Original Research
Endodontic Therapy

XP Endo Finisher-R and PUI as supplementary methods to remove root filling materials from curved canals

Felipe Barros MATOSO[a]
Ramiro Martins QUINTANA[a]
Alexander Pompermayer JARDINE[a]
Debora DELAI[a]
Vania Regina Camargo FONTANELLA[a]
Renata GRAZZIOTIN-SOARES[b]
Patricia Maria Poli KOPPER[a]

[a]Universidade Federal do Rio Grande do Sul – UFRGS, School of Dentistry, Porto Alegre, RS, Brazil.

[b]University of Saskatchewan, College of Dentistry, Saskatoon, SK, Canada.

Declaration of Interests: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

Corresponding Author:
Renata Grazziotin
E-mail: Renata.grazziotin@usask.ca

https://doi.org/10.1590/1807-3107bor-2022.vol36.0053

Abstract: This study assessed the ability of XP-endo Finisher R (FKG, La Chaux-de-Fonds, Switzerland) to remove filling remnants from curved mesiobuccal canals of maxillary molars, using the passive ultrasonic irrigation (PUI) technique as a comparison. Twenty-four curved main mesiobuccal canals (MB1) of maxillary molars were instrumented with Wave One (#25/07) and filled with gutta-percha points and AH Plus Sealer. Samples were then re-treated with a standardized protocol with Wave One (#35/06) as the master apical file. Micro-CT scans measured baseline volume of remaining filling material (in mm^3). Samples were divided into two groups (n = 12) according to the supplementary cleaning approach: (PUI) or XP-endo Finisher R. Statistics compared baseline and final volume of filling material (within-group); and the percentage of filling material reduction (between-group). Mean baseline volumes, final volumes, and percentages of reduction (%) of filling material for XP-endo Finisher R and PUI were respectively: 0.060 mm^3, 0.042 mm^3, and 31.28%; and 0.064 mm^3, 0.054 mm^3, and 16.57%. Both tested protocols reduced the amount of filling material ($p < 0.05$). XP-endo Finisher R had higher percentage of reduction as compared to PUI ($p < 0.05$). XP-endo Finisher R and PUI used as supplementary cleaning protocols during re-treatment improved the removal of root filling material in curved canals; but XP-endo Finisher R was approximately twice more efficient. The complete filling material removal during re-treatment procedures is still a challenge. Supplementary cleaning protocols may help to remove the remaining material after the complete mechanical preparation of curved canals. XP-endo Finisher R was approximately twice more efficient than PUI.

Keywords: Dental Pulp Cavity; Root Canal Therapy; X-Ray Microtomography.

Introduction

The aim of endodontic re-treatment is to clean and shape the root canal, removing previous contaminated filling material.[1] Removing intracanal infection will help the body to promote healing of the periradicular pathosis.[2] In re-treatment cases, even with appropriate intracanal disinfection, the average time (11.78 months) required for a

Submitted: August 21, 2021
Accepted for publication: December 1, 2021
Last revision: January 17, 2022

periapical lesion to heal is increased in comparison with a primary endodontic treatment.[3]

The great problem faced by the clinician during root canal re-treatment is that filling material always remains on canal walls, despite the considerable number of different instruments and techniques used.[4-6] This problem is more critical in the case of anatomical complexities as in narrow, oval, and curved canals.

