Original Article

Comparative assessment of retreatment systems for the removal of root canal filling materials using cone-beam computed tomography: An *in vitro* study

Shivani Deshwal, Gaudam Vijegopal[1], Parikshit Chakraborty[2], Supriya Bhatt[3], Sakshi Jain[4], S. Shruthi Lakshmi[5]

Department of Conservative Dentistry and Endodontics, Seema Dental College and Hospital, Rishikesh, [3]Department of Dentistry, Graphic Era Hospital, Dehradun, Uttarakhand, [1]Department of Conservative Dentistry and Endodontics, Vivekananda Dental College for Women, Tiruchengode, [5]Department of Dentistry, Kongu Dental Clinic, Erode, Tamil Nadu, [2]Department of Dentistry, Teeth Care Multispeciality Clinic, Kolkata, West Bengal, [4]Department of Conservative Dentistry and Endodontics, Kothiwal Dental College and Research Centre, Moradabad, Uttar Pradesh, India

Abstract

Introduction: Successful endodontic retreatment depends on effective removal of existing root canal filling materials to enable adequate disinfection. Persistent intraradicular microorganisms are a primary cause of endodontic failure, underscoring the importance of thorough obturation removal. Although several nickel–titanium (NiTi) rotary retreatment systems have been introduced to improve efficiency, their performance may vary depending on the type of endodontic sealer used. The present study compared the efficacy of four rotary retreatment file systems in removing filling materials obturated with either an epoxy resin-based or a bioceramic sealer using cone-beam computed tomography (CBCT).

Aim and Objectives: To evaluate and compare the efficacy of four NiTi rotary retreatment file systems in removing the root canal filling materials from the canals obturated with AH Plus or Bio-C Sealer.

Materials and Methods: Eighty extracted permanent mandibular molars were selected. Mesiobuccal canals were prepared and obturated with gutta-percha using either AH Plus or Bio-C Sealer. Retreatment was performed without solvents using HyFlex Remover, EdgeFile XR, ProTaper Universal Retreatment, or NeoEndo systems. Residual filling material volume was assessed using CBCT. Data were analyzed using two-way ANOVA followed by Tukey's *post hoc* test ($P < 0.05$).

Results: No significant difference was observed between the two sealers regarding the residual filling material ($P > 0.05$). HyFlex Remover and EdgeFile XR removed significantly more filling materials than ProTaper Universal Retreatment and NeoEndo systems ($P < 0.001$).

Conclusion: None of the systems achieved the complete removal of the filling material. HyFlex Remover and EdgeFile XR demonstrated superior efficacy irrespective of the sealer used.

Keywords: Bioceramic materials; cone-beam computed tomography; endodontic retreatment; epoxy resin-based sealers; nickel–titanium alloys; root canal filling materials

Address for correspondence:
Dr. Gaudam Vijegopal,
Department of Conservative Dentistry and Endodontics, Vivekanandha Dental College for Women, Tiruchengode - 637 205, Tamil Nadu, India.
E-mail: gaudamvijegopal@gmail.com

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INTRODUCTION

There has been a growing demand for endodontic treatment as patients increasingly prefer root canal therapy

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over extraction. Advances in instrumentation, irrigation protocols, magnification, and obturation techniques have significantly improved treatment predictability, with reported success rates ranging from 86% to 98%.[1-3] Nevertheless, even a modest incidence of post-treatment disease translates into a considerable number of retreatment cases. Persistent intraradicular infection, inadequate canal disinfection, deficient obturation, coronal leakage, and procedural errors are among the primary causes of endodontic failure.[4-6]

Nonsurgical root canal retreatment is regarded as the preferred management strategy for post-treatment disease because it aims to eliminate the residual microorganisms through the removal of the existing obturation material and the correction of the technical deficiencies.[7] Complete removal of gutta-percha and sealer is essential to facilitate reinstrumentation, irrigant penetration, and effective reobturation.[8] Although retreatment was traditionally performed using hand files and solvents, rotary nickel–titanium (NiTi) instruments have demonstrated improved flexibility, cutting efficiency, and safety, resulting in enhanced removal of filling materials when maintaining original canal anatomy.[9-11]

