

The Effect of XP-endo Finisher R and PIPS Technique Using Er: YAG Laser on Removal of Gutta-percha in Root Canals Obturated with Two Different Obturation Techniques

İki Farklı Obtürasyon Tekniği ile Doldurulan Kök Kanallarından Güta-perka Uzaklaştırılmasında XP-endo Finisher R ve Er:YAG Lazer ile PIPS Tekniğinin Etkisi

Gözde AKBAL DİNÇER^a(ORCID-0000-0001-5188-334X), Ali TÜRKYILMAZ^b(ORCID-0000-0003-0641-0062), Dilek HANÇERLİOĞULLARI^b(ORCID-0000-0002-0404-1200), Gülşen ERMİŞ^b(ORCID-0000-0002-4026-4532), Ali ERDEMİR^b(ORCID-0000-0003-1140-3887)

^aIstanbul Okan University, Faculty of Dentistry, Department of Endodontics, İstanbul, Türkiye

^aIstanbul Okan Üniversitesi Diş Hekimliği Fakültesi Endodonti AD, İstanbul, Türkiye

^bKırıkkale University, Faculty of Dentistry, Department of Endodontics, Kırıkkale, Türkiye

^bKırıkkale Üniversitesi Diş Hekimliği Fakültesi Endodonti AD, Kırıkkale, Türkiye

ABSTRACT

Background: The purpose of this study is to compare the efficacy of XP-endo finisher R file and PIPS technique using Er: YAG laser on gutta-percha removal in root canals obturated with two obturation techniques.

Methods: The root canals of sixty single-rooted teeth were prepared with ProTaper Next Rotary instruments up to X3 (Dentsply, Ballaigues, Switzerland). Half of the root canals were obturated with cold lateral condensation technique and the other half with System B technique (Kerr Corporation, CA, USA) and BioRoot RCS sealer (Setodont, Louisville, USA) was used in all groups as a root canal sealer. After one week, all samples were retreated with Protaper Universal retreatment instruments (Dentsply Maillefer, Ballaigues, Switzerland) and enlarged to ProTaper Next X5 File at the working length. Both groups were divided into 3 subgroups according to the additional cleaning methods: control group without an additional cleaning method, XP-endo Finisher R or PIPS technique using Er: YAG laser. Finally, all teeth were split longitudinally and images were taken using an operation microscope (Carl Zeiss, Heidelberg, Germany). The images were analyzed by Image J program. Two-way ANOVA and Tukey tests were used for statistical analysis.

Results: There was a statistically significant difference between the canal filling techniques applied in the evaluation of remnants ($p=0.010$). There was no significant difference between additional cleaning methods ($p=0.196$).

Conclusion: Within the limitations of this study, cleanliness is more difficult in root canals obturated with System B technique. Use of additional cleaning method was not effective in removal of root canal filling materials.

Keywords: XP-endo Finisher R, Er: YAG laser, PIPS, Retreatment, BioRoot RCS, Endodontics

ÖZ

Amaç: Bu çalışmanın amacı, iki farklı obtürasyon tekniği ile doldurulan kök kanallarında güta-perka çıkarılmasında Er: YAG lazer kullanılarak PIPS tekniğinin ve XP-endo Finisher R eğesinin etkinliğini karşılaştırmaktır.

Yöntemler: Altmış tek köklü dişin kök kanalları X3'e kadar (Dentsply, Ballaigues, İsviçre) ProTaper Next Rotary aletleri ile şekillendirildi. Kök kanallarının yarısı soğuk lateral kondenzasyon tekniği ile diğer yarısı System B tekniği (Kerr Corporation, CA, ABD) ile dolduruldu ve tüm gruplarda kök kanal patı olarak BioRoot RCS patı (Setodont, Louisville, ABD) kullanıldı. Bir hafta sonra tüm kök kanallarından Protaper Universal retreatment eğeleri (Dentsply, Ballaigues, İsviçre) kullanılarak gutta perka uzaklaştırıldı ve kök kanalları çalışma uzunluğunda ProTaper Next X5' kadar şekillendirildi. Her iki grup da ek temizleme yöntemlerine göre 3 alt gruba ayrıldı: Ek temizleme yöntemi olmayan kontrol grubu, XP-endo Finisher R veya Er: YAG lazer kullanılarak PIPS tekniği. Son olarak tüm dişler uzunlamasına ayrıldı ve operasyon mikroskobu (Carl Zeiss, Heidelberg, Almanya) kullanılarak görüntüler alındı. Görüntüler Image J programı ile analiz edildi. İstatistiksel analiz için iki yönlü ANOVA ve Tukey testleri kullanıldı.

Bulgular: Güta perka uzaklaştırılmasında uygulanan kanal doldurma teknikleri arasında istatistiksel olarak anlamlı fark vardı ($p=0.010$). Ek temizleme yöntemleri arasında anlamlı bir fark yoktu ($p=0,196$).

Sonuç: Bu çalışmanın sınırları dâhilinde System B tekniği ile doldurulan kök kanallarında güta perka uzaklaştırmak daha zordur. Kanal dolgu malzemelerinin çıkarılmasında ek temizleme yönteminin kullanılması etkili olmamıştır.

