

# Retreatment Efficacy of Three Rotary Ni–Ti Systems Using Computed Tomography

Khaled Beshr<sup>1</sup>, Shukry Gamal Mohammad<sup>1</sup>, Mohammad E Rokaya<sup>2</sup>, Ahmed Mustafa<sup>3</sup>, Essam Elkhltat<sup>4</sup>, Kusai Baroudi<sup>1</sup>

<sup>1</sup>Department of Restorative Dental Sciences, Al-Farabi Colleges, Riyadh, Saudi Arabia. <sup>2</sup>Department of Endodontics, Faculty of Dentistry, Al-Azhar University, Assuit, Egypt. <sup>3</sup>Department of Endodontics, Faculty of Dentistry, Al-Azhar University, Cairo, Egypt. <sup>4</sup>Department of Oral and Maxillofacial Sciences, Al-Farabi Colleges, Riyadh, Saudi Arabia.

## Abstract

**Objectives:** The efficacy of three different rotary Ni–Ti systems in root canal retreatment was evaluated.

**Materials and Methods:** A total of 135 intact single rooted freshly extracted mandibular premolars were selected. The specimens were randomly distributed into three main groups according to the root canal filling material (Gutta-percha, Realseal or EndoRez). Each group was then randomly distributed into three subgroups (15 each) to be retreated with K3, Protaper universal or R-Endo rotary systems. Pre- and postoperative computed tomography imaging was used to assess the percentage of residual filling material.

**Results:** The apical third had the most remaining filling material compared with the middle and cervical thirds. Retreatment of root canal filled with Real seal and Endo-Rez showed less residue than retreatment of gutta percha and AH plus sealer.

**Conclusions:** None of the techniques completely removed the root canal filling materials. Enlargement beyond the size before root filling may enhance the efficacy of retreatment.

*Key words: Gutta-percha, ProTaper, R-Endo, Retreatment*

## Introduction

Efficient removal of filling material from root canal system is essential for optimal root canal retreatment. Ideally, all filling materials and sealer should be removed from canal walls to gain access to microorganisms and pulp tissue remnants [1].

The techniques used to remove gutta-percha from root canals include manual endodontic hand instruments, [2,3] ultrasonic, [4-6] laser [7] and heat carrying instruments [8]. Various nickel–titanium (NiTi) rotary endodontic instruments have been developed to facilitate cleaning and shaping of root canals. To improve safety preparation and to prepare more appropriate shapes, new instrument designs with noncutting tips, radial lands, varying tapers and rake angles, and changing pitch lengths have been developed. Rotary NiTi instruments have also been proposed for the removal of filling materials from root canal walls, and various studies reported their efficacy, cleaning ability and safety [9].

R-Endo (Micro-Mega, Besancon, France) and, ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), systems have instruments that are specifically designed for retreatment. R-Endo system is composed of four instruments: Re (size 25, 0.12 taper) to flare the first few millimeters of the canal, and three files R1, R2 and R3 dedicated to each root canal third to a size 25, with 0.08, 0.06 or 0.04 tapers respectively. An optional finishing file Rs (size 30, 0.04 taper) is available if required. ProTaper rotary retreatment files consist of three instruments (D1, D2, and D3) with various tapers and diameters at the tip (size 30, 0.09 taper; size 25, 0.08 taper; and size 20, 0.07 taper). The active tip of the ProTaper D1 file might facilitate the penetration of the subsequent files. The non-active tips of D2 and D3 reduce the incidence of ledging, perforation and stripping during the removal of filling materials [10].

K3 file is a rotary instrument with a radial land relief in combination with a positive rake angle, a flattened noncutting

tip, and an asymmetrical constant tapered active file design with variable helical flute and variable core diameter. These are features that are claimed to enhance cutting-efficiency, debris removal, and file guidance and strength. K3 instruments were used in a crown-down manner according to manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument [11].

In recent years, there has been an increasing concern about the poor sealing properties of the conventional root-filling materials, gutta-percha and the different sealer cements. In vitro studies have demonstrated microleakage in canals filled with these materials that may allow ingress and propagation of bacteria resulting in infection [12].