Various NiTi rotary retreatment systems have been introduced with differences in taper design, cross-sectional geometry, heat treatment, and kinematics. Previous studies have shown significant variability in residual filling materials following retreatment using different systems.[12-14] Controlled-memory and heat-treated NiTi alloys have been reported to improve flexibility and fatigue resistance, to enhance adaptation to curved canals, and to potentially increase retreatment efficiency.[13,15] Cone-beam computed tomography (CBCT)-based studies have further demonstrated significant differences among contemporary retreatment systems in their ability to remove filling materials.[14,16]

The type of sealer used during primary obturation may also influence retreatment outcomes. AH Plus, an epoxy resin-based sealer, is widely regarded as a reference standard due to its favorable sealing ability and handling properties.[17] In contrast, bioceramic sealers have gained popularity because of their bioactivity, dimensional stability, and ability to form hydroxyapatite-like interfacial layers with dentin.[18] However, concerns regarding their retreatability have been raised due to dentin–sealer interaction and potential mineral infiltration zones.[19,20]

CBCT has emerged as a reliable nondestructive three-dimensional imaging modality for volumetric assessment of residual filling materials.[21,22] Compared with conventional radiography, CBCT provides enhanced visualization of canal anatomy and residual debris, making it suitable for comparative retreatment research.

Therefore, the present *in vitro* study aimed to evaluate and compare the amount of residual root canal filling materials following retreatment of canals obturated with an epoxy resin-based sealer (AH Plus) or a bioceramic sealer (Bio-C Sealer) using four different rotary retreatment systems, assessed using CBCT analysis.

Null hypotheses

Based on the study design and outcome variables, the following null hypotheses were formulated:

Null hypothesis 1 (H_{01})

There is no statistically significant difference in the percentage of remaining root canal filling materials among the different rotary retreatment file systems (HyFlex Remover, EdgeFile XR, ProTaper Universal Retreatment, and NeoEndo).

Null hypothesis 2 (H_{02})

There is no statistically significant difference in the percentage of remaining root canal filling materials between canals obturated with an epoxy resin-based sealer (AH Plus) and those obturated with a bioceramic sealer (Bio-C Sealer).

Null hypothesis 3 (H_{03})

There is no interaction effect between the type of retreatment file system and the type of sealer on the percentage of remaining root canal filling materials.

MATERIALS AND METHODS

Specimen selection and sample size calculation

Eighty extracted, intact permanent mandibular molars were selected for this *in vitro* study. Teeth exhibiting cracks, fractures, root resorption, previous endodontic treatment, or restorations were excluded. Only mesiobuccal canals with curvatures between 10° and 20°, determined using Schneider's method, were included. Ethical approval was obtained from the Institutional Ethics and Review Board (Protocol No. KDCRC/IERB/22/2022/22).

Sample size was calculated using power analysis, indicating that 80 specimens ($n = 10$ per group) would provide 80% power to detect an effect size of 0.45 at $\alpha = 0.05$. Specimens were randomly allocated into eight experimental groups using a computer-generated randomization sequence.

Canal preparation and obturation

Standardized access cavities were prepared using Endo Access Burs (Dentsply Sirona, USA) - Charlotte, North Carolina. Working length (WL) was determined by introducing a #10 K-file until the tip was visible at the apical foramen and subtracting 1 mm.

Root canals were prepared using EdgeTaper Platinum rotary files (EdgeEndo, USA)-Albuquerque, New Mexico, up to size F2 at 300 rpm and 3 N cm torque. Irrigation during instrumentation included 5.25% sodium hypochlorite, followed by saline. Smear layer removal was performed with 17% EDTA, and final irrigation was completed using saline.

Obturation was performed using the single-cone technique with F2 gutta-percha and either:

- AH Plus (Dentsply Sirona, Germany) Konstanz, Germany, epoxy resin-based sealer
- Bio-C Sealer (Angelus, Brazil)- Londrina, Paraná, Brazil, bioceramic sealer.

All specimens were stored at 37°C and 100% humidity for 2 weeks to ensure complete sealer setting.

Cone-beam computed tomography imaging parameters

Pre- and post-retreatment scans were obtained using Carestream CS 9300 Select (Carestream Dental, USA) - Atlanta, Georgia, USA, with:

- Tube voltage: 90 kV
- Tube current: 10 mA
- Exposure time: 19.96 s
- Isotropic voxel size: 90 μm
- Field of view: 5 cm × 5 cm.

