Original Article

MICRO-COMPUTED TOMOGRAPHIC EVALUATION OF REMOVAL AND EXTRUSION OF ROOT FILLING MATERIAL DURING CANAL RETREATMENT

AVALIAÇÃO POR MEIO DE MICROTOMOGRAFIA COMPUTADORIZADA DA REMOÇÃO E EXTRUSÃO DE MATERIAL OBTURADOR DURANTE RETRATAMENTO ENDODÔNTICO

Kellen Cristina Mendes AZEVEDO[1]; Analice Giovani PEREIRA[1]; Maria Antonieta Veloso Carvalho de OLIVEIRA[1]; Luís Henrique Araújo RAPOSO[2]; Manoel Damião SOUSA-NETO[3]; Jesus Djalma PÉCORA[3]; João Carlos Gabrielli BIFFI[1]

1. Department of Endodontics, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil. mariaoliveira@ufu.br; 2. Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil; 3. Department of Endodontics, School of Dentistry, University of Ribeirão Preto, Ribeirão Preto, SP, Brazil.

ABSTRACT: This study aimed to assess the efficiency of manual and rotary techniques for removing root filling material in endodontic treated canals and to evaluate the extrusion of debris via apical foramen. After access preparation, thirty human lower central incisors were instrumented, filled and divided into two groups (n=15): MN- manual retreatment technique; RT- rotary retreatment technique. The teeth were submitted to micro-computed tomographic scanning before and after the retreatment procedure, for quantifying the remaining filling material by relating the initial and final conditions. The analysis was conducted separately in all root thirds. The volume of material extruded through the apical foramen was also quantified. The data were statistically analyzed using t-test and two-way analysis of variance (ANOVA) at 5% of significance. No significant differences were detected between remaining filling material for the techniques evaluated ($p=0.74$), even considering the apical third only ($p>0.75$). Significant differences were found for the remaining filling material verified between the cervical third and middle/apical thirds, with lower values being observed at the cervical third for both groups ($p<0.05$). Apical extrusion of filling material was verified in seven specimens (2 from MN group and 5 from RT group). Both techniques showed similar performance for removing filling material from the root canal, considering the whole tooth or the root thirds independently. The apical extrusion of filling material observed was not sufficient to indicate which technique has increased tendency to induce more events during retreatments.

KEYWORDS: Apical extrusion. Micro-computed tomographic. Root canal filling materials.

INTRODUCTION

One of the most important points for the success of endodontic retreatment is the straight access to the root canal walls by removing root filling materials (BUENO et al., 2006). Necrotic pulp tissues or bacterial remnants may remain protected under the filling, being responsible for the maintenance of periapical infectious processes (HAMMAD, QUALTROUGH; SILIKAS, 2008). Therefore, the filling material should be carefully removed during endodontic retreatments, since pulp/dentin tissues, bacteria and material debris of filling materials can be extruded through the apical foramen, thus working as irritating agents (HUANG et al., 2007).

Different techniques have been used to remove filling material in endodontic retreatments, including the use of manual files (HÜLSMANN; BLUHM, 2004), heated instruments (ZMENER, PAMEIJER; BANEGAS, 2006), ultrasonic devices (PIRANI et al., 2009), rotary files (IMURA et al., 2000; HAMMAD, QUALTROUGH, SILIKAS, 2008; RÖDIG et al., 2012), reciprocating files (SILVA et al., 2015; CROZETA et al., 2016), adaptive motion systems (CROZETA et al., 2016), and specific systems developed for retreatment (GU et al., 2008; TAKAHASHI et al., 2009). Several studies used distinct methods such as bidimensional radiographic analysis or destructive approaches sectioning specimens to evaluate the remaining filling after endodontic retreatment (BARRIESHI-NUSAR, 2002; CUNHA et al., 2007; BARLETTA et al., 2008). Recently, micro-computed tomography has been increasingly employed in endodontic investigations, since this non-invasive method provides high-resolution images with good detailing of the root canals and endodontic treatments/retreatments (HAMMAD, QUALTROUGH; SILIKAS, 2008; RÖDIG et al., 2012; CROZETA et al., 2016).

