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Comparative Evaluation of Canal Centering Ability and Apical Transportation in Retreatment Procedures Using Solite RE Black and Hyflex Remover Systems: A Nano-CT Analysis

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Aim: Thorough removal of root canal filling materials is essential for achieving successful endodontic retreatment. This study evaluated the canal centering and apical transportation using Solite RE Black and Hyflex Remover retreatment file system during retreatment employing Nano-CT for detailed analysis.

Materials and Methods: Thirty extracted human mandibular molars were chosen, and the mesial roots were sectioned to a length of 16 mm followed by instrumentation with the ProTaper Gold system up to size F2, then obturated using the matched taper cone with AH Plus sealer. Teeth were randomly assigned to two groups (n=15 each) for retreatment: Group 1 using Solite RE Black files and Group 2 using Coltene Hyflex Remover files. Nano-CT scans were taken before and after retreatment to assess canal centering at 3 mm, 6 mm, and 9 mm from the apex and apical transportation at 1 mm, 2 mm, and 3 mm from the apex in mesio-buccal and mesio-lingual canals. Data was analyzed using SPSS Software.

Results: Nano-CT analysis revealed Solite RE Black system demonstrated superior canal centering ability with less apical transportation compared to the Hyflex Remover system at all levels respectively in both the mesiobuccal and mesiolingual canals ($p<0.05$).

Conclusion: In conclusion, the Solite RE Black system provides better canal centering and reduced apical transportation in the mesiobuccal and mesiolingual canals compared to the Hyflex Remover system during retreatment procedures. Nano-CT proved to be an effective tool for detailed analysis of endodontic retreatment outcomes.

Keywords: Apical transportation, Canal centering, Endodontics, Nano-CT, Retreatment

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Introduction

According to studies in endodontic literature, over 30% of teeth undergoing root canal treatment develop conditions like apical periodontitis and other periradicular diseases, despite receiving what is considered an appropriate level of treatment. This occurrence could stem from the continued presence of infectious organisms and toxic substances present in the complex structure of the root canals. Consequently, these factors may trigger an inflammatory or immune reaction, hindering tissue recovery and causing localised damage to the surrounding bone in affected regions.[1] The preferred approach for addressing failed root canal treatment in teeth is non-surgical retreatment. This process involves completely removing the previous obturating material from the canal, disinfecting the area, reshaping the canal, and then refilling it.[2] To ensure successful disinfection and subsequent root canal re-obturation, previous filling material must be thoroughly removed during non-surgical retreatment. Despite meticulous efforts, there is a possibility that some residual material might inadvertently remain within the root canal.[3] These residual materials can potentially harbour bacteria and compromise the success of root canal therapy, even with extensive irrigation protocols, as they remain unreachable.[4]

Various tools and methods have been utilized to remove obturating materials. Mechanized endodontic instruments facilitate the efficient removal of obturating material and instrumentation of root canals safely.[5] Engine-driven file systems offer a significant advantage over manual file systems due to their ability to reduce the time required for removal, which holds considerable importance in clinical settings.

The effectiveness of the system and the duration needed for retrieval are affected by multiple factors, including the cross-sectional design, surface treatment, active cutting tip and taper.[6] Over recent years, numerous rotary systems have become available. Two such retreatment file systems, Solite RE Black Retreatment System (Solite Dental, India) and Hyflex Remover (Coltene, Whaledent Pvt ltd,India) were assessed in this study. These systems employ a two-file approach designed to efficiently remove obturating material from the root canal. The modern trend of using fewer instruments for mechanical preparation not only accelerates the treatment process but also minimizes fatigue for both the operator and the patient.[7]

The HyFlex Remover retreatment system is a commonly employed choice for orthograde retreatment procedures. Specifically designed for retreatment, this file system features a non-active tip with a minimally invasive wire diameter.[8] During the procedure, upon locating the canal entrance, a widely recommended protocol suggests using HyFlex Orifice Opener 25.12 at 400 rpm to access the canal entrances and guide the remover for straighter access, followed by employing HyFlex Remover for removing the filling material at a continuous rotation speed of 400–800 rpm and 3.0–3.5 Ncm. The Solite RE Black retreatment system features a two-file design with variable taper, utilizing heat-treated C-wire technology. The first file is equipped with a cutting tip, optimized for efficient material removal, while the second file incorporates a non-cutting tip to minimize iatrogenic errors during root canal retreatment. This design configuration aims to provide clinicians with precise and safe instrumentation options, ensuring effective debris removal and preservation of dentin integrity throughout the treatment process while using at 300 rpm and 2.8 Ncm.