Volumetric analysis was performed using Anatomage Invivo Dental Imaging Software (Anatomage, USA) Santa Clara, California, USA.

Grouping for retreatment

Specimens were allocated into eight groups ($n = 10$) based on the sealer type and retreatment file system. Retreatment was performed according to the manufacturer's instructions by a single experienced operator in a blinded manner. WL and apical patency were reestablished using a #10 K-file (Dentsply Maillefer, Switzerland) - Ballaigues, Vaud, Switzerland. Final apical preparation was standardized with EdgeTaper Platinum F2.

Completion criteria

Retreatment was considered complete when smooth canal walls with no visible remnants were observed on the last instrument used.

Blinding

All retreatment procedures were performed by a single experienced operator to maintain consistency. The CBCT evaluator was blinded to group allocation to minimize assessment bias.

Postretreatment cone-beam computed tomography analysis

Residual root canal filling volume (mm^3) was measured using the CBCT software. The percentage of the remaining filling materials was calculated relative to preretreatment volume.

Statistical analysis

The data were analyzed using SPSS version 21.0 (IBM, USA) - Armonk, New York, USA. Normality was assessed using the Shapiro–Wilk test. Two-way ANOVA was used to evaluate:

1. Effect of sealer type
2. Effect of retreatment file system
3. Interaction between sealer type and file system.

Post hoc comparisons were performed using Tukey's test. Statistical significance was set at $P < 0.05$.

RESULTS

The percentage of residual root canal filling materials following retreatment was analyzed using two-way analysis of variance (ANOVA) to evaluate the effects of the retreatment file system and sealer type, as well as their interaction. Descriptive statistics for the main effects are presented in Table 1, and the results of the two-way ANOVA are summarized in Table 2.

Two-way ANOVA demonstrated a statistically significant main effect of the retreatment file system on the percentage of the remaining filling materials ($F = 91.648$, $P < 0.001$). In contrast, the main effect of sealer type was not statistically significant ($F = 1.274$, $P = 0.263$), indicating that the amount of residual filling materials was comparable between canals obturated with AH Plus and those obturated with Bio-C Sealer. In addition, no

Table 1: Grouping and methodology of retreatment in different groups

Group	Retreatment system	Sealer	File details/motion	Rotations/minute/torque
1	HyFlex Remover	AH Plus	Single file, 30/.07, pecking motion	400 rpm, 2.5 N·cm
2	HyFlex Remover	Bio-C Sealer	Single file, 30/.07, pecking motion	400 rpm, 2.5 N·cm
3	EdgeFile XR	AH Plus	R1–R4, crown-down, circumferential	350–500 rpm, 3 N·cm
4	EdgeFile XR	Bio-C Sealer	R1–R4, crown-down, circumferential	350–500 rpm, 3 N·cm
5	ProTaper Universal Retreatment	AH Plus	D1 (30/.09), D2 (25/.08), D3 (20/.07)	500 rpm, 2 N·cm
6	ProTaper Universal Retreatment	Bio-C Sealer	D1 (30/.09), D2 (25/.08), D3 (20/.07)	500 rpm, 2 N·cm
7	NeoEndo	AH Plus	N1 (30/.09), N2 (25/.08), N3 (20/.07), crown-down	350 rpm, 1.5 N·cm
8	NeoEndo	Bio-C Sealer	N1 (30/.09), N2 (25/.08), N3 (20/.07), crown-down	350 rpm, 1.5 N·cm

Table 2: Summary of two-way analysis of variance results for percentage of remaining filling materials

Comparison	Mean (%)	SD	df	*F*	*P*	*Post hoc* (Tukey)
Retreatment system (main effect)						
HyFlex Remover	4.73	1.12	3	91.648	<0.001*	
EdgeFile XR	5.70	0.91				
ProTaper Universal Retreatment	14.66	2.18				
NeoEndo	15.80	2.37				
Sealer type (main effect)						
AH Plus	9.92	5.49	1	1.274	0.263	Not significant
Bio-C Sealer	10.53	5.78				
Interaction (system × sealer)			3	0.842	0.475	Not significant
Error			72	-	-	
Post hoc Tukey (retreatment systems only)						
HyFlex Remover versus EdgeFile XR	-	-			0.41	Not significant
HyFlex Remover versus ProTaper UR	-				<0.001*	Significant
HyFlex Remover versus NeoEndo	-	-			<0.001*	Significant
EdgeFile XR versus ProTaper UR	-	-			<0.001*	Significant
EdgeFile XR versus NeoEndo	-	-			<0.001*	Significant
ProTaper UR versus NeoEndo	-	-			0.62	Not significant

