontic therapy is the complete elimination of microorganisms from the root canal system followed by three-dimensional obturation to prevent reinfection. Despite high success rates, failures may occur due to persistent intraradicular infection, inadequate cleaning and shaping, or improper obturation. In such situations, nonsurgical endodontic retreatment is considered the preferred approach, as it enables re-access to the canal system for disinfection and re-obturation.[3]

A critical step in retreatment is the effective removal of existing root canal filling materials, including gutta-percha and sealer. However, complete removal of these

materials remains a challenge due to their adhesion to canal walls and penetration into dentinal tubules. Previous studies have demonstrated that no retreatment technique can completely eliminate filling material from the root canal system, highlighting the need for improved techniques and instruments.[3,11]

The type of obturation technique plays a significant role in determining the ease of retreatment. Lateral compaction has long been considered a conventional and predictable technique; however, thermoplasticized obturation systems, such as injectable techniques, have gained popularity due to their ability to provide a more homogeneous and better adapted filling within the canal system. While this improved adaptation enhances the quality of obturation, it may adversely affect retrievability during retreatment procedures.[17,18] Studies have shown that thermoplasticized techniques tend to leave more residual filling material compared to conventional methods, thereby complicating retreatment.[18]

In addition to obturation technique, the choice of retreatment file system significantly influences the efficiency of removal of filling material and the preservation of dentin. Nickel–titanium (NiTi) rotary retreatment systems have become widely accepted due to their flexibility, cutting efficiency, and ability to maintain the original canal anatomy. Various systems have been introduced with modifications in design, taper, and metallurgy to enhance their performance.[3] Among these, heat-treated instruments such as Hyflex remover systems (Coltene-Whaledent, Allstetten, Switzerland) exhibit controlled memory properties that improve canal adaptability and removal efficiency.[8,11] Conversely, other rotary systems, such as Endostar Revision (Poldent, Warsaw, Poland), are designed for efficient cutting and rapid removal of obturating material, but may have varying effects on dentin preservation.

Preservation of remaining dentin thickness is a crucial factor in retreatment, as excessive dentin removal can weaken the tooth structure and increase the risk of vertical root fracture. Several studies have reported that different retreatment systems exhibit varying effects on dentin thickness depending on their design and work efficiency.[1,6,10] Instruments with greater taper or aggressive cutting action may result in more dentin removal, particularly in the coronal and middle thirds, whereas flexible instruments may influence the apical region more significantly.[4]

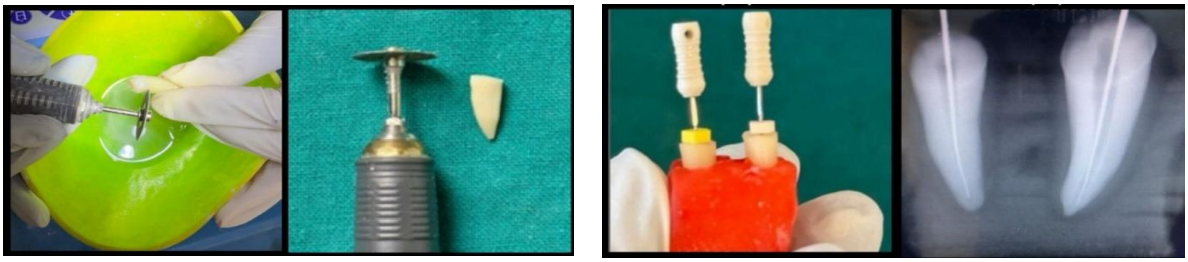
Advancements in imaging technologies have enabled more accurate evaluation of retreatment outcomes. Cone-beam computed tomography (CBCT) has been widely used for non-destructive assessment of remaining dentin thickness and canal morphology.[1,19] Additionally, three-dimensional volumetric analysis using software such as 3D Slicer allows precise quantification of residual filling material, thereby improving the reliability and reproducibility of results.[7]

Although numerous studies have evaluated retreatment systems and obturation techniques independently, there is limited literature assessing their combined effect on both removal efficiency and dentin preservation. Therefore, the present *in vitro* study was undertaken to comparatively evaluate the remaining dentin thickness and the removal of root canal filling material using two obturation techniques lateral compaction and thermoplasticized injectable technique (C-Fill) in combination with two retreatment file systems Hyflex Remover and Endostar REvision.

