DE GRUYTER
OPEN

10.1515/bjdm-2016-0003

BALKAN JOURNAL OF DENTAL MEDICINE

ISSN 2335-0245

Assessment of Apical Extrusion of Debris during Endodontic Retreatment with 3 Rotary Nickel-Titanium Retreatment Systems and Hand Files

S. Gkampesi, Z. Mylona, T. Zarra, T. Lambrianidis

Aristotle University of Thessaloniki
School of Dentistry
Department of Endodontology, Greece

SUMARRY

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.

ORIGINAL PAPER (OP)
Balk J Dent Med, 2016; 20:22-28

Introduction

Nonsurgical retreatment is the treatment of choice for the majority of failed endodontically treated teeth[7,10,36]. 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[19,34].

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[11,15,21,25]. 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[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[14]. Apically extruded materials have clinically been held responsible for discomfort, including postoperative inflammation, flare-ups and even failure or delayed apical healing[31,32,37]. The amount of extruded debris has been associated with the intensity of the periapical inflammatory reaction[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[8,14,27,32,38]. For example, Topcuoglu et al[38] compared the relative efficacy of 3 rotary retreatment systems (Pro-Taper retreatment instruments, D-RaCe and R-Endo instruments); Dincer et al[8] evaluated the amount of debris extruded by using ProTaper and MTwo retreatment files, Reciproc systems and hand Hedstroem files, Silva et al[32] evaluated the extrusion provoked by Reciproc, Wave One and Protaper retreatment files, Saad et al[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

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

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 $<5^0$ according to Schneider (1971) with no lateral exit of the apical foramen[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, Altststten, 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 measurement. Tooth length was standardized at 19 mm by removing the crown excess perpendicular to the long axis of the tooth with a diamond bur under constant water flow.

The canals 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. Mesiodistal and buccolingual radiographs were taken to confirm the technical quality of the obturation. The root canal fillings were removed coronally with the F/.06 tip of system B and limited to 15 mm from the apex. The access cavities were sealed with temporary filling material [Cavit (DeTrey/Dentsply, Konstanz, Germany)] and the teeth were stored in an incubator at 37^{o} C and 100% humidity for 1 month to allow the sealer to set.

The method used to measure the quantity of extruded debris was the one described by Myers & Montgomery (1991)[23]. Vials with metal caps were utilized. The vials were weighed prior to instrumentation by using a precise microbalance with an accuracy of 10^{-4}g. A hole was created at the center of metal cap with the aid of a drill. The tooth was inserted through the hole and was fixed to the cementoenamel junction by means of silicone. The apical part of the root was suspended within the vial, which acted as a collecting container for the material extruded through the foramen. The vial was shielded using a rubber dam so that the operator performing the procedure was not able to see the root during the procedure. A bent 27-gauge needle was also forced alongside the rubber stopper and silicone to use as a drainage cannula, balance between the air pressure inside and outside the vials. The assembly was secured to prevent any movement that might disrupt standardization of the instrumentation procedure. All vials were coded and then randomly assigned to 4 groups of 15 specimens each.

The 60 teeth were randomly divided into 4 groups:

Group A: The filling materials were removed using ProTaper Retreatment Files (Dentsply Maillefer, Ballaigues, Switzerland). D1 was used for the coronal third, D2 for the middle third and D3 reached the working length (WL). All instruments were gently pressed in gutta-percha. Crown down technique with brushing movements was accomplished. During the procedure, the instruments were removed from the root canal in order to be inspected and clean the flutes. Speed was set at 500 rpm and torque at 2 N/cm. Final canal preparation was performed using F3 and F4 ProTaper files (Dentsply Maillefer, Ballaigues, Switzerland).

Group B: The filling materials were removed using MTwo Retreatment Files (VDW, Munich, Germany). The coronal part of gutta-percha was removed with a Gates Glidden drill size 3 and then R25/.05, which progressively reached the WL. Crown down technique with brushing movements were used. Speed was set at 280 rpm and torque at 2 N/cm. Final canal preparation was performed using MTwo 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^{o}C in an incubator to allow the evaporation of the water. Evaluation of the extruded dry 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 dry 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.