In response to the shortcomings of gutta-percha and conventional sealers, the new Epiphany Soft Resin Endodontic Obturating System (Pentron Clinical Technologies, Willingford, CT, USA) has been introduced. This system consists of the core material Resilon, a thermoplastic, synthetic polymer resin engineered to have similar handling properties as gutta-percha, and the Epiphany sealer, a dual curable composite resin. The Epiphany System is expected to form a 'monoblock' within the canal space, whereby the core (Resilon) is bonded to the sealer (Epiphany), and the resulting complex is bonded to the root dentine by the resin-based primer [13]. Such a monoblock has been suggested to reduce bacterial ingress pathways and to strengthen the root to some extent [12,14].

The aims of this in vitro investigation were:

(a) To evaluate the efficacy of three rotary NiTi instruments; K3, ProTaper universal and R-Endo in the removal of gutta-percha, RealSeal and EndoRez during root canal retreatment.

(b) To compare the amount of residual filling material on the canal walls (apical third, middle third and coronal third) in root canals filled with Gutta-percha, Endorez or RealSeal after retreatment.

(c) To determine the retrievability of RealSeal, Endorez compared with conventional Gutta-percha.

#### Materials and Methods

A total of 135 intact single rooted straight freshly extracted human teeth (mandibular first and second premolar) were selected for this study. A prior patient's consent was given to use their extracted teeth to conduct the study. Approval of Al-Azhar University, faculty of oral and dental medicine, Egypt (under number 321/2009) was also obtained. The inclusion criteria included any teeth that needed to be extracted due to periodontitis, pericoronitis, unerupted or impacted teeth. The exclusion criteria included teeth that were decayed or damaged during the extraction in addition to those teeth that were congenitally affected such as enamel hypoplasia or amelogenesis/dentinogenesis imperfecta. The selected teeth were then immersed in 5.25% sodium hypochlorite for one hour to dissolve organic debris that was present on the external surface of the roots. Subsequently, they were cleaned with an ultrasonic scaler (Satelec, Acteon, France) to remove calculus, discarding teeth with previous root canal treatment, internal resorption, and external resorption, localized or diffuse calcifications. The selected teeth were stored in normal saline at room temperature until the time of use. The teeth were decoronated at the cemento-enamel junction with a double diamond disc. Roots were standardized to leave a root 16 mm in length. Working length (WL) was determined by inserting a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) which was passively introduced into the canal until the tip was seen to exit at the major foramen. The real length of the canal was recorded, and the working length calculated by subtracting 1 mm from this measurement. Root canals were prepared with a crown-down technique using K3 rotary NiTi system (SybronEndo, West Collins, CA, USA) to size 35 .04 taper at WL according to the manufacturer's instructions by one operator. Irrigation with 2.5% NaOCl was carried out using an irrigating needle placed 3 mm from working length. At each change of instrument, 2 mL of 2.5% NaOCl was used. When the instrumentation of root canals was completed, EDTA (17%) was applied for 3 min for smear layer removal and the canals flushed again with 2.5 % NaOCl. A final rinse with water was undertaken. Finally, the root canals were dried with paper points. The roots were then randomly distributed into 3 main groups.

Group 1: No.45, root canals were obturated using cold lateral condensation technique with gutta-percha (Meta Dental Co. Ltd., Korea) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany).

Group 2: No.45, root canals were obturated using cold lateral condensation technique with RealSeal point and sealer (SybronEndo, Orange, CA, USA).

Group 3: No.45, root canals were obturated using cold lateral condensation technique with EndoRez points and EndoRez sealer (Ultradent, South Jordan, UT).

The access cavities of all specimens were sealed with Cavitec (3M-Espe, Seefeld, Germany), and the teeth were stored at 37°C in a drying oven for 3 weeks to allow complete setting of the sealers.

#### Examination and evaluation of the specimen

The specimens were scanned using CT MULTISLICE SOMATOM SENSATION 64 VB30B.

The specimens were mounted in wax mold (18×13×2) with 30 Specimen.

Before CT images were obtained, the temporary filling material was removed from each canal entrance this was done to avoid interference with the root-filling readings by the radiopacity of the sealing material. Three-dimensional images of the roots were obtained using a Siemens Somatom C.T scanner. This CT scanner provides 0.6-mm-thick transverse sections at 0.1mm increments; it is equipped with a tube that rotates at 1 rpm and reconstruction tools of maximum-intensity projection and volume rendering. Siemens Somatom CT scanner (Siemens Corporation Germany) is a whole body CT scanner. These are obtained by a continuous and quick rotation of the complete X-ray detector system. The Somatom CT scanner is equipped with the pioneering Siemens multi-modality Software SYNGO. After CT scanning of all specimens, the total volume of root-filling mass in each canal was obtained by Siemens multi-modality Software SYNGO. The area corresponding to the root-filling mass was outlined with a software tool, the function "display tools" was selected, and the globe icon on the display was chosen to obtain the total volume of filling material in cubic millimetres, this value was recorded in a spreadsheet.