Despite the diversity of techniques for removing endodontic filling in canal retreatments and the methods used to evaluate their efficiency,

Received: 12/02/16
Accepted: 02/05/16

there is still no consensus about the most efficient clinical approach for endodontic retreatments. Our hypothesis is that differences between the manual and rotatory instrumentation techniques would be detected in the percentage of remaining filling material and in the amount of extruded debris after the retreatment procedures. Thus, the aim of this study was to assess the efficiency of manual and rotary techniques for removing root filling material in endodontic treated canals and to evaluate the extrusion of debris via apical foramen using micro-computed tomography (μCT) analysis.

MATERIAL AND METHODS

Human lower central incisors with single root canal were selected (gathered after informed consent approved by the Committee for Ethics in Research of the Federal University of Uberlândia: #451/11). The teeth had no previous endodontic treatment, intraradicular pins, fractures or extensive damage in crowns. The selected teeth were cleaned of debris and stored in physiological saline solution until use (PEREIRA et al., 2012). In order to attain the calculation of volume and surface area of the root canals, as well as an overall outline of internal anatomy, teeth were pre-scanned using a μCT scanner (SkyScan 1172; Bruker-microCT, Kontich, Belgium) at a resolution of 68 μm, 90 kV and 112 μA. Transverse cross sections of the inner structure of the teeth were acquired after reconstruction procedure (NRecon v.1.6.3 software; Bruker-microCT). Minimum and maximum diameters of the root canals were measured bucco-lingually and mesio-distally (DataViewer v.1.4.4; Bruker-microCT). Teeth showing apical curvature or more than one root canal were excluded. Based on these pre-scans, 30 lower central incisors were selected.

Coronal opening was performed using round diamond burs (#1016, KG-Soresen, Barueri, SP, Brazil) and tapered carbide burs with non-cutting tip (Endo-Z, Dentsply-Maillefer, Ballaigues, Switzerland). The root canals were located and explored with #10 K-file (Dentsply-Maillefer) and the working length determined subtracting 1 mm from the length measured when the tip of the file was first observed emerging from the apical foramen. Teeth were instrumented with a step-down technique, using K-files (Dentsply-Maillefer) up to #30 memory file. Irrigation was performed with 1 mL of 1% sodium hypochlorite after each instrument and 2 mL of physiological saline for final rinse. Canals were dried with paper points and filled with gutta-percha and mineral trioxide aggregate-based sealer (MTA Fillapex, Ângelus, Londrina, PR, Brazil). Coronal access was provisionally restored with zinc-oxide temporary cement (Interim, Biodinâmica, Ibiporã, PR, Brazil).

Afterwards, teeth were mounted on a custom attachment base and scanned with the μCT scanner at an isotropic pixel size of 19.6 μm, 90 kV, 112 μA, resulting in the acquisition of 800-1,000 transverse cross sections per tooth. The scanning procedure was carried out by 360º rotation around the vertical axis; camera exposure time of 2,600 ms, rotation step of 0.6°, frame averaging of 2 and medium filtering of the data were applied. X-rays were filtered with aluminum (500 μm) and copper (38 μm) filters and a flat field correction was performed prior to scanning to correct for variations in the pixel sensitivity of the camera. Reconstruction of the images was done (NRecon v.1.6.3) with a beam hardening correction of 15%, smoothing of 3, no ring artifact correction, and an attenuation co-efficient range of −0.002 to 0.15, providing axial cross sections of the inner structure of the specimens. The evaluation of each tooth was performed considering the total lengthening of the root canal and the initial volume of filling material was calculated using the CTVol software (v.2.2.1, Bruker-microCT). The specimens were then stored (100% humidity at 37ºC) for 3 weeks to allow the complete setting of the sealer.

Sequentially, the teeth were fixed in red wax blocks to collect filling any material that could be extruded through the apical foramen during retreatment, in order to allow its quantification. The whole set was fixed in a holding assembly to stabilize the specimen throughout the next steps. Then, teeth were randomly assigned into two experimental groups (n=15): MN- manual retreatment technique; and RT- rotary retreatment technique. For MN group, #2 and 3 Gattes-Glidden burs (Dentsply-Maillefer) were used to initially remove the filling material from the cervical and middle thirds. Then, eucalyptol-based solvent (Eucaliptol; Biodinâmica) was inserted in the filling with #15 and #20 K-files (Dentsply-Maillefer) using oscillatory movements, and the material was laterally removed with Hedströem files (Dentsply-Maillefer). The canal repreparation with K-files was performed up to #35 instrument, until obtaining 0.35 mm final diameter. For RT group, D1-D3 Nickel-Titanium (NiTi) files (ProTaper Universal Retreatment; Dentsply-Maillefer) were used to prepare the cervical, middle and apical thirds, respectively. The finishing of the canal repreparation was done with F1-F3 NiTi files (ProTaper Universal; Dentsply-Maillefer) to obtain

a final diameter compatible to that produced by #30 K-file.