MATERIALS AND METHODS

This *in vitro* study was conducted on a total of 60 extracted human mandibular premolars with single roots, single canals, and completely formed apices. Preoperative intraoral periapical radiographs were taken to confirm canal morphology. Teeth with resorption, calcified canals, fractures, multiple canals, open apices, or previously obturated canals were excluded from the study. Soft tissue remnants, plaque, and calculus were removed using an ultrasonic scaler, and the samples were stored in 0.9% normal saline until further use.

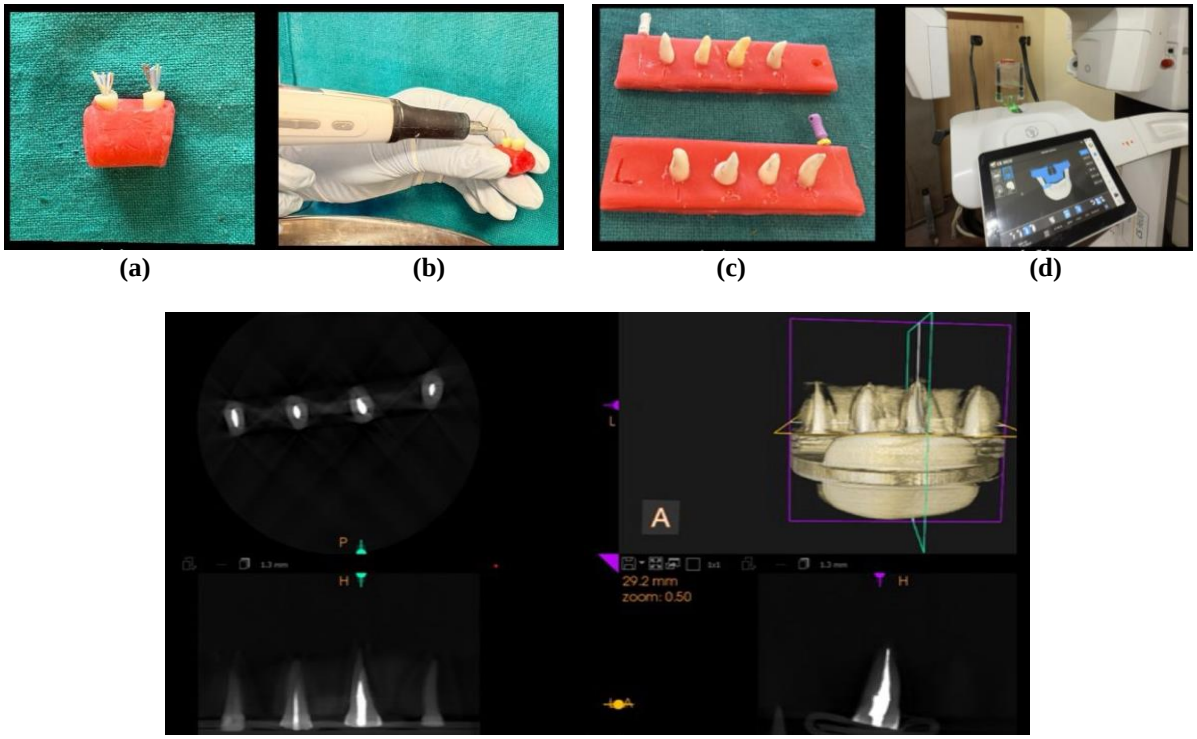
For standardization, all selected teeth were decoronated to obtain a uniform root length of 16 mm, measured from the apex. Sectioning was performed perpendicular to the long axis of the tooth using a diamond disc under copious water irrigation. Working length was established using a size #15 K-file by subtracting 1 mm from the apical foramen and confirmed radiographically. Root canal preparation was carried out using the ProTaper Gold rotary system (Dentsply Sirona, Ballaigues, Switzerland) up to size F3, following the manufacturer's instructions with an electronic endomotor. Apical patency was maintained using a size #10 K-file. Irrigation was performed using 5.25% sodium hypochlorite, 17% EDTA, and normal saline, followed by a final rinse with 2% chlorhexidine. The canals were then dried with absorbent paper points.