To overcome this problem, many supplementary methods have been proposed to improve the removal of root filling material. One of the most widely used techniques to be applied following endodontic re-treatment is passive ultrasonic irrigation (PUI). PUI consists of the insertion of an ultrasonic instrument (used in a power-driven ultrasonic unit) approximately 2 mm shorter of the working length. The instrument is then activated for 30 s in the presence of an irrigating solution. The cycle should be repeated three times.[4,7] Many experiments have claimed this technique is efficient, but it does not produce 100% material-free root canals.[8-10]

Another supplementary cleaning method, more recent and less researched, is the XP-endo Finisher R instrument (FKG, La Chaux-de-Fonds, Switzerland). This nickel-titanium re-treatment instrument has a #30 tip size (without tapering) and it is manufactured using a new alloy (MaxWire technology Martensite-Austenite Electropolish Flex, FKG Dentaire) that expands at body temperature. The instrument tip acquires a "spoon shape" when in rotary motion, being able to abrade the canal walls, allowing the displacement of filling material remnants.[7] This instrument also promotes the agitation of the irrigating solution. Recent microcomputed tomography (micro-CT) studies have claimed that XP-endo Finisher R reduced the amount of remaining root filling material; but similarly to the PUI technique, it did not produce a root canal free of remnants.[6,7] In addition, the effectiveness of XP-endo Finisher R in curved canals has not been studied yet.

Therefore, considering the need for a supplementary technique that lies close by an ideal/optimal removal of remaining root filling material, this study aimed to test the ability of XP-endo Finisher R to remove filling remnants from curved mesiobuccal canals of maxillary molars, using the PUI technique as a comparison. The null hypotheses for this study were: 1) there is no additional reduction of filling material after using these supplementary cleaning methods, and 2) XP-endo Finisher R does not differ from PUI in relation to the ability of promoting additional cleaning.

Methodology

After approval from the local Research Ethics Committee (CAAE: 51687215.3.0000.5347), 24 mesiobuccal roots of maxillary first molars were selected. A micro-CT scan was performed to obtain an overview of the root canal anatomy and the initial canal volume. Mesiobuccal roots without canal calcification, immature apex, resorption, fracture (or any other defect), and with one or two mesiobuccal canals were selected. Only root canals with curvatures between 20° and 40° and radius of curvature shorter than 10 mm were included.[11,12] The initial root canal volume in each group was analyzed by the Kruskal-Wallis and Dunn's post-hoc tests to ensure sample homogeneity. The values obtained were similar ($P>.05$). After having found similar anatomical parameters for the whole sample, the roots were randomly distributed into two groups, considering the mean values of the curvatures, radius, and initial volume of the root canals.

Teeth were longitudinally sectioned maintaining only the mesiobuccal root and its underlying crown. All the procedures were performed by a single trained operator. Treatment, re-treatment, and supplementary disinfection were restricted only to the main mesiobuccal (MB1) canal. The operator prepared the access cavity, performed crown enlargement with an LA AXXESS bur (SybronEndo, West Collins, Orange, CA, USA) and instrumented the root canal. The initial apical file was a #10 K-file, and the canal was shaped using Wave One Gold primary (#25.07) at the working length (1 mm short of the apical foramen). Canal patency was maintained with a #10 K-file and irrigation with 2.5% sodium hypochlorite, and final flush was done with 17% EDTA and distilled water. The canals were dried and filled with gutta-percha points and AH Plus Sealer (Dentsply Sirona Endodontics, Ballaigues, Switzerland) using the lateral

compaction filling technique. The samples were temporarily restored with Cavit™ (3M, St Paul, MN, USA) and incubated for 30 days at 37 °C and 100% humidity. Re-treatment procedures were performed by removing the previous filling material from the canal using an LA AXXESS bur (SybronEndo) at the first 3 mm of the canal, Wave One Gold primary (#25.07), and Wave One Gold medium (#35.06) up to the working length, and with a brushing motion towards the canal walls. Irrigation was performed with 10 mL of 2.5% sodium hypochlorite after each instrument change, followed by 2 mL of 17% EDTA and 2 mL of distilled water.

After re-treatment procedures, the samples were scanned on a micro-CT device (inspeXio SMX-90CT Plus, Shimadzu Benchtop Microfocus X-Ray CT System, SHIMADZU Corporation, Tokyo, Japan), with rotation around the vertical axis, operated at 70 kV and 100 mA, and image voxel size of 0.0013 mm/pixel. To obtain the baseline volume of the remaining filling material (in mm^3), the micro-CT images were imported to Image J software (National Institutes of Health, USA). This software was used to run the images of the root canal from the cementoenamel junction to the apex.