The removal procedure was interrupted when filling material was no longer detected in the instruments. Canal irrigation and drying was performed as described before. All endodontic procedures were conducted by one experienced operator. Then, teeth were submitted to final μCT scanning using the same parameters described previously. This analysis was conducted separately in all root thirds and the volume of filling material extruded was also quantified. The percentage of remaining filling material into the root canal was calculated by relating the initial and final volumes using the following formula: $\Delta\% = V_F*100/V_I$, where V_I and V_F are the initial and final volumes (mm^3) of the endodontic filling before and after the retreatment, respectively.

Normal distribution of the initial and final filling volumes was verified after square root simple transformation of the final volume data; then data of each group were compared using paired t-test. The remaining filling verified after the retreatment procedure was expressed as a percentage of the initial filling volume (Δ%). Normality was verified after square root simple transformation of the data, and t-test was applied for comparisons between groups. For comparing the residual volume of filling in each root third, normal distribution of the data was detected after square root simple transformation and two-way analysis of variance (ANOVA) with repeated measures was applied. All statistic tests were performed with a significance level of 5% (SigmaPlot for windows, v.12.0, Systat Software Inc., Chicago, IL, USA). The volume of extruded material (mm3) was analyzed descriptively since statistical analysis was not possible to be applied due to limited sampling.

RESULTS

The paired t-test showed significant differences between the initial and final volumes of filling material for both groups (P<0.001) (Table 1). The t-test revealed no significant differences for the percentage of remaining filling material (Δ%) for the two retreatment techniques (P=0.74) (Table 1). The two-way ANOVA with repeated measures showed no significant differences between the retreatment techniques (P=0.73), but significant differences were verified on the residual volume of filling material between the cervical and middle (P=0.04), and cervical and apical (P<0.001) thirds for the MN group (Table 2). For the RT group, differences on the residual volume of filling material were checked between the cervical and apical thirds (P=0.02) (Table 2). None of the retreatment techniques tested were effective in completely removing the filling material from the canals, with remnants being located mainly in the irregularities where anatomical interferences probably affected the full-action of files (Figure 1).

Table 1. Mean initial and final volume of filling material (mm^3) and percentage of remaining filling material (Δ%)

Technique	Initial (mm^3)	Final (mm^3)	Δ%
MN	4.43 ± 1.18^{Aa}	0.24 ± 0.26^{Ba}	$4.92\pm4.17^{\S}$
RT	4.89 ± 1.11^{Aa}	0.22 ± 0.21^{Ba}	$4.31\pm4.12^{\S}$

*Different capital letters indicate significant differences within groups (columns). Different small letters indicate significant differences between groups (grows). Different symbols indicate significant differences between the Δ% ($p < 0.05$).

Table 2. Mean residual volume of filling material (mm^3) for each root third according to the retreatment technique

Technique	Root third	Filling material (mm^3)
MN	Cervical	0.02 ± 0.03^{Aa}
	Middle	0.10 ± 0.15^{Ab}
	Apical	0.13 ± 0.15^{Ab}
RT	Cervical	$0.03\pm0.04^{A\S}$
	Middle	$0.08\pm0.09^{A\S¥}$
	Apical	$0.11\pm0.14^{A¥}$

*Different capital letters indicate significant differences between groups. Different small letters indicate significant differences within MN root thirds. Different symbols indicate significant differences within RT root thirds ($p < 0.05$).

