Original Article

Comparative analysis of novel heat-treated retreatment file system on the removal of obturating material using nano-computed tomography

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Abstract

Introduction: The aim of nonsurgical retreatment is to remove the previous filling material followed by chemo-mechanical preparation of the canal to achieve proper disinfection of the root canal system. This is then followed by re-obturation. This study evaluates the time taken to retrieve the gutta-percha and the quantity of remaining filling material after retreatment with two different file systems. The quantity of remaining filling material was assessed using nano-computed tomography (CT) due to its increased accuracy.

Materials and Methods: Forty extracted single-rooted teeth were split into two groups at random and decoronated and obturated at a standard root length of 16 mm. Solite RS3 (SRS-3) Retreatment and ProTaper Universal Retreatment (PTUR) systems were used to retrieve the gutta-percha after a preoperative nano-CT scan. Postoperative nano-CT scan was taken and both the scans were superimposed to quantify the remaining filling material. The time taken to remove gutta-percha was measured using a stopwatch. The statistical analysis comparing the two groups was conducted using the independent *t*-test.

Results: The quantitative analysis of remaining filling material using nano-CT showed no statistical difference between both the file systems used ($P > 0.05$). However, SRS-3 took significantly less time in the removal of gutta-percha ($P < 0.05$).

Conclusion: Hence, we can conclude that there is no significant difference in the amount of remaining filling material between both the file systems. However, time taken to remove the gutta-percha was lesser in SRS-3 compared to PTUR file system.

Keywords: Gutta-percha removal; micro-computed tomography; nano-computed tomography; remaining filling material; retreatment; Solite RS3

INTRODUCTION

Endodontic literature reports that despite the adequate standard of treatment being performed around 30% of root canal treated teeth end up with apical periodontitis and other periradicular diseases.[1] This might be due to the persistence of microorganisms or noxious factors within the intricate anatomy of the root canals, thereby inducing an inflammatory/immune response, leading to impaired tissue healing and localized bone destruction in the affected areas. Establishing access to the root canal by the complete elimination of the existing filling is imperative for proper disinfection and re-obturation in a nonsurgical mode of retreatment.[2] Despite our best efforts, some amount of filling material inadvertently ends up untouched and remains in the root canal system.[3] These isolated areas may

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serve as niches for bacterial growth and cause failure of the root canal treatment even with a good irrigation protocol, as these areas remain inaccessible. Various techniques such as hand instrumentation, ultrasonics, rotary systems, and reciprocation systems have been suggested, yet literature has shown us that no technique is capable of completely removing the filling material.[4] This becomes even more challenging in the isthmus region or when the canal is curved, oval, or C shaped.[5-8]

The major benefit of engine-driven file systems over manual file systems is the reduction in time taken for removal which plays a significant role in clinical scenarios. In this study, we attempt to assess a retreatment file system that can remove maximum possible filling material from the root canal. It is difficult and time-consuming to remove filling material, especially in curved canals.[9] Multiple factors such as an active cutting tip, the cross-sectional design, surface treatment, cutting angle, taper influence the efficiency of the system, and the time taken for removal.[10,11] Many rotary systems have come to be available in recent years. Two such retreatment file systems ProTaper Universal Retreatment (PTUR) (Dentsply Maillefer, Ballaigues, Switzerland) and Solite RS3 (SRS-3) Retreatment (Solite Dental, India) file systems have been evaluated in this study. Both file systems comprise of three files with one file each for removing the gutta-percha from the coronal, middle, and apical third, respectively.

Several experimental models have been used to evaluate the gutta-percha removal such as longitudinal or transverse sectioning at various levels. Various studies have been done using cone-beam computed tomography (CT) and micro-CT to analyze the quantity of remaining filling material. Despite the technical advancements existing, clinical imaging modalities have a maximum resolution of 240–600 μm. Therefore, histopathology is the gold standard for evaluation or quantification of products below 200 μm.[12] Micro-CT/nano-CT has been established as a complement to histopathology as it reduces preparation time, operator error, and does not involve destruction of specimens. The current study determines the volume of the remaining filling material under nano-CT. A technical advancement of the existing micro-CT technology, nano-CT is a high-resolution cross-sectional imaging technique with superior spatial resolution without specimen destruction. It also makes it possible for a precise evaluation of the filling material quantitatively. While micro-CT has a spatial resolution of 5–50 μm, with the help of specific detectors and protocols nano-CT has been shown to have a superior spatial resolution of up to 400 nm.[12] The higher spatial resolution of the nano-CT ensures that we accurately analyze and quantify the remaining filling present in the canal. This study aims to analyze quantitatively the amount of remaining filling material after retreatment with the above-mentioned retreatment file systems using nano-CT imaging analysis along with the time taken to remove the gutta-percha. The null hypothesis states that the PTUR file system and the SRS-3 retreatment file system have no significant difference in the filling material that remains and that there is no difference in the time taken by both the systems in removing the gutta-percha.

