

COMPARATIVE EVALUATION OF HEAT TREATED RETREATMENT FILES ON CANAL TRANSPORTATION AND DENTIN THICKNESS IN ENDODONTICALLY TREATED TEETH: AN IN VITRO CBCT STUDY

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Introduction: Non-surgical retreatment is a conservative approach for managing recurrent endodontic infections requiring efficient removal of obturating material while preserving dentin. Retreatment file systems, through their design and function, play a vital role in ensuring effective cleaning and minimal structural compromise.

Methods: Forty-five extracted mandibular molars were decoronated and obturated at a standardized root length of 16 mm in both mesial canals. Samples were divided into three groups (n=15): Group 1 – SoliteRS3, Group 2 – Dentsply Protaper Universal Retreatment Files and Group 3 – Neoendo Retreatment Files. Pre- and postoperative CBCT scans were used to assess remaining dentin thickness, canal centering ability and centering ratio. Data were analyzed using one-way ANOVA and post hoc Tukey tests ($p < 0.05$).

Results: There was a statistically significant difference among the three file systems in all evaluated parameters [$p < 0.05$]. SoliteRS3 showed better dentin preservation and superior centering ability.

Conclusions: SoliteRS3 files demonstrated superior dentin conservation and canal centering, making them a favorable choice for endodontic retreatment.

Keywords: Cone-beam computed tomography [CBCT], Endodontically treated teeth, Endodontic retreatment, Gutta-percha, Removal, Heat-treated files, Endodontic Instruments.

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Conflicts of interest:

The authors declare no conflicts of interest.

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ÉVALUATION COMPARATIVE DES FICHIERS DE RETRAITEMENT TRAITES THERMIQUEMENT SUR LE TRANSPORT CANALAIRE ET L'ÉPAISSEUR DE LA DENTINE DANS LES DENTS TRAITÉES ENDODONTIQUEMENT: UNE ÉTUDE CBCT IN VITRO

Introduction: Le retraitement non chirurgical est une approche conservatrice pour la prise en charge des infections endodontiques récurrentes nécessitant une élimination efficace du matériau d'obturation tout en préservant la dentine. Les systèmes de retraitement, de par leur conception et leur fonction, jouent un rôle essentiel pour assurer un nettoyage efficace et une atteinte structurelle minimale.

Méthodes: Quarante-cinq molaires mandibulaires extraites ont été décoronées et obturées à une longueur radiculaire standardisée de 16 mm dans les deux canaux mésiaux. Les échantillons ont été divisés en trois groupes ($n = 15$) : Groupe 1 – SoliteRS3, Groupe 2 – Limes de retraitement universelles Dentsply Protaper et Groupe 3 – Limes de retraitement Neoendo. Des scanners CBCT pré- et postopératoires ont été utilisés pour évaluer l'épaisseur de dentine restante, la capacité de centrage canalaire et le rapport de centrage. Les données ont été analysées à l'aide d'une ANOVA à un facteur et de tests de Tukey post-hoc ($p < 0,05$).

Résultats: Une différence statistiquement significative a été observée entre les trois systèmes de limes pour tous les paramètres évalués [$p < 0,05$]. SoliteRS3 a montré une meilleure préservation de la dentine et une capacité de centrage supérieure.

Conclusion: Les limes SoliteRS3 ont démontré une conservation de la dentine et un centrage du canal supérieurs, ce qui en fait un choix favorable pour le retraitement endodontique.

Mots-clés: Tomodensitométrie volumique à faisceau conique [CBCT], Dents traitées endodontiquement, Retraitement endodontique, Retrait, Gutta-percha, Limes traitées thermiquement, Instruments Endodontiques.