Numerous studies have employed various 3-dimensional modalities to assess residual filling material. Micro-CT is limited by its spatial resolution, particularly noticeable when imaging fine structures.

Taking advantage of advancements in micro-CT technology, nano-CT systems have been introduced, varying in design and performance factors such as spatial resolution, tube voltage, and tube power.[9] Nano-CT has emerged as a valuable adjunct to histopathology, reducing preparation time, minimizing operator error, and enabling non-destructive specimen analysis. Nano-CT allows for 3D assessment of the structure and comprehensive analysis of morphological aspects without harming the tooth sample. The use of nano-CT makes it easier to assess the morphology of the root canal pre and post retrieval of root canal materials.[10]
Given the clinical significance of minimizing procedural errors during root canal retreatment and the benefits of utilizing three-dimensional radiographs to evaluate the effectiveness of heat-treated retreatment instruments, this study aimed to assess Apical Transportation and Canal Centering ability in mesial canals of mandibular molars using a novel retreatment file, Solite Black, and Coltene Hyflex Remover, through nano-CT imaging. The null hypothesis suggests that there is no significant difference in apical transportation and canal centering ability between the Coltene Hyflex Remover file system and the Solite RE Black system after gutta-percha removal.

Materials and methods

The sample size was determined using the G power algorithm (3.1.9.7, UCLA), based on data from previous research employing a similar methodology.[11] The calculation aimed for 95% power with a significance level of 0.05. This resulted in a sample of 30 extracted permanent mandibular molars, divided into two groups of fifteen teeth each. This study was done following the approval of the Scientific Review Board Committee (SRB/SDC/ENDO-2103/24/112).

Specimen Preparation

The selected teeth for this study were mature teeth with two separate mesial root canals.[12] Only roots identified as Vertucci Type IV were included in the study, with this classification being confirmed via radiograph. Additionally, the mesial roots had an angle of curvature less than 20 degrees, determined using the methodologies described by Schneider.[13] Teeth exhibiting resorption, fractures, and pulp calcification were excluded. Radiographic assessments confirmed the anatomical criteria for the selection of teeth in the final sample. The distal roots were first separated using a diamond disc, while the mesial roots were standardized to 16 mm.[14] Coronal access was completed with a size 2 Endo-access bur (Dentsply Maillefer, Ballaigues, Switzerland), and further cavity refinement was done using an Endo Z bur (Dentsply Maillefer, Ballaigues, Switzerland).

Biomechanical Preparation and Obturation

The canals were initially explored up to the working length using sizes 10 and 15 K files (Dentsply Maillefer). Root canal preparation was carried out using the ProTaper Gold (Dentsply Maillefer) system, up to F2 (25, 8%). The instruments were connected to a Coltene CanalPro endo motor and used as per the manufacturer's instructions. Irrigation was done with 1 mL of 3% sodium hypochlorite solution and 2 mL of 17% EDTA for 1 minute, followed by 2 mL of distilled water to eliminate any debris. Sterile absorbent paper points dried the canals, which were subsequently filled using ProTaper F2 gutta-percha (Dentsply Maillefer) and AH Plus sealer (Dentsply, Petrópolis, RJ, Brazil) employing a matched taper cone technique. All roots were imaged using a digital radiography system to evaluate the quality of obturation. Subsequently, the samples were stored at 37°C with 100%

humidity for seven days to ensure a thorough setting.[11]

Nano Computed Tomography Scanning

The specimens underwent scanning with the Bruker SKYSCAN2214 (Bruker Micro-CT, Kontich, Belgium), renowned for its precise scanning capabilities. The scanning was performed with parameters including a voltage of 80 kV (2.14 W and 90 µA), an exposure time of 1100 ms, and utilizing a flat panel detector with a 360° rotation and 0.250° rotation step. Image reconstruction was performed using the modified Feldkamp cone-beam reconstruction algorithm through NRecon v. 2.1.0.2 software (Bruker-microCT, Kontich, Belgium). To enhance image quality, original grayscale images underwent noise reduction through various fine-tuning functions. The resulting scaled image had a voxel size of 10 µm with a fixed row and column size of 1944 × 3041.

Retreatment of Samples

The teeth were randomly assigned to two groups with 15 samples each. Group 1 utilized the Solite RE Black system, while Group 2 utilized the Coltene Hyflex Remover system. Both systems consist of two files.
Solite RE Black retreatment system consists of a 2-file system. The first file features a convex triangular shape with the variable taper and is crafted from austenitic alloy, ensuring a 3-point contact and an apical diameter of 0.30 mm. The second file utilizes variable taper C-wire technology and alternating cutting edges, facilitating a 2-point contact with an apical diameter of 0.20 mm.