(a) (b) (c) (d)

Fig 1: (a)Teeth de-crowned with a double-sided diamond disc using a low-speed hand piece, (b) root canal length standardized at 16mm, (c) Apical patency was obtained by K-file size #15 (Mani Inc., Utsunomiya, Tochigi, Japan.), (d) WL confirmed radiographically.

The specimens were randomly divided into two groups (n = 30) based on the obturation technique employed. Group 1 was obturated using the lateral compaction technique, while Group 2 was obturated using the thermoplasticized injectable technique with the C-Fill obturating system ((COXO, Guangdong China Mainland). In both groups, gutta-percha was used along with AH Plus sealer (Dentsply Sirona, Konstanz, Germany). The quality and apical extent of obturation were verified using digital radiographs in both buccolingual and mesiodistal directions. The access cavities were sealed with a temporary restorative material, and the specimens were mounted on wax blocks (four teeth per block). These blocks were stabilized and subjected to cone-beam computed tomography (CBCT) scanning using the Carestream CS 9600 system to record baseline root canal volume and remaining dentin thickness. The specimens were then stored at 37°C and 100% humidity for two weeks to allow complete setting of the sealer.



(a) (b) (c) (d)

(e)

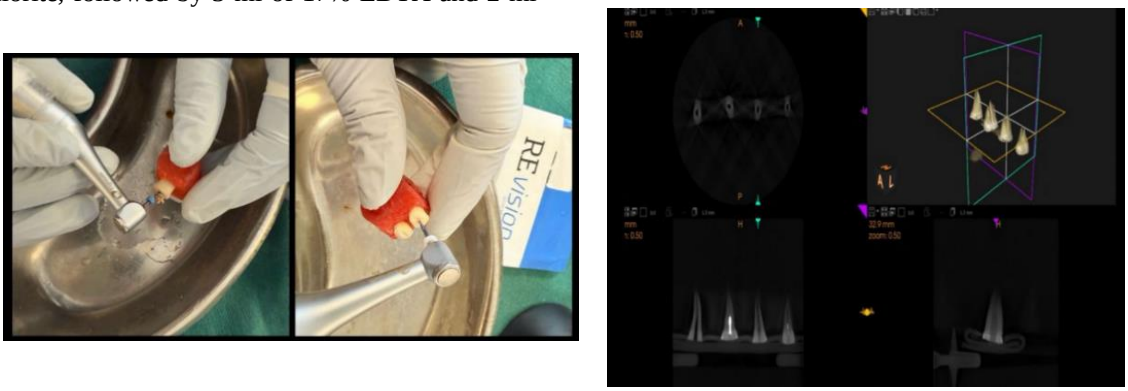
Fig 2: (a) Obturation done with lateral compaction, (b) Obturation using C-Fill system, (c) Specimen mounted on wax block, (d) and (e) CBCT scan and images obtained post obturation.

CBCT imaging was performed using a high-resolution dental mode. The acquired images were reconstructed in axial, coronal, and sagittal planes using Carestream CS 3D imaging software.

Following obturation, the samples in each group were further randomly subdivided into two subgroups (n = 15) based on the retreatment file system used. Subgroups 1A and 2A were retreated using the Hyflex Remover system, while subgroups 1B and 2B were retreated using the Endostar REvision system. Retreatment procedures were carried out according to the manufacturers' instructions. Hyflex Remover files were operated in continuous rotation at 400–800 rpm with a torque of 2.5 Ncm. The Endostar REvision system was used in a sequence starting with 30/.08 for the coronal third followed by

25/.06 for the middle and apical thirds at 300 rpm and 2.0 Ncm torque.