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

Group	Mean	SD	Median	Min	Max
ProTaper	0.00366	0.00047	0.00359	0.00285	0.00438
MTwo	0.00384	0.00044	0.00379	0.00304	0.00452
REndo	0.00364	0.00031	0.00363	0.00301	0.00424
Hedstroem	0.00788	0.00033	0.00792	0.00732	0.00835

The mean, median, standard deviation, minimum and maximum time needed for reaching the WL, complete removal of gutta-percha (GP) and completion of the retreatment procedure are represented in figure 1. 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).

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).

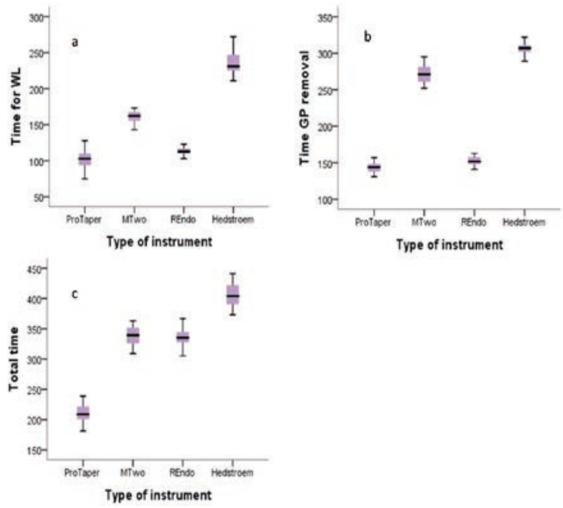

Figure 1. Mean, median, standard deviation, minimum and maximum of time in seconds needed for a) reaching the WL, b) complete removal of GP, and c) total retreatment procedure

Discussion

Apical extrusion of debris during endodontic treatment and retreatment can lead to postoperative pain and discomfort[31,33]. The apical extrusion of debris and irrigants by different instrumentation techniques during initial endodontic treatment has been studied thoroughly in the literature[37]. Few studies have investigated the amount of debris extruded during root canal retreatment by using NiTi rotary retreatment systems[8,14,32,38]. 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[3,28].

Several laboratory experimental set-ups have been designed in order to evaluate the amount of debris extrusion into periapical tissues during root canal shaping[37]. The system that has been widely adopted is the one described by Myers and Montgomery[23]. The main disadvantage of this model is that the pulpal 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 Salzgeber and Brilliant[29], 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[29]. 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[27]. Some studies have utilized agar or floral foam to simulate periapical tissues[13]. 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 *ex-vivo* experimentation 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[35]. 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 unpredictable sources may alter the weight[37]. 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[35].

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[39]. Distilled water was preferred as an irrigant in order to avoid the possible effect of crystallization of sodium hypochlorite on the results[14]. However, there is no sufficient literature data whether type of irrigant can affect the amount of debris extrusion[6].

Step back instrumentation technique causes more debris extrusion compared to crown down techniques[1,2]. 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[4,12]. 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[8,1432,38], but in contrast with the study of Mittal and Jain[22], 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[35] 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[14,18,38]. 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[5]; rotary NiTi retreatment files operate with a combination of a rotational movement and a crown-down pressureless action, which direct the debris coronally[16]. Furthermeore, 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[17], where ProTaper was faster than MTwo, but in contrast with the findings of Somma et al[35] and Marfisi et al[20].

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[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[41]. *In vitro* studies have shown that MTA Fillapex has lower push out bond strength to root dentine compared to epoxy resin sealers and leads to less remaining root canal filling material during retreatment procedures[3,24,28]. Therefore, it could be expected that less time is needed for complete removal of root canal filling material compared to cases in which an epoxy resin sealer has been used. However, no differences were noticed between the results of the present study and those of Dincer et al[8] in which AH 26 epoxy resin sealer was utilized regarding the total time needed for the retreatment procedure.

