Rom J Morphol Embryol 2011, 52(1 Suppl):443–448

ORIGINAL PAPER

RJME
Romanian Journal of Morphology & Embryology
http://www.rjme.ro/

Computer-assisted photomicrographic evaluation of root canal morphology after removal of the filling material during retreatment

LUMINIŢA NICA[1)], MIHAELA GRIGORIE[2)], D. RUSU[3)], MIRONA MESAROS ANGHEL[4)], ANDREEA DIDILESCU[5)], S. I. STRATUL[3)]

[1)]*Department of Endodontics, Faculty of Dental Medicine, "Victor Babeş" University of Medicine and Pharmacy, Timisoara*

[2)]*Department of Endodontics, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest*

[3)]*Department of Periodontology, Faculty of Dental Medicine, "Victor Babeş" University of Medicine and Pharmacy, Timisoara*

[4)]*"Dr. Stratul" Dental Clinic, Timisoara*

[5)]*Department of Anatomy and Embryology, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest*

Abstract

Aim: The purpose of this study was to evaluate the morphology of the apical third of the root canal and the effectiveness of rotary instrumentation for the removal of lateral condensed gutta-percha during endodontic retreatment. *Materials and Methods*: Thirty roots with canals with regular morphology were prepared to apical size #30 and were filled with gutta-percha/AHPlus using lateral condensation. Digital radiographs of teeth were captured. After two weeks, canals were retreated to size 40 using ProTaper rotary instruments, without solvent. Roots were embedded in resin blocks and reduced incrementally at four different apical levels (at 0.5, 1.0, 1.5 and 2.0 mm from the apical foramen). The sectioned surfaces were observed under a metallographic optical microscope and digital micrographic images were captured and processed. Perimeter covered with root-filling residue was expressed as percentage of total canal perimeter for all specimens. *Results*: Residue percentage was greater at 2.00 mm from apical level than at other levels. Most residue of filling material in all specimens was observed at 0.5 and at 2.0 mm from apex. The use of ProTaper instruments allowed the removal of gutta-percha and AHPlus sealer in the apical 2 mm in average 50% of the cases. *Conclusions*: The resulting morphology of the prepared canals allowed root fillings performed with gutta-percha and AHPlus sealer that were efficiently removed by using rotary instruments. More material residue was found adhering to the canal walls in the apical segments of canals. The removal of this residue was enhanced by apical enlargement beyond the diameter of the canal before retreatment.

Keywords: anatomy, root canal filling materials, retreatment, photomicrography.

Introduction

Regular morphology of the endodontic space is usually modified by rotary instrumentation to a certain amount; however, it dictates the clinically satisfactory shape of the root canal filling. Gutta-percha in conjunction with a variety of sealers is the most widely accepted root canal filling material. In order to allow retreatment when indicated, root-filling materials should be removable [1].

The main goal of non-surgical endodontic retreatment is to remove the existing root filling material throughout the canal length and to regain access to the apical foramen. This will allow disinfection of the root canal space and creation of favorable conditions for periradicular healing [2].

Endodontic hand files, rotary and ultrasonic instruments, solvents and heat carriers can be used to remove gutta-percha from the root canal [3–7].

Despite its easiness to be removed during endodontic retreatment, *in vitro* studies have demonstrated residue of gutta-percha on the canal walls, especially in the apical third of the root canal, regardless of the sealer used and the method of retreatment. It has been suggested that the residual material can be minimized if the canal enlargement during retreatment exceeds that achieved prior to root filling [8–10].

Thus, in this study, the efficacy of retreatment of canals filled with gutta-percha was assessed using computer-assisted photo-micrographic evaluation, with particular reference to the last 2 mm of their apical part. Rotary instrumentation with ProTaper Universal System (Dentsply Maillefer, Baillagues, Switzerland) was used for removal of the filling material.