*Statistically significant at $P<0.05$. SD: Standard deviation, df: Degrees of freedom

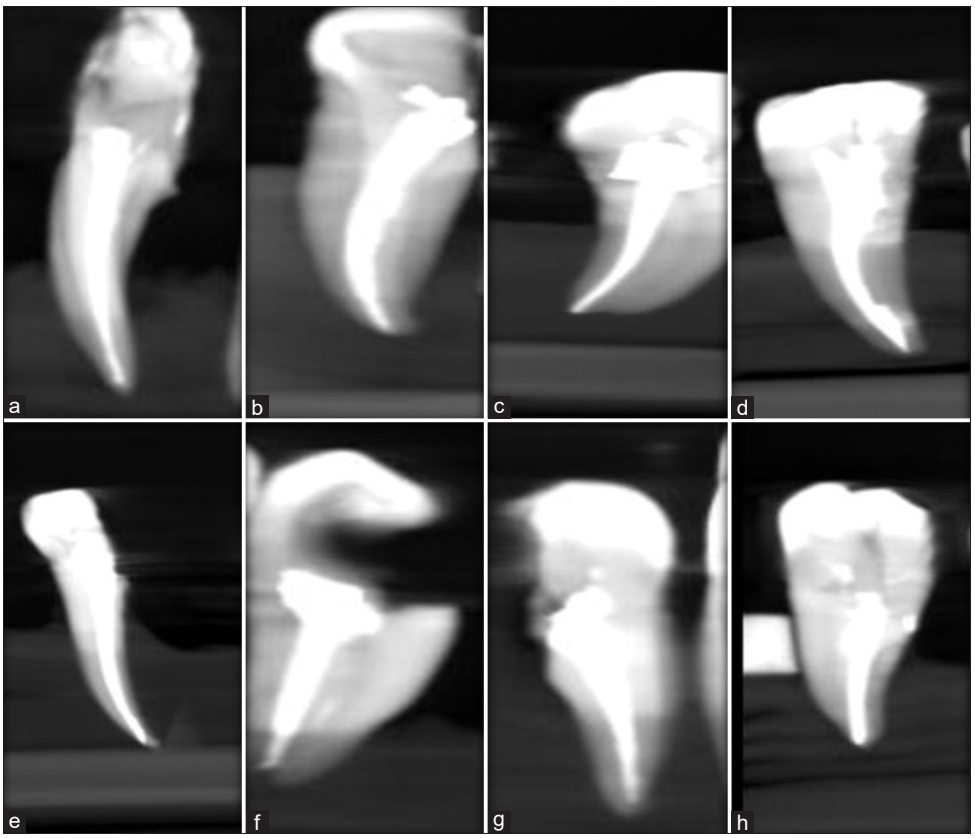

Figure 1: (a-h) Preretreatment cone-beam computed tomography images demonstrating root canal obturation in representative samples from Groups 1–8

statistically significant interaction was observed between the retreatment file system and sealer type ($F = 0.842$, $P = 0.475$), suggesting that the efficacy of the retreatment systems was independent of the sealer used.

When data were pooled across sealers, HyFlex Remover exhibited the lowest mean percentage of residual filling materials (4.73%), followed by EdgeFile XR (5.70%). Both systems demonstrated significantly greater removal of filling materials compared with ProTaper Universal Retreatment (14.66%) and NeoEndo systems (15.80%). *Post hoc* Tukey analysis revealed no statistically significant difference between HyFlex Remover and EdgeFile XR ($P > 0.05$). However, both systems showed significantly lower residual filling materials than ProTaper Universal Retreatment and NeoEndo ($P < 0.001$) [Table 2]. No statistically significant difference was observed between ProTaper Universal Retreatment and NeoEndo systems ($P > 0.05$).

