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Comparative Efficacy of ProTaper Universal Retreatment, D-RaCe and R-Endo in Removing Bioceramic and Resin-Based Sealers During Retreatment: An *In vitro* CBCT and Stereomicroscopic Study

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Abstract **Background:** Endodontic retreatment depends on effective removal of previous obturation materials so that the canal can be re-cleaned, disinfected and re-obturated. The retreatability of contemporary bioceramic and resin-based sealers remains clinically relevant because their different bonding mechanisms may influence how much material persists after reinstrumentation. **Objective:** This *in vitro* study compared the efficacy of three continuous-rotation retreatment systems-ProTaper Universal Retreatment (PTR), D-RaCe (DRC) and R-Endo (REN)-in removing bioceramic and resin-based sealers from instrumented root canals. The primary outcome was percentage residual filling material on CBCT. Secondary outcomes were retreatment time and stereomicroscopic residual score. **Methods:** Ninety extracted human mandibular premolars with single canals were prepared to ProTaper Universal F3 (30/.09 taper) and obturated with gutta-percha plus either bioceramic sealer (n = 45) or resin-based sealer (n = 45). Each sealer group was randomly subdivided into PTR, DRC and REN subgroups (n = 15). Baseline and post-retreatment residual filling volumes were assessed using CBCT volumetric analysis. Retreatment time was recorded and stereomicroscopic scoring was performed after longitudinal sectioning. Chloroform (0.1 mL) was used only when necessary according to the same retreatment protocol. **Results:** Resin-based sealer showed significantly higher residual material than bioceramic sealer across all systems ($p<0.001$). Mean residual filling percentages for bioceramic sealer were 8.42±2.18% (PTR), 11.36±3.24% (DRC) and 12.84±2.96% (REN), whereas corresponding values for resin-based sealer were 14.28±3.46%, 18.52±4.12% and 19.74±3.88%. PTR demonstrated superior cleaning efficacy ($p = 0.002$) and shorter retreatment time. Residual material was concentrated predominantly in the apical third. None of the systems achieved complete removal. **Conclusion:** Under the conditions of this *in vitro* model, PTR was the most effective of the tested systems and bioceramic sealer was easier to remove than resin-based sealer. However, all systems left residual material, especially in the apical third, indicating that supplementary cleaning procedures may still be required during retreatment.

Key Words Endodontic Retreatment, Bioceramic Sealer, Resin-Based Sealer, Protaper Universal Retreatment, D-RaCe, R-Endo, CBCT, Residual Filling Material

INTRODUCTION

Nonsurgical endodontic retreatment is performed to re-access the root canal system, remove previous filling materials, reduce the residual microbial load and permit renewed chemomechanical preparation and obturation [1-4]. Residual sealer and gutta-percha may block irrigant penetration, mask infected recesses and compromise the quality of reinstrumentation. For that reason, the retreatability of modern sealers has become a clinically important issue rather than a purely laboratory concern.

Bioceramic and resin-based sealers are widely used because of their favorable sealing properties, dimensional stability and compatibility with contemporary obturation techniques [5-9]. Their behavior during retreatment may differ. Calcium silicate-based bioceramic sealers are

reported to interact chemically with dentin and form interfacial mineral deposits, whereas epoxy resin-based sealers such as AH Plus penetrate dentinal tubules and may create mechanically interlocked resin tags. These differences in adhesion and penetration may influence how much material remains after retreatment.

Rotary nickel-titanium retreatment systems are routinely used because they shorten treatment time and improve filling material removal compared with manual techniques [10-16]. ProTaper Universal Retreatment, D-RaCe and R-Endo represent commonly studied continuous-rotation systems with different file designs, taper progression and cutting behavior. Comparing these systems against different sealer types remains clinically relevant because retreatment decisions are often made in cases where the original sealer is already set and difficult to identify clinically.