Materials and Methods

Study samples

Thirty extracted human single-rooted teeth of similar morphology, length and diameter, having one single straight root canal, fully formed apices and no root fillings were included in the study. The original anatomy of the teeth was evaluated radiographically, as the roots were verified as having each one a straight, patent root canal. The teeth were cleansed of soft tissue and attachment apparatus and stored in 0.2% thymol solution (Sigma Chemical Co., St. Louis, MO, USA) until used. The access cavities were prepared using high-speed diamonds and water spray. Apical patency was established by inserting a size 15 K-type file (VDW, Antaeos, Munich, Germany) to 1 mm beyond the apex. The working length was established 1 mm short of this measurement. ProTaper Universal System instruments (Dentsply Maillefer, Ballaigues, Switzerland) S1, S2 and F1–F3 were used in a crown-down manner in combination with a torque–controlled engine (NSK, Japan) at 300 rpm according to the manufacturer's instructions. Instrument F3 size 30/.09 taper reached the working length. Apical patency was maintained with size 15 K-files. Root canals were intermittently irrigated with 5 mL of 5.25% NaOCl during cleaning and shaping. Five mL of 17% EDTA were used during and after the instrumentation to remove the smear layer.

Root canals filling technique

The canals were dried with sterile paper points and then filled with gutta-percha and AH Plus (Dentsply, DeTrey, Konstanz, Germany) as the sealer using lateral condensation. A #30 master cone was fitted in each canal with tug-back at working length. The sealer was placed into the canal by means of the master cone and the root filling was laterally condensed with accessory cones using a size #25 finger spreader (Kerr Co., Romulus, MI, USA). The Touch'n Heat device (Kerr Co.) was used to sear the filling material at the canal orifice. Teeth were radiographed in buccolingual and mesiodistal directions to confirm the adequacy of the root filling (Figure 1).

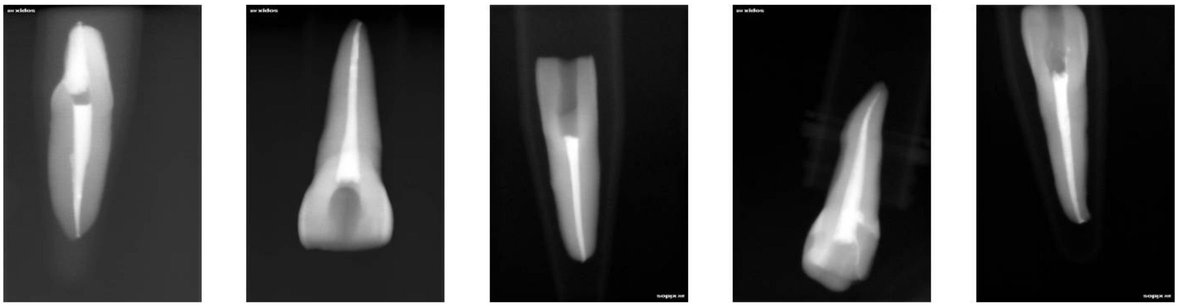

Figure 1 – *Radiographs of the endodontic space, confirming the adequacy of the root filling.*

All canals were sealed with Cavit (Premier Dental Products Co, Philadelphia, PA, US) and the specimens were stored in a humidor at 37^{0}C for two weeks to allow complete setting of the sealer, as in previous studies [6, 11, 12]. To reduce inter-operator variables, each canal was prepared and filled by the same operator (M.M.).

Retreatment technique

After regaining access, all roots were retreated using ProTaper Universal System rotary instruments for re-treatment. These files were used in a crown-down manner in combination with a torque-controlled engine (NSK, Japan) at 500 rpm, according to the manufacturer's instructions. The root-filling material was gradually removed using light apical pressure, until the working length was reached with D3 size 20 instrument, 7% taper. The D1 instrument (9% taper, size 30) was first used to create a pilot hole into the filling material; then the D2 instrument (8% taper, size 25) was used in the middle third of the root canal and the D3 in the apical part of it. Apical enlargement was then performed with ProTaper Universal instruments F1–F4, until instrument F4 (size 40, 6% taper) reached the working length. Preparation was deemed complete when there was no obturation material covering the instruments. One set of ProTaper instruments was used for the retreatment of five root canals. The canals were irrigated with 5 mL 5.25% NaOCl and 5 mL of sterile saline and dried with paper points. Each root canal was retreated by one experienced operator in order to reduce inter-operator variability (M.M.).

Embedding histological procedure

One of the most used methods to evaluate the general outer- and inner morphology of teeth is the embedding in acrylic blocks, followed by various sectioning procedures [6]. Metal rings were used to embed the roots in clear self-curing acrylic resin (ETI, Fields Landing, CA, US). The acrylic resin was poured into the ring until full, then each root was inserted vertically into the acrylic at the centre of the ring until setting of the acrylic. The metallic ring was then removed leaving the acrylic block with the embedded root. To prepare each root for viewing the canal at different levels, the acrylic block containing the root was sectioned horizontally. The flat surfaces necessary for examination in optical microscopy were obtained by grinding and polishing the samples in a grinding machine for metallographic samples, under running water, at 0.5, 1.00, 1.5 and 2.0 mm from the apex. The embedded roots were divided into four study groups, according to the grinding level: group 1 at 0.5 mm from apex, group 2 at 1.0 mm, group 3 at 1.5 mm from apex and group 4 at 2.00 mm.

