

Comparison of the Effectiveness of Various Continuous Rotary and Reciprocating Systems to Remove Gutta-Percha and an Epoxy-based Sealer from Root Canals Using CBCT: An in Vitro Study¹⁻⁵Dr. Shrashti Kasera, Dr. Indra Gupta, Dr. Dipali Kumari, Dr. Vaishnavi Laychettivar, Dr. Madhulika Banerjee**Corresponding Author:** Dr. Shrashti Kasera**Citation of this Article:** Dr. Shrashti Kasera, Dr. Indra Gupta, Dr. Dipali Kumari, Dr. Vaishnavi Laychettivar, Dr. Madhulika Banerjee, “Comparison of the Effectiveness of Various Continuous Rotary and Reciprocating Systems to Remove Gutta-Percha and an Epoxy-based Sealer from Root Canals Using CBCT: An in Vitro Study”, IJDSIR- August – 2025, Volume – 8, Issue – 4, P. No. 75 – 85.**Copyright:** © 2025, Dr. Shrashti Kasera, et al. This is an open access journal and article distributed under the terms of the creative common’s attribution non-commercial License. Which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given, and the new creations are licensed under the identical terms.**Type of Publication:** Original Research Article**Conflicts of Interest:** Nil**Abstract**

Aim: The aim of this in vitro study was to compare the effectiveness of four different continuous rotary and reciprocating retreatment systems—ProTaper Universal Retreatment, HyFlex Remover, WaveOne Gold, and Mtwo Retreatment files—in removing gutta-percha and epoxy resin-based sealer (AH Plus) from root canal walls, using Cone Beam Computed Tomography (CBCT) for volumetric analysis.

Materials and Methods: Sixty extracted single-rooted mandibular premolars with fully formed apices were selected, instrumented using ProTaper Gold rotary files, and obturated with AH Plus sealer and ProTaper gutta-percha (F3 size) using the single-cone technique. Following a one-month incubation period at 37°C, specimens were randomly divided into four groups (n=15) and retreated using the designated systems. Pre- and post-retreatment CBCT scans were performed to evaluate the volume of residual filling material. Data were statistically analyzed using one-way ANOVA,

Games-Howell post hoc tests, and paired t-tests ($p < 0.05$).

Results: All systems demonstrated significant reduction in obturation material ($p < 0.001$), but none achieved complete removal. HyFlex Remover exhibited the lowest mean residual volume ($5.76 \pm 0.67 \text{ mm}^3$), followed closely by ProTaper Universal ($5.81 \pm 0.37 \text{ mm}^3$) and Mtwo ($6.92 \pm 0.50 \text{ mm}^3$). WaveOne Gold showed the highest residual volume ($7.51 \pm 0.88 \text{ mm}^3$), indicating the least efficacy. The differences among the groups were statistically significant ($p = 0.001$).

Conclusion: Within the limitations of this CBCT-based in vitro study, HyFlex Remover was found to be the most effective system for removing gutta-percha and AH Plus sealer, while WaveOne Gold was the least effective. The performance of each system is influenced by factors such as file design, metallurgy, and motion dynamics. Complete removal remains a challenge, especially when epoxy resin-based sealers are used, emphasizing the need for continued advancements in retreatment strategies.

Keywords: Root canal retreatment, HyFlex Remover, WaveOne Gold, ProTaper Universal Retreatment, Mtwo files, Gutta-percha removal, AH Plus sealer, CBCT, Epoxy resin-based sealer, Endodontic retreatment efficacy.

Introduction

The success of endodontic treatment hinges on the thorough debridement and effective cleaning of the root canal system. Following adequate biomechanical preparation, the root canal is three-dimensionally obturated with an inert filling material to seal the canal and prevent reinfection. The reported clinical success rate of endodontic therapy ranges between 86% and 98%.¹

Despite these favorable outcomes, endodontic treatment can fail due to multiple factors, including iatrogenic procedural errors, persistent microbial infection, inadequate cleaning or obturation, coronal leakage, and complications such as ledge formation, overextended fillings, untreated canals, fractured instruments, or root perforations.¹

In the retrospective study titled "Success or failure of endodontic treatments: A retrospective study" by Santos-Junior AO et al., 2019, the authors evaluated the outcomes of previously performed root canal treatments and assessed the rate of failure requiring retreatment.