Each main group was randomly distributed into 3 sub-groups of 15 specimens each to be retreated with K3, ProTaper or R-Endo.

#### Retreatment procedure

In subgroup (A), K3 instruments were used in a crown-down manner according to manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument. File sequences were as follows: size 06/25 was used at one-half of the working length; size 06/20 was used between one-half and two-thirds of working length; and instruments of sizes 04/20, 04/25, 04/30, 04/35 and 04/40 were used to the working length.

In subgroup (B), the root canal fillings were removed using ProTaper Universal retreatment instruments (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper D1, D2 and D3 files, which were operated with an X-Smart motor (Dentsply Maillefer) at a speed of 500 rpm. D1 was used in the coronal third, D2 was used in the middle third, and D3 was carried to working length.

In subgroup (C), R-Endo instruments (Rm, Re, R1, R2, R3) were used in a gentle in-and-out motion on canal walls according to the manufacturer's instructions. A manual file was used first to relocate the canal orifices, then the Re instrument removed the first 2–3 mm of the filling. R1 and R2 were used to one third and two-thirds of the estimated

working length respectively. Finally, R3 was used at the working length to complete the removal of filling material from the root canal.

All instruments were used in a crown-down technique on a low-torque rotary engine driven motor\* (X-Smart; Dentsply Maillefer) in the preset torque levels recommended by the manufacturer for each type of instrument. In all the techniques a drop of solvent (chloroform) was first placed into the access cavity to soften the root filling material. Rotary instruments were used to remove filling material in a brushing circumferential motion whilst pressing against the root canal walls. Preparation was deemed complete when the working length was obtained, there was no root filling material/sealer covering the instruments, the canal walls were smooth and when the irrigating solution appeared clear of debris. To standardize procedures throughout the study, only one operator conducted the experiments to avoid variables during specimen preparation. All instruments were used for a maximum of three root canals and then discarded. Also, any deformed instruments were discarded. During retreatment, root canals were constantly irrigated with 2.5% NaOCl. The irrigant was delivered by disposable plastic syringe with an attached 27-gauge stainless steel needle that was placed down the canal until slight resistance was felt.

The specimens were scanned pre- and postoperatively using CT (Multislice Somatom Sensation 64 VB30B) and Three-dimensional images of the roots were obtained using a Siemens Somatom CT scanner (Figure 1 and 2). Pre- and postoperative measurements of the volume of filling material in coronal, middle and apical thirds allowed calculation of the mean percentage of residual filling material (%) during retreatment procedures; this value was recorded in a spreadsheet.



Figure 1. CT machine used in the study.

### Statistical analysis

Data were statistically analyzed by One-way ANOVA followed by tukey's *post hoc* test at the significance level of  $\alpha = 0.05$ .

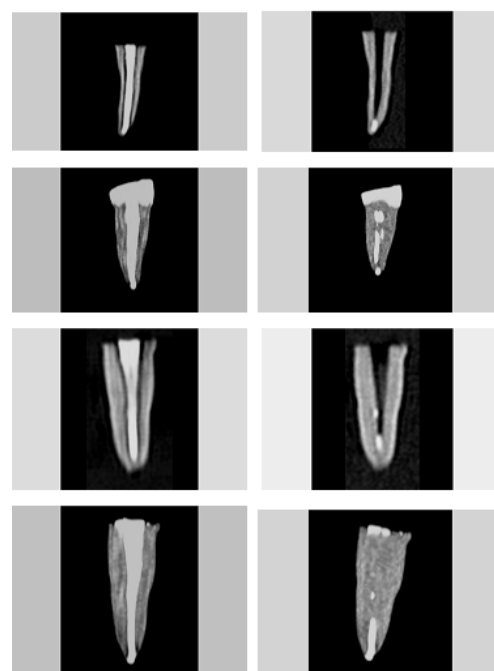


Figure 2. CT scan of filling material in root canal before and after removal of root canal filling (4 cases). (A) Pre-operative. (B) Postoperative

### Results

There was statistically significant differences amongst gutta percha, Real Seal and Endo-Rez removal from canal walls at apical segment irrespective of the technique used (K3, Protaper and R-Endo). A greater amount of filling material remained with gutta percha while the minimal amount recorded with Endo-Rez. There was no statistically significant difference between mean remnant % of the three materials at coronal and middle thirds of the canal walls ( $P = 0.813 > 0.05$ ) (Figure 3).

