Evaluation of Gutta-Percha Removal from the Dentinal Tubules Using Different Instrumentation Techniques with or Without Solvent: An *In vitro* Study

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ABSTRACT

Aim: The cleanliness of dentinal tubules was compared after using different techniques for the removal of root filling material during root canal retreatment with and without solvent. **Materials and Methods:** Root canals of 90 extracted teeth were prepared and filled *in vitro* using lateral compaction with gutta-percha and sealer. In the control group (n = 10), the canals were left unfilled. In four experimental groups (n = 20 each), the root fillings were removed after 2 weeks using Hedstrom file, one of two rotary nickel–titanium instruments (ProTaper and Mtwo retreatment files), or a neodymium-doped yttrium aluminum garnet laser with H-file. Each experimental group was further subdivided into two subgroups (n = 10) according to whether the solvent N,N-dimethylformamide was used or not. After final irrigation, the samples were split longitudinally and photographed. The dentinal tubules' cleanliness was evaluated at the microscopic level by a scanning electron microscope in the coronal, middle, and apical thirds of each root half. **Results:** The number of open tubules was more prevalent in the control group, followed by the nonsolvent subgroups, than in the solvent subgroup (P < 0.05). **Conclusions:** All of the instruments left some filling materials inside the root canal both with and without solvent, but using solvent led to more remnants inside the dentinal tubules.

KEYWORDS: *Dentinal tubules, gutta-percha solvent, retreatment, scanning electron microscope*

INTRODUCTION

Root canal therapy, despite having a high degree of success, may not lead to the desired healing response.[1,2] A certain number of cases may not respond to initial therapy for a variety of reasons, which may lead to eventual failure. The main goal of retreatment is to regain access to the apical foramina by complete removal of the root canal filling material. This is done to facilitate sufficient cleaning and shaping of the complete root canal system and final obturation.[3]

Several techniques can be used to remove the gutta-percha and sealer, including the use of stainless steel hand files, nickel–titanium (NiTi) rotary instruments, heat-bearing instruments, ultrasonics, and recently, the laser.[4,5] Furthermore, solvents can be used to soften and dissolve gutta-percha with sealer in the filled root canal to facilitate its penetration and removal. However, in some studies, such as that of Hülsmann and Bluhm,[6] the effectiveness of solvent use has been found to be questionable. Whether

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solvents are helpful during gutta-percha removal or not is inconclusive.

Several *in vitro* studies have demonstrated traces of root canal filling material inside the dentinal tubules even after complete removal of the filling material from the canal walls. As the dentinal tubules can be a reservoir for bacteria, they should be thoroughly decontaminated with irrigants after the complete removal of filling material.[7] However, it seems that no treatment approach guarantees the complete removal of debris from the canal walls and dentinal tubules; therefore, the aim of this study was to evaluate the dentinal tubules after the removal of gutta-percha by one of four methods – a Hedstrom file, one of two rotary NiTi instruments (ProTaper or Mtwo retreatment files), or a neodymium-doped yttrium aluminum garnet (Nd: YAG) laser with or without solvent, in root canals of extracted and previously filled teeth *in vitro*, using scanning electron microscope (SEM).

Materials and Methods

Ninety freshly extracted maxillary central incisors and canines were collected and rendered free of calculus and other soft-tissue debris using hand scalers. The samples were then stored in aqueous solution containing 0.001% thymol at room temperature for no longer than 6 months. The inclusion criteria were single straight-rooted teeth with mature and intact apices, patent canals with a curvature angle of 0°–10° that was recommended by Schneider,[8] no prominent cracks, and no developmental anomalies.

Specimen preparation

The access cavities were prepared using #½ round and straight fissure diamond burs in a high-speed air rotor handpiece under water spray. The working length was determined using #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) inserted into the canal until it was visible at the apical foramen and established 1 mm short of this length. The incisal edge was adjusted so that the working length of each tooth sample was 18 mm. The root surfaces of the sample teeth were grooved horizontally at a distance of 2 mm, 6 mm, and 10 mm from the anatomical apex, using a straight diamond point in a contra-angle low-speed handpiece. The grooving was done in order to define the position of SEM images for evaluation.

