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Evaluation Of Root Canal Cleanliness After Re-Root Canal Treatment Using Two Different File System: A Scanning Electron Microscopy Study

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ABSTRACT

Aim: To evaluate the root canal cleanliness after root canal retreatment with ProTaper Universal and Solite RS rotary file system.

Materials and Methods: Twenty extracted single-rooted premolar teeth were selected. The root canals were enlarged with nickel-titanium (NiTi) rotary files, filled with gutta-percha and sealer, and randomly divided into the two experimental groups. The filling materials were removed with either one of the following file systems: ProTaper Universal or Solite RS. No solvent was used for removal of gutta percha. Teeth were sectioned longitudinal and assessed under the microscope.

Results: Both instrumentation techniques left obturating material in the canal at apical, coronal and middle third. There was no significant difference in both groups in regards to canal cleanliness at all the three levels ($p>0.05$).

Conclusion: Based on the findings of our in vitro study conducted on mandibular premolars with single roots, we can conclude that both instruments used in the study left filling material inside the root canal. The evaluation of the coronal, middle, and apical thirds did not reveal any significant variations in the remaining material between the instruments or the type of filling material.

Keywords: *Gutta-percha removal, ProTaper Universal, Re-root canal treatment, Scanning electron microscopy, Solite RS3*

INTRODUCTION

Numerous factors have been linked to the lack of success in endodontic treatment. Improper removal of debris using mechanical methods, the presence of bacteria in the canals and apex, inadequate quality of sealing, excessive or insufficient filling of the root canal, and leakage in the crown area are among the frequently identified reasons for such failures. Despite the generally favorable outcomes of endodontic treatment, failures do happen in a significant proportion of cases. (1)

According to a study conducted by Kojima et al. in 2004, the success rates of root canal fillings are lower when they are either underfilled or overfilled, while the highest success rates are observed when the fillings end at the same level as the apex or within a 2 mm range. (2) Another research conducted by Akbar in 2015 revealed that the most common cause of failure in endodontic treatment was underfilling, followed by inadequate filling and overfilling. (3)

Nonsurgical endodontic retreatment aims to restore the health of periapical tissues in cases where the initial root canal treatment was ineffective or reinfection occurred due to leakage in the crown or apex. The process involves regaining access to the entire root canal system by removing the original filling, performing additional cleaning, and resealing the canal (4). The removal of gutta-percha and sealer plays a crucial role in root canal retreatment. It is important because any necrotic tissue or bacteria that might be covered by the remaining gutta-percha or sealer could potentially lead to periapical inflammation or pain (5).

Nonsurgical approaches necessitate the complete removal of filling materials from the root canal space to achieve thorough cleaning, shaping, and obturation of the root canal system (4). Various techniques employing rotary nickel-titanium (NiTi) instruments (6–8), ultrasonic instruments (9,10), heat pluggers (11,12), and manual instruments with chemical solvents (such as chloroform, eucalyptol, and orange oil) (13,14) have been proposed for removing root filling materials. Among these, rotary NiTi instruments have demonstrated effectiveness (7,15) and time efficiency(16,17) in the removal of filling materials. However, none of the existing treatment alternatives appear to ensure complete debris-free canal walls (13,16).

Introduced in 2001, the ProTaper Universal Tulsa (Dentsply Tulsa, Tulsa, OK) system, integrated with three ProTaper retreatment files (D1, D2, D3), was developed to facilitate the removal of filling materials (21, 22). The D1 PTUS instrument features an active tip, measuring 16 mm in length, 0.30 mm in tip diameter, and exhibiting a 0.09% taper. The D2 PTUS instrument has a length of 18 mm, a tip diameter of 0.25 mm, and an 0.08% taper. The D3 PTUS instrument measures 22 mm in length, 0.20 mm in tip diameter, and possesses a 0.07% taper (18).