Introduction

Endodontic retreatment is a procedure performed on the tooth that has received prior attempted definitive treatment; this may occur due to persistent infection or incomplete removal of the pulp tissue and debris during the initial treatment [1]. The goal of retreatment is to eliminate any remaining pathogens, seal the canals effectively, and promote healing of the surrounding tissues. The prevalence of periapical lesions in endodontically treated teeth is between 12%[2]. The wide range in periapical lesion prevalence after endodontic treatment may be due to differences in diagnostic methods, treatment quality, operator skill, and patient-related factors. Use of CBCT, varying lesion definitions, and inconsistent follow-up durations may further contribute to this variability [2]. This periapical lesion or radiolucency indicates an endodontic failure. To stop the tooth from becoming infected again, the main goal of a root canal treatment is to thoroughly clean and shape the root canal system in three dimensions [3]. Preserving the natural tooth is the rationale of any endodontic treatment.

Root canal treatment failure can arise from various biological, technical or iatrogenic causes. Any alteration or deviation in the canal's original path can result in complications such as ledge formation, canal transportation, strip perforation, or zipping [4]. Recent advancements in rotary instrumentation have introduced dedicated retreatment files designed to enhance the efficiency of this complex procedure[5]. These files boast unique design features, including a non-end cutting tip for preventing ledge formation and navigating past existing gutta percha and aggressive flutes for effective material removal [5].

Despite these advancements, retreatment carries inherent challenges. The process of removing

the obturation material can lead to reduced remaining dentinal thickness, thus weakening the tooth structure. According studies the taper of endodontic files affects the development of cracks. In our study, the orifice opener had a larger taper of 8%, which likely generated higher stress in the root dentin, contributing to the formation of microcracks. Iatrogenic complications such as apical transportation, where the canal is inadvertently enlarged beyond its original path, can compromise the apical seal and long-term process [6, 7].

A few of the variables which impact the effectiveness of the system and removal time are the cross-sectional design, surface treatment, cutting angle, taper, and active cutting tip. Recent years have seen the availability of numerous rotary systems. This study examined three such retreatment file systems: Solite RS3 [SRS-3] Retreatment [Solite Dental, India], ProTaper Universal Retreatment [PTUR] [Dentsply Maillefer, Ballaigues, Switzerland] and Neo Endo Retreatment files [Orikam Healthcare India Pvt. Ltd., India].

This study uses cone beam computed tomography for the evaluation of remaining dentinal thickness and apical transportation. The null hypothesis states that there is no significant difference among the three systems in terms of gutta-percha removal efficiency, remaining dentin thickness, or apical transportation during endodontic retreatment. The aim of the study is to compare the effectiveness of three different endodontic retreatment systems in terms of gutta-percha removal, preservation of remaining dentin thickness, and minimization of apical transportation.

Materials and Methods

This research was done with the approval of the institutional ethical committee [SRB/SDC/ENDO-2301/24/449]. The sample size for the present study was calculated from a previous study that assessed

canal transportation between two retreatment file systems using Cone Beam Computerised Tomography. Based on the assessment a total sample size of 45 was calculated at a power of 90% [$1 - \beta = 0.95$, $\alpha = 0.05$] [8]. Forty-five extracted human mandibular molar teeth with similar root canal anatomy [Vertucci Type 1] were chosen. Samples were stored in regular saline after being disinfected for one hour with 0.5% chloramine-T [Infutec Healthcare Ltd., Indore, India]. All samples underwent diagnostic X-rays to rule out any additional canal, canal curvature, apex development, resorption, caries, or calcification. Moreover, any soft tissue or calculus deposits on the root surfaces of the samples were mechanically removed.

Utilizing a diamond disc [DFS Diamon, Germany] and water spray, the decoration was carried out resulting in roots which measured approximately 16 mm long. The access cavities were prepared using an endo access bur [Mani Inc., Japan]. The working length [WL] was calculated using a 10 K file. Chemomechanical preparation was done using the protaper gold rotary file series [Dentsply Maillefer, Switzerland] upto F2 size [as per manufacturers instructions]. Subsequently irrigation was done using 3% sodium hypochlorite and 17% ethylenediaminetetraacetic acid. Thereafter the canals were dried using a size 25 paper point.