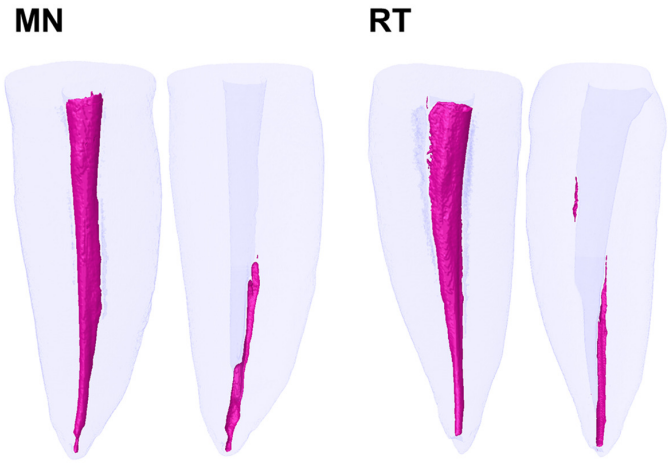

Figure 1. Micro-tomographic assessment of the specimens showing the initial and final filling material after each retreatment approach: MN- manual retreatment technique; RT- rotary retreatment technique.

Extrusion of filling material was observed in seven specimens following the retreatment procedure, of which, two were from MN group and five from RT group (Figure 2). The volume and percentage of extruded material were analyzed descriptively, and an increased tendency of RT specimens to present extrusion of filling after retreatment was shown (Table 3).

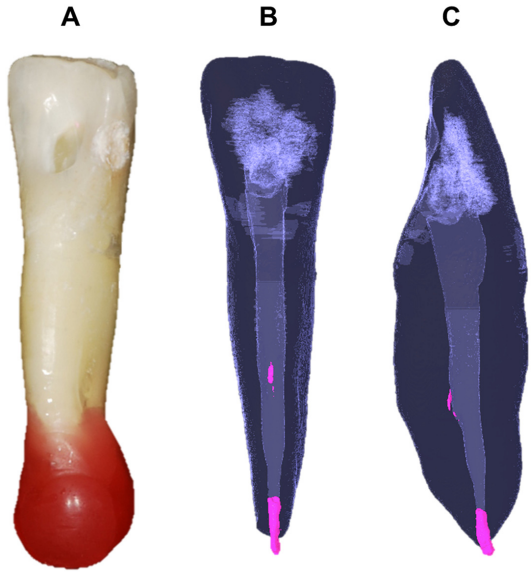

Figure 2. Evaluation of the filling material extruded through the apical foramen: A- tooth fixed in red wax block to collect filling material; B and C- bucco-lingual and mesio-distal micro-tomographic images of the specimen showing remaining filling material in the middle third and extrusion of material through the apical foramen.

Table 3. Descriptive volume (mm^3) and percentage (%) of filling material extruded through the apical foramen according to the retreatment technique

Technique	Specimens	Filling material (mm^3)
MN	1	0.0127 (0.26%)
	2	0.0359 (0.77%)
RT	1	0.0053 (0.14%)
	2	0.0047 (0.12%)
	3	0.0189 (0.47%)
	4	0.0014 (0.04%)
	5	0.0156 (0.35%)

DISCUSSION

The development of rotary NiTi instruments especially designed to endodontic retreatments intended to overcome the previous limitations imposed by manual instruments, aiming to remove the root filling material more efficiently (ZMENER, PAMEIJER; BANEGAS, 2006; SOMMA et al., 2008). However, it has been shown that a significant volume of filling material may remain retained in the root canal walls following different retreatment approaches with manual or mechanized instruments (GIULINI, COCHETTI; PAGAVINO, 2008; HAMMAD, QUALTROUGH; SILIKAS, 2008). These findings are in accordance to the results of the present investigation, which showed no significant differences in the percentage of remaining filling material after retreatment techniques performed using manual or rotary instrumentation techniques. Extrusion of filing material through apical foramen after retreatment was detected in few specimens from the two experimental groups. Thus, the hypothesis tested in this study was rejected, since no significant differences were found between both retreatment techniques evaluated.