Another recently developed system, the Solite RS3 system, offers distinct features in its retreatment files. Each file within the Solite RS3 retreatment files possesses distinct lengths, tapers, and apical tip diameters. The Solite RS1 file features a 0.30 cutting tip, for initial penetration into the filling material, an 8% taper, a length of 15 mm, and 10 mm of active blades. The Solite RS2 file, designed for middle third filling material removal, includes a 0.25 cutting tip, a 7% taper, an 18 mm length, and 13 mm of active blades, which are heat treated. The Solite RS3 file is equipped with a 0.20 non-cutting tip, a 6% taper, a length of 23 mm, and 18 mm of active blades, utilized for apical filling removal, also heat treated.

To the best of our knowledge, limited studies have investigated the application of the Solite RS3 file system retreatment files. After the removal of gutta-percha, open dentinal tubules are necessary to effectively eliminate bacteria using irrigants. However, there is currently no literature available regarding the cleanliness of dentinal tubules following retreatment, including the use of the Solite RS3 file system, using scanning electron microscopy (SEM).

Previously our team had a rich experience in working on various research projects across multiple disciplines (19–26).Now the growing trend in this area motivated us to pursue this project. Therefore, the purpose of this study was to compare the cleanliness of root canal walls after retreatment using ProTaper instruments (Dentsply Maillefer) and the Solite RS3 file system in single-rooted human teeth.

MATERIALS AND METHODS

A total of twenty mandibular premolar teeth with single straight canals were selected for this study. Prior to the experiment, the teeth were

thoroughly cleaned using an ultrasonic scaler and rinsed with a sterile solution. Mesiodistal and buccolingual radiographs were taken to confirm the presence of a single canal. To ensure uniformity among the samples, the teeth were decoronated at the cementoenamel junction using a diamond disc (Isomet 2000; Buehler Ltd, Lake Bluff, IL), and their root lengths were standardized to approximately 16 mm.

Canal Preparation

All procedures were performed by a single operator, and teeth with calcification or multiple canals were excluded from the study. The access cavity was created using a high-speed carbide bur with water spray. After removal of the pulp tissue, a size 10 K-file (Dentsply Maillefer) was used to confirm the patency of the canal, and the working length was established at the apical foramen. The working length was set 1 mm short of the measured length. The glide path was created, and the ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) files were used for cleaning and shaping with the assistance of the X-Smart Plus Endomotor (Dentsply Maillefer, OK, USA) operating at 500 rpm and 2 Ncm torque for the rotary file system. Before each file was introduced into the canal, it was lubricated with Endo Prep RC (Stedman Anabond, Chennai, India). During the preparation, 2 ml of 5% sodium hypochlorite (NaOCl) was used as an irrigant between each file. The canals were prepared until the F3 instrument. Following instrumentation, the canals were irrigated with 5 ml of 17% liquid ethylenediaminetetraacetic acid (EDTA), followed by 5 ml of saline solution. Finally, the canals were dried using paper points (Dentsply Maillefer, Ballaigues, Switzerland) corresponding to the file sizes.

Canal Obturation

After drying the root canals with paper points, lateral compaction was used for obturation. A master gutta-percha cone size 30 was selected, and the tug-back was checked. AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) was mixed according to the manufacturer's instructions. The master cone was coated with sealer and placed in the canal. Additional gutta-percha cones were laterally compacted until they could not be inserted more than 5 mm into the canal. Temporary filling material (Cavit, Detrey, Dentsply) was used to seal the access cavity. The quality of the root filling was assessed by examining mesiodistal and buccolingual radiographs to ensure the absence of voids. The teeth were stored at 37°C in a humid environment for two weeks to allow complete sealer setting.

Retreatment Technique

The teeth were randomly divided into two groups of ten each. The coronal filling was removed to provide access to the canal entrance. The X-Smart Plus Endomotor (Dentsply Maillefer, OK, USA) was used at the manufacturer-recommended preset torque levels for each type of instrument in the two experimental groups. In group A, ProTaper System (Dentsply Maillefer) instruments D1, D2, and D3 were used in the crown-down technique until the D3 instrument reached the working length. In group B, the gutta-percha and sealer were removed using the Solite RS3 file system in a crown-down technique, utilizing the RS1, RS2, and RS3 files in sequence until the working length was reached. No solvents were used for the removal or softening of gutta-percha in both groups.