MATERIALS AND METHODS

Sample preparation

Forty freshly extracted single-rooted teeth with one canal were chosen for the study after initial radiographic screening. The exclusion criteria for the study included teeth with pulp calcification, resorption, prior root canal treatment, and radicular fractures. All the teeth were de-coronated with diamond discs to bring the teeth to a standard working length of 16 mm. Access opening was done using Endo-access bur size 2 (Dentsply Maillefer, Ballaigues, Switzerland). With 2.5 mL of 3% sodium hypochlorite (Prime Dental, India), the root canal was rinsed. 10K files (Mani, Japan) were used to check the patency of the canal until the tip of the file was seen at the apex, and a length 0.5 mm short of this was considered to be the working length. Cleaning and shaping was done using ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) until F3 under irrigation with 2.5 mL, 3% sodium hypochlorite between each file. The canals were dried with paper points. Obturation was done using F3 gutta-percha cones (Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply DeTrayGmBH, Konstanz, Germany) using matched taper single cone technique. Excess gutta-percha was removed at the level of the orifice with a heated plugger. Filling was deemed adequate when it appeared to be homogeneous without any voids and the teeth with inadequate filling were eliminated and replaced. The teeth were then assessed with a periapical radiograph for the quality of obturation to avoid preprocedural errors. The orifice was sealed using Composite restoration (Neospectra ST, Dentsply Sirona, USA). The samples were stored in 1.5 mL graduated Eppendorf microcentrifuge tube filled with distilled water for 2 weeks at 37°C and 100% humidity to allow the sealer to fully set. A single operator carried out all the endodontic procedures. The time taken to retrieve the filling material was recorded on a stop clock and noted down on an excel sheet.

Nano-computed tomography scanning

The prepared specimens were then scanned using Bruker SKYSCAN2214 (Bruker Micro-CT, Kontich, Belgium) that allows ultraprecise scanning. The parameters used were a voltage of 100 kV (10W and 100 μA) with an exposure time of 1100 ms. The detector used was a flat panel detector with 360° rotation and 0.3° rotation step.

The images were rebuilt using the modified Feldkamp cone-beam reconstruction algorithm with the help of NRecon v. 1.6.9 software (Bruker-microCT, Kontich,

Belgium). For noise reduction, the original grayscale images were processed using the following fine-tuning functions: gaussian filter (Smoothing, kernel = 2), 40% beam hardening correction, 0.50 postalignment to account for potential acquisition misalignment, and ring artifact correction of 10. The scaled image pixel size was 11,999.58 nm with a fixed row and column size of 1944 × 3072.

Retreatment procedure

The teeth were then randomly divided into two groups, each containing 20 samples. Group 1 - SRS-3 retreatment file system and Group 2 - PTUR file system. Both of these are three file systems with one file each for the apical, middle, and coronal third of the root canal system.

Solite RS3 specifications

- RS1 – 30/0.08 (15 mm) – cutting tip, nonheat treated, and convex triangular cross section
- RS2 – 25/0.07 (18 mm) – cutting tip, heat treated, and convex triangular cross section
- RS3 – 20/0.06 (23 mm) – noncutting tip, heat treated, and rhomboidal cross section.

Protaper universal retreatment specifications

- D1 – 30/0.09 (16 mm) – cutting tip, nonheat treated, and convex triangular cross section
- D2 –25/0.08 (18 mm) – noncutting tip, nonheat treated, and convex triangular cross section
- D3 – 20/0.07 (22 mm) – noncutting tip, nonheat treated, and convex triangular cross section.

Both the systems were used as directed by the manufacturer and without the use of a solvent. When the walls of the root dentin were smooth and the working length was reached, the retreatment was believed to be finished. All the procedures were performed under an optical microscope with ×12 (OPMI Pico, ZEISS). During the process of retreatment, the canals were irrigated with 2.5 mL of 3% sodium hypochlorite (Prime Dental, India) in between each of the files used. 10 mL of 3% sodium hypochlorite (Prime Dental, India) was used for the final irrigation followed by 10 mL of normal saline and dried with paper points. No matter the retreatment system, each file was discarded after four uses or whenever we felt that there was obvious damage to the flutes. The samples were once again scanned after the retreatment procedure using SKYSCAN2214 scanner with the sample parameters.