Failure rate: Approximately 17.7% of the endodontically treated teeth evaluated in this study required retreatment, indicating clinical failure.²

The primary objective of root canal retreatment is the complete removal of existing filling materials, microorganisms, and necrotic debris contributing to apical periodontitis.³⁻⁴ Gutta-percha (GP), in conjunction with epoxy resin-based sealers, remains the most commonly used obturation material. Effective removal of these materials is vital for successful retreatment, as

Grossman emphasized the importance of using retrievable root-filling substances.⁵

Various techniques exist for the removal of gutta-percha, including hand instrumentation, rotary files, ultrasonic tips, heat carriers, and chemical solvents.⁶⁻¹¹ Among these, hand files without solvents are time-consuming and less efficient, particularly when dealing with well-compacted fillings. In contrast, the advent of nickel-titanium (NiTi) rotary instruments has revolutionized root canal preparation and retreatment by improving efficiency, reducing clinical time, minimizing operator fatigue, and enhancing patient comfort.¹²⁻¹⁷

Several NiTi systems have been developed to facilitate effective retreatment. The ProTaper Universal Retreatment System consists of three sequential files—D1 (30/0.09), D2 (25/0.08), and D3 (20/0.07)—designed for the coronal, middle, and apical thirds respectively.¹⁸

The HyFlex™ Remover (Coltene) is a novel rotary file made from thermomechanically treated NiTi alloy that enhances flexibility and fracture resistance.¹⁹

The WaveOne™ Gold (Dentsply) system utilizes reciprocating motion with files composed of M-Wire alloy, enhancing fatigue resistance and cutting efficiency.²⁰

The Mtwo® Retreatment System (VDW) features an S-shaped cross-section and active cutting tips in sizes R15/.05 and R25/.05, enabling effective removal of both gutta-percha and dentin.²¹

Gutta-percha remains popular for its biocompatibility, ease of handling, and retrievability.²² It is typically used in combination with AH Plus, an epoxy resin-based sealer with excellent dimensional stability, biocompatibility, and sealing ability.²³ While solvents can assist in removing obturating materials, their use is controversial due to concerns over safety and incomplete dissolution.²⁴

Although many systems have been developed for retreatment, no single instrument consistently ensures complete removal of obturating material.²⁵ This variability underscores the need for a standardized, evidence-based comparison of retreatment efficacy.

This in vitro study aims to evaluate and compare the effectiveness of four endodontic retreatment systems—ProTaper Universal Retreatment, HyFlex Remover, WaveOne Gold, and Mtwo Retreatment—in removing gutta-percha and AH Plus sealer from root canals. Cone Beam Computed Tomography (CBCT) will be used for three-dimensional, non-destructive evaluation and volumetric analysis of residual material. The findings aim to guide clinicians in selecting the most efficient retreatment protocol to enhance canal cleanliness and improve treatment outcomes.

Materials and Methods

Armamentarium

The following equipment and materials were utilized throughout the study:

- **Access Preparation:** High-speed airtor handpiece (NSK, Nakanishi Inc., Japan)
- **Working Length Determination:** Endo gauge and K-files (#10, #15, #20) (Mani Dental Inc., Japan)
- **Irrigation**
 - 5.25% Sodium Hypochlorite (Azure Laboratories, Maharashtra, India)
 - 17% EDTA (Avue Prep, Dental Avenue Pvt. Ltd., Maharashtra, India)
 - 0.9% Saline (Baxter India Pvt. Ltd., Tamil Nadu, India)
- **Root Canal Instrumentation**
 - ProTaper Gold rotary files (Dentsply Maillefer) with X-Smart Plus endodontic motor.

- **Retreatment Systems**

- ProTaper Universal Retreatment Files (D1, D2, D3)
- HyFlex Remover (Coltene, Switzerland)
- WaveOne Gold (Dentsply Maillefer)
- Mtwo Retreatment Files (R15/.05, R25/.05) (VDW, Germany)

- **Obturation Materials:**

- ProTaper Gutta-percha (F3) and AH Plus epoxy resin-based sealer (Dentsply)
- Absorbent paper points (Dentsply)

- **Temporary Restoration:** Cavit (3M ESPE, Germany)

- **Mounting & Cutting Tools:** Modeling wax strips, diamond cutting disc, micromotor with straight handpiece

- **Imaging Equipment:**

- Digital RVG
- Cone Beam Computed Tomography (CBCT) – CS 3D Imaging (Carestream Dental)

Sample Selection

Sixty freshly extracted human single-rooted mandibular premolars were collected from oral surgery departments following therapeutic extractions, with informed consent from patients.