CBCT permits three-dimensional volumetric assessment of residual filling material and can provide a more comprehensive estimate than two-dimensional radiography [17-19]. Nevertheless, CBCT is still less precise than micro-CT for detecting very thin remnants and findings should therefore be interpreted as volumetric estimates rather than absolute measurements. Stereomicroscopic scoring remains useful as a complementary method for direct surface assessment after sectioning [20].

The present study was designed to compare PTR, D-RaCe and R-Endo for the removal of bioceramic and resin-based sealers from standardized mandibular premolars. The null hypothesis was that neither sealer type nor retreatment system would significantly influence residual filling volume, retreatment time or stereomicroscopic residual score.

METHODS

Study Design and Ethics

Study design and ethics. This *in vitro* experimental study was conducted at the Department of Endodontics, University Dental Research Center, between February and August 2024. Ethical approval for the use of extracted human teeth was obtained from the institutional review board. Teeth were collected from orthodontic or periodontal extractions according to institutional policy, de-identified before laboratory processing and stored in 0.1% thymol solution at 4 C until use [21].

Sample selection. Ninety extracted human mandibular premolars with single canals and curvature <10 degrees according to Schneiders method were included [22]. Teeth with multiple canals, resorption, fractures, calcification, prior endodontic treatment or severe curvature were excluded. Crowns were sectioned to obtain standardized root lengths of 14±1 mm. The use of mild-curvature premolars improved standardization but limits extrapolation to molars, highly curved canals and complex oval anatomy [23].

Canal Preparation and Obturation

Working length was established 1 mm short of the apical foramen. All canals were prepared using ProTaper Universal to F3 (30/.09 taper). Irrigation consisted of 2 mL 2.5% sodium hypochlorite between instruments, followed by 5 mL 17% EDTA for 1 minute and a final distilled water rinse. Teeth were randomly allocated to a bioceramic sealer group (EndoSequence BC Sealer; n = 45) or a resin-based sealer group (AH Plus; n = 45). Obturation was completed using the continuous wave compaction technique with a System B heat source and matching gutta-percha cones [24-25]. Specimens were stored at 37°C and 100% humidity for 14 days to allow complete setting.

CBCT Baseline Evaluation

Pre-retreatment scans were obtained using a 3D Accuitomo 170 scanner (90 kV, 5 mA, voxel size 0.125 mm, exposure 17.5 seconds). Total filling volume for each canal was measured using OnDemand3D software [26]. The CBCT operator was not involved in retreatment instrumentation and measurements were performed using the same acquisition parameters for baseline and post-retreatment scans.

Retreatment Groups and Protocol

Each sealer group was randomly subdivided into PTR, DRC and REN subgroups (n = 15 each). All instruments were used in continuous rotation with a torque-controlled motor according to manufacturer recommendations at 500 rpm. New instrument sets were used for every five teeth. Chloroform (0.1 mL) was applied only when needed to soften compacted coronal gutta-percha according to the same predefined protocol for all groups. Retreatment was considered complete when the working length had been reached, no material was visible on the instrument flutes and canal walls appeared clean under 3.5x magnification [27-29]. Total retreatment time was recorded from initial instrument insertion to completion of this endpoint.

Post-Retreatment Evaluation

Residual filling material was reassessed on CBCT and percentage residual volume was calculated relative to baseline volume. Roots were then split longitudinally and examined under a stereomicroscope at 20x. Residual material was scored on a 4-point ordinal scale: score 0, no visible material; score 1, <25% wall coverage; score 2, 25%-50%; score 3, >50%. Two calibrated examiners independently evaluated the specimens; inter-examiner agreement was assessed with Cohens kappa [30].

Statistical Analysis

Data were analyzed using SPSS version 27.0. Shapiro-Wilk testing assessed normality. Two-way ANOVA evaluated the main effects of sealer type and retreatment system on residual percentage and Tukey post-hoc testing was used for pairwise comparisons while controlling type I error. Kruskal-Wallis testing was used for ordinal stereomicroscopic scores. Statistical significance was set at $p<0.05$.