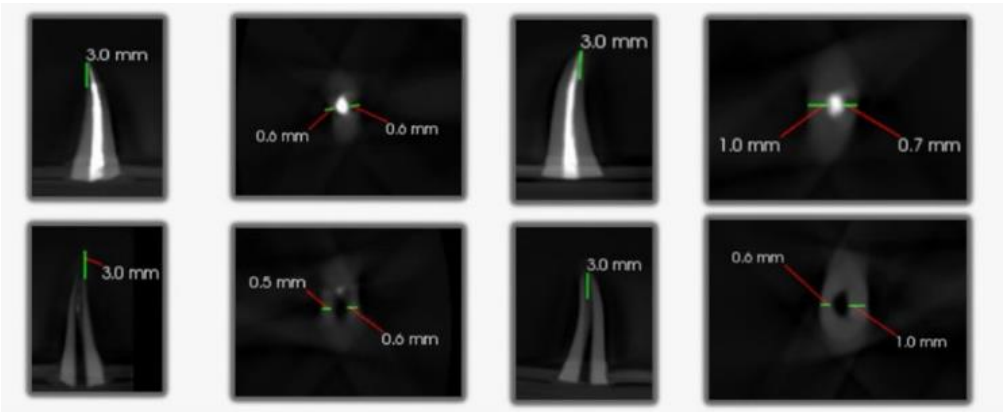
No chemical solvents were used during retreatment. Irrigation was performed using 15 ml of 5.25% sodium hypochlorite, followed by 3 ml of 17% EDTA and 2 ml of distilled water. Retreatment was considered complete when the working length was reached, the canal walls appeared smooth, and no visible remnants of filling material were observed on the instruments or during irrigation.



(a) (b) (c)

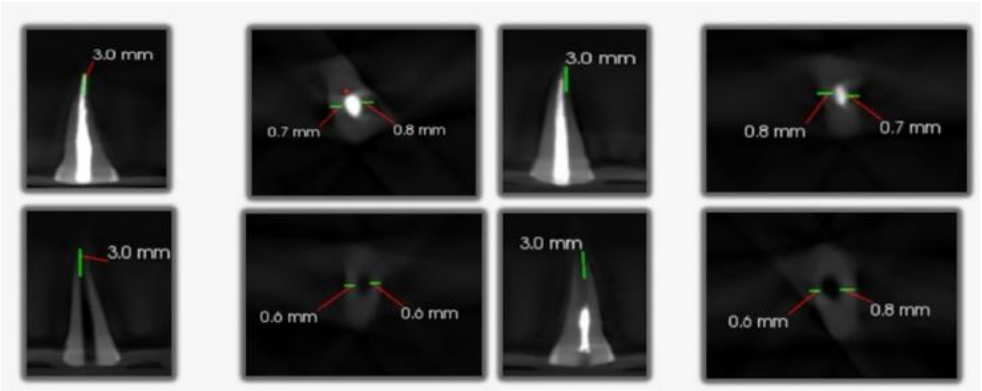
Fig 3: (a) Retreatment using Hyflex remover, (b) Retreatment using Endostar REvision file system, (c) CBCT done post removal of obturation.

Post-retreatment CBCT scans were obtained under the same conditions as the preoperative scans. The specimens were repositioned in the same orientation using wax blocks to ensure reproducibility. Remaining dentin thickness (RDT) was measured at three levels—3 mm, 6 mm, and 9 mm from the apex using CS 3D imaging software on axial sections. Volumetric analysis of residual filling material was performed by comparing pre- and post-retreatment scans using 3D Slicer software (version 5.8.1), with measurements taken in all three planes relative to the long axis of the tooth to minimize error.



(a) (b)

Fig 4: (a) and (b) Measurement of dentin thickness from axial view for group1.



(a) (b)

Fig 5: (a) and (b) Measurement of dentin thickness from axial view for group2.

RESULTS

All groups demonstrated a statistically significant reduction in remaining filling material following retreatment ($p < 0.001$). The Lateral Compaction + Hyflex Remover group showed the greatest reduction in RFM (mean reduction: 21.13), followed by Lateral Compaction + REvision (19.60). Among the Obtura groups, Obtura II + Hyflex (15.47) exhibited better removal efficiency compared to Obtura II + REvision (13.00). Overall, retreatment using the Hyflex system resulted in more effective removal of filling material compared to the REvision system, irrespective of the obturation technique. (Table 1)

A statistically significant difference in post-operative RFM was observed among the four groups (ANOVA, $p < 0.001$). The lowest mean RFM was seen in the Lateral Compaction + Hyflex group (2.47 ± 0.52), whereas the highest was observed in the Obtura II + REvision group (9.00 ± 0.76). Intermediate values were noted for Lateral + REvision and Obtura + Hyflex groups. These findings indicate that both the obturation technique and retreatment system significantly influence the efficiency of filling material removal, with the combination of lateral compaction and Hyflex being the most effective. (Table 2)