Canals were coated with AH PLUS sealer and Standard Gutta percha size 25 with a 6% taper was used for obturation. Excess gutta percha was removed using a heated plugger. Cavit was used to fill the access cavities, and the samples were stored in a humidifier for 2 weeks at 37°C with 100% humidity.

The samples were scanned for a volumetric study using a cone beam computed tomography scanner [carestream 9600] with CS3D imaging, version 3.10.21. Exposure parameters were 120kVp 4mA exposure time 30-40s after being embedded in a wax arch. The

coronal [9mm from apex], middle [6mm from apex], and apical [3mm from apex] thirds were used to measure the dentinal thickness and obturation material for every sample. A perpendicular line across the long axis of the tooth was drawn which was standardised across all samples. Line measurement tool was used to calculate the distance in mm.

Technique used for retreatment

The samples were divided into 3 retreatment groups [n=45]

Group 1: Solite RS3 at 350 RPM and 2.6 N/cm Torque [n=15]

Group 2: Dentsply universal Retreatment Files at 500 RPM and 2.5 N/cm Torque [n=15]

Group 3: Neo Endo Retreatment files at 350 RPM and 1.5 N/cm Torque [n=15]

RPM and torque according to manufacturers instructions.

A 3% sodium hypochlorite irrigation was carried out with each advancement of the instrument in all file systems. Retreatment was considered complete when there was no longer any discernible gutta percha residue on the instrument. After the gutta-percha was removed, 3 mL of 17% EDTA was irrigated into the root canal for three minutes, followed by a saline rinse, and absorbent paper points were used to dry the area. A single calibrated operator performed the retreatment procedure to maintain standardization.

Canal Centering Ability

The ability of the instrument to stay in the centre of the channel is indicated by the average centre ratio. The third [apical], sixth [medial], and ninth [coronal] millimetres of the root tip were used to calculate instrument CA using the formula of Gambill et al [9] $C[\text{canal central capacity}] = M1 - M2/D1 - D2$ or $D1 - D2/M1 - M2$.

where M1 and M2 are the shortest distances between the root and the medial edge of the non-instrumented canal and the mesial edge of the

instrumented canal. D1 and D2 are the shortest distances between the distal edge of the root and the distal edge of the non-instrumented canal and the instrumented canal[10,11]. The ability of the instrument to maintain root canal centrality was found to be weakest when values were close to 0 [zero] and best when close to 1[one][10–12].

Canal Transportation

Canal transportation refers to the unintended removal of dentinal structure from the outer curve in the apical portion of the canal, caused by the instrument's natural tendency to revert to its original straight shape during canal shaping[13]. The extent and direction of canal migration can be determined by measuring the distance in both mesial and distal directions from the edge of the uninstrumented canal to the edge of the tooth and comparing this with the measurement obtained from the instrumented images[14]. Gambill's formula determined the channel flow as follows:

$$T[\text{channel transport}] = [M1 - M2] - [D1 - D2]$$

where $T = 0$ means no transport, $T > 0$ means flow towards the middle side of the root canal.

$T < 0$ means migration towards the distal sides of the root canal[9,14].

Statistical Analysis

SPSS [Statistical Package for the Social Sciences] software version 23.0 [IBM, Chicago, Illinois] was used for statistical analysis. One-way ANOVA was performed within the groups and post hoc tukey was performed between groups

Results

Remaining dentin thickness

Oneway ANOVA post hoc tukey showed for Remaining Dentin thickness for ML canal at 3mm no significant difference seen between all the three groups ($p > 0.05$). At 6 mm no significant difference for solite RS3 compared to PTUR and Neo Endo ($p > 0.05$), PTUR showed significant difference when compared to Neo Endo ($p = 0.005$). At 9mm, Solite RS3 preserved more dentin compared to the other two groups, Neo Endo ($p = 0.000$), PTUR ($p = 0.031$).