Inclusion Criteria

- Single root with a single canal
- Fully formed apices
- No prior endodontic treatment

Exclusion Criteria

- Root resorption or calcifications
- Fractured or curved roots
- More than one canal
- Open apices
- Previously obturated teeth

Specimen Preparation

Radiographs were taken to confirm canal anatomy. Teeth were cleaned of soft tissue and calculus using ultrasonic scalers, then stored in 0.9% saline until use.

To standardize working length, crowns were partially removed using a diamond disc under water cooling. Working length was determined by inserting a #15 K-file 1 mm short of the radiographic apex.

Canals were instrumented using the crown-down technique with ProTaper Gold rotary files (up to F3). Irrigation was alternated with 5.25% NaOCl and 17% EDTA, followed by a final saline rinse. Drying was done using absorbent paper points.

Obturation was performed using the single-cone technique with F3 gutta-percha and AH Plus sealer. The coronal access was sealed with Cavit. Specimens were stored at 37°C for one month to allow complete sealer setting.

Retreatment Procedure

After storage, samples were randomly divided into four groups (n = 15 each) and retreated using the following systems:

- **Group I:** ProTaper Universal Retreatment (D1, D2, D3)
- **Group II:** HyFlex Remover
- **Group III:** WaveOne Gold
- **Group IV:** Mtwo Retreatment

No solvents were used in any group. Each group followed the respective manufacturer's protocol using the X-Smart Plus endodontic motor.

CBCT Imaging and Volumetric Analysis

Specimens underwent CBCT scanning at 74 kV and 2.5 mA in high-resolution dental mode with a 360° rotation and 20-second scan time. Root canal volume was assessed using CS 3D Imaging software in axial, coronal, and sagittal planes.

Volumetric changes were measured pre- and post-retreatment. The percentage of remaining filling material was calculated as:

$$\text{Volume Percentage of Remaining Filling Material} = \frac{\text{Volume of Remaining Filling Material} \times 100}{\text{Total Volume of Material in Canal before Retreatment}}$$

A qualified maxillofacial radiologist performed all image assessments.

Statistical Analysis

Data were analyzed using **SPSS Version 17.0**. Descriptive statistics (mean \pm SD) were calculated for all groups.

- **One-way ANOVA** was used to assess differences in mean remaining filling material between groups.
- **Games–Howell post hoc test** was applied for pairwise comparisons.
- **Paired t-test** assessed volume change significance within each group (pre- vs. post-treatment).

A p-value < 0.05 was considered statistically significant.

Results

Baseline Equivalence of Groups

A one-way ANOVA was conducted to evaluate any pre-existing differences in the volume of root canal filling material among the four groups before retreatment. As shown in Table 1, the mean volume ranged from 36.54 mm³ to 37.42 mm³. The statistical analysis revealed no significant difference among the groups (p = 0.451), confirming the baseline uniformity of the sample distribution.

Table 1: Comparison of Mean Volume before Retreatment Among the Four Groups

Group	Mean Volume (mm ³)	Standard Deviation	Standard Error	95% Confidence Interval	Minimum	Maximum	p-value
Group I – ProTaper Universal	37.26	1.59	0.412	36.38 – 38.15	34.83	39.50	
Group II – HyFlex Remover	36.54	1.28	0.330	35.82 – 37.25	34.83	38.51	0.451
Group III – WaveOne Gold	37.42	1.72	0.440	36.46 – 38.37	34.83	39.90	
Group IV – Mtwo Retreatment	36.97	1.70	0.440	36.02 – 37.92	34.03	39.90	

Comparison of Remaining Filling Material After Retreatment

The volume of residual filling material was measured post-retreatment using CBCT imaging. As summarized in Table 2, the WaveOne Gold (Group III) system showed the highest mean residual volume (7.51 mm³), while HyFlex Remover (Group II) demonstrated the lowest (5.76 mm³).

One-way ANOVA revealed a statistically significant difference among the four groups (p = 0.001), indicating varying efficacy among the tested systems.