The samples were then randomly divided into two groups (n =12 in each), according to the supplementary cleaning approach using PUI and XP-endo Finisher R (FKG, La Chaux-de-Fonds, Switzerland) (Figure 1). The supplementary cleaning protocol for both groups was adapted from a previous study.[13]

In the XP-endo Finisher R group, the instrument was inserted in a contra-angle handpiece (X-Smart Plus, Dentsply, Maillefer), cooled (Endo-Frost; Roeko, Langenau, Germany), and removed from the plastic tube in rotation mode. The instrument was inserted into the canal without rotation and then rotated (800 rpm and 1 Ncm) using light in-and-out movements up to the working length for approximately 20 s. This procedure was repeated three times/cycles (Figure 1).

In the PUI group, an E1-Irrisonic ultrasonic tip (Helse Dental Technology, Santa Rosa de Viterbo, Brazil) was mounted on an ultrasonic unit (Piezon 150, Electron Medical Systems, Nyon, Switzerland) and inserted into the root canal at approximately 2 mm shorter of the working length and activated for 20 s. This procedure was repeated three times/cycle (Figure 1).

An experienced operator performed all supplementary cleaning procedures in a heated cabinet at 37 °C. A digital ceramic tower heater regulated and controlled the temperature (HPQ15C-EA, Hunter, Marietta, USA).

After using the supplementary cleaning approaches, the samples were scanned on a micro-CT scanner for the second time using the same parameters described before. The images were 3D reconstructed and the final volume of the remaining filling material was

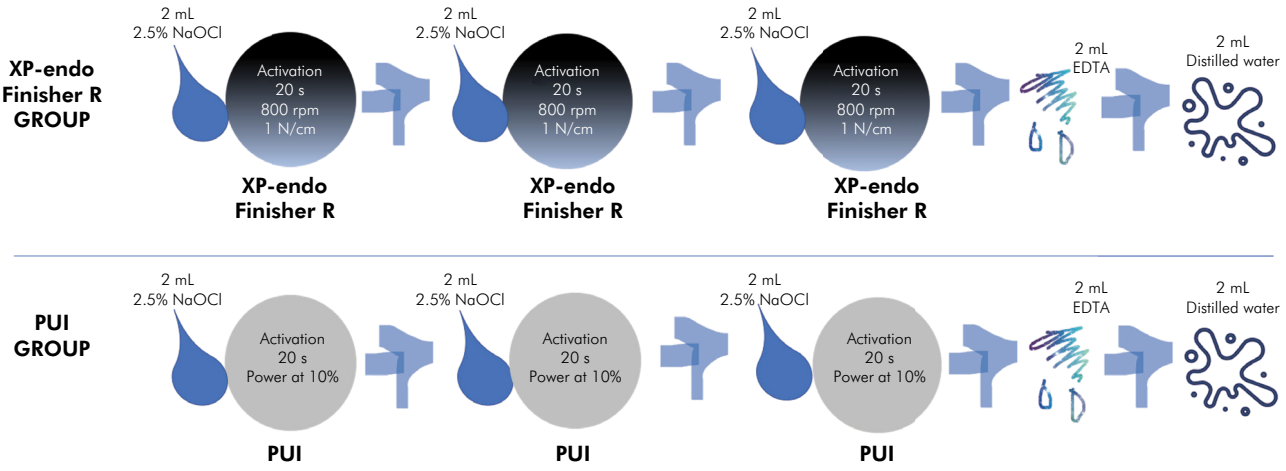

Figure 1. Protocol of supplementary cleaning methods used for XP-endo Finisher R and PUI.

measured (in mm^3). The percentage of filling material reduction was calculated considering the final volume in relation to the baseline. The volume of filling material was quantified using CTAN version 1.14.4 (Bruker-microCT) After volumetric analysis and 3D image reconstruction, the specimens were aligned and the apical and cervical sections were standardized for later binarization with thresholding of representative pixels of the material. Quantitative 3D evaluation of the root canal filling volume was obtained using the plug-in 3D analysis tool. The assessor was blinded to the study groups.