In all groups, a reduction in remaining dentin thickness was observed following retreatment across both mesiodistal and buccolingual directions at all root levels. Most comparisons demonstrated statistically significant reductions ($p < 0.001$), indicating dentin removal during retreatment procedures. The Hyflex system consistently showed greater reduction in dentin thickness, particularly in the mesiodistal direction and at apical levels, suggesting more aggressive dentin removal. In contrast, the REvision system exhibited comparatively smaller reductions in dentin thickness, indicating a more conservative approach in preserving root dentin.

Although some reductions were numerically small, the overall trend across all groups confirms that retreatment procedures result in measurable dentin loss, with variations depending on the file system and obturation technique used. (Table 3)

Table 4 shows Intergroup comparison revealed statistically significant differences in remaining dentin thickness among the four groups at all evaluated levels, except at the 6 mm buccolingual level ($p = 0.604$), where no significant difference was observed.

In the mesiodistal direction, the REvision groups consistently demonstrated greater remaining dentin thickness compared to the Hyflex groups at 3 mm, 6 mm, and 9 mm levels ($p < 0.001$), indicating better dentin preservation. Similarly, in the buccolingual direction, REvision showed higher dentin thickness at most levels, particularly at the coronal and apical thirds.

These findings suggest that while the Hyflex system is more efficient in removing filling material, it is associated with greater dentin removal. In contrast, the REvision system preserves more dentin, highlighting a trade-off between cleaning efficiency and dentin conservation.

The present study demonstrates that both obturation technique and retreatment file system significantly influence retreatment outcomes. The Hyflex system showed superior efficacy in removing root canal filling material but was associated with greater dentin removal. Conversely, the REvision system preserved more dentin thickness, though with comparatively reduced cleaning efficiency. Lateral compaction technique, when combined with Hyflex, yielded the most favorable results in terms of filling material removal. These findings highlight the importance of selecting an appropriate retreatment system to achieve an optimal balance between effective cleaning and preservation of tooth structure.

Table 1: Comparison of Remaining Filling Material (RFM) Before and After Retreatment Across Study Groups.

Obturation Technique	Retreatment System	n	Pre-op RFM (Mean ± SD)	Post-op RFM (Mean ± SD)	Mean Reduction	p-value
Lateral Compaction	Hyflex Remover	15	23.60 ± 1.12	2.47 ± 0.52	21.13	0.001*
Lateral Compaction	Endostar REvision	15	23.61 ± 1.12	4.00 ± 0.76	19.60	0.001*
Obtura II	Hyflex Remover	15	22.00 ± 0.76	6.53 ± 0.52	15.47	0.001*
Obtura II	Endostar REvision	15	22.00 ± 0.76	9.00 ± 0.76	13.00	0.001*

*Statistically significant

Table 2: Intergroup Comparison of Post-operative Remaining Filling Material (ANOVA and Tukey Post-hoc).

Group	Mean ± SD	ANOVA p-value
Lateral + Hyflex	2.47 ± 0.52	**0.001***
Lateral + REvision	4.00 ± 0.76	
Obtura + Hyflex	6.53 ± 0.52	
Obtura + REvision	9.00 ± 0.76	

*Statistically significant

Table 3: Intragroup Comparison of Remaining Dentin Thickness (RDT) Before and After Retreatment.

Group	Level	Direction	Mean Diff	t-value	p-value
Lateral + Hyflex	3 mm	MD	0.10	5.77	0.001*
	6 mm	MD	0.18	16.83	0.001*
	9 mm	MD	0.07	6.20	0.001*
	3 mm	BL	0.18	16.83	0.001*
	6 mm	BL	0.15	11.50	0.001*
	9 mm	BL	0.10	5.77	0.001*
Lateral + REvision	3 mm	MD	0.20	10.39	0.001*
	6 mm	MD	0.10	7.75	0.001*
	9 mm	MD	0.10	7.75	0.001*
	3 mm	BL	0.10	7.75	0.001*
	6 mm	BL	0.18	16.83	0.001*
	9 mm	BL	0.10	7.75	0.001*
Obtura + Hyflex	3 mm	MD	0.17	14.66	0.001*
	6 mm	MD	0.17	14.66	0.001*
	9 mm	MD	0.07	6.20	0.001*
	3 mm	BL	0.10	6.45	0.001*
	6 mm	BL	0.10	6.45	0.001*
	9 mm	BL	0.07	6.20	0.001*
Obtura + REvision	3 mm	MD	0.07	6.20	0.001*
	6 mm	MD	0.07	6.20	0.001*
	9 mm	MD	0.05	3.50	0.004*
	3 mm	BL	0.10	4.47	0.001*
	6 mm	BL	0.10	4.47	0.001*
	9 mm	BL	0.07	6.20	0.001*