The Hyflex Remover is a file engineered specifically for efficiently removing obturation material, distinguished by its singular design and heat treatment process. Available in size No. 30, it features a variable triple helix cross-section with an open flute, symmetrical in the initial 3 mm and asymmetrical towards the shaft. It presents a 7-degree taper limited to the first 10 mm, followed by a 0-degree taper towards the shaft, promoting efficient debris removal while safeguarding peri-radicular dentin. During the procedure, the HyFlex Orifice Opener was used to access the canal entrances and create a straighter path for the remover. Subsequently, the HyFlex Remover files were employed to eliminate the obturating material.

The retreatment procedure for both systems was done without the use of solvents. Retreatment was considered complete upon achieving smooth root dentin walls and reaching the working length. All procedures were conducted with the help of a Dental Operating Microscope (OPMI Pico, ZEISS). It is important to emphasize that no solvents were utilized during the retrieval of the obturating material. These procedures were carried out by a single operator specialized in endodontics. Subsequently, the samples underwent rescanning following retreatment using the SKYSCAN2214 scanner with the specified sample parameters.[15]

Nano Computed Tomography Analysis

The pre-and postoperative scans were aligned geometrically using the 3D registration function of DataViewer v. 1.5.1 software, and the image datasets were processed using CTAn v. 1.14.4 software (Bruker micro-CT, Bruker Corp. Billerica, MA, USA). Dentin and obturating material images were created in binary format. Grayscale thresholding was applied to delineate the dentin area, and the area occupied by filling materials, and to identify void spaces. The obturating materials were identified as the region of interest (ROI). Each cross-section underwent this procedure, and by integrating the ROIs from all cross-sections, the volume of interest was computed and calibrated.

Apical Transportation

Images at 1 mm, 2 mm, and 3 mm from the apical third were selected for apical transportation analysis. Pre- and post-treatment images of the samples for the Solite RE Black group and Coltene Hyflex Remover group were obtained using nano-CT, and the remaining dentin thickness was measured with OsiriX Imaging Software. These values of the mesiobuccal and mesiolingual root canal walls were used to calculate apical transportation using the formulae:

AT = (X1–X2)–(Y1–Y2).

Here, X1 represented dentinal wall thickness in the mesial root post-instrumentation; X2 was the dentinal wall thickness in mesial root post-reinstrumentation; Y1 represented the dentin wall thickness in distal root post-instrumentation; and Y2 was the dentin wall thickness in distal root post-reinstrumentation. A value of zero for AT indicated no transportation; negative values indicated transportation in the distal direction, while positive values indicated transportation towards the mesial direction.[16]

Centering Ability

The instrument's capacity to maintain centering within the canal is assessed using the mean centering ratio. The 3rd (apical), 6th (middle), and 9th (coronal) millimetres from the apex of the root were utilized to compute the CA (Canal Centering ability) of the instrument, following a formula by Gambill et al.[17] The formula is:

C = (M1 - M2) / (D1 - D2) or (D1 - D2) / (M1 - M2)

where M1 and M2 represent the shortest distances between the mesial edge of the root and the mesial edge of the uninstrumented canal and the instrumented canal, respectively, and D1 and D2 denote the shortest distances between the distal edge of the root and the distal edge of the uninstrumented canal and the instrumented canal, respectively. Values close to 1 indicate optimal centering ability, while values approaching 0 suggest reduced capability of the instrument to retain centrality in the root canal. All the samples were analysed by a trained operator to assess the apical transportation and canal centering values at all levels for the respective groups.

Statistical analysis

Statistical analysis was done using SPSS software (SPSS 23.0, IBM, Chicago, USA). Results were deemed statistically significant if the P value was less than 0.05. An independent t-test was used to compare the outcomes between the different groups.

Results

The mean canal-centering ratio and standard deviation values at three levels (3 mm, 6 mm, and 9 mm from the apex) for both file systems are demonstrated in Table 1.