Data analysis

Student's paired t-test was used to compare the baseline volume with the final filling material volume in each group. An unpaired t-test compared the percentage of filling material reduction between groups. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) v.20 (IBM SPSS Inc., Chicago, USA). Statistical power was set at $\alpha = 5\%$.

Results

Table summarizes the results. Within-group comparison showed that both supplementary cleaning tested protocols significantly reduced the amount of remaining filling material (XP-endo Finisher R, p =0.0035; PUI, p =0.0120). Moreover, XP-endo Finisher R had a higher percentage of reduction of filling material than PUI (p = 0.0195). Figure 2 illustrates the results.

Table. Mean and standard deviation (±SD) of reduction (%) and volume (mm^3) of remaining filling material at baseline (after re-treatment) and at the final micro-CT analysis (after supplementary cleaning procedures) of XP-endo Finisher R and PUI.

Variable	XP-endo Finisher R	PUI
Baseline volume (mm^3)	0.060 ± 0.047^{a}	0.064 ± 0.052^{a}
Final volume (mm^3)	0.042 ± 0.036^{b}	0.054 ± 0.044^{b}
Reduction (%)	31.828 ± 15.641^{A}	16.577 ± 10.434^{B}

*Lowercase letters indicate statistical differences in the same column, paired t-test ($p < 0.05$). Uppercase letters indicate statistical differences in the same row, unpaired t-test ($p < 0.05$).

Discussion

This *in vitro* study used micro-CT analysis to measure the volume (mm^3) of remaining filling material after using XP-endo Finisher R (or PUI) as a supplementary cleaning method in extracted human teeth. Our first null hypothesis was rejected because both methods reduced the volume of the remaining filling material, when compared to baseline volumes (after re-treatment procedures) and to the final volume (after supplementary cleaning). Our second null hypothesis was also rejected because XP-endo Finisher R promoted higher additional cleaning: 31.82% of material reduction compared to 16.57% promoted by PUI. This experiment had less than 5% of chance to falsely reject the null hypotheses (Type I error).

Although the differences in the experiments (techniques for re-treatment, use of solvents, type of canal, root third evaluated, etc.), previous studies have also shown that the supplementary cleaning step with the XP-endo Finisher R instrument is associated with favorable percentages of additional filling material removal, for instance, 38%,[14] 42%,[15] and 60%.[6] A recent study has shown that XP-endo Finisher R instruments were associated with greater root filling removal in oval-shaped canals (32.79%) when compared to PUI (12.81%).[7] These values are in line with our findings, as we found a similar percentage for curved canals: 31.82% for XP-endo Finisher R and 16.57% for PUI. In another published study, six out 35 canals in which XP-endo Finisher R was used had complete removal of filling material.[14]

The increased ability of XP-endo Finisher R instrument to additionally remove filling material, as demonstrated in this study, when compared to the PUI technique, can be attributed to its change in dimension due to the variation in temperature. At the same time that the rotary instrument agitates the irrigating solution, it also expands. When the instrument expands, it consequently becomes more adjusted to the root canal, touching and abrading the canal walls, displacing the filling material. The PUI technique does not touch the canal wall; instead, it only activates the irrigating solution.[7,16] In addition, the XP-endo Finisher R has an off-centered rotation, and it is non-tapered, which allows it to reach the canal walls. This mechanical action of XP-endo