RESULTS

All specimens completed baseline and post-retreatment assessment. Baseline filling volumes did not differ significantly among groups ($p = 0.624$), indicating comparable starting conditions before retreatment. Two-way

Table 1: Residual Filling Material Percentage by Sealer Type and Retreatment System

Retreatment system	Bioceramic sealer (%)	Resin-based sealer (%)	p-value
ProTaper Universal Retreatment	8.42±2.18	14.28±3.46	<0.001
D-RaCe	11.36±3.24	18.52±4.12	<0.001
R-Endo	12.84±2.96	19.74±3.88	<0.001
Between-system p-value	0.003	0.004	-

Table 2: Mean Retreatment Time (Seconds) by Sealer Type and Retreatment System

Retreatment system	Bioceramic sealer	Resin-based sealer	p-value
ProTaper Universal Retreatment	186.4±28.6	248.2±36.4	<0.001
D-RaCe	224.8±32.4	298.6±42.8	<0.001
R-Endo	242.6±38.2	324.4±48.6	<0.001
Overall mean	217.9±38.4	290.4±52.6	<0.001

Table 3: Distribution of Stereomicroscopic Scores by Group

Group	Score 0	Score 1	Score 2	Score 3	Median
BC-PTR	4 (26.7)	8 (53.3)	3 (20.0)	0 (0.0)	1
BC-DRC	2 (13.3)	7 (46.7)	5 (33.3)	1 (6.7)	1
BC-REN	1 (6.7)	6 (40.0)	6 (40.0)	2 (13.3)	2
RB-PTR	1 (6.7)	5 (33.3)	7 (46.7)	2 (13.3)	2
RB-DRC	0 (0.0)	4 (26.7)	7 (46.7)	4 (26.7)	2
RB-REN	0 (0.0)	3 (20.0)	6 (40.0)	6 (40.0)	2.5

ANOVA showed significant main effects for sealer type ($p<0.001$) and retreatment system ($p = 0.002$), whereas the sealer-system interaction was not significant ($p = 0.318$), suggesting that the relative ranking of the tested systems remained similar across both sealer types (Table 1).

PTR showed the lowest residual percentage for both sealers. In every retreatment system, resin-based sealer left more residual material than bioceramic sealer. None of the groups achieved complete removal. These findings were corroborated by the stereomicroscopic scores, which also favored PTR and bioceramic sealer removal (Table 2).

Retreatment time was consistently shorter in the bioceramic groups and shortest with PTR. The longer time required for resin-based sealer removal is clinically relevant because it may reflect stronger dentin interaction and may increase operator fatigue and instrument stress during retreatment (Table 3).

Inter-examiner agreement was excellent (Cohens kappa = 0.86). Regional distribution analysis showed that the apical third contained the largest share of the remaining filling material in all groups, accounting on average for 52.4% of the total residual volume, followed by the middle and coronal thirds.

DISCUSSION

This study showed that complete sealer removal was not achieved by any of the tested retreatment systems. That finding is consistent with the broader retreatment literature and highlights the inherent difficulty of completely debriding prepared canals, particularly when modern sealers are used and canal walls include inaccessible recesses and apical irregularities [31].

Bioceramic sealer was easier to remove than the resin-based sealer in the present design. The resin-based sealer likely resisted retreatment because of deeper dentinal tubule penetration and stronger micromechanical interlocking. By contrast, although bioceramic materials are often described as bonding chemically to dentin, the present results indicate that under the present preparation, obturation and aging conditions, they left less residual material and required less retreatment time than AH Plus [32-33].

PTR produced lower residual percentages and shorter retreatment times than D-RaCe and R-Endo. The likely explanation is instrument design, including active cutting geometry and progressive taper sequence, which may improve coronal debulking and apical penetration of the retreatment files. Because the sealer-system interaction was not significant, the superiority of PTR appeared consistent across both sealer categories rather than being limited to only one obturation condition.

The apical third remained the most difficult region to clean. This is clinically important because persistent sealer remnants in the apical segment may shield bacteria and limit irrigant penetration during retreatment. The finding also reflects the restricted contact of rotary files with canal walls in the apical third, particularly in canals that are not perfectly round. Even in standardized premolars, anatomical variation and instrument-centered preparation may still leave untouched surfaces [23,31].