Each root canal was prepared using Mtwo Ni-Ti rotary files (VDW, Munich, Germany) with the crown-down technique according to the manufacturer's recommendations. The apical preparation was then enlarged up to size #40 with a 4% taper while irrigating frequently with 3% NaOCl, 17% ethylenediaminetetraacetic acid (EDTA), and normal saline with a needle inserted 1–2 mm short of the working length. All of the samples were randomly divided into five groups (Control Group 1 [n = 10] and Experimental Groups 2–5: n = 20 each). The roots in Group 1 (control group) were left unfilled.

A thin mix of Bioseal resin sealer (Ogna Lab Farma, Italy) was prepared according to the manufacturer's instructions and applied to the root canal walls using lentulo-spirals with a slow-speed handpiece. The samples in each experimental group were obturated with gutta-percha and Bioseal using a lateral condensation technique. The extent of root filling was limited to 16 mm from the apex, so that the volume of gutta-percha was nearly equal in all of the roots. The sample teeth were then radiographed in buccolingual and mesiodistal directions to confirm the adequacy of obturation. The access cavities in all the samples were sealed using temporary filling material (Coltosol, Coltene/Whaledent, Altstatten, Switzerland). The samples were then stored in a humidor at 37°C and 100% relative humidity for 2 weeks to allow the complete setting of the sealer.

Distribution of samples

The obturated samples (n = 80) were randomly divided into four experimental groups (n = 20) with two subgroups (A and B; n = 10 each) in each group.

Retreatment technique

Gates Glidden drill burs, size #2–4, were used in crown-down fashion to remove 6 mm of root filling material in the cervical third of each of the samples. The middle and apical parts of the canal were retreated as per the following groups.

Group 2: Hedstrom files with and without solvent (n = 20)

Gutta-percha was removed from the root canals of Group 2 using #40-15 Hedstrom files (in descending order). The H-file was inserted up to the working length using a slight rotary motion with a circumferential filling technique. Once the working length was reached with size #15 H-file, it was further instrumented up to size #40, and the gutta-percha was removed simultaneously with and without solvent subject to subgroups.

Group 3: Mtwo retreatment rotary file system with and without solvent (n = 20)

The samples of Group 3 were retreated using a rotary Mtwo retreatment file system in a reduction gear handpiece at an approximately constant speed of 300 rpm using the crown-down technique. Mtwo retreatment instruments of size #25 followed by size 20 were used up to the working length for removal of filling material in the crown-down technique. The rotary

motion was altered with push-pull movement with and without the same solvent.

Group 4: ProTaper retreatment files with and without solvent (*n* = 20)

Retreatment of Group 4 was performed using ProTaper retreatment instruments in a reduction gear handpiece at an approximately constant speed of 500 rpm using the crown-down technique. A low-torque control motor (VDW Silver; VDW, Munich, Germany), at preset torque levels recommended by the manufacturer of the system, was used. Rotary ProTaper instruments (ProTaper System, Dentsply Maillefer, Ballaigues, Switzerland) containing 3 retreatment files, D1, D2, and D3, were used for retreatment in the crown-down technique. Gutta-percha was removed until file D3 with a 4% taper was able to reach the working length of the root canal.

Group 5: Neodymium-doped yttrium aluminum garnet laser plus hand filing with and without solvent (*n* = 20)

In Group 5, a combination of hand instruments (H file) and Nd:YAG laser (TwinLight dental laser, Fotona, Slovenia) and irrigation were used intermittently with and without solvent to remove the gutta-percha and sealers. The laser beam was delivered through an optic fiber 200 μm in diameter using a pulsed beam and using a contact mode with laser irradiation (20 Hz/W). The optic fiber was introduced into the root canal in the crown-apex direction up to 1 mm from the apex and back to the crown while rotating 360°. For each tooth, three cycles were performed for 10 s each, with a break of 20 s between cycles. During each break interval, the root canal was irrigated with normal saline solution or the same solvent with the other experimental groups and instrumented with a hand file to remove debris. The treatment was considered as completed each time a #40 H-file could reach the apical foramen. The gutta-percha remnants on the optical fiber were constantly removed to eliminate the possibility of influencing the laser parameters.