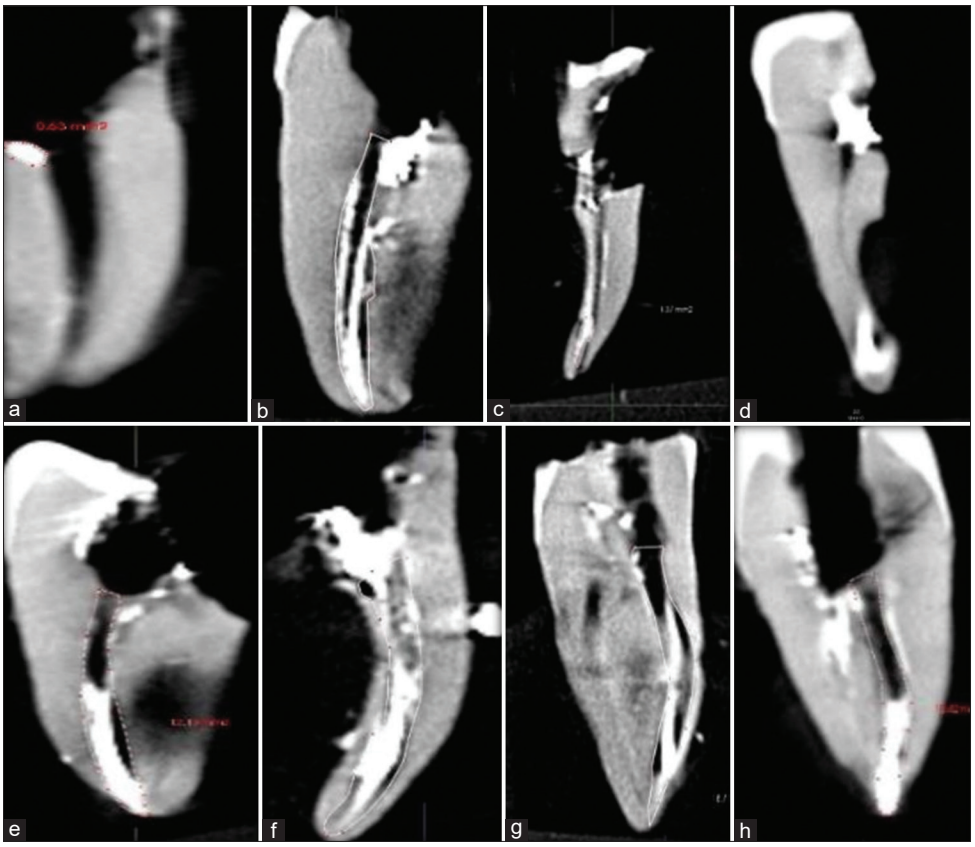

Figure 2: (a-h) Postretreatment cone-beam computed tomography images demonstrating residual root canal filling materials in representative samples from Groups 1–8 following rotary retreatment procedures

None of the retreatment systems achieved complete removal of the root canal filling materials. Nevertheless, HyFlex Remover and EdgeFile XR demonstrated superior retreatment efficacy compared with ProTaper Universal Retreatment and NeoEndo, irrespective of the sealer type used [Figures 1 and 2].

DISCUSSION

The primary objective of nonsurgical endodontic retreatment is the elimination of persistent intraradicular infection through removal of existing obturation materials, thereby enabling thorough reinstrumentation and irrigation.[7] Despite advances in rotary instrumentation, complete removal of filling materials remains challenging, particularly in curved canals and anatomically complex regions such as isthmuses and lateral canals.[12,13]

The present study demonstrated that the retreatment file system significantly influenced the percentage of residual filling materials, whereas sealer type and the interaction between file system and sealer did not. These findings align with previous CBCT and micro-CT investigations, reporting that instrument design and alloy properties play a greater role in retreatment efficacy than sealer composition alone.[14-16]

Influence of design features on retreatment efficiency

The superior performance of HyFlex Remover and EdgeFile XR may be attributed to their metallurgical and geometric characteristics. HyFlex Remover is manufactured using controlled-memory NiTi alloy, which enhances flexibility and cyclic fatigue resistance. Increased flexibility allows the instrument to conform to canal curvature and maintain circumferential wall contact, improving mechanical disruption of obturation materials. Its 30/.07 taper and active cutting flutes facilitate engagement and coronal transportation of gutta-percha.[13]