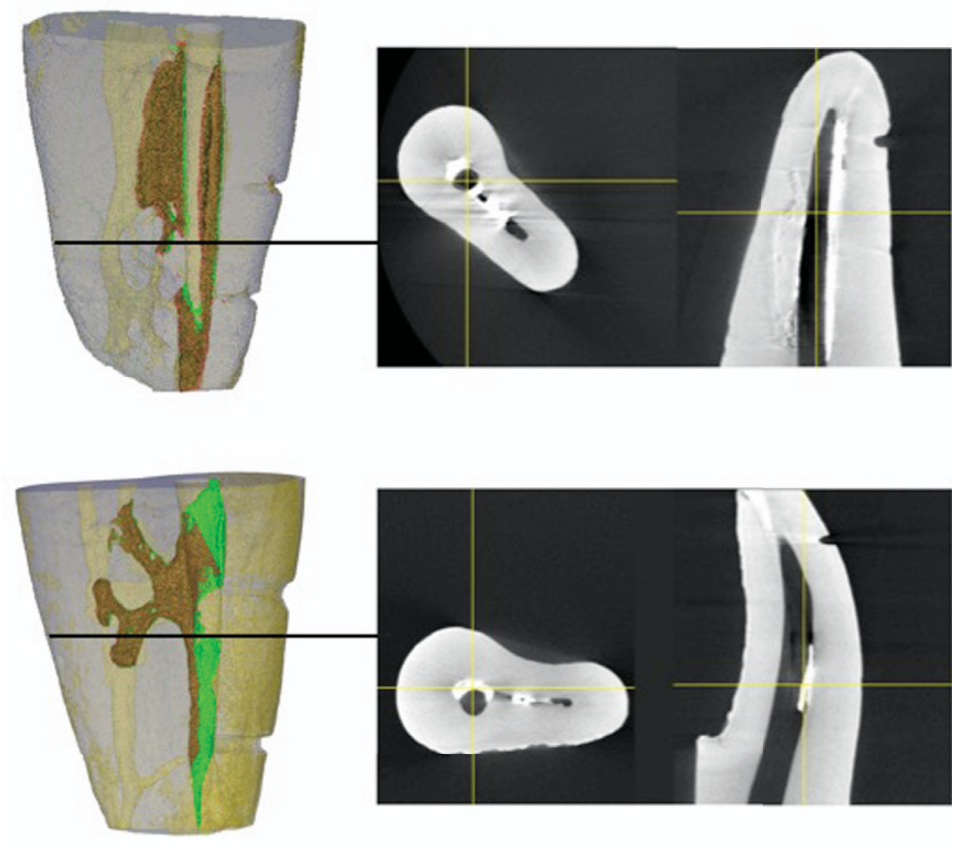

Figure 2. 3D reconstruction with superimposed images (before and after supplementary cleaning protocol); and 2D views after supplementary cleaning protocols of two representative samples: PUI group (at the top), and XP endo Finisher R groups (at the bottom). The position of these images was chosen with the aim of illustrating the greatest amount of remaining filling material. Please notice that the position of the PUI group is rotated and the position of the XP endo Finisher R is straight (evidencing the curvature of the root).

Finisher R is important to displace the endodontic sealer from the canal walls, which is more difficult than displacing gutta-percha remnants.[17] Perhaps, the increased removal of endodontic sealer was the reason for the higher efficacy of XP-endo Finisher R instruments when compared to the PUI technique.

Some strengths of this study were: 1) we used PUI as a comparative technique that has proven to reduce the remnants of filling material;[4,8,10,18] 2) the baseline volume (after re-treatment) of filling material was statistically similar between groups, reducing the bias introduced by the anatomical features;[7] and 3) we chose mesiobuccal canals of maxillary molars[19] because they represent a challenge for proper cleaning during re-treatment, given that they are usually curved and have different axial configurations (oval, circular, triangular) depending on the root third.[20,21]