Sample Analysis

Two longitudinal grooves were made on the outer surface of the roots, and the roots were split longitudinally using a diamond disk and chisel. Care was taken to avoid entering the canal lumen with the disk. The remaining gutta-percha and sealer were evaluated in three segments: 1 mm above the apex (apical), 8 mm from the apex (middle), and 2 mm below the cementoenamel junction (coronal). The half of each specimen with the most filling material was selected for analysis. There was no distinction made between residual sealer and gutta-percha.

SEM Preparation

Selected specimens were dehydrated using graded alcohol concentrations, dried, and then coated with gold using a sputter coater (Sputter Coater; SPI, Toronto, Canada). The specimens were observed using a scanning electron microscope (JEOL 5200; JEOL, Tokyo, Japan). SEM photos of each third of the root canal (coronal, middle, and apical) were taken at a magnification of X 2000 to assess the cleanliness of the canals. The images were digitally saved

using proprietary software (SemA-fore; JEOL) and blindly evaluated by two trained operators.

SEM Evaluation Method

The amount of residual filling material was scored according to Ezzie *et al*.'s (27) criteria:

1. No to slight presence (0-25%) of obturation debris on the dentinal surface
2. Some presence (25-50%) of obturation debris on the dentinal surface
3. Moderate presence (50-75%) of obturation debris on the dentinal surface
4. Heavy presence (75%) of obturation debris on the dentinal surface

Each portion of the canal was divided into two fields each having a diameter of 2 to 3 mm to be evaluated and graded.

RESULTS

Statistical Analysis

The intraclass correlation coefficient was calculated to estimate the reliability of the measurements taken by the 2 examiners. The percentage of remaining filling material was evaluated for each group. Mean values for debris score were tabulated and analyzed using the statistical analysis software the Statistical Package for Social Sciences (SPSS). The chi-square test and Independent sample t-test was used to identify differences between the groups at the apical, middle, and coronal levels. The *P* value was considered statistically significant if <0.05.

Electron Microscopy

SEM of selected representative samples from each group revealed Canals in both groups tended to have increasingly more debris apically (Fig. 1) (Fig 2). In the apical area, canal walls appeared to be covered with residual obturation material and smear layer, no open dentinal tubules can be seen. Clean dentin walls and patent dentinal tubules can be observed in areas in the coronal third (Fig3). The result stated that both instrumentation techniques left obturating material with no statistically significant difference at coronal($p=0.180$), middle(0.756), apical($p=0.753$).

TABLE 1: The percentage of canals with different cleanliness scores in each treatment group

Areas	**Score**	**Group**		**p-values**
		ProTaper Universal	**Solite RS3**	
Coronal	1	35%	35%	0.18
	2	50%	40%	
	3	5%	25%	
	4	10%	0%	
Middle	1	20%	10%	0.753
	2	45%	60%	
	3	30%	25%	
	4	5%	5%	
Apical	1	10%	5%	0.756
	2	40%	50%	
	3	35%	25%	
	4	15%	20%	

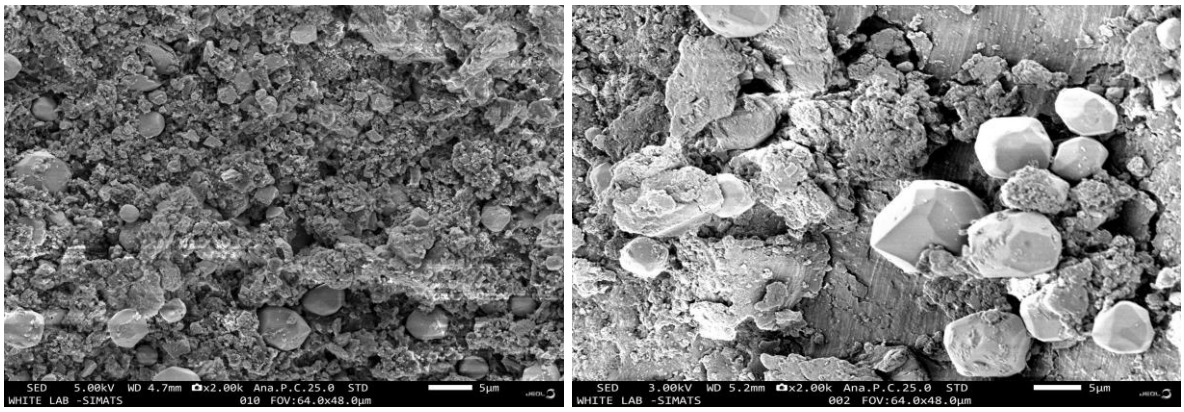

FIG 1: Representative SEM image for Group 1(left) and Group 2(right) at the apical third showing complete obturation of dentinal tubules with obturation material.

