Aim: to evaluate the amount of debris extruded apically as well as the time needed for removal of root canal filling material using ProTaper, MTwo, REndo NiTi rotary retreatment systems and hand files.

Materials and methods: 60 freshly extracted human single-rooted teeth were instrumented with Protaper files and obturated with gutta-percha and MTA Fillapex sealer with the cold lateral compaction technique. Teeth were then randomly assigned to 4 groups. ProTaper, MTwo, REndo rotary retreatment systems and Hedstroem hand files were utilized for root canal filling removal. Debris extruded apically was collected into pre-weighed vials. The weight of the dry extruded debris was established by subtracting the pre-retreatment and post-retreatment weight of vials. Time needed for reaching WL, complete removal of gutta-percha and total retreatment time were also recorded with a stopwatch. The data obtained were analyzed using One-way ANOVA (the level of significance was set at P=0.05).

Results: Hand instrumentation caused significantly more debris extrusion compared with rotary systems (P<0.001). There was no significant difference among the other groups (P>0.05). Hedstroem hand files needed significantly more time for the completion of the retreatment procedure than rotary systems (P<0.001). Among rotary retreatment files, ProTaper completed the procedure significantly quicker than MTwo and REndo (P<0.001).

Conclusion: Rotary retreatment files caused less apical extrusion of debris and needed less time for the completion of the retreatment procedure compared to hand files.

Keywords: Endodontic retreatment, Gutta-percha, ProTaper rotary instruments.

Introduction

Nonsurgical retreatment is the treatment of choice for the majority of failed endodontically treated teeth. The main goal of endodontic retreatment is to regain access to the apical foramen by complete removal of the filling materials, and to facilitate sufficient cleaning and shaping of the root canal system.

Numerous techniques have been described for removal of the root canal filling materials, including the use of hand or rotary instruments, heat, ultrasonics or chemical solvents in different combinations. Some rotary NiTi systems have been especially designed for root canal retreatment. Studies on clinical use and efficacy of rotary retreatment files have concluded that they are efficient in adequate and less time consuming.
removal of filling material during retreatment as opposed to hand files\textsuperscript{22,26}.

The ProTaper Universal Retreatment system has 3 files D1, D2 and D3, one for each third of the root canal. REndo system consists of 4 files (Table 1): Re to be used in the first few millimeters of the canal and R1, R2 and R3 progressively for the coronal, middle and apical thirds of the root canal respectively. MTwo Retreatment system consists of one file for narrow canals and another for medium and wide canals (Table 1).

Filling material, necrotic pulp tissue, dentine, bacteria or irrigant may be extruded into the periapical tissues during endodontic retreatment\textsuperscript{14}. Apically extruded materials have clinically been held responsible for discomfort, including postoperative inflammation, flare-ups and even failure or delayed apical healing\textsuperscript{31,32,37}. The amount of extruded debris has been associated with the intensity of the periapical inflammatory reaction\textsuperscript{9,14}. Therefore, the apical extrusion is a subject of interest.

A literature review revealed relatively few studies evaluating the amount of apically extruded debris during the removal of root canal filling material using rotary retreatment instruments\textsuperscript{8,14,27,32,38}. For example, Topcuoglu et al\textsuperscript{38} compared the relative efficacy of 3 rotary retreatment systems (Pro-Taper retreatment instruments, D-RaCe and R-Endo instruments); Dincer et al\textsuperscript{8} evaluated the amount of debris extruded by using ProTaper and MTwo retreatment files, Reciproc systems and hand Hedstroem files, Silva et al\textsuperscript{32} evaluated the extrusion provoked by Reciproc, Wave One and Protaper retreatment files, Saad et al\textsuperscript{27} studied the extrusion of debris caused by Protaper Universal and K3 rotary files used for the removal of gutta-percha.

The aim of this study was to evaluate the amount of debris extruded apically during removal of filling materials using ProTaper, MTwo and R-Endo NiTi rotary retreatment instruments and hand files. The null hypothesis tested was that there is no significant difference among the groups concerning the amount of debris extrusion, as well as the time needed for completion of the retreatment procedure.

Table 1. Characteristics of representative rotary retreatment files

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Manufacturer</th>
<th>Number of instruments needed for 1 root canal</th>
<th>Size/taper</th>
<th>Length (mm)</th>
<th>Rotation Speed (rpm)</th>
<th>Cutting tip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protaper Universal</td>
<td>Dentsply Maillefer, Ballaigues, Switzerland</td>
<td>3</td>
<td>D1:30/.09, D2:25/.08, D3:20/.07</td>
<td>D1:16, D2:18, D3:22</td>
<td>500</td>
<td>Only for D1</td>
</tr>
<tr>
<td>REndo</td>
<td>MicroMega, Besancon, France</td>
<td>4</td>
<td>Re:25/.12, R1:25/.08, R2:25/.06, R3:25/.04</td>
<td>Re:15, R1:15, R2:19, R3:23</td>
<td>300-400</td>
<td>No</td>
</tr>
<tr>
<td>Mtwo</td>
<td>VDW, Munich, Germany</td>
<td>1</td>
<td>R15/.05, R25/.05</td>
<td>21</td>
<td>280</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Materials and Methods