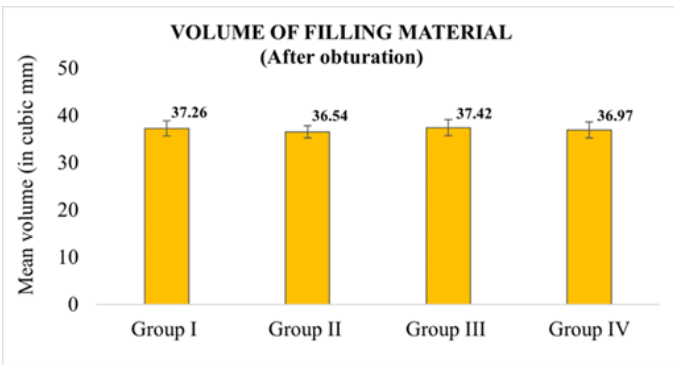
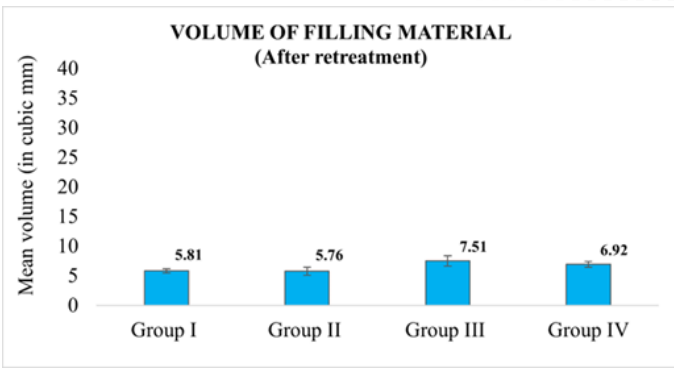


Table 2: Comparison of Mean Volume After Retreatment Among the Four Groups

Group	Mean Volume (mm ³)	Standard Deviation	Standard Error	95% Confidence Interval	Minimum	Maximum	p-value
Group I – ProTaper Universal	5.81	0.37	0.09	5.60 – 6.02	5.00	6.62	
Group II – HyFlex Remover	5.76	0.67	0.17	5.39 – 6.13	5.85	6.75	
Group III – WaveOne Gold	7.51	0.88	0.22	7.02 – 8.00	6.44	8.61	0.001 **
Group IV – Mtwo Retreatment	6.92	0.50	0.13	6.64 – 7.20	6.06	7.75	



Intragroup Comparison: Volume Before vs. After Retreatment

A paired t-test was performed to evaluate the effectiveness of each retreatment system by comparing the volume of obturating material before and after retreatment within the same group.

All four groups demonstrated a statistically significant reduction in filling material post-retreatment ($p < 0.001$ for all), indicating effective material removal by each system.

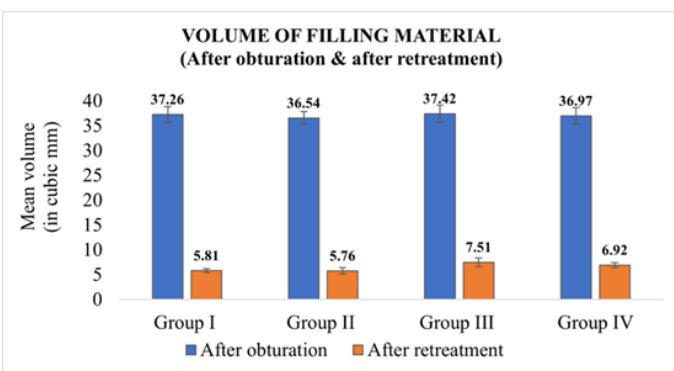
Table 3: Paired Comparison of Volume Before and After Retreatment Within Each Group

Group	Before Retreatment (Mean ± SD)	After Retreatment (Mean ± SD)	Mean Difference	Std. Dev of Difference	Standard Error	p-value
Group I – ProTaper Universal	37.26 ± 1.59	5.81 ± 0.37	30.70	1.30	0.35	0.001 **
Group II – HyFlex Remover	36.54 ± 1.28	5.76 ± 0.67	29.80	1.94	0.50	0.001 **
Group III – WaveOne Gold	37.42 ± 1.72	7.51 ± 0.88	29.80	1.94	0.50	0.001 **
Group IV – Mtwo Retreatment	36.97 ± 1.70	6.92 ± 0.50	30.05	1.86	0.48	0.001 **

- HyFlex Remover exhibited the highest efficacy, followed by ProTaper Universal, Mtwo, and WaveOne Gold, in that order.
- WaveOne Gold showed significantly more residual material, indicating comparatively lower retreatment efficiency.