Studying coronal, middle and apical thirds of the canal walls, a greater amount of filling material remained in the apical third than in the middle and coronal thirds. In the apical segment the result showed that there was statistically significant differences between K3, Protaper and R-Endo. K3 showed the lowest mean remnant percent. This was statistically significant ( $P = 0.040 < 0.05$ ).

In the middle and coronal segments, There was no statistically significant difference amongst the the three systems K3, Protaper and R-Endo irrespective of the root canal filling material used.

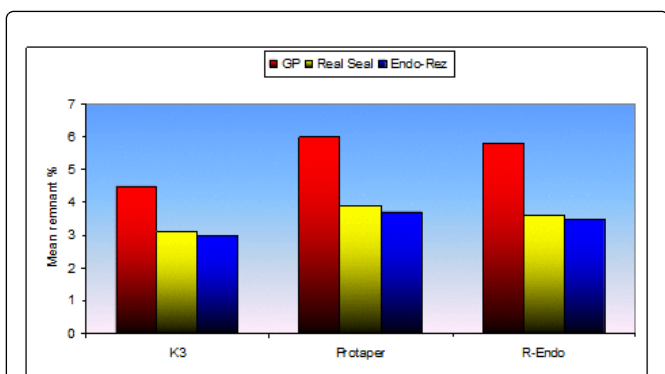


Figure 3. Mean values of the remnant percentages of different materials at the apical segment with different rotary systems.

## Discussion

Safe, efficient and complete removal of root filling materials is critical to successful non-surgical retreatment [15]. The use of CT in endodontic research has enabled 3-dimensional appraisal of treatments performed within the root canal system. This noninvasive method has been used to assess mechanical removal of root-filling material [16]. In the present study, CT was used to assess the volume of filling material that remained inside root canals after mechanical removal. The coronal tooth tissue was removed for purpose of standardisation. Decoronation of teeth assures standardization of specimens as it eliminates the effect of crown anatomy and the root canals access and increase the reliability [17]. The K3 0.04 taper instruments were selected to match the shape of the filled canals that were cleaned and shaped with the same instruments. Also, the design of the K3 instruments is helpful in drawing out debris coronally and their efficiency in removal of gutta-percha and Resilon was confirmed in a recent study [18]. K3 system promoted better apical cleaning compared with other techniques because the shape of canals reinstrumented with the K3 system was similar to the original canal section [19]. Sodium hypochlorite 2,5 % was used in the study as an irrigant solution. Siqueira et al., (2000) found no significant difference in the antibacterial activity between Sodium hypochlorite 2.5% and 5% [20].

The results reveal that retreatment of root canal filled with Real seal and Endo-Rez showed less residue than retreatment of gutta percha and AH plus sealer. This might be explained by the formation of a monoblock in the RealSeal and EndoRez. The resin-based points combined with the resin-based sealers bind together in the canal. Thus, sealer might be better removed if it is bound together with the core material regardless technique of removal [21]. On the other hand, it can be difficult to achieve complete coating of the canal walls with the resin-based bonding agent; thus, the connection between resin-based materials (RealSeal and EndoRez) and dentin may be inadequate. There are several causes that impair resin-dentin adhesion in the root canal system, such as ineffective EDTA conditioning in the deeper part of the canal wall, the use of sodium hypochlorite that may adversely affect bond strength, and the presence of uninstrumented areas that may be unfavorable to adhesion. These could explain, why it has been reported that Realseal and Endorez system showed

lower adhesive strength to dentin [22] and was easier to removed compared with Gutta-percha and a conventional epoxy resin sealer (AH Plus) [23].

Conversely, with gutta-percha, there is no chemical attachment between the core material and the sealer. Therefore, the amount of remaining material is higher as the sealer that is brushed on the canal wall is not completely removed because of its inadequate connection with the gutta-percha [24,25]. This is in agreement with the result of other investigators. They reported that retreatment of canals filled with resin-based materials left less residue than retreatment of Gutta-percha and AH plus [10,24,26].