References

1. *Al-Haddad A, Che A, Aziz Z*. Apically extruded debris during removal of realseal using two re-treatment rotary systems. *Aus J Basic & Appl Sci*, 2011; 5:114-119.
2. Al-Omari M, Dummer P. Canal blockage and debris extrusion with eight preparation techniques. *J Endod*, 1995; 21:154-158.
3. *Assmann E, Scarparo RK, Boetcher DE, Grecca FS*. Dentin bond strength of two mineral aggregate based and one epoxy resin-based sealers. *J Endod*, 2012; 38:219-221.
4. *Baratto-Filho F, Ferreira EL, Fariniuk LF*. Efficiency of the 0.04 taper ProFile during the re-treatment of gutta-percha filled root canals. *Int Endod J*, 2002; 35:651-654.
5. *Brown DC, Moore BK, Brown CE Jr, Newton CW*. An in vitro study of apical extrusion of sodium hypochlorite during endodontic canal preparation. *J Endod*, 1995; 21:587-591.
6. *Burklein S, Schafer E*. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. *J Endod*, 2012; 38:850-852.
7. *Caliscan M*. Nonsurgical retreatment of teeth with periapical lesions previously managed by either endodontic or surgical intervention. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 2005; 100:242-248.
8. *Dincer AN, Er O, Canakci BC*. Evaluation of apically extruded debris during root canal retreatment with several NiTi systems. *Int Endod J*, 2015; 48:1194-1198.
9. *Elmsallati EA, Wadachi R, Suda H*. Extrusion of debris after use of rotary nickel-titanium files with different pitch: a pilot study. *Aust Endod J*, 2009; 35:65-69.
10. *Friedman S, Stabholz A*. Endodontic retreatment: case selection and technique -part 1: Criteria for case selection. *J Endod*, 1986; 12:28-33.
11. *Friedman S, Stabholz A, Tamse A*. Endodontic retreatment: case selection and technique - part 3: Retreatment techniques. *J Endod*, 1990; 16:543-549.
12. *Friedman S*. Management of post-treatment endodontic disease - a current concept of case selection. *Aust Endod J*, 2000; 23:104-109.
13. *Hachmeister DR, Schindler WG, Walker WA, Thomas DD*. The sealing ability and retention characteristics of mineral trioxide aggregate in a model of apexification. *J Endod*, 2002; 28:386-390.
14. *Huang X, Ling J, Wei X, Gu L*. Quantitative evaluation of debris extruded apically by using ProTaper Universal Tulsa rotary system in endodontic retreatment. *J Endod*, 2007; 33:1102-1105.
15. *Hülsmann M, Stotz S*. Efficacy, cleaning ability and safety of different devices for gutta-percha removal in root canal retreatment. *Int Endod J*, 1997; 30:227-233.
16. *Imura N, Kato AS, Hata GI, et al*. A comparison of the relative efficacies of four hand and rotary instrumentation techniques during endodontic retreatment. *Int Endod J*, 2000; 33:361-366
17. *Iriboz E, Sazak Ovecoglu H*. Comparison of ProTaper and Mtwo retreatment systems in the removal of resin-based root canal obturation materials during retreatment. *Aust Endod J*, 2014; 40:6-11.
18. *Lu Y, Wang R, Zhang L, et al*. Apically extruded debris and irrigant with two Ni-Ti systems and hand files when removing root fillings: a laboratory study. *Int Endod J*, 2013; 46:1125-1130.
19. *Mandel E, Friedman S*. Endodontic retreatment: a rational approach to root canal reinstrumentation. *J Endod*, 1992; 18:565-569.
20. *Marfisi K, Mercade M, Plotino G, Duran-Sindreu F, Bueno R, Roig M*. Efficacy of three different rotary files to remove gutta-percha and Resilon from root canals. *Int Endod J*, 2010; 43:1022-1028.
21. *Masiero AV, Barletta FB*. Effectiveness of different techniques for removing gutta-percha during retreatment. *Int Endod J*, 2005; 38:2-7.
22. *Mittal N1, Jain J*. Spiral computed tomography assessment of the efficacy of different rotary versus hand retreatment system. *J Conserv Dent*, 2014; 17:8-12.
23. *Myers GL, Montgomery S*. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. *J Endod*, 1991; 17:275-279.
24. *Neelkantan P, Grotra D, Sharma S*. Retreatability of two mineral trioxide aggregate based root canal sealers. A cone beam computed tomography analysis. *J Endod*, 2013; 39:893-896.
25. *Pitt Ford TR, Rhodes JS*. Root canal retreatment: 2 practical solutions. *Dent Update*, 2004; 31:97-102.