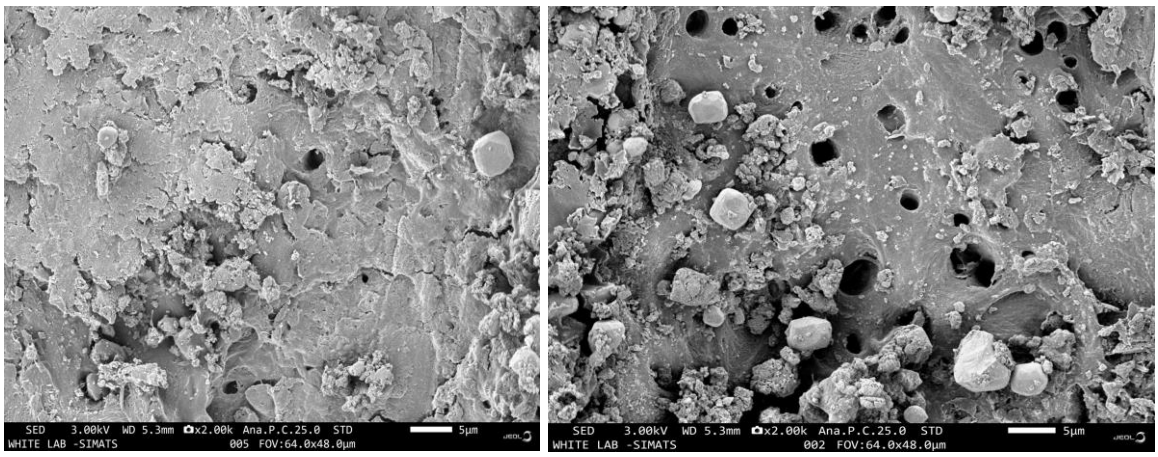

FIG 2: Representative SEM image for Group 1(left) and Group 2(right) at the middle third showing partial or complete obturation of dentinal tubules with obturation material. Comparatively higher number of dentinal tubules visible.

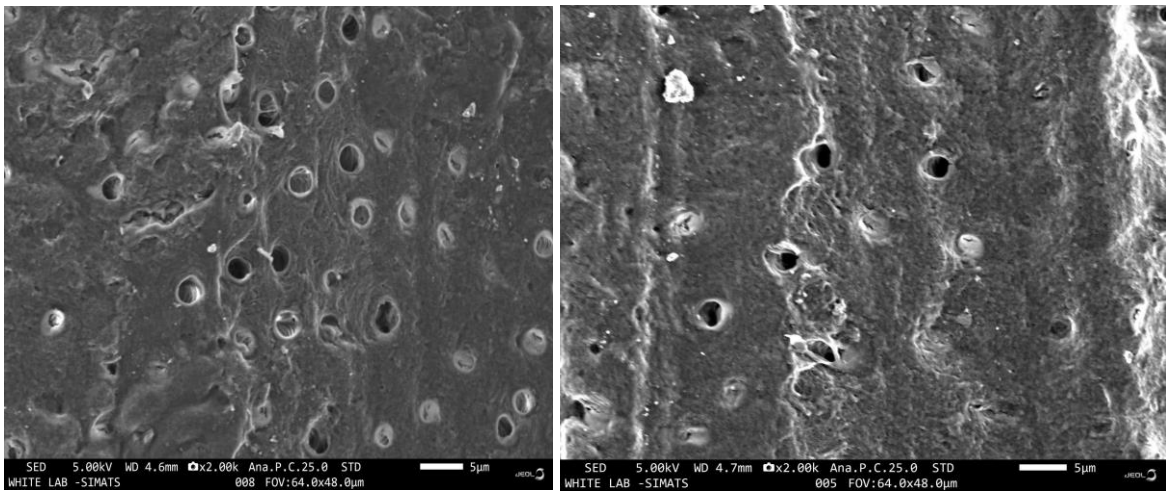

FIG 3: Representative SEM image for Group 1(left) and Group 2(right) at the coronal third showing more open dentinal tubules in both the groups.