*Statistically significant

Table 4: Intergroup Comparison of Post-operative Remaining Dentin Thickness (RDT).

Level	Direction	Lateral + Hyflex	Lateral + REvision	Obtura + Hyflex	Obtura + REvision	p-value
3 mm	MD	0.84 ± 0.11	1.04 ± 0.11	0.83 ± 0.05	1.41 ± 0.07	0.001*
6 mm	MD	1.35 ± 0.05	1.45 ± 0.05	1.33 ± 0.08	1.51 ± 0.07	0.001*
9 mm	MD	2.07 ± 0.08	2.25 ± 0.05	1.83 ± 0.08	2.23 ± 0.08	0.001*
3 mm	BL	2.52 ± 0.09	3.00 ± 0.07	2.45 ± 0.12	2.80 ± 0.20	0.001*
6 mm	BL	3.05 ± 0.05	3.57 ± 0.04	3.05 ± 0.12	3.08 ± 0.16	0.604
9 mm	BL	3.20 ± 0.08	3.66 ± 0.11	2.73 ± 0.12	3.68 ± 0.14	0.001*

*Statistically significant

DISCUSSION

The present in vitro study was undertaken to evaluate the influence of obturation techniques and retreatment file systems on the efficiency of removal of root canal filling material and preservation of remaining dentin thickness. Successful endodontic retreatment relies not only on the effective elimination of obturating material but also on maintaining the structural integrity of the root dentin, as excessive removal may predispose the tooth to fracture.

In the current study, the lateral compaction technique demonstrated significantly better retrievability of filling material compared to the thermoplasticized Obtura (C-Fill) system. This finding is in agreement with the observations of Sarı and Yılmaz[18], who reported that thermoplasticized obturation techniques tend to leave more residual filling material after retreatment due to their better adaptation to canal walls and deeper penetration into dentinal tubules. Similarly, Pedullà et al.[17] emphasized that obturation techniques influence the retreatment process by affecting the compactness and distribution of gutta-percha within the canal system. The more homogeneous mass created by thermoplasticized systems, while advantageous for sealing, can hinder complete removal during retreatment.

With respect to retreatment systems, the Hyflex Remover exhibited superior efficiency in removing root canal filling material, as evidenced by the lowest residual filling material in the lateral compaction + Hyflex group. This finding is consistent with the results reported by Valan et al.[8], who demonstrated improved removal efficiency of the HyFlex system using nano-computed tomography analysis. Similarly, Singh et al.[11] reported that heat-treated NiTi retreatment systems show enhanced ability for gutta-percha removal due to improved flexibility and better canal adaptability. The controlled memory property of Hyflex instruments allows them to conform closely to canal irregularities, thereby facilitating more effective debridement.

However, efficient removal of filling material must be balanced against dentin preservation. The present study revealed that the Endostar REvision system caused greater dentin removal in the coronal and middle thirds, whereas the Hyflex Remover system resulted in increased dentin removal in the apical third. These findings are partially in agreement with Kulkarni et al.[1] and Sneha et al.[6], who reported that different retreatment systems exhibit variable effects on remaining dentin thickness depending on their design, taper, and cutting efficiency. Instruments with larger tapers and more aggressive cutting edges tend to remove more dentin, particularly in the coronal portion of the canal.