The success in endodontic retreatment is dependent upon the efficient removal of filling material from the root canal walls (CUNHA et al., 2007; BARLETTA et al., 2008). Anatomical complexities can challenge root canal preparation due to the limitations on the appropriate adaptation of files in the canal (PEREIRA et al., 2012). Indeed, complete removal of root fillings can also be influenced by difficulties imposed to the action of files in some irregular regions of the canal walls presenting irregularities (DUARTE et al., 2010) (Figure 1). This fact is probably responsible for the several controversies existing among different studies, since root canal anatomy can influence the amount of remaining filling material after retreatment, irrespective of the technique used (BARRIESHI-NUSAR, 2002; GIULINI, COCHETTI; PAGAVINO, 2008; HAMMAD, QUALTROUGH, SILIKAS, 2008). Despite this, some investigations also showed that both retreatment techniques evaluated in this study are incapable to completely remove filling material from root canal walls (ZMENER, PAMEIJER; BANEGAS, 2006; HAMMAD, QUALTROUGH, SILIKAS, 2008; BARLETTA et al., 2008; SOMMA et al., 2008; PIRANI et al., 2009; MOLLO et al., 2012), corroborating our findings.

No significant differences were found in the percentage of remaining filling material (Δ%) after the two retreatment techniques, indicating that both approaches presented similar efficacy (Table 1). Other reports have also shown similarity between these retreatment techniques (TAKAHASHI et al., 2009; RÖDIG et al., 2012), confirming our results. On the other hand, some investigations revealed superior performance of the rotary system tested in this study for retreatment procedures as compared to manual files (GIULINI, COCHETTI; PAGAVINO, 2008; GU et al., 2008). A differential to be taken into account is that the rotary retreatment technique does not require solvent solutions, allowing a reduced working time, since files work removing filling material and existing canal interferences concomitantly. By its turn, the manual technique requires solvents and may favor rectification of root canals in the apical region during the filling material removal.

When analyzing the efficacy of the retreatment techniques in the root thirds independently, no significant differences were detected between both approaches tested (IMURA et al., 2000; PIRANI et al., 2009; ERSEV et al., 2012). However, significant differences on the residual volume of filling material were verified between the cervical and the middle/apical thirds and between the cervical and the apical thirds for the MN and RT groups, respectively (Table 2). The easier access and the increased diameter of the root canal in the cervical region may explain the better results found in this region. Some studies have shown increased removal of root filling material in the apical and middle thirds when using rotary instruments (SAE-LIM et al., 2000; SAAD, AL-HADLAQ; AL-KATHEERI, 2007), while others, verified more effectiveness for manual files in cleaning canal walls in the apical third (ZMENER, PAMEIJER; BANEGAS, 2006; SOMMA et al., 2008). The complete removal of filling material from apical thirds is clinically relevant as endodontic treatment failures are usually related to bacterial remnants at the apical portion of root canals (CROZETA et al., 2016). The presence of remaining filling material in this region must be avoided when performing retreatments since the success of the endodontic intervention will depend on appropriate cleaning of this area will be impossible (SILVA et al., 2015).

Several studies on extrusion of root filling used methods in which the extruded material was freely released, without any barrier to block debris (IMURA et al., 2000; HUANG et al., 2007; SOMMA et al., 2008; MOLLO et al., 2012). This fact does not correspond to the clinical reality, because periodontal structures prevent larger amounts of debris to reach the apical region

(SELTZER et al., 1968). Thus, red wax blocks were used to simulate this situation and collect the extruded filling material (Figure 2). Besides, most studies that evaluated extruded filling material during retreatment procedures only registered whether the event occurred, not quantifying the volume of debris (SOMMA et al., 2008; MOLLO et al., 2012). Our concern was not only to detect material extrusion, but also to quantify its volume. Despite statistical analysis was not possible due to reduced sampling, an increased tendency of RT specimens to present extrusion of filling after retreatment was verified (Table 3).

In overall view, none of the retreatment techniques evaluated in this study was capable to completely removed the endodontic filling material from the root canals, once the action of files was probably affected by the irregularities present in the canal walls. However, both retreatment techniques proved their efficacy since the mean percentage of remaining filling material was lower than 5% for both groups. Regarding the extrusion of filling material, none of the techniques provided enough specimens for carrying out statistical analysis and this probably occurred due to the barrier used to collect debris. According to the methodology used and on the basis of the results of the present study, the choice of a manual or rotary technique for performing endodontic retreatments should consider aspects such as cost-benefit and technical ability in view of the similar performance presented by both approaches.