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DISCUSSION

In this particular study, the focus was on mandibular premolars, which typically have an average root length of 14 mm. However, to standardize the samples and eliminate the influence of varying lengths, the teeth were decoronated at 16 mm from the apex, leaving 2 mm of coronal structure for the coronal seal. This approach ensured consistency and comparability with previous research (27–29).

The root canals were filled using a lateral condensation technique prior to their removal, as this technique has been commonly employed in similar studies (7,30,31). The speed of the instruments used was adjusted according to the manufacturers' recommendations.

To assess the effectiveness of root filling removal, debris scores were analyzed based on Ezzie et al.'s criteria, chosen for its simplicity (27,29,32) . Another scoring method provided by Hulsmann and Bluhm in 2004, involving measuring gutta-percha and sealer in millimeters on a scale of 1–7, has also been used in endodontic research (6).

Various techniques have been employed in endodontic research to evaluate the efficacy of root filling removal, including radiography, digitized images, longitudinal tooth splitting, stereomicroscope visualization, digital camera imaging with software analysis, and tooth transparency methods (7,31,33–37). Each method has its advantages and limitations, providing either two-dimensional or three-dimensional information for analysis.

The results of this study indicated that none of the experimental techniques used in retreatment procedures ensured complete removal of filling materials, consistent with previous findings (7,29,38). In this study, solvent application was not employed, as recent research by Horvath et al. demonstrated that it resulted in more gutta-percha remnants on canal walls and dentinal tubules (39).

The present in vitro study employed two different rotary instruments for endodontic retreatment. Both groups of retreated teeth had relatively straight root canals initially enlarged to size 30/06, ensuring uniformity among the samples in both experimental groups. The amount of remaining filling material was evaluated through longitudinal cleavage and quantitative analysis under SEM with 2000X magnification (28,37).

The characteristics of the cross-sectional design of Ni-Ti rotary files may contribute to variations in their cleaning ability, as observed by Hülsmann and Bluhm (6). The ProTaper Universal retreatment files remove gutta-percha in spirals around the instruments, while the Solite RS1 and RS2 files with a triple helix cross-section separate the gutta-percha from the canal walls. The ProTaper Universal files both rotate and cut the gutta-percha, whereas the Solite file System does not always cut the filling materials.

Different methods have been used in assessing canal wall cleaning, including split tooth longitudinal analysis, linear measurements of gutta-percha and sealer, microcomputer tomography, microradiographic technique, SEM, and transparent teeth methods (17,40–43). Each method has its strengths and weaknesses, providing either qualitative or quantitative evaluations.

Our institution is passionate about high quality evidence based research and has excelled in various fields.(21,24,44–54)The removal of root filling material from dentinal tubules is crucial to eliminate potential bacteria responsible for post-treatment disease and to ensure proper adaptation and adhesion of sealers and cements used for posts. SEM analysis in this study showed more open tubules in the coronal third of the root canal compared to the middle and apical thirds. These findings align with previous studies that reported higher remnants in the apical third (55,56).

Our institution is passionate about high quality evidence based research and has excelled in various fields.(57)(20–22,24,57–64).It is important to note that SEM analysis provides a more accurate assessment of dentinal tubule debris compared to macroscopic evaluation of surface remnants. The challenge in retreatment cases is that clinicians often rely on visual and radiographic analysis to evaluate the thoroughness of canal cleansing(30). In this study, a magnification of 2000X was consistently used for all SEM images, and the results were evaluated considering the specific part of the root from which the images were taken. Operator bias was minimized by grooves in the root surface indicating the designated investigation areas.

CONCLUSION

Based on the findings of our in vitro study conducted on mandibular premolars with single roots, we can conclude that both instruments used in the study left filling material inside the root canal. The evaluation of the coronal, middle, and apical thirds did not reveal any significant variations in the remaining material between the instruments or the type of filling material.

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