Table 1: Demonstrates mean canal centering ability of Solite RE Black and Coltene Hyflex remover files in mesiobuccal and mesiolingual canals, with statistically significant difference at all levels (p<0.05)

	CANAL CENTERING IN MESIOBUCCAL CANAL			CANAL CENTERING IN MESIOLINGUAL CANAL		
GROUPS	At 3mm	At 6mm	At 9mm	At 3mm	At 6mm	At 9mm
Solite RE Black	0.83 ± 0.05	0.78 ± 0.09	0.66 ± 0.14	0.85 ± 0.06	0.78 ± 0.09	0.67 ± 0.12
Hyflex Remover	0.64 ± 0.10	0.59 ± 0.05	0.58 ± 0.07	0.66 ± 0.12	0.59 ± 0.05	0.59 ± 0.07
P Value	**0.016**	**0.038**	**0.022**	**0.006**	**0.042**	**0.028**

The results indicate that the Solite Black system demonstrated less deviation from the actual canal morphology compared to the Coltene Hyflex Remover system in both the mesiobuccal and mesiolingual canals at all three levels with a statistical significance of p< 0.05. (Figure 1)

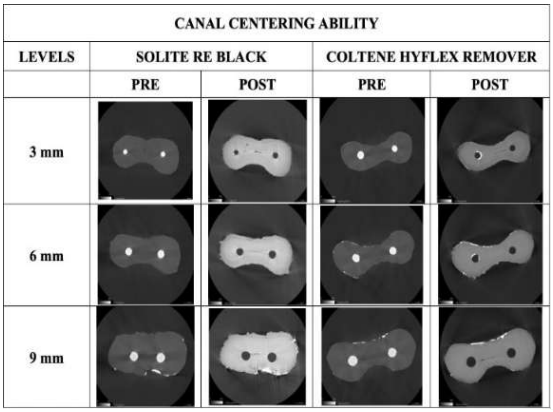

Figure 1: Demonstrates the pre- and post-instrumentation images of the Solite RE Black group and Coltene HyFlex Remover group at 3 mm, 6 mm, and 9 mm

The mean apical transportation and standard deviation values at three levels (1 mm, 2 mm, and 3 mm from the apex) for both file systems are demonstrated in Table 2.

Table 2: Demonstrates mean apical transportation of Solite RE Black and Coltene Hyflex remover files in mesiobuccal and mesiolingual canals with statistically significant differences at all levels (p<0.05)

	APICAL TRANSPORTATION IN MESIOBUCCAL CANAL			APICAL TRANSPORTATION IN MESIOLINGUAL CANAL		
GROUPS	**At 1 mm**	**At 2 mm**	**At 3 mm**	**At 1 mm**	**At 2 mm**	**At 3 mm**
Solite RE Black	0.02± 0.004	0.02± 0.005	0.02± 0.004	0.024 ±0.005	0.026 ±0.005	0.028 ±0.004
Hyflex Remover	0.04 ±0.008	0.044 ±0.008	0.047 ±0.008	0.043 ±0.009	0.045 ±0.008	0.046 ±0.008
P Value	**0.003**	**0.032**	**0.025**	**0.008**	**0.039**	**0.030**

The results indicate that the Solite Black system demonstrated significantly less apical transportation compared to the Coltene Hyflex Remover system in both the mesiobuccal and mesiolingual canals at all three levels ($p < 0.05$). (Figure 2)

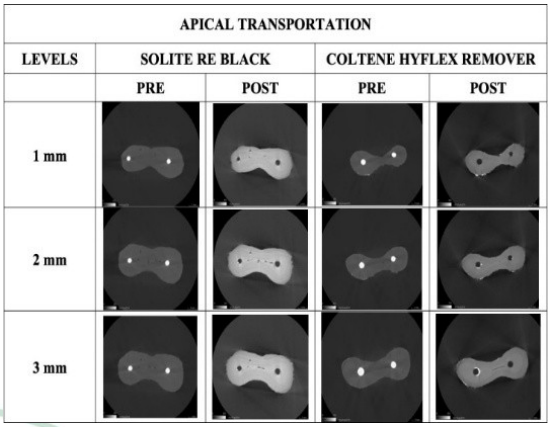

Figure 2: Demonstrates the pre- and post-instrumentation images of the Solite RE Black group and Coltene HyFlex Remover group at 1mm, 2 mm, and 3 mm

Discussion

Retreatment procedures involve eliminating remnant-infected filling materials that contribute to failure, thereby enabling chemical and mechanical disinfection.[18] Numerous studies indicate that neither manual nor mechanized instrumentation systems or techniques can eliminate obturating material from the root canal when undergoing endodontic retreatment.[19,20] Consequently, newer file systems such as the Solite Black retreatment file (Solite Dental, Chennai, India) have been developed to remove all gutta-percha while maintaining the original root canal curvature.