Evaluation

Each specimen was observed under a metallographic optical microscope (Olympus BX51, Olympus GmbH, Hamburg, Germany) equipped with a video camera at 50× and 100× magnification, in normal and in polarized light. Digital micrographic images (Figures 2 and 3) of the grinded samples were captured with an image acquisition system (Olympus Digital Color Camera UC30).

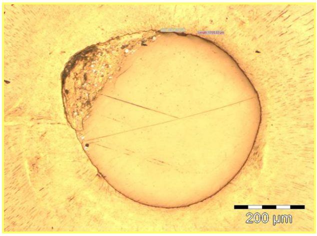

Figure 2 – ***Serial section of a root canal at 1 mm from apex, with accurate morphological details (OM, ×50).***

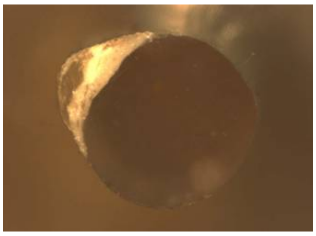

Figure 3 – ***The same section in polarized light (×50).***

The images were digitalized and processed. The amount of residue on canal walls at these four different levels was quantified with the Olympus software program analySIS auto. Perimeter segments covered with root-filling material residue were observed in each canal segment (at 0.5, 1.0, 1.5 and 2.0 mm from the apex level), without any attempt to distinguish between residual sealer and gutta-percha (Figure 4, a–d and Figure 5, a–d). Residue perimeters were expressed as percentage of total canal perimeter at corresponding level. The time necessary to remove the gutta-percha was not evaluated in the present study.

Statistical analysis

Mean values and standard deviations (SD) of measurements were calculated; one-way ANOVA test was used to assess mean differences between debris perimeters expressed as percentages, at different levels. StataIC 11 statistical software (StataCorp LP, Texas, USA, version 2009) was used for data analysis. A p-value <0.05 was considered statistically significant.

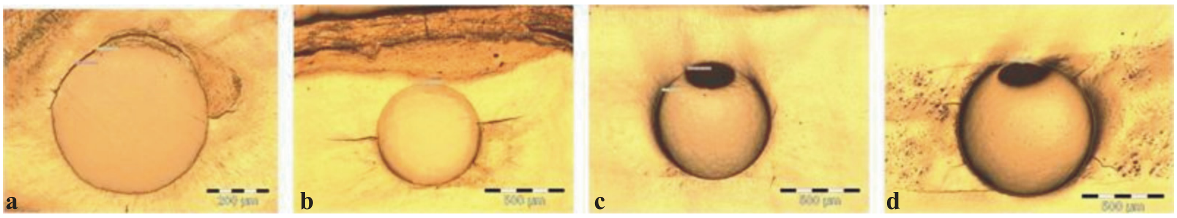

Figure 4 – (*a) Morphology of the serial sections at 0.5 mm from the apical foramen (OM, ×100); (b) Morphology of the serial sections at 1 mm from the apical foramen (OM, ×50); (c) Morphology of the serial sections at 1.5 mm from the apical foramen (OM, ×50); (d) Morphology of the serial sections at 2 mm from the apical foramen (OM, ×50).*

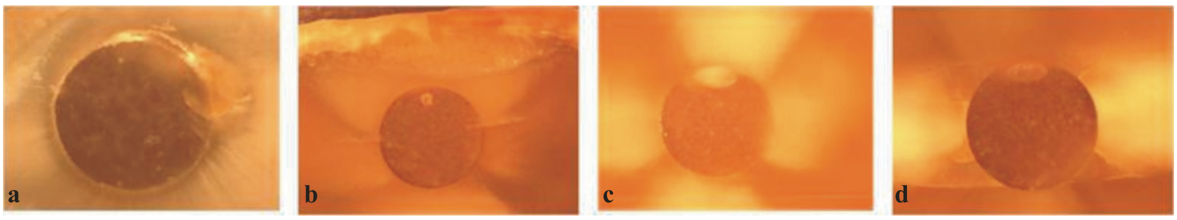

Figure 5 – ***(a) The same serial section in polarized light (Group 1, ×100); (b) The same serial section in polarized light (Group 2, ×50); (c) The same serial section in polarized light (Group 3, ×50); (d) The same serial sections in polarized light (Group 4, ×50).***