RESUMO: Este estudo objetivou avaliar a eficiência das técnicas manual e rotatória na remoção de material obturador de dentes tratados endodonticamente, além de verificar a extrusão de resíduos via forame apical. Após acesso endodôntico, trinta incisivos centrais inferiores humanos foram instrumentados, obturados e divididos em dois grupos (n=15): MN- técnica de retratamento manual; RT- técnica de retratamento rotatória. Os dentes foram submetidos à escaneamento micro-tomográfico previamente e após os procedimentos de retratamento para quantificação do remanescente de material obturador relacionando as condições inicial e final. Esta análise foi conduzida separadamente em todos os terços radiculares. O volume de material extruído via forame apical também foi quantificado. Os dados foram analisados estatisticamente por meio dos Testes T e de Análise de Variância em dois níveis com significância em 5%. Diferenças significantes não foram detectadas entre a quantidade de material remanescente para as duas técnicas avaliadas ($p=0,74$), mesmo considerando o terço apical separadamente ($p>0.75$). Diferenças significantes foram encontradas na quantidade de material remanescente verificado entre os terços cervical e médio/apical, com menores valores detectados no terço cervical para ambos os grupos ($p<0.05$). Extrusão apical de material obturador foi identificada em sete espécimes (2 do grupo MN e 5 do grupo RT). As duas técnicas avaliadas apresentaram desempenho similar na remoção do material obturador do canal radicular, considerando o dente como um todo ou os terços radiculares separadamente. A extrusão apical de material obturador verificada não foi suficiente para indicar qual técnica possui maior tendência de promover eventos durante o retratamento.

PALAVRAS-CHAVE: Extrusão apical. Microtomografia computadorizada. Obturação do canal radicular.

REFERÊNCIAS

BARLETTA, F. B.; DE SOUSA REIS, M.; WAGNER, M.; BORGES, J. C.; DALL'AGNOL, C. Computed tomography assessment of three techniques for removal of filling material. **Aust Endod J.**, Austrália, v. 34, n. 3, p. 101-105, dec. 2008.

BARRIESHI-NUSAIR, K. M. Gutta-percha retreatment: effectiveness of nickel-titanium rotary instruments versus stainless steel hand files. **J Endod.**, Baltimore, v. 28, n. 6, p. 454-456, jun. 2002.

BUENO, C. E.; DELBONI, M. G.; DE ARAÚJO, R. A.; CARRARA, H. J.; CUNHA, R. S. Effectiveness of rotary and hand files in gutta-percha and sealer removal using chloroform or chlorhexidine gel. **Braz Dent J.**, Ribierão Preto, v. 17, n. 2, p. 139-43, april 2006.

CROZETA, B. M.; SILVA-SOUZA, Y. T. C.; LEONI, G. B.; MAZZI-CHAVES, J. F.; FANTIANO, T.; BARATTO-FILHO, F. Micro computed tomography study of filling material removal from oval-shaped canals by using rotary, reciprocating, and adaptive motion systems. **J Endod.,** Baltimore, v. 42, n. 2, p. 1-5, mar. 2016.

CUNHA, R. S.; DE MARTIN, A. S.; BARROS, P. P.; DA SILVA, F. M.; JACINTO, R. C.; BUENO, C. E. In vitro evaluation of the cleansing working time and analysis of the amount of gutta-percha or Resilon remnants in the root canal walls after instrumentation for endodontic retreatment. **J Endod.**, Baltimore, v. 33, n. 12, p. 1426-1428, dec. 2007.

DUARTE, M. A.; SO, M. V.; CIMADON, V. B.; ZUCATTO, C.; VIER-PELISSER, F. V.; KUGA, M. C. Effectiveness of rotary or manual techniques for removing a 6-year-old filling material. **Braz Dent J.**, Ribeirão Preto, v. 21, n. 2, p. 148-152, mar. 2010.

ERSEV, H.; YILMAZ, B.; DINCOL, M. E.; DAGLAROGLU, R. The efficacy of ProTaper Universal rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. **Int Endod J.**, Oxford, v. 45, n. 8, p. 756-762, aug. 2012.

GIULIANI, V.; COCHETTI, R.; PAGAVINO, G. Efficacy of ProTaper Universal retreatment files in removing filling materials during root canal retreatment. **J Endod.**, Baltimore, v. 34, n. 11, p. 1381-1384, nov. 2008.