Root canal retreatment systems that employ limited instruments for mechanical preparation have gained widespread acceptance.[21] As far as we know, there is limited data available on the apical transportation and centering ability of these instruments when used for removing filling materials. Just as these instruments can inadvertently alter the path of the canal during initial preparation, similar complications can occur during retreatment.[7,22] Rigid endodontic instruments, particularly larger stainless-steel files, often exert significant lateral forces in curved canals, potentially causing canal

deviation and straightening in the middle and apical thirds.[23] The introduction of thermal treatment for Ni-Ti alloys aimed to improve flexibility, enhance torsional and cyclic fatigue resistance, and reduce the unwanted shape memory effect.[24] This process renders the instrument more deformable, imparting pseudoelasticity and inducing a controlled memory effect. Consequently, thermomechanically treated instruments mitigate root canal transportation by maintaining the curvature of curved root canals during preparation.[25]

This study focused on examining the mesial roots of mandibular molars classified as Vertucci Type IV.[26] Mesial roots were chosen due to their anatomical complexity, characterized by narrow and curved canals, providing an opportunity to assess both systems within the same root. This approach helped minimize bias associated with canal selection.[27]

Several methodologies have been employed to determine the quantity of obturating material remaining post-retreatment. Radiography has traditionally been utilized for this purpose, offering an estimation of residual root-filling material. However, radiographic examination provides a 2D depiction of a 3D structure, which leads to magnification and distortion.[2] To overcome these limitations, three-dimensional imaging such as CBCT, micro-CT and nano-CT was utilised. Micro-CT provides a spatial resolution between 5 and 50 µm, while nano-CT, utilizing advanced detectors and techniques, can reach a significantly higher spatial resolution of 400 nm. Due to its superior imaging capabilities, nano-CT was selected for use in this study. Nano-CT serves as a non-invasive method offering both qualitative and quantitative three-dimensional data pertinent to retreatment procedures.[28]

The findings of this study demonstrated that the Solite RE Black files exhibited superior canal-centering capabilities compared to the Coltene Hyflex Remover files. Additionally, the Solite RE Black files caused significantly less apical transportation than the Coltene Hyflex Remover files. This enhanced performance can be attributed to several factors, including the Solite RE Black files' apical diameter of 0.3 mm, their variable taper wire technology, and their two-point contact design with alternating cutting edges. These features likely contribute to the files' improved ability to maintain the original canal morphology and minimize deviations during root canal retreatment.

In a prior study by Shankar et al[8], it was observed that Solite files aided in preserving more dentin compared to the Hyflex Remover file system. This finding is advantageous as it could potentially enhance the fracture resistance of the teeth. Another study by Sairaman et al[23] indicated that the Solite RS3 files, which preceded the Solite RE Black files, demonstrated better canal-centering ability than ProTaper files during retreatment. These files had also shown better preservation of remaining dentin when compared to other file systems.[29]

Previously it has been indicated that apical transportation values exceeding 0.3 mm may potentially compromise the prognosis of root canal treatment, particularly the sealing capacity of root canal fillings.[30] In this study, it was observed that Solite RE Black files exhibited values below 0.3 mm, while Coltene Hyflex Remover files had values greater than 0.3 mm, indicating poorer sealing ability for the latter.

In endodontic retreatment, eucalyptol and chloroform solvents are commonly used since they promote the dissolution of gutta-percha, making it easier for instruments to work during root canal re-instrumentation.[31] However, these compounds are cytotoxic and can also cause the residue of softened gutta-percha to adhere strongly to the walls of the root canal, particularly in the apical

region.[32,33] The manufacturers of both files used in this study do not endorse the use of solvents. Therefore, the same protocol was followed in this study, consistent with previous studies, to avoid the use of solvents.

The current study did not address other critical factors such as the amount of remaining filling material, the thickness of dentin left after retreatment, and the potential for crack propagation. These aspects are essential for determining the optimal file system for retreatment procedures. This limitation must be considered while the results are being interpreted. Future research should focus on evaluating these additional parameters, especially in curved canals, to offer a more thorough assessment of the effectiveness of retreatment systems.

Conclusion

Based on the findings of this study, Solite RS3 demonstrates promising potential as a retreatment file system. Its unique properties facilitate the efficient removal of gutta-percha while preserving dentin integrity and minimizing iatrogenic errors. These attributes are crucial in ensuring successful endodontic retreatment by maintaining structural integrity and minimizing risks associated with procedural errors. Further research and clinical trials are warranted to validate these observations across a broader spectrum of clinical scenarios and canal anatomies, thereby enhancing the evidence base for its use in routine endodontic practice.

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Data Availability statement: The data set used in the current study is available within the article

Ethical approval: This study was done following the approval of the Scientific Review Board Committee (SRB/SDC/ENDO-2103/24/112).

Conflicting Interest: No conflict of interest.

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