During the use of all of the retreatment files, the file penetration was carried out by exerting very slight apical pressure. The instruments used were withdrawn frequently, in order to inspect and remove the debris from their flutes before continuing. In case resistance was felt during rotation, hand files were used to confirm canal permeability. Finally, the canal size was enlarged with #45 K-file with frequent irrigation in all the samples of the experimental groups.

In subgroups 2A–5A (the solvent subgroups), a few drops of Endosolv-R solvent (Septodont, France) were initially deposited into the access cavity with the help of a disposable syringe. During the entire procedure, more Endosolv-R was delivered intermittently into the root canal using a disposable syringe. The total amount of solvent used was 60 μl, with 15 μl applied each of four times, in each canal. In subgroups 2B–5B (the subgroups without solvent), retreatment was performed in the same manner using an H-file, Mtwo retreatment files, ProTaper retreatment files, or the Nd: YAG laser with H-files according to the appropriate group, but no solvent was used for material removal. A total volume of 20 ml of 3% NaOCl was used as an irrigant for each tooth during the canal repreparation in all of the groups. After gutta-percha removal, the canals were irrigated for 1 min with 17% EDTA (5 ml), followed by 3% NaOCl (10 ml) using the irrigation needle 1–2 mm short of the working length. For all of the experimental groups, retreatment was considered complete when the working length was reached, and no more visible gutta-percha was removed with the device being used. At this point, the canals were dried using paper points.

Evaluation

The samples were grooved with diamond burs from the coronal to apical third using double-sided abrasive diamond discs mounted in a straight handpiece. The samples were then split longitudinally into two halves using a rongeur instrument.

For SEM analysis, the specimens were dehydrated at 37°C for 7 days and sputtered with gold (SCD 050 Sputter Coater, Bal-Tec, Balzers, Liechtenstein). The coronal, middle, and apical thirds of all of the root halves were examined using a SEM (LEO 435 VP; LEO Electron Microscopy, Cambridge, UK) at 10–15 kV and at a standard magnification of ×1000. One image was made at the position of each groove prepared in the root surface [Figures 1-3]. For statistical analysis, the ratios of the number of

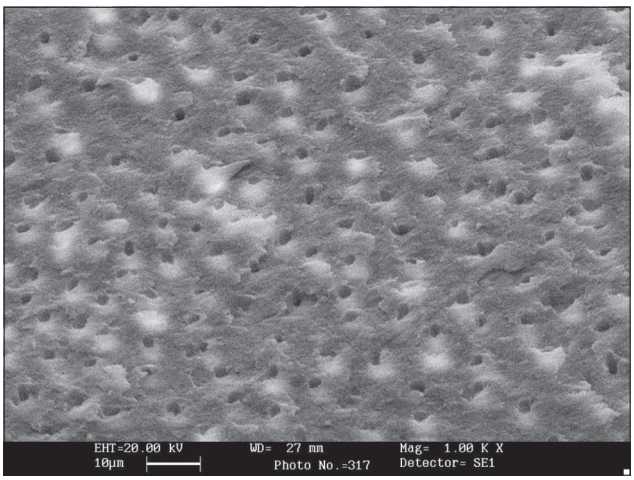

Figure 1: representative scanning electron microscope image showing minimum debris and empty dentinal tubules from a sample in the control group, that is, without obturation (magnification ×1000)

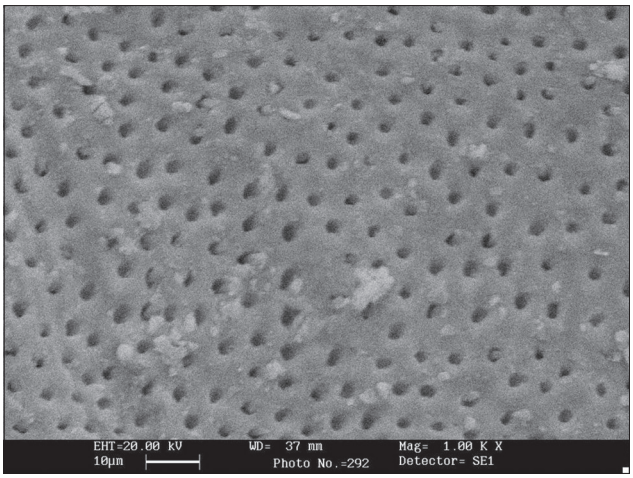

Figure 2: representative scanning electron microscope image of the dentinal tubules from a sample cleaned without solvent showing some tubules' blockage (magnification ×1000)