On the other hand, the result contradict with Hassanloo et al., 2007 [27] and Tasdemir et al., 2008 [28] who concluded that there was less filling residue in the Gutta-percha sealer combination than in the Epiphany system when they performed retreatment in teeth after they had kept them in an anaerobic environment for 8 weeks after filling.

The result reveals more residual filling material in the apical thirds than in the middle and cervical thirds. This may be due to increased anatomical variability and difficulty of instrumentation in the apical area [26,27]. The existence of curvatures in many planes of deep grooves and depressions on dentine walls in the apical area may well explain the presence of these less instrumented areas making it impossible to direct Nickel-titanium instruments against entire root canal walls. This finding is with agreement with many studies [28-30].

In apical area, the ProTaper and R-Endo showed highest debris. This was also seen in recent studies [23,29,31]. Probably, the smaller apical size of the last ProTaper and R-Endo retreatment instrument (size 20 and 25) was disadvantage of these groups compared to the other group (size 40 for k3) in this study. This result is contradicted to Schirmeister et al., 2006, [24] thus continuation of instrumentation with F2 and F3 ProTaper files would have improved the outcome in ProTaper retreatment group [32]. While k3 system showed the lowest debris in apical area, this may be due to large apical size of the last k3 instrument (size 40), these findings consistent with many studies which concluded that when retreated canals were enlarged file beyond the size before root filling this enlargement may enhance the efficacy of retreatment [10,24,33]. Rotary instrumentation (K3 system) promoted better apical cleaning compared with other techniques because the shape of canals re-instrumented with the K3 system was similar to the original canal section. The result of the present study showed that neither material could be removed completely from the canal walls. This observation was consistent with those of previous studies on retreatment efficacy in which various root-filling materials and retreatment techniques were used [32,34].

## Conclusion

Removal of Real seal and Endo REZ filling material resulted in fewer remnants than removal of gutta-percha/AH Plus filling. Enlargement beyond the size before root filling may enhance the efficacy of retreatment.