Results

The anatomy of the endodontic space was not significantly modified during the instrumentation and re-instrumentation. Residue of gutta-percha and sealer were observed in all the specimens, regardless the distance from the apical foramen. Respecting its naturally tapered morphology, the total perimeter of the root canal increased from level 1 of observation (at 0.5 mm from apex – group no. 1) to level 4 (at 2.0 mm from apex – group no. 4), as expected. The recorded data of the total perimeter of the canal in group no. 1 showed a minimum value of 1203 µm, and a maximum value of 2211 µm. For group no. 2, values between 1705 µm and 3661 µm were recorded. A trend of continuous growth of the canal diameter was obtained in group no. 3, from 1934 µm to 4141 µm and in group no. 4, and from 2391 µm to 4551 µm. Data of clean perimeter were compared to the total perimeter of the canal and expressed as percentages.

Table 1 represents the mean percentage of the perimeter segments with gutta-percha residue and the standard deviation for each of the four groups. The mean percentage of clean perimeter compared to the perimeter of the remaining filling material in group no 1 was 51% *vs.* 49%. The mean total residue percentage values for the groups grinded at 1.0 mm and at 1.5 mm from the apical foramen (groups no. 2 and 3), as recorded in Table 1, were lower related to the group sectioned at 2 mm from apex (group no. 4). The residue percentage value for the group sectioned at 1 mm from the apex (group no. 2) was the lowest of all the four groups (35.77%). However, no significant differences were recorded (p>0.05).

The total residue percentage value for each tooth, regardless the level of the section, varied from 8% to 92%, with a mean value of 44.24%. The mean percentage of clean perimeter comparative to the total perimeter of the root canal section for each group from all four is represented in Figure 6. The mean percentage of the clean perimeter for all groups was 56%, when compared to 44% of perimeter with debris.

Table 1 – ***Mean percentage of the perimeter segments with gutta-percha residue (DB = debris perimeter)***

Variable DB	Observations	Mean	SD	Range
Group 1	30	48.97	34.1	0 to 100
Group 2	30	35.77	32.59	0 to 100
Group3	30	39.6	34.43	0 to 100
Group 4	30	52.37	26.87	0 to 100

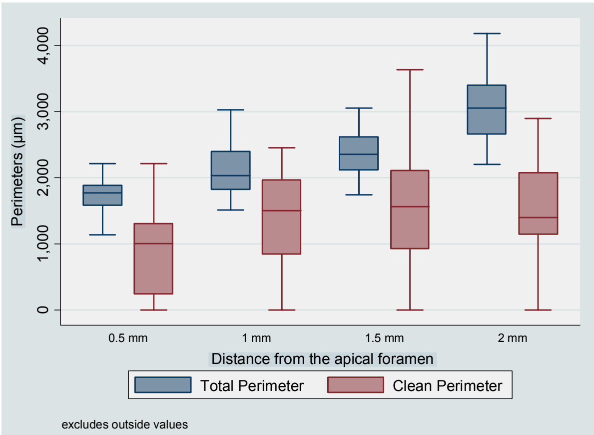

Figure 6 – ***Boxplots representing clean and total perimeters.***

From the total of 120 measurements recorded in all four study groups, only 20 measurements displayed a 100% "clean" perimeter: three samples in group no. 1, nine samples in group no. 2, six samples in group no. 3, and, respectively, two samples in group no. 4. Also, totally untouched areas were recorded in 12 of the samples – three for each observation level out of 30 observations/level.

No lateral canals, fins or recesses were observed during the evaluation of the sections.