Freshly extracted human single-rooted teeth, which were collected from a pool of teeth extracted for periodontal reasons, were used for this study. Criteria for tooth selection included a single root canal, no visible root caries, no fractures or cracks under a stereoscopic microscope at x32 magnification, no signs of internal or external resorption or calcification, a completely formed apex, and a curvature of <50\degree according to Schneider (1971) with no lateral exit of the apical foramen\textsuperscript{30}. The teeth were preoperatively radiographically exposed in both buccolingual and mesiodistal directions to confirm a single canal anatomy and to rule out any aberrant canal morphology. The soft-tissue remnants and calculi from the external root surface were removed with a hand scaler.

Root canal preparation and obturation: Endodontic access cavities were prepared with diamond burs (Diatech; ColteneWhaledent, Altstetten, Switzerland) in a high speed contra angle handpiece with water cooling. Canal patency was then established with a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). Canals patent to greater than ISO #15 were discarded, and finally 60 teeth were selected with compliance to the dimension criteria. A #10 K-file (Dentsply Maillefer Ballaigues, Switzerland) was introduced into the canal until the file tip was observed at the apical foramen. The working length (WL) was determined by subtracting 1 mm from this
were stored in an incubator at 37°C and the teeth were prepared with ProTaper Universal rotary files (Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer’s instructions with F3 as a finishing file. The canals were irrigated with 2 ml 2.5% sodium hypochlorite (NaOCl) between each file. Upon completion of preparation, the canals were irrigated with 5 ml 17% EDTA, dried with paper points F3 (Dentsply Maillefer, Ballaigues, Switzerland) and obturated with gutta-percha and MTA Fillapex sealer (Angelus, Londrina, Brazil) using the cold lateral compaction technique.

The canals were prepared with ProTaper Universal rotary files (Dentsply Maillefer, Ballaigues, Switzerland) and clean the flutes. Speed was set at 350 rpm and torque at 1.5 N/cm. Final canal preparation was performed using ReTwo files 30/.06, 35/.06 and 40/.06 (VDW, Munich, Germany).

Group C: The filling materials were removed using REndo Retreatment Files (Micro-Mega, Besancon, France). Re was used for the coronal part of the root canal, R1 for the coronal part and the beginning of the middle third, R2 for the middle third and R3 reached the WL. Crown down technique with brushing movements was accomplished. Speed was set at 350 rpm and torque at 1.5 N/cm. Final canal preparation was performed using 30/.06, 35/.06 and 40/.06 RevoS rotary files (Micro-Mega, Besancon, France).

Group D: The filling materials were removed using Hedstroem Files (VDW, Munich, Germany). The coronal part of gutta-percha was removed with a Gates Glidden drill size 3 and then Hedstroem files sizes 30, 25, 20 and 15 were sequentially used in a “crown-down” manner. Once the WL was reached, Hedstroem files 20, 25, 30, 35 and 40 were used at the WL for final canal preparation.

The solvent was not used in any group. Ni-Ti rotary retreatment files were used according to manufacturer’s instructions. After the instrument change, the canals were irrigated with 2 ml distilled water. The root canals of all groups were irrigated with a side-vented needle of 27 Ga which was inserted into the canal until slight resistance was felt. In each group, 15 ml of distilled water was totally used for irrigation. Retreatment was deemed complete when no debris was visible on the instrument surfaces and no remnants of gutta-percha were visible with the operating microscope (magnification x10) (OPMI Zeiss Pico, Germany) on the canal walls. All teeth were treated by the same operator. In order to evaluate the debris extruded but were still on the root surface the roots were washed with 0.5 ml distilled water. The time needed to reach the WL, the time needed for complete removal of gutta-percha and the total time required for the retreatment procedure of each tooth were recorded in seconds by the aid of a stopwatch. Time needed for file change, file cleaning and irrigation was excluded.

After the completion of the retreatment procedure, the metal caps were removed from the vials and the vials were stored for five days at 68°C in an incubator to allow the evaporation of the water. Evaluation of the extruded debris was performed by a second operator blinded to group assignment. The vials were weighed again in the same manner as in the initial measurement. The extruded debris was finally calculated by subtracting the weight of the empty vials from the weight of vials with dry debris. 3 consecutive measurements were taken for each vial, and the mean value was recorded.
The total time needed for the completion of the retreatment procedure was significantly longer for hand instrumentation compared to ProTaper (P<0.001), MTwo (P<0.001) and REndo (P<0.001). Among rotary retreatment files, ProTaper needed significantly less time compared to MTwo (P<0.001) and REndo (P<0.001); there was no significant difference between MTwo and REndo files (P=1.000).

### Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (IBM SPSS Statistics v.19, New York, NY, USA). Kolmogorov-Smirnov test was employed to evaluate the normal distribution of continuous variables within each group and Levene’s test to verify the equality of variances assumption. The normality hypothesis was retained both for time and weight. Therefore, one-way Analysis of Variance (ANOVA) was performed; Bonferroni correction was used for multiple comparisons among the groups. The level of significance was set in all cases at P=0.05.

### Results

The mean, standard deviations, median, minimum and maximum weight of debris extruded apically in each group are summarized in table 2. There was a statistically significant difference among the groups (P<0.001). Bonferroni correction showed that Hedstroem files caused significantly more debris extrusion compared to ProTaper (P<0.001), MTwo (P<0.001) and REndo (P<0.001) rotary files. There was no significant difference between ProTaper and MTwo (P=1.000), ProTaper and R-Endo (P=1.000) and MTwo and R-Endo (P=0.988).

#### Table 2. Mean, standard deviations (SD), median, minimum (min) and maximum (max) weight in grammars of debris extruded apically in each group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProTaper</td>
<td>0.00366</td>
<td>0.00047</td>
<td>0.00359</td>
<td>0.00285</td>
<td>0.00438</td>
</tr>
<tr>
<td>MTwo</td>
<td>0.00384</td>
<td>0.00044</td>
<td>0.00379</td>
<td>0.00304</td>
<td>0.00452</td>
</tr>
<tr>
<td>REndo</td>
<td>0.00364</td>
<td>0.00031</td>
<td>0.00363</td>
<td>0.00301</td>
<td>0.00424</td>
</tr>
<tr>
<td>Hedstroem</td>
<td>0.00788</td>
<td>0.00033</td>
<td>0.00792</td>
<td>0.00732</td>
<td>0.00835</td>
</tr>
</tbody>
</table>

The mean time needed to reach the WL as well as to completely remove the GP from the root canals was significantly longer when using Hedstroem files compared to ProTaper (P<0.001 and P<0.001 respectively), MTwo (P<0.001 and P<0.001 respectively) and REndo (P<0.001 and P<0.001 respectively) rotary files. Regarding rotary instruments, MTwo needed significantly more time compared to ProTaper (P<0.001 and P<0.001 respectively) and REndo (P<0.001 and P<0.001 respectively); there was no significant difference between ProTaper and REndo files (P=0.094 and P=0.116 respectively).

### Discussion

Apical extrusion of debris during endodontic treatment and retreatment can lead to postoperative pain and discomfort. Apical extrusion of debris and irrigants by different instrumentation techniques during initial endodontic treatment has been studied thoroughly in the literature. Few studies have investigated the amount of debris extruded during root canal retreatment by using NiTi rotary retreatment systems. To our knowledge, this is the first study evaluating apical extrusion of debris during retreatment which uses an MTA based sealer for cold lateral compaction. This material has different physical and chemical properties from epoxy resin sealers utilized in previous studies and therefore it may account for differences in the amount of debris extrusion, as well as the time needed to reach working length (WL) to remove gutta-percha (GP) and to complete the retreatment procedure.

Several laboratory experimental set-ups have been designed in order to evaluate the amount of debris extrusion into periapical tissues during root canal shaping. The system that has been widely adopted is the one described by Myers and Montgomery. The main disadvantage of this model is that the pulp status and condition of the periapical tissues as well as the pressure at the periapex...
cannot be mimicked. Even if some sort of simulation is provided, the structure and condition of the tissues as well as pulpal status cannot be standardized. This has been well demonstrated by Salzeber and Brilliant, who used a radiopaque material to delineate apical penetration in vivo. The authors concluded that the solution was confined to the root canal space in teeth with vital pulps; in teeth with necrotic pulps and/or periapical lesions, the solution dispersed randomly into the periapical lesions. Also, the radiopaque material used as an irrigant reached the end-point of the preparation sooner in teeth with necrotic pulps than in teeth with vital pulps. Therefore, tissue pressure and resistance by the periapical tissues in the in vivo condition may reduce the occurrence and extent of periapical extrusion of debris, although the exact effect of this variable is difficult to determine. Some studies have utilized agar or floral foam to simulate periapical tissues. However, as these may absorb some irrigant and debris when they are used as barriers, no attempt was made in this study to simulate in vivo conditions. Therefore, the results of the present study need to be interpreted with caution as experiment cannot be directly extrapolated in the clinical situation.