26. *Rodig T, Hausdörfer T, Konietschke F, Dullin C, Hahn W, Hülsmann M*. Efficacy of D-RaCe and ProTaper Universal Retreatment NiTi instruments and hand files in removing gutta-percha from curved root canals - a micro-computed tomography study. *Int Endod J*, 2012; 6:580-589.
27. *Saad AY, Al-Hadlag SM, Al-Katheeri NH*. Efficacy of two rotary NiTi instruments in the removal of gutta-percha during root canal retretament. *J Endod*, 2007; 33:38-41.
28. *Sagsen B, Ustu Y, Demirbuga S, Palla K*. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. *Int Endod J*, 2011; 44:1088-1091.
29. *Salzgeber RM, Brilliant JD*. An in vivo evaluation of the penetration of an irrigating solution in root canals. *J Endod*, 1977; 3:394-398.
30. Schneider SW. A comparison of canal preparation in straight and curved root canals. *Oral Surg Oral Med Oral Pathol*, 1971; 32:271-275.
31. *Seltzer S, Naidorf IJ*. Flare-ups in endodontics: Etiological factors. *J Endod*, 1985; 11:472-478.
32. *Silva E, Sa L, Belladona FG*. Reciprocating Versus Rotary Systems for Root Filling Removal: Assessment of the Apically Extruded Material. *J Endod*, 2014; 40:2077-2080.
33. *Siqueira JF Jr*. Microbial causes of endodontic flare-ups. *Int Endod J*, 2003; 36:453-463.
34. *Stabholz A, Friedman S*. Endodontic retreatment: case selection and technique - part 2: treatment planning for retreatment. *J Endod*, 1988; 14:607-614.
35. *Somma F, Cammarota G, Plotino G*. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. *J Endod*, 2008; 34:466-469.
36. *Taintor J, Ingle J, Fahid A*. Retreatment versus further treatment. *Clin Prevent Dent*, 1983; 5:8-14.
37. *Tanalp J, Gungor T*. Apical extrusion of debris: a literature review of an inherent occurrence during root canal treatment. *Int Endod J*, 2014; 47:211-221.
38. *Topcuoglu HS, Akti A, Tuncay O, Dincer AN, Duzgun S, Topcyoglu G*. Evaluation of Debris Extruded Apically during the Removal of Root Canal Filling Material Using ProTaper, D-RaCe and R-Endo Rotary Nickel-Titanium Retreatment Instruments and Hand Files. *J Endod*, 2014; 40:2066-2069.
39. *Vande Visse JE, Brilliant JD*. Effect of the irrigation on the production of extruded material at the root apex during instrumentation. *J Endod*, 1975; 1:243-246.
40. *Vitti R, Prati C, Silva E, Sinboreti M, Zanchi C, Silva S. Ogliary F, Gandolfi M*. Physical properties of MTA Fillapex. *J Endod*, 2013; 39:915-918.

Corresponding author:

Z. Mylona
2A Sofokleous Street
Thessaloniki, 54633
Greece
E-mail: myliaptol@windowslive.com