In MB canal at 3 mm, no significant difference seen between all the three groups ($p > 0.05$). At 6mm, Solite RS3 preserved more dentin when compared to PTUR ($p = 0.005$), no significant difference seen when compared to Neo Endo ($p = 0.063$). At 9mm, Solite RS3 preserved more dentin compared to the other two groups, Neo Endo ($p = 0.000$), PTUR ($p = 0.000$). (Table 1)

Table 1. Mean and Standard Deviation, One Way ANOVA - Remaining Dentin thickness (RDT) for all the three groups at different levels in Mesio Buccal canal and Mesio Lingual canal.

GROUPS	ML RDT 3MM	ML RDT 6MM	ML RDT 9MM	MB RDT 3MM	MB RDT 6MM	MB RDT 9MM
SOLITE RS3	.39±.442 ^a	.48±.092 ^a	.71±.099 ^a	.30±.245 ^a	.43±.095 ^a	.66±.097 ^a
NEO ENDO	.31±.218 ^a	.32±.169 ^b	.16±.052 ^b	.35±.178 ^a	.30±.082 ^b	.04±.052 ^b
PTUR	.23±.082 ^a	.57±.200 ^a	.52±.249 ^c	.17±.048 ^a	.24±.171 ^b	.13±.048 ^b
posthoc -Oneway ANOVA	0.472	0.006*	0.001*	0.081	0.006*	0.000*

* Significant if $p < 0.05$. Across the column similar superscript alphabet shows no significant difference.

Canal Transportation

Oneway ANOVA post hoc tukey showed in ML canal at 3 mm, Solite RS3 showed significant difference when compared to Neo endo ($p=0.008$), and no significant difference seen when compared to PTUR ($p=0.104$). At 6 mm Solite RS3 showed significant difference when compared to PTUR ($p=0.02$), no difference seen when compared to Neo Endo ($p=0.052$). At 9 mm Solite RS3 showed significant difference when compared to both PTUR and Neo Endo ($p=0.000$).

In MB canal at 3mm no significant difference between all the three groups ($p>0.05$). At 6mm Solite RS3 showed significant difference when compared to Neo Endo ($p=0.000$), no significant difference seen when compared to PTUR ($p=0.221$). At 9mm Solite RS3 showed significant difference when compared to both the groups, Neo Endo ($p=0.00$) and PTUR ($p=0.019$) respectively. (Table 2)

Canal Centering Ratio

Oneway ANOVA post hoc tukey showed in both the canals at all the three levels Solite RS3 showed significant difference when compared to other two files ($p<0.05$). no significant difference seen between Neo Endo and PTUR in both the canals at all three levels ($p>0.05$). (Table 3)

Discussion

The efficacy of endodontic retreatment is primarily determined by three critical factors: meticulous irrigation, effective disinfection, and thorough sealing of the root canal system[15]. Among these, cleaning and shaping are considered the most crucial steps in root canal therapy, as they significantly influence dentin thickness and structural integrity[15,16]. Proper canal preparation is essential for the optimal flow of irrigants and successful obturation, while

Table 2. Mean and Standard Deviation, One Way ANOVA – Canal Transportation (CT) for all the three groups at different levels in Mesio Buccal canal and Mesio Lingual canal.

GROUPS	ML CT 3MM	ML CT 6MM	ML CT 9MM	MB CT 3MM	MB CT 6MM	MB CT 9MM
SOLITE RS3	.31 ± .218 ^a	.31 ± .152 ^a	.16 ± .052 ^a	.17 ± .048 ^a	.22 ± .132 ^a	.04 ± .052 ^a
NEO ENDO	.57 ± .200 ^b	.49 ± .192 ^a	.71 ± .099 ^b	.35 ± .178 ^b	.43 ± .095 ^b	.66 ± .097 ^b
PTUR	.48 ± .092 ^b	.58 ± .320 ^b	.52 ± .248 ^b	.30 ± .245 ^b	.30 ± .082 ^a	.13 ± .048 ^b
One-way ANOVA	0.010*	0.003*	0.000*	0.081	0.000 *	0.000*

* Significant if $p < 0.05$. Across the column similar superscript alphabet shows no significant difference.