Several methods, such as the scoring system and weighing the material using a microbalance, have been proposed to evaluate the amount of debris extruded apically, with the latter providing more accurate measurements. However, as the calculated amount of extruded material is extremely low, often in fractions of mg, there is always the possibility of additional influence by touching the devices by fingers or even pollution by contents from the environment in which the specimens are preserved. Even contact of fingertips moist to the assembly or contamination from other uncontrollable sources may alter the weight. In order to avoid this parameter in the present study, there was no direct contact between the operator’s fingertips and the assembly.

All techniques and methods that have been utilized in the literature are based on a quantitative measurement of debris, liquid or bacteria. This approach may not be rational as it lacks the accomplishment of a qualitative analysis on the content of extruded material. A low amount of extruded material may have a higher potential of initiating periapical response due to a bacterial content of high virulence and antigenic characteristics compared to a higher quantity, lacking the specific threshold value of irritation.

In this study, instrumentation was followed by copious irrigation. It has been concluded that instrumentation combined with irrigation lead to more debris extrusion compared to instrumentation without irrigation. Distilled water was preferred as an irrigant in order to avoid the possible effect of crystallization of sodium hypochlorite on the results. However, there is no sufficient literature data whether type of irrigant can affect the amount of debris extrusion.

Step back instrumentation technique causes more debris extrusion compared to crown down techniques. As NiTi rotary retreatment files operate in a crown down manner, the crown down technique was also utilized for hand instrumentation in this study in order to avoid differences among the groups.

The apical diameters of the retreatment instruments utilized in the present study to reach WL were as follows: D3 (ProTaper system) has apical size 20, R3 (REndo system) has apical size 25 and Mtwo has apical size 25. These sizes may not provide complete removal of filling material from the apical third of the root canal as the initial preparation was completed with F3 file with apical size of 30. Clinically, an apical diameter larger than the apical diameter of the master apical file used in the initial canal preparation is needed to provide complete removal of the root canal filling material. Previous investigations have suggested that files 2 sizes larger than that of the master apical file of the initial treatment are necessary. In order to standardize experimental conditions and allow a direct comparison among the groups, apical enlargement up to #40 was provided in all groups. Moreover, except for hand instruments and ProTaper files which do not have a standard taper throughout their length, a taper of .06 was selected for the other groups.

In this study, no solvent was used in any of the groups as this has been associated with a fine layer of softened GP that adheres to the root dentine walls. This is in accordance with the methodology of most studies on the topic, but in contrast with the study of Mittal and Jain, in which solvent was utilized in some experimental groups.

There is controversy in the literature regarding the amount of debris extrusion by different instrumentation techniques. Somma et al concluded that NiTi rotary retreatment files cause more debris extrusion compared to manual instrumentation; others in accordance with the findings of the present study, found that hand instrumentation is associated with more extrusion. In the present study, apical extrusion of debris was noticed in all groups. Therefore the null hypothesis was rejected. Among the groups, hand instrumentation resolved in more debris extrusion compared to NiTi rotary retreatment files. This could be attributed to the following reasons: hand instruments operate in a push-pull filing motion, which tends to act as a piston, pushing the debris to periapical tissue through the apical foramen; rotary NiTi retreatment files operate with a combination of a rotational movement and a crown-down pressureless action, which direct the debris coronally. Furthermore, most retreatment files have a triangular cross sectional design, which reduces the contact area between the file and the root canal wall and consequently the amount of debris extrusion.
As re-treatment is more time-consuming compared to initial root canal treatment, more effective techniques for removal of root canal filling materials would be advantageous. In the present study, rotary NiTi retreatment instruments were faster than hand files. Among NiTi instruments, ProTaper needed significantly less time than the others. This is in accordance with the findings of Iriboz et al\textsuperscript{17}, where ProTaper was faster than MTwo, but in contrast with the findings of Somma et al\textsuperscript{35} and Marfisi et al\textsuperscript{36}.

GP is the most widely used and accepted core root canal filling material, which is utilized in combination with a sealer as a luting agent. Previous studies on the topic\textsuperscript{8,14,32,38} utilized an epoxy resin sealer for obturation. In this study, an MTA based root canal sealer (MTA Fillapex) was used for this purpose. MTA Fillapex (Angelus, Londrina, Parana) is a new calcium silicate-based sealer. It is composed of MTA, salicylate resin, natural resign, bismuth oxide and silica\textsuperscript{41}. In vitro studies have shown that MTA Fillapex has lower push out bond strength to root dentine compared to epoxy resin sealers\textsuperscript{32,38}. Therefore, it could be expected that less time is needed for complete removal of root canal filling material during retreatment procedures\textsuperscript{3,24,28}. However, no differences were noticed between the results of the present study and those of Dincer et al\textsuperscript{8} in which AH 26 epoxy resin sealer has been used. However, no differences were noticed between the results of the present study and those of Dincer et al\textsuperscript{8} in which AH 26 epoxy resin sealer was utilized regarding the total time needed for the retreatment procedure.

References


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