Discussion

Endodontic orthograde retreatment aims to remove all the filling material from the root canal space, because it allows the chemomechanical preparation and disinfection of the entire endodontic system [2, 6, 13]. To date, it has been proven that complete removal of the filling material is not possible, regardless the method of retreatment or the root canal filling material [5, 6, 10, 12, 14]. In these studies, different methods such as hand files, ultrasonic files and engine-driven instruments, have been used to remove the root-filling materials from the endodontic space. According to these studies, the greatest amount of residue of filling material remained in the apical segment of the canals. Therefore, the present study aimed to quantify only the remaining root filling material from the last two apical mm of the root canal. Our results confirmed that only mechanical rotary root canal preparation cannot by itself entirely remove the former used filling material, although in some of the samples this was reached, but never simultaneously for all levels of observation within the entire evaluated length of the same canal. Also, in 12 samples (10% of the total number of measurements), completely untouched areas remained at different levels of observation, in all four groups. This raises the issue of the reinfection possibility after the endodontic orthograde retreatment. If natural morphology details as lateral canals, multiple foramens, fins and recessions are present, the prognostic value of the endodontic retreatment becomes questionable.

The experimental protocol developed for this study was a modification of previous experimental studies regarding the efficiency of retreatment in endodontics. Although gutta-percha can be softened by using solvents [5, 6, 8–10, 12, 14], in the present study no solvent was used. Only rotary instrumentation with nickel-titanium (NiTi) instruments was used to remove the root-filling material with the ProTaper Universal System for retreatment. The ProTaper Universal System for retreatment was preferred in the present study, because this system has proven its effectiveness and fastness in removing gutta-percha from the root canal [6, 7, 15–21].

All these modern engine-driven instruments, when used with proper technique, claim to facilitate safe and efficient preparations, by allegedly respecting the natural initial root canal morphology [3, 15, 18]. Studies recently appeared also concluded that the use of rotary devices, heat or solvents in endodontic retreatment should be followed by thorough hand instrumentation, to achieve optimal cleanliness of root canal walls [19, 20].

However, in the present study, only rotary instruments D1, D2 and D3 from the ProTaper retreatment kit were used in accordance with the manufacturer's instructions, at 500 rpm, in a crown-down manner. In previous studies, RaCe instruments [6, 16], K3 files [12, 22], and ProTaper Universal as compared to ProFile [23] were used to remove gutta-percha and Resilon from the root canals. In all above-mentioned studies, not only the efficiency of the used instruments was tested and compared, but also the time for retreatment. In the present study, no attempt was made to record the meantime for retreatment, because it had no relevance for the data compared. On the other side, the nature and consistency and age of the filling plays a crucial role in the overall quality of the removal. [3, 15, 18, 21, 23].

Thus, when evaluating the efficiency of different retreatment techniques, literature data show that not only the instrument type count, but also the technique of the initial filling and the filling material used. Here, the method used for filling the endodontic space was the lateral condensation of gutta-percha, as in most studies concerning the efficacy of retreatment [4, 15, 16, 24, 25]. Other methods are widely nowadays used in clinical practice to fill the root canals: the vertical compaction (Schilder H, 1967) and the so-called "continuous wave of compaction" (Buchanan LS, 1996) [26, 27]. These methods are to be employed in conjunction with the term "microstructural replication" [28] as they "replicate" more likely the morphology of the endodontic system, by using because warm thermoplasticized compacted gutta-percha. Although our study does not aim to evaluate the quality of the root canal filling, but only the quality of the retreatment, as quantified in the areas considered as clean.

An important aspect in endodontic therapy is the taper and the diameter of the preparation, which has to respect the natural morphology of the tooth and the curvatures of the root canal. Simultaneously, the design of the preparation must allow a proper cleaning and shaping, in order to disinfect the anatomic system. The taper of the preparation after retreatment achieved in our study corresponds to the last instrument used in retreatment (6% in the F4 ProTaper instrument) [7–9, 12–17, 21, 23].

The value of the measured apical foramen is critical and of major therapeutical importance. Even though the morphology of the endodontic space varies from one group of teeth to another, and even between teeth of the same morphological group, no standard values of the prepared apical diameter are currently given. Yet, in what concerns the endodontic retreatment, different studies suggest that the cleaning of the entire filling material requires a bigger enlargement. There is no total agreement in the literature regarding the final size of the retreatment preparation, but all known studies recommend one or two numbers beyond the initial size of instrumentation. The natural initial size of the foramen should be also taken into account when retreatment procedures are decided [2, 3, 10].

In our study, the apical enlargement in re-instrumentation was two sizes beyond the initial apical preparation (master apical size was #30 in the initial preparation and became #40 after re-instrumentation), which may influence the cleanliness [6, 29, 30]. No differences in debris left on the canal walls were noticed between gutta-percha and AH Plus sealer, although the amount of sealer is higher when using lateral condensation than vertical compaction.