## References

- Friedman S, Rotstein I, Shar-Lev S. Bypassing gutta-percha root fillings with an automated device. *Journal of Endodontics*. 1989; **15**: 432-37.
- Schirrmeyer JF, Hermanns P, Meyer KM, Goetz F, Hellwig E. Detectability of residual Epiphany and gutta-percha after root canal retreatment using a dental operating microscope and radiographs--an ex vivo study. *International Endodontic Journal*. 2006; **39**: 558-65.
- Betti LV, Bramante CM, Quantec SC. rotary instruments versus hand files for gutta-percha removal in root canal retreatment. *International Endodontic Journal*. 2001; **34**: 514-19.
- Ladley RW, Campbell AD, Hicks ML, Li SH. Effectiveness of halothane used with ultrasonic or hand instrumentation to remove gutta-percha from the root canal. *Journal of Endodontics*. 1991; **17**: 221-24.
- de Mello Junior JE, Cunha RS, Bueno CE, Zuolo ML. Retreatment efficacy of gutta-percha removal using a clinical microscope and ultrasonic instruments: part I--an ex vivo study. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics*. 2009; **108**: 59-62.
- Pirani C, Pelliccioni GA, Marchionni S, Montebugnoli L, Piana G, Prati C. Effectiveness of three different retreatment techniques in canals filled with compacted gutta-percha or Thermafil: a scanning electron microscope study. *Journal of Endodontics*. 2009; **35**: 1433-440.
- Farge P, Nahas P, Bonin P. In vitro study of a Nd:YAP laser in endodontic retreatment. *Journal of Endodontics*. 1998; **24**: 359-63.
- Wolcott JF, Himel VT, Hicks ML. Thermafil retreatment using a new "System B" technique or a solvent. *Journal of Endodontics*. 1999; **25**: 761-64.
- Saad AY, Al-Hadlaq SM, Al-Katheeri NH. Efficacy of two rotary NiTi instruments in the removal of Gutta-Percha during root canal retreatment. *Journal of Endodontics*. 2007; **33**: 38-41.
- de Oliveira DP, Barbizam JV, Trope M, Teixeira FB. Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment. *Journal of Endodontics*. 2006; **32**: 362-64.
- Akpinar KE, Altunbaş D, Kuştarıcı A. The efficacy of two rotary NiTi instruments and H-files to remove gutta-percha from root canals. *Medicina Oral, Patologia Oral Cirurgia Bucal*. 2012; **17**: e506-11.
- Shipper, Fabricio B, Teixeira, Roland R, Arnold, Martin Trope. Periapical inflammation after coronal microbial inoculation of dog roots filled with gutta-percha or resilon. *Journal of Endodontics*. 2005; **31**: 91-6.
- Teixeira FB, Teixeira EC, Thompson J, Leinfelder KF, Trope M. Dental bonding reaches the root canal system. *Journal of Esthetic and Restorative Dentistry*. 2004; **16**: 348-54.
- Shipper G, Trope M. In vitro microbial leakage of endodontically treated teeth using new and standard obturation techniques. *Journal of Endodontics*. 2004; **30**: 154-58.
- Ungor M, Onay EO, Orucoglu H. Push-out bond strengths: the Epiphany-Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha. *International Endodontic Journal*. 2006; **39**: 643-47.
- Barletta FB, Rahde Nde M, Limongi O, Moura AA, Zanesco C, Mazocatto G. In vitro comparative analysis of 2 mechanical techniques for removing gutta-percha during retreatment. *Journal of Canadian Dental Association*. 2007; **73**: 65.
- Ferreira JJ, Rhodes JS, Ford TR. The efficacy of guttapercha removal using ProFiles. *International Endodontic Journal*. 2001; **34**: 267-74.
- de Oliveira DP, Barbizam JV, Trope M, Teixeira FB. Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment. *Journal of Endodontics*. 2006; **32**: 362-64.
- Masiero AV, Barletta FB. Effectiveness of different techniques for removing gutta-percha during retreatment. *International Endodontic Journal*. 2005; **38**: 2-7.
- Siqueira JF Jr, Rôças IN, Favieri A, Lima KC. Chemomechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1%, 2.5%, and 5.25% sodium hypochlorite. *Journal of Endodontics*. 2000; **26**: 331-34.
- Verdelis K, Eliades G, Oviir T, Margelos J. Effect of chelating agents on the molecular composition and extent of decalcification at cervical, middle and apical root dentin locations. *Endodontic Dental Traumatology*. 1999; **15**: 164-70.
- Ari H, Yaşar E, Belli S. Effects of NaOCl on bond strengths of resin cements to root canal dentin. *Journal of Endodontics*. 2003; **29**: 248-51.
- Peters OA, Schönenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. *International Endodontic Journal*. 2001; **34**: 221-30.
- Schirrmeyer 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. *International Endodontic Journal*. 2006; **39**: 150-56.
- Viducić D, Jukić S, Karlović Z, Božić Z, Miletić I, Anić I. Removal of gutta-percha from root canals using an Nd:YAG laser. *International Endodontic Journal*. 2003; **36**: 670-73.
- Bueno CE, Delboni MG, de Araújo RA, Carrara HJ, Cunha RS. Effectiveness of rotary and hand files in gutta-percha and sealer removal using chloroform or chlorhexidine gel. *Brazilian Dental Journal*. 2006; **17**: 139-43.
- Hassanloo A, Watson P, Finer Y, Friedman S. Retreatment efficacy of the Epiphany soft resin obturation system. *International Endodontic Journal*. 2007; **40**: 633-43.
- Taşdemir T, Er K, Yildirim T, Celik D. Efficacy of three rotary NiTi instruments in removing gutta-percha from root canals. *International Endodontic Journal*. 2008; **4**: 191-96.
- Unal 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. *International Endodontic Journal*. 2009; **42**: 344-50.
- Gergi R, Sabbagh C. Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an ex vivo study. *International Endodontic Journal*. 2007; **40**: 532-37.
- Schirrmeyer 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 Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics*. 2006; **101**: 542-47.
- Kfir A, Tsesis I, Yakirevich E, Matalon S, Abramovitz I. The efficacy of five techniques for removing root filling material: microscopic versus radiographic evaluation. *International Endodontic Journal*. 2012; **45**: 35-41.
- Ezzie E, Fleury A, Solomon E, Spears R, He J. Efficacy of retreatment techniques for a resin-based root canal obturation material. *Journal of Endodontics*. 2006; **32**: 341-44.
- Mollo A, Botti G, Principi Goldoni N, Randellini E, Paragliola R, Chazine M, Ounsi HF, Grandini S. Efficacy of two Ni-Ti systems and hand files for removing gutta-percha from root canals. *International Endodontic Journal*. 2012; **45**: 1-6.