Table 3. Mean and Standard Deviation, One Way ANOVA – Canal Centering Ratio (CCR) for all the three groups at different levels in Mesio Buccal canal and Mesio Lingual canal.

GROUPS	ML CCR 3MM	ML CCR 6MM	ML CCR 9MM	MB CCR 3MM	MB CCR 6MM	MB CCR 9MM
SOLITE RS3	.930 ± .103 ^a	.850 ± .241 ^a	.910 ± .145 ^a	.937 ± .133 ^a	.850 ± .242 ^a	.865 ± .221 ^a
NEO ENDO	.694 ± .082 ^b	.648 ± .080 ^b	.556 ± .110 ^b	.665 ± .053 ^b	.565 ± .052 ^b	.437 ± .070 ^b
PTUR	.635 ± .040 ^c	.571 ± .085 ^c	.503 ± .086 ^c	.746 ± .112 ^c	.614 ± .126 ^c	.547 ± .108 ^c
Oneway ANOVA	0.000	0.001	0.000	0.000	0.001	0.000

* Significant if $p < 0.05$. Across the column similar superscript alphabet shows no significant difference.

excessive enlargement must be avoided to preserve dentin and enhance the long-term survival of the tooth [17].

According to Krikeli et al. [18], dentin thickness directly impacts the fracture resistance of endodontically treated teeth. This is supported by Limongi et al.[19], who found that excessive dentin removal during retreatment weakens the tooth structure. Research suggests that mechanical instrumentation during retreatment procedures primarily removes dentin in the mesial and distal directions, which necessitates careful shaping techniques to minimize excessive dentin loss. Achieving an optimal canal taper enhances the penetration of irrigants

into complex root canal areas and facilitates effective disinfection. However, during retreatment, clinicians must be particularly cautious, as dentin thickness may already be compromised from the initial root canal procedure.

The primary goal of retreatment is to completely remove the previous obturation materials to allow for proper cleansing, disinfection, and re-obturation of the canal space. According to Shahriari et al. [20], the most widely used techniques for obturation material removal include manual files, heated instruments, rotary files with or without solvents, and ultrasonic systems. Each method facilitates the removal of debris from the dentinal

walls, but no single technique achieves complete obturation material removal [20]. CBCT and microcomputed tomography [CT] have revolutionized the assessment of root canal cleanliness, allowing for three-dimensional evaluation of the canal system while exposing patients to significantly lower radiation doses than traditional CT scans [21].

When the primary endodontic treatment fails, nonsurgical retreatment is the first line of treatment before surgical retreatment can be considered. Gutta-percha removal from a canal using traditional Hedstrom files is challenging and time-consuming. Rotary NiTi technology may expedite the process and reduce operator and patient fatigue [22]. However, these techniques carry the risk of iatrogenic errors such as perforation, ledge formation, canal straightening, or altered canal architecture. To mitigate these risks, this study selected teeth with a mean curvature of less than 20° apically to minimize iatrogenic errors.

Studies indicate that residual obturation material remains despite both manual and mechanical retreatment techniques. According to previous research, neither manual nor mechanized instrumentation systems can entirely remove obturating material from the root canal system during endodontic retreatment [22, 23]. To address this, newer file systems, such as the Solite RS3 retreatment files [Solite Dental, Chennai, India], have been developed to efficiently remove gutta-percha while preserving root canal curvature [8]. The Solite RS3 retreatment system comprises three files of varying lengths—15 mm, 18 mm, and 23 mm—designed for use in the coronal, middle, and apical thirds of the root canal, respectively [Patent No. 202241008949]. The RS1 file features an 8% taper with a 0.30 mm tip diameter and a modified convex triangular cross-section, providing three-point contact to facilitate gutta-percha removal

from the coronal third. The RS2 file is a heat-treated instrument with a cutting tip, measuring 0.25 mm in diameter and tapering at 7%. The RS3 file, also heat-treated, has a non-cutting tip with a 0.20 mm diameter and 6% taper, and its offset rectangular cross-section enhances gutta-percha removal, particularly in curved canals.