The limitations of this study were the reduced possibility to extrapolate the findings to patients, just as any other *in vitro* experiment, and the impossibility to know what would be the 'acceptable' volume of remaining filling material that could be compatible with periapical health. Despite the fact that XP-endo Finisher R had a relatively good percentage (~32%) of supplementary reduction of material, this represents only 0.01 mm^3 (mean) of filling material. For size comparison, a strand of human hair can measure 0.01 mm in diameter.[22] But, if the filling material remains compacted into the anatomical complexities of the canal or at the entrance of dentinal tubules, even a very small volume of material may harbor microorganisms, which will negatively interfere with the endodontic outcomes. Therefore, implications of filling material remnants for root canal disinfection

and for root canal re-treatment outcome are still unclear. In this way, clinical studies using long-term cone beam computed tomography to investigate clinical and radiographic outcomes after XP-endo finisher R instrumentation will be welcome.

Conclusion

This *in vitro* study found that both supplementary methods for root canal cleaning additionally improved the removal of root filling material from curved mesiobuccal canals of maxillary molars, and also that the XP-endo Finisher R instrument was approximately twice more efficient than PUI technique.

Acknowledgments

This study was approved by the Research Ethics Committee of the University where the study was developed (CAAE: 51687215.3.0000.5347).

References

1. Das S, De Ida A, Das S, Nair V, Saha N, Chattopadhyay S. Comparative evaluation of three different rotary instrumentation systems for removal of gutta-percha from root canal during endodontic retreatment: An in vitro study. J Conserv Dent. 2017 Sep-Oct;20(5):311-6. https://doi.org/10.4103/JCD.JCD_132_17
2. Siqueira JF Jr. Aetiology of root canal treatment failure: why well-treated teeth can fail. Int Endod J. 2001 Jan;34(1):1-10. https://doi.org/10.1046/j.1365-2591.2001.00396.x
3. Azim AA, Griggs JA, Huang GT. The Tennessee study: factors affecting treatment outcome and healing time following nonsurgical root canal treatment. Int Endod J. 2016 Jan;49(1):6-16. https://doi.org/10.1111/iej.12429
4. Crozeta BM, Souza LC, Silva-Sousa YTC, Sousa-Neto MD, Jaramillo DE, Silva RM. Evaluation of passive ultrasonic irrigation and GentleWave system as adjuvants in endodontic retreatment. J Endod. 2020 Sep;46(9):1279-85. https://doi.org/10.1016/j.joen.2020.06.001
5. Zuolo AS, Zuolo ML, Bueno CES, Chu R, Cunha RS. Evaluation of the efficacy of TRUShape and Reciproc file systems in the removal of root filling material: an ex vivo micro-computed tomographic study. J Endod. 2016 Feb;42(2):315-9. https://doi.org/10.1016/j.joen.2015.11.005
6. Silva EJ, Belladonna FG, Zuolo AS, Rodrigues E, Ehrhardt IC, Souza EM, et al. Effectiveness of XP-endo Finisher and XP-endo Finisher R in removing root filling remnants: a micro-CT study. Int Endod J. 2018 Jan;51(1):86-91. https://doi.org/10.1111/iej.12788
7. De-Deus G, Belladonna FG, Zuolo AS, Cavalcante DM, Carvalhal JC, Simões-Carvalho M, et al. XP-endo Finisher R instrument optimizes the removal of root filling remnants in oval-shaped canals. Int Endod J. 2019 Jun;52(6):899-907. https://doi.org/10.1111/iej.13077
8. Bernardes RA, Duarte MA, Vivan RR, Alcalde MP, Vasconcelos BC, Bramante CM. Comparison of three retreatment techniques with ultrasonic activation in flattened canals using micro-computed tomography and scanning electron microscopy. Int Endod J. 2016 Sep;49(9):890-7. https://doi.org/10.1111/iej.12522
9. Jiang S, Zou T, Li D, Chang JW, Huang X, Zhang C. Effectiveness of sonic, ultrasonic, and photon-induced photoacoustic streaming activation of NaOCl on filling material removal following retreatment in oval canal anatomy. Photomed Laser Surg. 2016 Jan;34(1):3-10. https://doi.org/10.1089/pho.2015.3937
10. Silveira SB, Alves FR, Marceliano-Alves MF, Sousa JC, Vieira VT, Siqueira Junior JF, et al. Removal of root canal fillings in curved canals using either Mani GPR or HyFlex NT followed by passive ultrasonic irrigation. J Endod. 2018 Feb;44(2):299-303.e1. https://doi.org/10.1016/j.joen.2017.09.012
11. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971 Aug;32(2):271-5. https://doi.org/10.1016/0030-4220(71)90230-1
12. Pruett JP, Clement DJ, Carnes Junior DL. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod. 1997 Feb;23(2):77-85. https://doi.org/10.1016/S0099-2399(97)80250-6
13. Bao P, Shen Y, Lin J, Haapasalo M. In Vitro efficacy of XP-endo Finisher with 2 different protocols on biofilm removal from apical root canals. J Endod. 2017 Feb;43(2):321-5. https://doi.org/10.1016/j.joen.2016.09.021
14. Machado AG, Guilherme BP, Provenzano JC, Marceliano-Alves MF, Gonçalves LS, Siqueira Junior JF, et al. Effects of preparation with the Self-Adjusting File, TRUShape and XP-endo Shaper systems, and a supplementary step with XP-endo Finisher R on filling material removal during retreatment of mandibular molar canals. Int Endod J. 2019 May;52(5):709-15. https://doi.org/10.1111/iej.13039