Discussion

Nonsurgical root canal retreatment aims to eliminate persistent or recurrent periapical infection by removing existing obturating materials, thereby facilitating reinstrumentation, disinfection, and three-dimensional re-obturation. The success of retreatment is heavily dependent on the complete removal of gutta-percha and epoxy resin-based sealers like AH Plus, which, while



Summary

- All systems were effective in reducing obturation volume significantly.

beneficial during initial treatment due to their excellent sealing properties, pose challenges for complete removal due to strong adhesion and dimensional stability.

Rationale for Sample Selection

This study employed mandibular first premolars due to their consistent single canal anatomy and moderate curvature. These characteristics allowed for standardization across samples while still simulating clinically relevant challenges, such as oval- or ribbon-shaped canals, particularly in the apical third. These anatomical variations are known to hinder complete removal of filling material, providing a valid platform to test the adaptability and efficacy of different retreatment systems.

Efficacy of Retreatment Systems

This in vitro investigation compared four contemporary retreatment systems:

- **Group I:** ProTaper Universal Retreatment
- **Group II:** HyFlex Remover
- **Group III:** WaveOne Gold (WOG)
- **Group IV:** Mtwo Retreatment Files

All groups were tested for their ability to remove gutta-percha and AH Plus sealer, with Cone Beam Computed Tomography (CBCT) used for non-destructive, three-dimensional volumetric evaluation.

Baseline Standardization

The initial canal volumes across the four groups showed no statistically significant difference ($p = 0.451$), confirming sample homogeneity. This ensured that the retreatment systems were compared under similar anatomical conditions and that the results reflect true differences in file performance rather than canal variability.

Post-Retreatment Comparison

After retreatment, a statistically significant difference in residual obturation volume was observed across the

groups ($p = 0.001$), affirming that file design and kinematics play a vital role in material removal.

- HyFlex Remover (Group II) showed the lowest residual volume ($5.76 \pm 0.67 \text{ mm}^3$), indicating superior efficacy.
- ProTaper Universal (Group I) followed closely with a mean residual volume of $5.81 \pm 0.37 \text{ mm}^3$.
- Mtwo (Group IV) exhibited moderate performance ($6.92 \pm 0.50 \text{ mm}^3$).
- WaveOne Gold (Group III) recorded the highest residual volume ($7.51 \pm 0.88 \text{ mm}^3$), suggesting limited cleaning efficacy.

Performance Analysis of Instruments

HyFlex Remover (Group II)

HyFlex Remover exhibited the **best performance**, likely due to its:

- Controlled Memory (CM) NiTi alloy, allowing optimal flexibility and canal adaptability.
- Non-cutting tip, ensuring safe progression without canal transportation.
- Triangular cross-section and open flute design, which aid debris removal and prevent blockage.

These features may explain its superior engagement in complex apical geometries. Previous studies, such as those by Khedmat et al. (2020) and Alani et al. (2020), support the finding that HyFlex Remover is highly effective in removing gutta-percha from irregular canal shapes.

WaveOne Gold (Group III)

WOG displayed the poorest performance, possibly due to its single-file reciprocating design. Although the M-wire alloy enhances flexibility and fatigue resistance, the limited engagement area and reduced tactile feedback may hinder thorough debridement, particularly in the apical and buccolingually extended canals. Similar outcomes were reported by Rödiger et al. (2016), who

observed limitations in reciprocating systems in anatomically complex canals.

ProTaper Universal Retreatment (Group I)

ProTaper Universal files showed high efficacy, attributable to their three-file system (D1-D3) designed to address the coronal, middle, and apical thirds individually. However, their lack of heat-treated metallurgy and progressive taper may reduce performance in narrow, curved apical sections, as supported by findings from Unal et al. (2015).

Mtwo Retreatment Files (Group IV)

Mtwo files performed moderately well. Their S-shaped cross-section and active cutting tip provide aggressive cutting and good debris transportation, but the inherent stiffness limits flexibility in curved canals. Studies by Karamifar et al. (2018) have reported similar observations, noting that Mtwo performs well in straight canals but less so in more complex anatomies.