The increased dentin removal observed with the Endostar REvision system in the coronal and middle thirds may be attributed to its higher taper and cutting efficiency, which can lead to more dentin removal during coronal flaring. This observation is supported by Suresh et al.[10], who noted that certain heat-treated rotary systems may cause significant dentin loss due to their aggressive design characteristics. On the other hand, the greater dentin removal in the apical third by the Hyflex system could be explained by its enhanced flexibility, allowing deeper penetration and more engagement of the apical canal walls. A similar trend has been noted in studies by Sowmya et al.[4], where flexible NiTi instruments showed increased shaping ability in the apical region, albeit with potential dentin loss.

The use of advanced imaging modalities in this study strengthens the reliability of the findings. CBCT-based evaluation of remaining dentin thickness has been widely accepted as a non-destructive and accurate method, as demonstrated by Kulkarni et al.[1] and Kapasi et al.[19] Additionally, volumetric analysis using 3D Slicer software provided precise quantification of residual filling material, reducing possible observational bias. Abraham et al.[7] also emphasized the importance of advanced imaging techniques, such as confocal microscopy and CBCT, in accurately assessing retreatment outcomes.

Despite the advancements in retreatment systems, complete removal of filling material remains challenging. As highlighted by Isa et al.[3], no single system can achieve complete cleanliness of the root canal system. This is consistent with the findings of the present study, where residual material was observed in all groups, although in varying amounts.

Overall, the findings of this study emphasize that both obturation technique and retreatment system significantly influence retreatment outcomes. While thermoplasticized obturation techniques may enhance sealing ability, they compromise retrievability. Similarly, while advanced rotary retreatment systems improve efficiency, they may lead to undesirable dentin removal depending on their design and site of action within the canal.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that both the obturation technique and the retreatment file system significantly influence the efficiency of removal of root canal filling material as well as the preservation of remaining dentin thickness. The combination of lateral compaction and Hyflex Remover demonstrated the highest retreatment efficacy, with the least amount of residual filling material. In contrast, the Obtura (C-Fill) technique in conjunction with the Endostar REvision system exhibited the lowest removal efficiency.

Furthermore, the pattern of dentin removal varied between the retreatment systems, with the Endostar REvision system causing greater dentin loss in the coronal and middle thirds, while the Hyflex Remover system resulted in increased dentin removal in the apical third. These findings underscore the need for a balanced clinical approach that ensures effective removal of obturating material while minimizing unnecessary loss of dentin, thereby preserving the structural integrity and long-term prognosis of endodontically treated teeth.

CLINICAL SIGNIFICANCE

Understanding the interaction between obturation techniques and retreatment systems can help clinicians select appropriate strategies that maximize removal of filling material while preserving dentin, thereby improving the long-term prognosis of endodontically treated teeth.

REFERENCES

1. Kulkarni NR, Kamat SB, Hugar SI, Nanjannawar GS, Patil PD. Evaluation of remaining dentin thickness following use of three different rotary nickel–titanium retreatment files: A cone-beam computed tomography study. Journal of Conservative Dentistry and Endodontics, Nov. 1, 2019; 22(6): 588-92.
2. Vasava N, Modi S, Joshi C, Thumar S, Parmar A, Jadawala K. Stereomicroscopic evaluation of dentinal microcracks after instrumentation of curved canal with rotary files in two motions. Journal of Dentistry Indonesia, 2022; 29(3): 202-10.
3. Isa MM, Ramlan NA, Ayoub AA. Rotary systems for root canal gutta-percha removal: A Review. Compendium of Oral Science, 2023; 10(1): 57-75.
4. Sowmya MR, Solete P, Jeevanandan G, Surendar S, Bavabeedu SS, Ahmad ZH, Balaji TM, Bhandi S. Influence of heat-treated files on conserving the remaining dentin thickness during endodontic retreatment–An invitro CBCT study. J King Saud Univ. Sci., 2023; 35(11): 102969.
5. Sairaman S, Solete P, Jeevanandan G, Antony SD, Kavoor S, Sandeep AH. Comparative evaluation of the remaining dentin thickness using Solite RS3 and ProTaper universal retreatment files: A nanocomputed tomography study. Endodontology, Apr. 1, 2024; 36(2): 175-80.