Our results confirm previous conclusions [6, 15, 24, 30, 31], *i.e.* the filling material cannot be completely removed from the endodontic space in the apical third of the root canal. However, the removal of the previous filling material could be regarded as satisfactory under described working conditions.

The natural morphology of the root canal is tapered, with an increasing of its diameter from the apical foramen to the coronal orifice. According to the mechanical principles of the endodontic treatment, this conic shape has to be respected by the preparation instruments, in endodontic treatment and in retreatment as well. The most critical area is considered to be the apical zone of the root canal [4, 13, 21, 23]. A continuum-tapered preparation without parallelism (i.e. without cylindrical shaping) would prevent the extrusion of the filling material in the periapical tissues. Our study brought the evidence that the tapered initial natural morphology of the root canal and its original shape can be respected during retreatment, so the diameter of the root canal constantly increased in from level 1 to level 4 of observation, in every evaluated sample, as expected.

The present investigation evaluated the root canal morphology after retreatment only in teeth with straight root canals. Future studies are expected to evaluate the way the natural morphology in teeth with severely apical curvatures is respected during the retreatment.

Conclusions

The morphology of the root canals after retreatment allows a good handling of the terminal third of the endodontic space. The present study is in accordance with the results previously described in the literature on the remaining gutta-percha in the apical 2 mm of the root canal. The ProTaper Universal rotary instruments allowed the removal of more than 50% gutta-percha, in average, without significantly changing the anatomic features of the area. The removal of the root filling material from the canal walls allows a good disinfection of the endodontic space, thus creating a favorable environment for healing of the periapical lesions and maintaining the tooth on the dental arch for as long as possible. Therefore, the orthograde endodontic re-treatment is still the method of choice for endodontic failures, when gross modifications of the regular morphology of the canalar system have to be avoided. Other research directions in this field can be developed by evaluating the additional use of solvents, various temperatures, irrigation in various quantities, lasers, different rotary NiTi instruments, increased speed, etc.

Acknowledgements

This study was funded by the Romanian National Centre for Research Programs Management (CNMP) within the research project 41–034.

References

[1] GROSSMAN LI, *Endodontic practice*, 8th edition, Lea & Febiger, Philadelphia, 1970, 283–285.

[2] STABHOLZ A, FRIEDMAN S, *Endodontic retreatment – case selection and technique. Part 2: Treatment planning for retreatment*, J Endod, 1988, 14(12):607–614.

[3] FRIEDMAN S, STABHOLZ A, TAMSE A, *Endodontic retreatment – case selection and technique. 3: Retreatment techniques*, J Endod, 1990, 16(11):543–549.

[4] HÜLSMANN M, STOTZ S, *Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment*, Int Endod J, 1997, 30:227–233.

[5] WILCOX LR, KRELL KV, MADISON S, RITTMAN B, *Endodontic retreatment: evaluation of gutta-percha and sealer removal and canal reinstrumentation*, J Endod, 1987, 13(9):453–457.

[6] SCHIRRMEISTER JF, MEYER KM, HERMANNS P, ALTENBURGER MJ, WRBAS KT, *Effectiveness of hand and rotary instrumentation for removing a new synthetic polymer-based root canal obturation material (Epiphany) during retreatment*, Int Endod J, 2006, 39(2):150–156.

[7] SAAD AY, AL-HADLAQ SM, AL-KATHEERI NH, *Efficacy of two rotary NiTi instruments in the removal of gutta-percha during root canal retreatment*, J Endod, 2007, 33(1):38–41.

[8] FRIEDMAN S, MOSHONOV J, TROPE M, *Efficacy of removing glass ionomer cement, zinc oxide eugenol, and epoxy resin sealers from retreated root canals*, Oral Surg Oral Med Oral Pathol, 1992, 73(5):609–612.

[9] FRIEDMAN S, MOSHONOV J, TROPE M, *Residue of gutta-percha and glass ionomer cement sealer following root canal retreatment*, Int Endod J, 1993, 26(3):169–172.

[10] MOSHONOV J, TROPE M, FRIEDMAN S, *Retreatment efficacy 3 months after obturation using glass ionomer cement, zinc oxide-eugenol, and epoxy resin sealers*, J Endod, 1994, 20(2):90–92.

[11] EZZIE E, FLEURY A, SOLOMON E, SPEARS R, HE J, *Efficacy of retreatment techniques for a resin-based root canal obturation material*, J Endod, 2006, 32(4):341–344.