Chloroform was used only when necessary and this should be considered when interpreting both removal percentage and retreatment time. Although solvent use facilitates gutta-percha softening, it may also alter the consistency of filling remnants and influence how effectively the files engage the material. For that reason, future studies should standardize solvent application more strictly or compare solvent-assisted and solvent-free retreatment protocols directly.

This study has several limitations. It was performed *in vitro* using mildly curved mandibular premolars, so the findings cannot be extrapolated directly to molars, highly curved canals or more complex anatomy. CBCT volumetric analysis is practical and three-dimensional but it remains less precise than micro-CT for very small remnants. Instrument deformation or separation was not evaluated in this protocol. Accordingly, the present findings

should be interpreted as controlled laboratory data rather than direct predictors of clinical retreatment success.

Clinically, the findings suggest that sealer composition should be considered when planning retreatment. Rotary retreatment files alone are unlikely to achieve complete material removal, especially apically. Additional steps such as ultrasonic activation, finishing instruments or enhanced irrigation may be required, particularly when resin-based sealers are being retreated.

CONCLUSIONS

Within the limitations of this *in vitro* study, none of the evaluated retreatment systems completely removed filling material from the root canals.

ProTaper Universal Retreatment showed the best overall performance and bioceramic sealer was easier to remove than resin-based sealer under the present conditions.

Residual material persisted mainly in the apical third, indicating that supplementary cleaning strategies may be necessary during retreatment, especially when resin-based sealers are involved.

Ethical Approval

Approval for the use of extracted human teeth was obtained from the institutional review board.

REFERENCES

[1] Siqueira, J.F., Jr

[2] Siqueira, J.F., Jr. and I.N. Rôças. "Clinical Implications and Microbiology of Bacterial Persistence after Treatment Procedures." *Journal of Endodontics*, vol. 34, no. 11, 2008, pp. 1291-1301. https://doi.org/10.1016/j.joen.2008.07.028.

[3] Torabinejad, M. *et al.* "Outcomes of Nonsurgical Retreatment and Endodontic Surgery: A Systematic Review." *Journal of Endodontics*, vol. 35, no. 7, 2009, pp. 930-937. https://doi.org/10.1016/j.joen.2009.04.023.

[4] Stabholz, A. and S. Friedman. "Endodontic Retreatment-Case Selection and Technique. Part 2: Treatment Planning for Retreatment." *Journal of Endodontics*, vol. 14, no. 12, 1988, pp. 607-614. https://doi.org/10.1016/S0099-2399(88)80059-X.

[5] Ørstavik, D. "Materials Used for Root Canal Obturation: Technical, Biological and Clinical Testing." *Endodontic Topics*, vol. 12, no. 1, 2005, pp. 25-38. https://doi.org/10.1111/j.1601-1546.2005.00197.x.

[6] Zhang, W. *et al.* "Assessment of a New Root Canal Sealer's Apical Sealing Ability." *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, vol. 107, no. 6, 2009, pp. e79-e82. https://doi.org/10.1016/j.tripleo.2009.02.024.

[7] Han, L. and T. Okiji. "Uptake of Calcium and Silicon Released from Calcium Silicate-Based Endodontic Materials into Root Canal Dentine." *International Endodontic Journal*, vol. 44, no. 12, 2011, pp. 1081-1087. https://doi.org/10.1111/j.1365-2591.2011.01924.x.

[8] Resende, L.M. *et al.* "A Comparative Study of Physicochemical Properties of AH Plus, Epiphany and Epiphany SE Root Canal Sealers." *International Endodontic Journal*, vol. 42, no. 9, 2009, pp. 785-793. https://doi.org/10.1111/j.1365-2591.2009.01584.x.