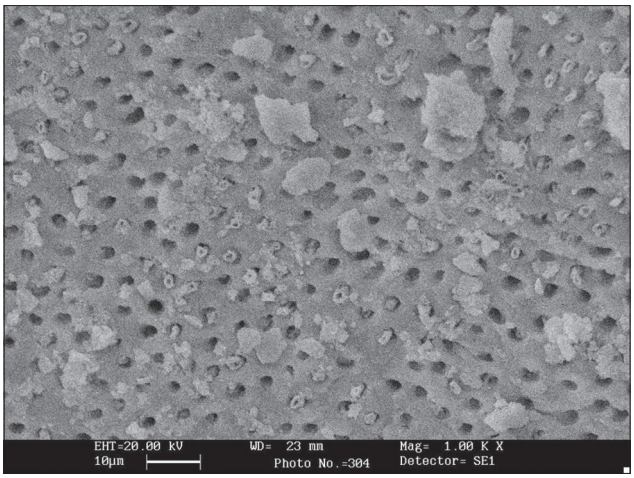

Figure 3: representative scanning electron microscope image of dentinal tubules from a sample cleaned with solvent showing maximum blockage of the tubules with debris (magnification ×1000)

dentinal tubules either completely or partially filled with material and the total number of dentinal tubules were taken.

The images taken in the buccolingual and mesiodistal direction were evaluated by three examiners. The observers were unaware of the method of retreatment and the type of filling material used. The observers were encouraged to change the brightness and contrast and to perform gray-scale inversion (positive/negative) in order to enhance the image quality. No time limit was set for viewing.

Statistical analysis

For statistical analysis, analysis of variance (ANOVA) was used to compare the variance within each group and between groups among the study groups. ANOVA at a particular time interval revealed the differences among them.

Results

Irrespective of the use of solvent, the mean scores at the coronal level were the lowest and those at the apical level were the highest among different levels for all of the groups ($P < 0.05$). In SEM analysis, intergroup comparisons did not show a significant intergroup difference either with or without solvent measurements, except Group 5. For all of the comparisons, the difference between the values with and without solvent was statistically significant ($P < 0.05$). For all of the comparisons, the mean values were significantly lower without solvent than with solvent [Table 1].

In SEM, a significant difference was found between those with and without the use of solvent overall as well as in each of the groups.

In SEM analysis, the ratios of the number of dentinal tubules either completely or partially filled with material and the total number of dentinal tubules were compared.

Discussion

Retreatment in endodontic therapy is one of the foremost challenges in present-day endodontic practice. The success of nonsurgical endodontic retreatment largely depends on the complete removal of root canal filling material. Thus, the removal of filling material from a failed root canal is mandatory to uncover the remnants of necrotic tissue or bacteria that may be responsible for endodontic failure.[9] This will allow the endodontic irrigants to flow freely and flush out micro-organisms present in the root canal space and dentinal tubules.[10]

The application of solvent along with different gutta-percha retrieval systems has also been evaluated in the past and shown to facilitate gutta-percha removal from the canal wall.[11,12] Nevertheless, no method had been found to be completely satisfactory.[13] Thus, different categories of instruments, including the Hedstrom hand files, Ni-Ti rotary files (ProTaper and Mtwo retreatment systems), and Nd:YAG laser, each with and without solvent, were tested in this study. These instruments are routinely used for retreatment in different combinations. It has been noted that the apical third of the root canal presents the greatest challenge while cleaning with different techniques employed in previous studies.[14,15] Thus, the effectiveness of different techniques employed in this study was evaluated at every level of the root canal (coronal, middle and apical), and these were compared.