GU, L. S.; LING, J. Q.; WEI, X.; HUANG, X. Y. Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from root canals. **Int Endod J.**, Oxford, v. 41, n. 4, p. 288-295, dec. 2008.

HAMMAD, M.; QUALTROUGH, A.; SILIKAS, N. Three-dimensional evaluation of effectiveness of hand and rotary instrumentation for retreatment of canals filled with different materials. **J Endod.**, Baltimore, v. 34, n. 11, p. 1370-1373, nov. 2008.

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.**, Baltimore, v. 33, n. 9, p.1102-1105, sep. 2007.

HÜLSMANN, M.; BLUHM, V. Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment. **Int Endod J.**, Oxford, v. 37, n. 7, p. 468-476, oct. 2004.

IMURA, N.; KATO, A.S.; HATA, G.I.; 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.**, Oxford, v. 33,n. 4, p. 361-366, july 2000.

MOLLO, A.; BOTTI, G.; PRINCIPI GOLDINO, N.; RANDELLINI, E.; PARAGLIOLA, R.; CHAZINE, M.; et al. Efficacy of two Ni-Ti systems and hand files for removing gutta-percha from root canals. **Int Endod J.**, Oxford, v. 45, n. 1, p. 1-6, jan. 2012.

PEREIRA, A.G.; SANTOS, R.M.F.; AZEVEDO, K.C.M.; RAPOSO, L.H.A.; BIFFI, J.C.G. Assessment of influence of flexion angles of files in apical stop preparation by using manual and rotary instrumentation techniques. **J Endod.**, Baltimore, v. 38, n. 10, p. 1383-1386, oct. 2012.

PIRANI, C.; PELLICCIONI, G.A.; 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. **J Endod.**, Baltimore, v. 35, n. 10, p. 1433-1440, oct. 2009.

RÖDIG, T.; HAUSDORFER, T.; KONIESTCHKE, 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.**, Oxford, v. 45, n. 6, p. 580-589, jun. 2012.

SAAD, A.Y.; AL-HADLAQ, S.M.; AL-KATHEERI, N.H. Efficacy of two rotary NiTi instruments in the removal of Gutta-Percha during root canal retreatment. **J Endod.**, Baltimore, v. 33, n. 1, p. 38-41, jan. 2007.

SAE-LIM, V.; RAJAMANICKAM, I.; LIM, B.K.; LEE, H.L. Effectiveness of ProFile .04 taper rotary instruments in endodontic retreatment. **J Endod.**, Baltimore, v. 26, n. 2, p.100-104, feb. 2000.

SELTZER, S.; SOLTANOFF W.; SINAI, I.; GOLDENBERG, A.; BENDER, I.B. Biologic aspects of endodontics. 3. Periapical tissue reactions to root canal instrumentation. **Oral Surg Oral Med Oral Pathol.**, St Louis, v. 26, n. 4, p. 534-546, oct. 1968.

SILVA, E.J.N.L.; ORLOWSK, N.B.; HERRERA, D.R.; MACHADO, R.; KREBS, R.L.; COUTINHO-FILHO, T.S. Effectiveness of rotator and reciprocating movements in root canal filling material removal. **Braz Oral Res.**, São Paulo, v. 29, n. 1, p. 1-6, dec. 2015.

SOMMA, F.; CAMMAROTA, G.; PLOTINO, G.; GRANDE, N.M.; PAMEIJER, C.H. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. **J Endod.**, Baltimore, v. 34, n. 4, p. 466-469, april 2008.

TAKAHASHI, C.M.; CUNHA, R.S.; MARTIN, A.S.; FONTANA, C.E.; SILVEIRA, C.F.; BUENO, C.E.S. In vitro evaluation of the effectiveness of ProTaper universal rotary retreatment system for gutta-percha removal with or without a solvent. **J Endod.**, Baltimore, v. 35, n. 11, p. 1580-1583, nov. 2009.

ZMENER, O.; PAMEIJER, C.H.; BANEGAS, G. Retreatment efficacy of hand versus automated instrumentation in oval-shaped root canals: an ex vivo study. **Int Endod J.**, Oxford, v. 39, n. 7, p. 521-526, jul. 2006.