Within-Group Improvements

All groups demonstrated statistically significant reduction in obturation material post-retreatment ($p < 0.001$), indicating that each system was effective in removing a substantial portion of gutta-percha and sealer. Nonetheless, none of the systems achieved complete removal, consistent with existing literature.

Challenges with Epoxy Resin Sealer Removal

AH Plus, used in all specimens, is an epoxy resin-based sealer with strong adhesive properties and excellent dimensional stability. Its penetration into dentinal tubules and chemical bonding with root canal walls makes its removal particularly challenging, especially in apical or inaccessible areas. This explains the universal presence of residual material despite the use of advanced instrumentation, and aligns with previous conclusions by Saad et al. (2007) and Zehnder & Paqué (2011).

Role of CBCT

CBCT proved to be a reliable, non-invasive tool for three-dimensional evaluation of filling remnants. Unlike traditional radiography or destructive sectioning, CBCT enabled precise volumetric assessment, as validated by studies such as those by Tay et al. (2010) and Somma et al. (2008). While micro-CT provides higher resolution, it remains impractical for routine use due to higher cost and limited availability.

Clinical Relevance and Future Directions

This study highlights the need for careful instrument selection during retreatment, especially in the presence of resistant sealers and complex apical morphology. The superior performance of HyFlex Remover suggests it may be the preferred system in clinical settings, particularly for irregular or curved canals.

While ProTaper and Mtwo offer effective alternatives, systems like WaveOne Gold may benefit from adjunctive strategies—such as the use of solvents, ultrasonic activation, or hybrid instrumentation—to improve removal efficacy.

Limitations and Recommendations

Although this was a well-controlled in vitro study, in vivo variables such as canal curvature, patient movement, root canal calcifications, and operator fatigue were not replicated. Future research should:

- Incorporate multi-rooted and curved canals,
- Evaluate combined use of mechanical and chemical adjuncts,
- Explore hybrid retreatment protocols for more complete material removal.

Conclusion

Within the limitations of this in vitro CBCT-based study, it can be concluded that none of the tested retreatment systems were able to completely remove gutta-percha and AH Plus epoxy resin-based sealer from the root canal

walls. However, significant differences in efficacy were observed among the systems evaluated.

Among all tested groups:

- HyFlex Remover demonstrated the highest efficacy, exhibiting the lowest mean residual volume of obturation material after retreatment.
- This was followed by the ProTaper Universal Retreatment system and the Mtwo Retreatment system, both of which showed moderate effectiveness.
- WaveOne Gold was the least effective, showing the highest volume of residual material post-retreatment.

The differences in performance can be attributed to factors such as:

- Instrument design (e.g., tip configuration, taper),
- Cross-sectional geometry,
- Metallurgical properties (e.g., heat treatment and controlled memory alloys),
- Kinematics (rotary vs. reciprocating motion).

HyFlex Remover's controlled memory alloy, enhanced flexibility, and innovative flute design contributed to improved canal wall adaptation and debris removal. In contrast, WaveOne Gold, despite its metallurgical advantages and fatigue resistance, may have been limited by its single-file reciprocating design, which potentially reduced engagement with canal walls, particularly in the apical third.

The use of AH Plus sealer, known for its strong dentinal bonding and dimensional stability, presented an additional challenge, reinforcing why none of the systems achieved complete removal. Its persistence across all groups highlights the need for advanced file designs and adjunctive techniques in achieving optimal retreatment outcomes.

This study underscores the importance of three-dimensional imaging modalities such as CBCT, which

provide accurate, non-destructive assessment of obturation remnants and enable more precise evaluation of endodontic procedures.

Clinical Implications and Future Recommendations

- Clinicians should carefully select retreatment systems based on canal anatomy, obturation techniques, and material properties.
- HyFlex Remover may be the system of choice in retreatment cases involving complex apical anatomy or challenging sealers like AH Plus.
- Further clinical studies, involving larger sample sizes, multi-rooted teeth, and in vivo scenarios, are recommended to validate these findings and expand their clinical applicability.
- Future research should also explore the synergistic use of mechanical files with chemical solvents, ultrasonic activation, and hybrid retreatment protocols for enhancing removal efficacy.

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