[12] DE OLIVEIRA DP, BARBIZAM JV, TROPE M, TEIXEIRA FB, *Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment*, J Endod, 2006, 32(4):362–364.

[13] BERGENHOLTZ G, LEKHOLM U, MILTHON R, HEDÉN G, ÖDESJÖ B, ENGSTRÖM B, *Retreatment of endodontic fillings*, Scand J Dent Res, 1979, 87(3):217–224.

[14] FERREIRA JJ, RHODES JS, FORD TR, *The efficacy of gutta-percha removal using ProFiles*, Int Endod J, 2001, 34(4):267–274.

[15] HÜLSMANN M, BLUHM V, *Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment*, Int Endod J, 2004, 37(7):468–476.

[16] SCHIRRMEISTER JF, WRBAS KT, SCHNEIDER FH, ALTENBURGER MJ, HELLWIG E, *Effectiveness of a hand file and three nickel-titanium rotary instruments for removing gutta-percha in curved root canals during retreatment*, Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006, 101(4):542–547.

[17] GU LS, LING JQ, WEI X, HUANG XY, *Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from root canals*, Int Endod J, 2008, 41(4):288–295.

[18] BARLETTA FB, RAHDE NDE M, LIMONGI O, MOURA AA, ZANESCO C, MAZOCATTO, *In vitro comparative analysis of 2 mechanical techniques for removing gutta-percha during retreatment*, J Can Dent Assoc, 2007, 73(1):65.

[19] SOMMA F, CAMMAROTA G, PLOTINO G, GRANDE NM, PAMEIJER CH, *The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials*, J Endod, 2008, 34(4):466–469.

[20] ÜNAL GC, KAYA BU, TAÇ AG, KEÇECI AD, *A comparison of the efficacy of conventional and new retreatment instruments to remove gutta-percha in curved root canals: an ex vivo study*, Int Endod J, 2009, 42(4):344–350.

[21] TAKAHASI CM, CUNHA RS, DE MARTIN AS, FONTANA CE, SILVEIRA CF, DA SILVEIRA BUENO CE, *In vitro evaluation of the effectiveness of ProTaper universal rotary retreatment system for gutta-percha removal with or without a solvent*, J Endod, 2009, 35(11):1580–1583.

[22] KOCH K, BRAVE D, *The ultimate rotary file?* Oral Health J, 2002, 92:59–63.

[23] GIULIANI V, COCCHETTI R, PAGAVINO G, *Efficacy of ProTaper universal retreatment files in removing filling materials during root canal retreatment*, J Endod, 2008, 34(11):1381–1384.

[24] IMURA N, KATO AS, HATA GI, UEMURA M, TODA T, WEINE F, *A comparison of the relative efficacies of four hand and rotary instrumentation techniques during endodontic retreatment*, Int Endod J, 2000, 33(4):361–366.

[25] SAE-LIM V, RAJAMANICKAM I, LIM BK, LEE HL, *Effectiveness of ProFile.04 taper rotary instruments in endodontic retreatment*, J Endod, 2000, 26(2):100–104.

[26] SCHILDER H, *Filling root canals in three dimensions*, Dent Clin North Am, 1967, 12:723–744.

[27] BUCHANAN LS, *The continuous wave of condensation: "centered" condensation of warm gutta-percha in 12 seconds*, Dent Today, 1996, 15:60–67.

[28] NAHMIAS Y, SEROTA K, WATSON WR JR, *Predictable endodontic success: Part II – Microstructural replication*, Oral Health J, 2003, 93:1–3.

[29] 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(8):651–654.

[30] HASSANLOO A, WATSON P, FINER Y, FRIEDMAN S, *Retreatment efficacy of the Epiphany soft resin obturation system*, Int Endod J, 2007, 40(8):633–643.

[31] MASIERO AV, BARLETTA FB, *Effectiveness of different techniques for removing gutta-percha during retreatment*, Int Endod J, 2005, 38(1):2–7.

Corresponding author

Luminița Nica, Senior Lecturer, DDS, PhD, Department of Endodontics, Faculty of Dental Medicine, "Victor Babeş" University of Medicine and Pharmacy, 9 Revoluției Avenue, 300070 Timişoara, Romania; Phone +40744–862 557, e-mail: nical78@yahoo.com

Received: November 10th, 2010

Accepted: December 15th, 2010