[9] Tay, F.R. *et al.* "Ultrastructural Evaluation of the Apical Seal in Roots Filled with a Polycaprolactone-Based Root Canal Filling Material." *Journal of Endodontics*, vol. 31, no. 7, 2005, pp. 514-519. https://doi.org/10.1097/01.don.0000152298.06247.69.

[10] Gesi, A. *et al.* "Interfacial Strength of Resilon and Gutta-Percha to Intraradicular Dentin." *Journal of Endodontics*, vol. 31, no. 11, 2005, pp. 809-813. https://doi.org/10.1097/01.don.0000158230.15306.72.

[11] Hülsmann, M. and S. Stotz. "Efficacy, Cleaning Ability and Safety of Different Devices for Gutta-Percha Removal in Root Canal Retreatment." *International Endodontic Journal*, vol. 30, no. 4, 1997, pp. 227-233. https://doi.org/10.1046/j.1365-2591.1997.00073.x.

[12] Tasdemir, T. *et al.* "Efficacy of Three Rotary NiTi Instruments in Removing Gutta-Percha from Root Canals." *International Endodontic Journal*, vol. 41, no. 3, 2008, pp. 191-196. https://doi.org/10.1111/j.1365-2591.2007.01335.x.

[13] Giuliani, V. *et al.* "Comparison of the Efficacy of Rotary and Manual Retreatment Systems for Gutta-Percha Removal during Root Canal Retreatment." *Australian Endodontic Journal*, vol. 34, no. 2, 2008, pp. 86-91. https://doi.org/10.1111/j.1747-4477.2008.00127.x.

[14] Gu, L.S. *et al.* "Efficacy of ProTaper Universal Rotary Retreatment System for Gutta-Percha Removal from Root Canals." *International Endodontic Journal*, vol. 41, no. 4, 2008, pp. 288-295. https://doi.org/10.1111/j.1365-2591.2007.01350.x.

[15] Rödig, T. *et al.* "Evaluation of a Newly Designed Root Canal Instrument." *Journal of Endodontics*, vol. 32, no. 6, 2006, pp. 578-580. https://doi.org/10.1016/j.joen.2005.09.011.

[16] de Carvalho Maciel, A.C. and M.F. Zaccaro Scelza. "Efficacy of Automated versus Hand Instrumentation during Root Canal Retreatment: An Ex Vivo Study." *International Endodontic Journal*, vol. 39, no. 10, 2006, pp. 779-784. https://doi.org/10.1111/j.1365-2591.2006.01148.x.

[17] Zuolo, A.S. *et al.* "Efficacy of Reciprocating and Rotary Techniques for Removing Filling Material during Root Canal Retreatment." *International Endodontic Journal*, vol. 46, no. 10, 2013, pp. 947-953. https://doi.org/10.1111/iej.12085.

[18] Hess, D. *et al.* "Retreatability of a Bioceramic Root Canal Sealing Material." *Journal of Endodontics*, vol. 37, no. 11, 2011, pp. 1547-1549. https://doi.org/10.1016/j.joen.2011.08.016.

[19] Moura-Netto, C. *et al.* "Three-Dimensional Volumetric Quantification of Root Canal Filling Material Using Cone Beam Computed Tomography." *Journal of Endodontics*, vol. 42, no. 1, 2016, pp. 113-118. https://doi.org/10.1016/j.joen.2015.08.027.

[20] Schirrmeister, J.F. *et al.* "Efficacy of Different Rotary Instruments for Gutta-Percha Removal in Root Canal Retreatment." *Journal of Endodontics*, vol. 32, no. 5, 2006, pp. 469-472. https://doi.org/10.1016/j.joen.2005.09.009.

[21] Siqueira, J.F., Jr. "Aetiology of Root Canal Treatment Failure: Why Well-Treated Teeth Can Fail." *International Endodontic Journal*, vol. 34, no. 1, 2001, pp. 1-10. https://doi.org/10.1046/j.1365-2591.2001.00396.x.