15. Campello AF, Almeida BM, Franzoni MA, Alves FR, Marceliano-Alves MF, Rôças IN, et al. Influence of solvent and a supplementary step with a finishing instrument on filling material removal from canals connected by an isthmus. Int Endod J. 2019 May;52(5):716-24. https://doi.org/10.1111/iej.13047
16. Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J. 2007 Jun;40(6):415-26. https://doi.org/10.1111/j.1365-2591.2007.01243.x
17. Kosti E, Lambrianidis T, Economides N, Neofitou C. Ex vivo study of the efficacy of H-files and rotary Ni-Ti instruments to remove gutta-percha and four types of sealer. Int Endod J. 2006 Jan;39(1):48-54. https://doi.org/10.1111/j.1365-2591.2005.01046.x
18. Cavenago BC, Ordinola-Zapata R, Duarte MA, Carpio-Perochena AE, Villas-Bôas MH, Marciano MA, et al. Efficacy of xylene and passive ultrasonic irrigation on remaining root filling material during retreatment of anatomically complex teeth. Int Endod J. 2014 Nov;47(11):1078-83. https://doi.org/10.1111/iej.12253
19. Delai D, Jardine AP, Mestieri LB, Boijink D, Fontanella VR, Grecca FS, et al. Efficacy of a thermally treated single file compared with rotary systems in endodontic retreatment of curved canals: a micro-CT study. Clin Oral Investig. 2019 Apr;23(4):1837-44. https://doi.org/10.1007/s00784-018-2624-6
20. Hargreaves K, Berman L. Tooth morphology, isolation, and access preparation. Cohen's Pathways of the Pulp. 11th ed. Canada: Expert Consult Hardcover Elsevier; 2015.
21. Ordinola-Zapata R, Martins JN, Niemczyk S, Bramante CM. Apical root canal anatomy in the mesiobuccal root of maxillary first molars: influence of root apical shape and prevalence of apical foramina - a micro-CT study. Int Endod J. 2019 Aug;52(8):1218-27. https://doi.org/10.1111/iej.13109
22. Birch MP, Messenger JF, Messenger AG. Hair density, hair diameter and the prevalence of female pattern hair loss. Br J Dermatol. 2001 Feb;144(2):297-304. https://doi.org/10.1046/j.1365-2133.2001.04018.x