Nano-computed tomography imaging analysis and measurements

The pre- and postoperative scans were geometrically aligned using the 3D registration function of DataViewer v. 1.5.1 software and the CTAn v. 1.14.4 software (Bruker micro-CT, Bruker Corp. Billerica, MA, USA) was used to process the image datasets. Binary images of the dentin and filling material were generated by utilizing task lists. A customized processing tool with functions and mathematical operations was used for this purpose. Using the grayscale threshold, we were able to clearly define the area that is dentin, the area that constituted filling materials and which areas were actually voids. The area that constituted the filling materials was chosen as the region of interest. This was done in each cross section and by the integration of the regions of interest of all the cross sections, the final volume of interest was calibrated and calculated. For the quantitative volumetric analysis of the remaining filling material including gutta-percha and sealer, CTVol v. 2.2.1 (Bruker micro-CT, Bruker Corp. Billerica, MA, USA) was used. A blinded observer then analyzed the remaining volume of filling material in each specimen.

Statistical analysis

SPSS software (IBM Corp, SPSS Inc., USA) version 23 for Windows was used to conduct the statistical analysis. Normality was analyzed using the Shapiro–Wilk test and it was found to be parametric. To ascertain the statistical difference between the two groups, the Independent *t*-test with a 95% confidence interval ($P < 0.05$) was used. The time taken for removal of endodontic material by every group was documented on an Excel sheet. To assess the statistical significance, Independent *t*-test was performed.

RESULTS

Nano CT showed remnants of filling material in both the SRS-3 [Figure 1] and ProTaper retreatment [Figure 2] groups. Although SRS-3 retreatment file system is seen to have removed more filling material, there is no significant difference between both the groups as $P > 0.05$ [Figure 3]. However, SRS-3 has taken less time to remove the gutta-percha [Table 1].

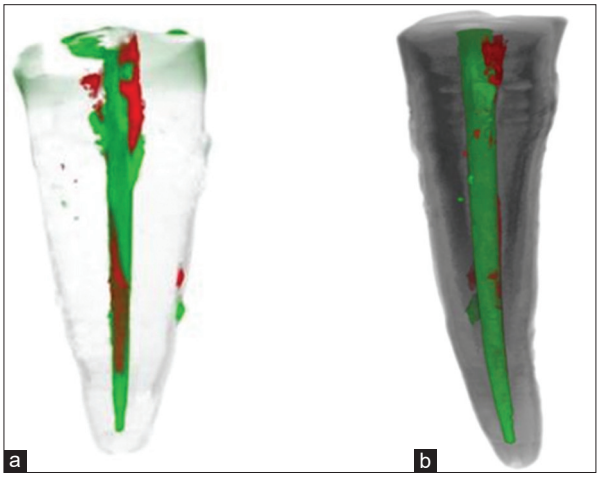

Figure 1: (a and b) The merged preoperative and postoperative nano computed tomography images of two different samples from Solite RS3 group. Green colour represents the filling material that has been removed while red colour refers to the remaining filling material remaining after retreatment

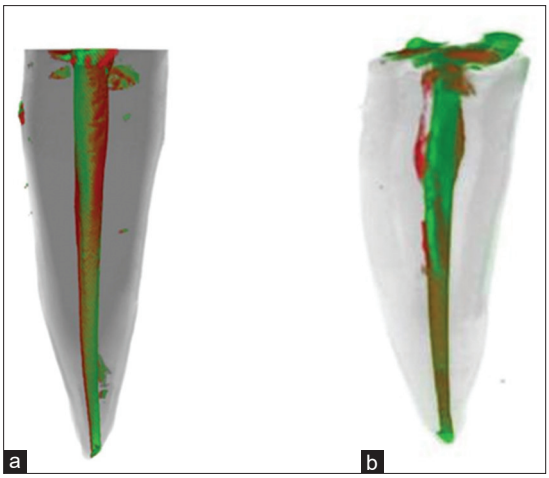

Figure 2: (a and b) The merged preoperative and postoperative nano computed tomography images of two different samples from ProTaper universal retreatment group. Green colour represents the filling material that has been removed while red colour refers to the remaining filling material remaining after retreatment

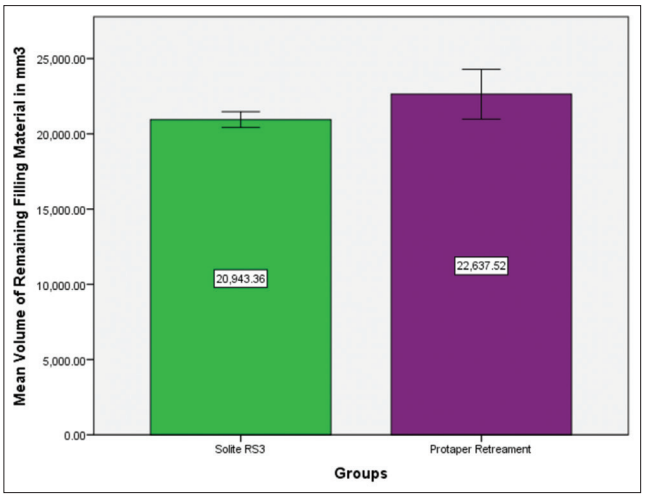

Figure 3: Represents the mean volume of remaining filling material in cubic mm after retreatment using the different file systems. X-axis represents the two different retreatment systems while Y-axis represents the mean volume of remaining filling material in cubic mm