The application of solvent has been a topic of long debate in endodontic retreatment. Solvents can be used

Table 1: Comparison of mean scores and standard deviation for scanning electron microscope measurements of groups with and without solvent at each level

	SEM analysis		*P*
Levels	**With solvent**	**Without solvent**	
Total (irrespective of group)			
Overall	0.73±0.09	0.39±0.20	<0.001
Coronal	0.68±0.06	0.47±0.07	<0.001
Middle	0.81±0.07	0.55±0.15	<0.001
Apical	0.70±0.07	0.15±0.04	<0.001
Group 2			
Overall	0.75±0.07	0.33±0.16	0.000
Coronal	0.71±0.05	0.46±0.05	<0.001
Middle	0.82±0.06	0.40±0.10	<0.001
Apical	0.72±0.04	0.14±0.03	<0.001
Group 3			
Overall	0.72±0.07	0.38±0.18	<0.001
Coronal	0.67±0.03	0.45±0.05	<0.001
Middle	0.79±0.07	0.54±0.05	<0.001
Apical	0.70±0.05	0.15±0.03	<0.001
Group 4			
Overall	0.73±0.10	0.45±0.25	<0.001
Coronal	0.69±0.07	0.48±0.08	<0.001
Middle	0.81±0.07	0.73±0.10	0.009
Apical	0.68±0.10	0.15±0.05	<0.001
Group 5			
Overall	0.72±0.10	0.40±0.19	<0.001
Coronal	0.67±0.07	0.49±0.08	<0.001
Middle	0.80±0.08	0.53±0.09	<0.001
Apical	0.69±0.08	0.15±0.03	<0.001

"*P*" is the level of significance and $P<0.05$ was considered significant. In scanning electron microscope, a significant difference was found between those with and without the use of solvent overall as well as in each of the groups. In SEM analysis, the ratios of the number of dentinal tubules either completely or partially filled with material and the total number of dentinal tubules were compared. SD=Standard deviation; SEM=Standard error of mean

to soften and dissolve obturating material in the root canal, and it further facilitates instrument penetration and removal.[16] Whether solvents are helpful during gutta-percha removal is inconclusive. In this study, the evaluation dentinal tubules' cleanliness was checked at the microscopic level by SEM The ratios of the number of obturated dentinal tubules (partial or total) to the total number of dentinal tubules for each group were evaluated and compared using SEM images, both with and without solvent.

The use of solvent increased the solubility of the sealer within the dentinal tubules, which, in turn, partially blocked the tubules. The results of SEM analysis in the present study showed that the quantity of debris left inside the dentinal tubules in the solvent subgroups was statistically significant irrespective of the instrument technique used. This might be explained by the fact that the softened root filling material may easily be compacted into dentinal tubules from which it cannot be removed. The results are similar to those of a previous study by Horvath *et al*.[14] Whether this effect is more or less pronounced for solvents other than dimethylformamide needs to be investigated.

The present study used high-resolution SEM images to evaluate the effectiveness of the retreatment techniques at microscopic levels. Only two studies using SEM to evaluate retreatment techniques have been published previously. However, only a few representative SEM images were taken, without evaluating the dentinal tubules. The effectiveness of evaluating canal filling remnants using SEM remains in question, as the studies did not report the magnifications used, or used different magnifications during the investigation Therefore, in this study, a magnification of ×1000 was set for all images, and the results were evaluated at 2, 6, and 10 mm from the anatomical apex.

Under the present experimental conditions and limitations, none of the methods completely removed the filling debris from the dentinal tubules, particularly in the apical third of the root canal. There is an increased anatomical variability and difficulty of instrumentation in the apical region of the root canal area. The existence of curvatures in many planes of deep grooves and depressions on dentin walls in the apical third may well explain the presence of these less instrumented areas.[17] Thus, it was impossible to direct the instruments against all areas of the root canal walls.

Conclusions

Within the limitations of this study, it can be concluded that all of the retreatment techniques showed similar performances in terms of removing filling material from tubules. Solvents led to more gutta-percha and sealer remnants inside dentinal tubules; therefore, the use of solvents should not be a standard practice during endodontic retreatment.

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Conflicts of interest

There are no conflicts of interest.

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