The Solite RS3 retreatment file system demonstrated statistically significant improvements in canal centering ratio [CCR] at 3 mm in the mesiodistal direction and at 6 mm and 9 mm in the buccolingual direction. These results can be attributed to the unique flute design, which efficiently collects and directs gutta-percha toward the canal opening while preserving dentin thickness. According to Limongi et al. [19], file systems with increased flexibility and optimized design help in maintaining root canal integrity. The heat-treated memory wire construction of Solite RS3 provides enhanced flexibility, reducing stress on curved canals and minimizing the risk of iatrogenic errors such as canal transportation and perforation [24].

A study by Solite et al. [8] evaluated the impact of heat-treated retreatment files on canal transportation and centering ability. Their findings indicated that heat-treated files performed better in preserving dentin while achieving complete obturation material removal. Similarly, Sankar et al. [15] conducted a comparative study on the time efficiency of different retreatment file systems and concluded that heat-treated retreatment files significantly reduced retreatment time without compromising canal integrity.

In comparison, the HyFlex Remover retreatment files, the HyFlex Remover, a single-file retreatment system with a 7% taper designed for use across the coronal, middle, and apical thirds, may contribute to substantial dentin and gutta-percha removal. This aggressive cutting action could compromise canal centering

and increase the risk of structural weakening [25]. Similarly, the Dentsply ProTaper Universal retreatment files exhibited superior cutting efficiency but resulted in reduced remaining dentin thickness (4). These findings support previous research by Shahriari et al. [20], who found that greater taper files tend to remove more dentin but may compromise structural integrity. In contrast, the Solite RS3 system achieved efficient obturation material removal while preserving dentin thickness, highlighting its advantage in endodontic retreatment [5].

On the contrary, none of the evaluated systems showed a CCR value of 1 after re-instrumentation. The risks of decentralization are increased during retreatment since the instruments employed for retreatment have a greater diameter than those used in primary endodontic therapy [11]. However, the Solite RS3 retreatment file used in the apical third has a tip diameter of 0.20 mm with a taper of 6%, which is similar to the files used for primary endodontic therapy. This similarity may contribute to the preservation of canal centrality in the Solite RS3 group compared to the HyFlex group.

The results of this study offer practical guidance for clinicians when selecting retreatment file systems. The Solite RS3 system, with its heat-treated design and flexible structure, showed improved preservation of dentin and better canal centering, particularly in curved canals. These advantages make it a suitable choice for retreatment procedures where maintaining the original canal anatomy is essential. By minimizing structural damage and enhancing efficiency, the findings encourage the use of conservative file systems like Solite RS3 to improve treatment outcomes and reduce the risk of procedural complications.

Despite its promising findings, the study had certain limitations. The sample size was limited to 45 teeth,

and in vitro conditions may not fully replicate clinical scenarios where variations in anatomy and patient factors influence outcomes. Operator experience was not accounted for, which may affect retreatment success rates. Additionally, CBCT imaging, while useful for measuring remaining dentin thickness [RDT] and canal centering ratio [CCR], may introduce measurement variability (4). The study did not assess long-term outcomes on tooth integrity or treatment success, nor did it include histological analyses to evaluate the

condition of surrounding tissues post-retreatment. Future studies can include advanced imaging like micro-CT that can offer more precise evaluation of residual material and dentin preservation. Research on its performance in complex anatomies and assessments of fatigue resistance, instrument separation, and patient outcomes will strengthen clinical relevance. Exploring combinations with adjunctive techniques and cost-effectiveness could further guide its integration into routine retreatment protocols.

Conclusion

Evaluation of the remaining dentin thickness, canal centering ratio, and canal transportation demonstrated better results for the novel heat-treated retreatment files by Solite Dental when compared to the Protaper retreatment files and the Neoendo retreatment files under the conditions of this study.

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