DISCUSSION

Currently, a variety of systems are used to remove filling material during retreatment such as hedstrom files, Reciproc-Blue, D-RaCe, Mani-GTR, HyFlex NT, WaveOne-Gold, R-Motion, Fanta-AF-One, Tango-Endo and so on which are further supplemented by other aids such as XP Endo Finisher, Solvents, and Passive Ultrasonic Irrigation.[13,14]

Rios *et al*. compared the effectiveness of two reciprocating systems with PTUR.[15] The systems compared were WaveOne and Reciproc. The study concluded that the filling material that was remaining showed no statistically significant difference among the three groups, although the reciprocating systems were not specifically developed for retreatment. Infact fractures and deformations were noted in some D3 files of PTUR System, according to Beasley *et al*.[16] Another study by Solomonov *et al*. compared the efficiency of PTUR with profile followed by self-adjusting files and concluded that the latter was more efficient in removing the obturating material.[17]

Alberto Rubino *et al*. employed micro-CT to compare the effectiveness of PTUR and Mani-NRT-GTR and clearly established that the PTUR file system was superior. However it is also important that the study reported that there was significantly more loss of dentin in the PTUR system.[18] Kulkarni *et al*. analysed PTUR file system with D-Race and M-Two systems under cone-beam computerized tomography and concluded that there was no significant difference between the file systems but also said that PTUR removed more dentin, hence substantiating the above results.[19]

Table 1: The mean time taken by both the file systems in minutes for gutta-percha removal - Solite RS3 took significantly lesser time in gutta-percha removal ($P<0.05$)

Groups	Samples	Mean±SD	*P*
Solite RS3 retreatment file	20	3.2±0.72	<0.05
ProTaper Universal retreatment	20	4.35±1.3	

SD: Standard deviation

Despite the said disadvantages and drawbacks, PTUR system is still the most extensively tested and used choice of file system, which is why the present study compares the efficacy of the relatively new SRS3 system to the former. Further studies need to be done comparing the efficacy of SRS3 with other retreatment file systems. In all the samples, the gutta-percha was removed without solvents. The lesser time taken by SRS3 may be attributed to its heat treatment.

The results of this study show that despite the difference in the taper between both the file systems, there is no significant difference in the amount of remaining filling material seen. Our results are consistent with that of Bramhecha *et al*. who compared the remaining filling material of PTUR and SRS3 under scanning electron microscopy.[20] Thus, SRS3 shows the same efficiency as PTUR with an ability to preserve more dentin due to its lesser taper. The remaining dentin thickness postinstrumentation has been seen to directly influence the fracture resistance of the tooth.[21,22] Ganesh *et al*. compared the fracture resistance of endodontically treated teeth with retreated teeth and the results showed that retreatment significantly decreases the fracture resistance of the teeth due to considerable loss of root dentin.[23] Hence, the preservation of tooth structure is of paramount importance for long-term success. The remaining dentin thickness also plays an important role

in withstanding the lateral forces exerted during the compaction of gutta-percha.

Endodontic literature clearly establishes the increased incidence of vertical root fracture in teeth that have undergone endodontic therapy.[24] Thus it is vital to prevent the further loss of dentin due to excessive re-instrumentation. This in turn will result in increased structural durability of the tooth. The key to a long-term holistically successful endodontic therapy is to achieve optimal disinfection of the root canal system while preserving as much peri-cervical and root dentin as possible. The present study however has the following limitations of testing the file systems only on straight root canal systems, using only one technique of obturation and not supplementing the removal of filling materials using solvents or PUI. Further studies need to be done considering all these additional factors in order to infer which file system is truly better. Literature has also established the fact that no technique is enough by itself and the use of hybrid techniques[25] that varies from case to case and the operator experience plays a significant role in the success of retreatment.

CONCLUSION

The study's findings revealed that there was no significant difference in the amount of remaining filling material between the two groups. Thus we can say that there is no difference in the gutta-percha removing ability between both the file systems. However, considering the fact that the PTUR system has a higher taper, a lesser taper SRS-3 will definitely preserve more dentin and it can be considered more efficient. Further studies will be required in curved canals and multirooted teeth and with different techniques of obturation to substantiate the results obtained.

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Conflicts of interest

There are no conflicts of interest.

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