6. Sneha PK, Nainan MT, Nirupama DN, Vijay R, Thomas H, Patil PR. An in vitro study evaluating the canal centering ability, canal transportation, and remaining dentin thickness of three retreatment systems. Journal of Conservative Dentistry and Endodontics, Jan. 1, 2026; 29(1): 47-52.
7. Abraham MS, Kudva AR, Nair PM, Kini S, Kalander S, Farookh FM. Comparative evaluation of the efficacy of three different retreatment files in removing root canal filling material: An In vitro confocal microscopy study. Endodontology, Apr. 1, 2025; 37(2): 136-41.
8. Valan AS, Solete P, Antony SD, Ramamoorthi S, Alasqah M, Arunachalam V. Qualitative and quantitative assessment of solite RE black and HyFlex remover systems for endodontic retreatment-An in vitro nano-computed tomography analysis. Saudi Endodontic Journal, Jan. 1, 2025; 15(1): 59-66.
9. Lodha S, Nanda Z. A comparative evaluation of different retreatment methods on apical root microcracks initiation and propagation: An in vitro study. Endodontology, Apr. 1, 2025; 37(2): 175-82.
10. Suresh S, Solete P, Antony DP, Teja KV, Sandeep AH, Sairaman S, Cicciù M, Minervini G. Efficacy of Various Heat-treated Retreatment File Systems on Dentin Removal and Crack Analysis: An in vitro Study. Pesquisa Brasileira em Odontopediatria e Clínica Integrada, Sep. 30, 2024; 24: e240146.
11. Singh KB, Akhtar MS, Nagar R, Agarwal A, Azhar S, Singh V, Ansari S, Singh Sr V. Comparative analysis of the efficacy of various retreatment file systems in the removal of gutta-percha in retreatment cases and time taken during the procedure: An in vitro cone beam CT Study. Cureus, Mar. 5, 2024; 16(3).
12. Aarthi S, Sivakumar JS, Sivakumar AA, Soundappan JS, Chittrarasu M, Jayanthi G. Comparative evaluation of incidence of dentinal defects after root canal preparation using three different endodontic retreatment systems–An in vitro study. Journal of Conservative Dentistry and Endodontics, Mar. 1, 2024; 27(3): 262-7.
13. Tiwari R, Kaur GP, Garg M, Nain JK, Sharma D, Dixit H, Prashant MC. Efficacy of retreatment files in removing bio-ceramic vs resin sealers a comparative study. International Journal of Life Sciences, Biotechnology and Pharma Research, July-Sep 2023; 12(3).
14. Newase P, Bhargava K, Paunikar M, Bhawalkar A, Kumar T, Sarode G. Comparative Evaluation of the Effect of Hand File, Different Nickel-Titanium Retreatment Files, and Self-Adjusting File System on the Incidence of Dentinal Microcrack Formation during the Removal of Root Canal Filling Material: An In vitro Stereomicroscopic Study. Medical Journal of Dr. DY Patil Vidyapeeth, Sep. 1, 2023; 16(5): 670-8.
15. Tomer AK, Kumari S, Rastogi D, Ramachandran M, Mushtaq H, Cecilia LL, Tyagi A, Poonia S. Evaluation of Gutta Percha removal from different NITI rotary file system: An in vitro study. Int J App Dent Sci., 2021; 7(2): 1-4.
16. Işık M, Aydın ZU. Effect of different obturation techniques on treatment results in single-visit non-surgical endodontic retreatment: randomized controlled clinical study. BMC Oral Health, Nov. 28, 2024; 24(1): 1449.
17. Pedullà E, Iacono F, Pitrolo M, Barbagallo G, La Rosa GR, Pirani C. Assessing the impact of obturation techniques, kinematics and irrigation protocols on apical debris extrusion and time required in endodontic retreatment. Australian Endodontic Journal, Dec. 2023; 49(3): 623-30.
18. Sarı M, Yılmaz K. The effect of different obturation techniques using different root canal sealers on the residual filling material after retreatment procedures. Nigerian Journal of Clinical Practice, Feb. 1, 2024; 27(2): 174-9.
19. Kapasi K, Kesharani P, Kansara P, Patil D, Kansara T, Sheth S. In vitro comparative evaluation of efficiency of XP-endo shaper, XP-endo finisher, and XP-endo finisher-R files in terms of residual root filling material, preservation of root dentin, and time during retreatment procedures in oval canals–A cone-beam computed tomography analysis. Journal of Conservative Dentistry and Endodontics, Mar. 1, 2020; 23(2): 145-51.