[22] Viapiana, R. *et al.* "Investigation of the Effect of Sealer Use on the Heat Generated at the External Root Surface during Root Canal Obturation Using Warm Vertical Compaction Technique with System B Heat Source." *Journal of Endodontics*, vol. 40, no. 4, 2014, pp. 555-561. https://doi.org/10.1016/j.joen.2013.09.026.

[23] Tay, F.R. and D.H. Pashley. "Monoblocks in Root Canals: A Hypothetical or a Tangible Goal." *Journal of Endodontics*, vol. 33, no. 4, 2007, pp. 391-398. https://doi.org/10.1016/j.joen.2006.10.009.

[24] Oltra, E. *et al.* "Retreatability of Two Endodontic Sealers, EndoSequence BC Sealer and AH Plus: A Micro-Computed Tomographic Comparison." *Restorative Dentistry & Endodontics*, vol. 42, no. 1, 2017, pp. 19-26. https://doi.org/10.5395/rde.2017.42.1.19.

[25] Ersev, H. *et al.* "Comparative Clinical Evaluation of Retreatment with Reciprocating and Continuous Rotation Instruments on the Removal of Different Bioceramic and Conventional Sealers." *Journal of Endodontics*, vol. 44, no. 3, 2018, pp. 456-461. https://doi.org/10.1016/j.joen.2017.10.020.

[26] Somma, F. *et al.* "The Effectiveness of Manual and Mechanical Instrumentation for the Retreatment of Three Different Root Canal Filling Materials." *Journal of Endodontics*, vol. 34, no. 4, 2008, pp. 466-469. https://doi.org/10.1016/j.joen.2008.01.003.

[27] Bramante, C.M. *et al.* "Heat Release, Time Required and Cleaning Ability of MTwo R and ProTaper Universal Retreatment Systems in the Removal of Filling Material." *Journal of Endodontics*, vol. 36, no. 11, 2010, pp. 1870-1873. https://doi.org/10.1016/j.joen.2010.08.013.

[28] Barletta, F.B. *et al.* "Procedural Errors during Root Canal Preparation Using Rotary NiTi Instruments Detectable Only by Computed Tomography." *Journal of Endodontics*, vol. 34, no. 6, 2008, pp. 715-720. https://doi.org/10.1016/j.joen.2008.03.003.

[29] Sae-Lim, V. *et al.* "Effectiveness of ProFile .04 Taper Rotary Instruments for Retreatment of Gutta-Percha Root Canal Filling Material." *International Endodontic Journal*, vol. 33, no. 4, 2000, pp. 364-369. https://doi.org/10.1046/j.1365-2591.2000.00311.x.

[30] Wu, M.K. *et al.* "Prevalence and Extent of Long Oval Canals in the Apical Third." *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, vol. 89, no. 6, 2000, pp. 739-743. https://doi.org/10.1067/moe.2000.106344.

[31] Alves, F.R. *et al.* "Removal of Root Canal Fillings in Curved Canals Using Either Reciprocating Single- or Rotary Multi-Instrument Systems and a Supplementary Step with the XP-Endo Finisher." *Journal of Endodontics*, vol. 42, no. 7, 2016, pp. 1114-1119. https://doi.org/10.1016/j.joen.2016.04.007.

[32] Kim, H.C. *et al.* "Evaluation of Root Canal Filling Removal by Three NiTi Retreatment Instruments Using Micro-Computed Tomography." *International Endodontic Journal*, vol. 48, no. 3, 2015, pp. 283-289. https://doi.org/10.1111/iej.12311.

[33] Uzunoglu, E. *et al.* "Retreatability of Root Canals Obturated Using Gutta-Percha with Bioceramic, MTA and Resin-Based Sealers." *Iranian Endodontic Journal*, vol. 10, no. 2, 2015, pp. 93-98.

[34] Chybowski, E.A. *et al.* "Clinical Outcome of Non-Surgical Root Canal Treatment Using a Single-Cone Technique with EndoSequence Bioceramic Sealer: A Retrospective Analysis." *Journal of Endodontics*, vol. 44, no. 6, 2018, pp. 941-945. https://doi.org/10.1016/j.joen.2018.02.019.