EdgeFile XR instruments undergo proprietary heat treatment, resulting in improved flexibility and cutting efficiency. The crown-down technique reduces torsional stress and promotes progressive coronal removal of filling materials, enhancing debris elimination. Heat-treated NiTi instruments have been shown to exhibit superior adaptability and reduced canal transportation during retreatment.[13,15]

ProTaper Universal Retreatment files feature a progressive taper and convex triangular cross-section, which may limit uniform wall contact in irregular canal anatomy. Differences in rake angle, flute depth, and core diameter may influence debris removal efficiency and apical penetration.[14]

The NeoEndo retreatment system incorporates design features specifically intended for efficient gutta-percha removal. These instruments typically present an active cutting tip for initial penetration, a progressive taper to facilitate coronal flaring and bulk removal, a modified cross-sectional geometry to enhance cutting efficiency, and a continuous rotary motion for debris transportation.[13] The active tip allows penetration without reliance on solvents, improving initial engagement efficiency, whereas the progressive taper enhances coronal enlargement and creates space for coronal extrusion of softened gutta-percha. Sharp cutting edges and optimized flute design promote mechanical scraping of sealer and gutta-percha from canal walls.[13]

However, unlike heat-treated or controlled-memory systems, conventional NiTi metallurgy used in NeoEndo files may offer reduced flexibility in severely curved canals, potentially limiting complete circumferential wall contact in apical thirds, particularly in flattened or oval canals.[8,14] Core diameter and cross-sectional mass influence torsional resistance and debris transportation dynamics, with instruments possessing larger core mass exhibiting greater rigidity.[11] While NeoEndo retreatment files are effective in bulk removal of obturation materials, their efficiency in eliminating thin sealer films adherent to dentinal walls may depend on canal morphology and the use of supplementary instrumentation or irrigant activation.[8,15]

Influence of sealer type

Although bioceramic sealers form chemical bonds with dentin and may create mineral infiltration zones, several investigations have reported comparable retreatability between epoxy resin-based and bioceramic sealers when standardized mechanical protocols are used.[19,20] The present findings support the notion that mechanical instrumentation rather than the sealer chemistry predominantly governs retreatment efficiency.

Sequelae of incomplete filling removal

Importantly, none of the tested systems achieved complete removal of filling materials [Figures 1 and 2]. Residual obturation materials may harbor persistent microbial biofilms and impede irrigant penetration into dentinal tubules and canal irregularities.[6,8] This may result in sustained periapical inflammation, delayed healing, persistent symptoms, and increased risk of retreatment failure.[4] Residual sealer and gutta-percha may also compromise adaptation of new obturation materials, potentially creating voids and microleakage.

Adjunctive methods such as ultrasonic activation, irrigant agitation, or supplementary finishing files may be required to enhance the canal cleanliness.[11,22]

Imaging considerations

CBCT was used for volumetric assessment due to its nondestructive nature and reproducibility. Although micro-CT offers higher spatial resolution, CBCT provides clinically relevant three-dimensional analysis and has been widely used in retreatment research.[14,21]

Within the limitations of this *in vitro* study, instrument design and metallurgy appear to play a more significant role in retreatment efficiency than sealer type. Nevertheless, complete canal debridement remains challenging, emphasizing the need for combined mechanical and adjunctive strategies.

CONCLUSION

Within the limitations of this *in vitro* study, the efficacy of the removal of root canal filling materials during nonsurgical retreatment was significantly influenced by the retreatment file system used, whereas the type of sealer had no significant effect. None of the evaluated systems achieved complete removal of obturation materials. HyFlex Remover and EdgeFile XR demonstrated significantly superior retreatment efficacy compared with ProTaper Universal Retreatment and NeoEndo systems, irrespective of whether an epoxy resin-based sealer (AH Plus) or a bioceramic sealer (Bio-C Sealer) was used. These findings suggest that instrument design and metallurgical characteristics play a more critical role in retreatment efficiency than sealer type. The use of adjunctive techniques may be necessary to further enhance the removal of residual filling materials and optimize clinical retreatment outcomes.

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Conflicts of interest

There are no conflicts of interest.

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