Anahtar Kelimeler: XP-endo Finisher R, Er: YAG lazer, PIPS, Retreatment, BioRoot RCS, Endodonti

Introduction

Root canal treatment is a safe procedure that aims to keep the tooth with decay or periapical lesion in the mouth without pain, with high success rate between 86-93 percent.¹ However, in some cases, success may not be achieved, infection continues in the periapical tissues, causing the patient's symptoms to persist. Nonsurgical retreatment is suggested in order to reconstruct healthy periapical tissues after secondary infection of the obturated root canals in consequence of inadequate root canal treatment or coronal-apical leakage.²

Adequate removal of primary root canal filling materials is the most important step during retreatment to reach residual bacteria. Although there are many retreatment techniques (hand files, ultrasonic devices, nickel-titanium (NiTi) rotary and reciprocating systems, solvents) and most of them are found to be effective, it has been shown that the complete removal of filling materials could not be achieved.³ As a result of this, while the success rate in the primary root canal treatment is very high, the success rate in retreatment falls between 60-85 percent.¹

Hand file usage for gutta-percha removal can be difficult and takes a lot of time and effort, particularly if the root canal filling material is well condensed.⁴ Accordingly, the use of rotary files is the most common technique for removal of root canal filling materials. ProTaper Universal retreatment system (Dentsply Maillefer, Ballaigues, Switzerland) is specially designed and widely used retreatment system, containing 3 instruments (D1, D2 and D3). All three instruments have different tapers and tip diameters (0.09/0.30 mm for coronal, 0.08/0.25 mm for middle and 0.07/0.20 mm for apical portion) for removal of the root canal filling materials in different portions of root canals.

Additionally, supplementary methods have been designed to raise the removal efficiency of obturation materials.⁵ One of these supplementary methods is laser activated approach known as photon induced photo acoustic streaming (PIPS). PIPS is a protocol which Er: YAG laser is used with 20 mJ energy and 50 μ s pulse rate. Shock waves and intracanal cavitations are produced as a result of photo-acoustic-mechanic effect in the root canal system. The use of PIPS technique has been informed to improve the removal efficacy of root canal filling materials.⁶

Gönderilme Tarihi/Received: 26 Ekim, 2022

Kabul Tarihi/Accepted: 10 Ocak, 2024

Yayınlanma Tarihi/Published: 26 Nisan, 2024

Atf Bilgisi/Cite this article as: Akbal Dinçer G, Türkyılmaz A, Hançerlioğulları D, Ermiş G, Erdemir A. The Effect of XP-endo Finisher R and PIPS Technique Using Er: YAG Laser On Removal of Gutta-percha in Root Canals Obturated With Two Different Obturation Techniques. Selcuk Dent J 2024;11(1): 23-26 Doi: 10.15311/ selcukdentj.1188720

Sorumlu yazar/Corresponding Author: Gözde AKBAL DİNÇER

E-mail: gozdeakbal1@gmail.com

Doi: 10.15311/ selcukdentj.1188720

Recently, the XP-endo Finisher (FKG Dentaire, La Chaux-de-Fonds, Switzerland), another finishing file, was presented for use as a final step in root canal disinfection. The non-tapered rotary NiTi instruments, made of a MaxWire alloy with #25 tip, are straight at room temperature (M-phase), could modify their shape owing to their molecular memory to the A-phase, when they are placed to the root canal and subjected to the body temperature. It is claimed that areas that cannot be reached with standard instruments can be accessed and cleaned with the A-phase shaped files. The XP-endo Finisher R (FKG Dentaire) which has a core diameter larger than the XP-endo Finisher, is a novel variation. This feature makes it slightly stiffer and also more effective in removing remnants in root canals cleaving to the canal walls, especially hard-to-touch areas such as curved and oval areas.

PIPS technique with Er: YAG laser and XP-endo finisher R have been shown to be useful as an additional cleaning method in gutta-percha removal⁶⁻¹²; however, there is no study compared with each other in removal efficiency of obturation materials in the literature. Therefore, the purpose of this study is to compare the efficacy of PIPS technique and XP-endo finisher R files in removal of root canal filling materials from the root canals obturated with System B and cold lateral condensation technique.

Materials and Methods

Specimen Selection and Initial Preparation

February 2, 2021 dated and 2021.01.19 numbered ethics committee approval certificate from the Kirikkale University Non-interventional Research Ethics Committee, Turkey, was obtained for this study. The sample size calculation was performed using the G* Power v3.1 (Heinrich Heine, Universitat Dusseldorf, Dusseldorf, Germany) with 0,05 alpha-type error and beta power of 0.95.'

Sixty straight single-rooted teeth with completely formed roots and without internal resorption or calcifications were used in this study. Calculus and soft tissues were eliminated from the root surfaces with a periodontal scaler. The samples were decoronated to leave a 16-mm root length for standardization. The working length (WL) was determined 1 mm shorter than the length at which it appears at the apical foramen by inserting a #10 K-file into the root canal. The root canals were prepared with ProTaper Next Rotary instruments (Dentsply, Ballaigues, Switzerland) up to X3 at the WL and irrigated with 2 ml %2.5 NaOCl solution after each instrument. A final irrigation with 5 ml of %2.5 NaOCl, distilled water and %17 EDTA, was performed respectively. Then the root canals were dried using paper points.

After the preparation, 60 samples were divided into two groups according to the obturation techniques and half of the root canals were obturated with cold lateral condensation and the other half with System B technique (Kerr Corporation, CA, USA). BioRoot RCS sealer (Setodont, Louisville, USA), mixed in accordance with the manufacturer's instructions, was used in both groups as a root canal sealer. The samples were stored at 37°C, %100 humidified atmosphere for 1 week for the sealer to set completely.

After 1 week, retreatment was performed with Protaper Universal retreatment instruments which were used (300 rpm with 2 N/cm torque) in a crown-down motion. The root canals were irrigated with 2 ml of 2.5% NaOCl solution during retreatment procedure and then all root canals were instrumented to ProTaper Next X5 File at the WL.

Supplementary cleaning approach

Both groups were divided into 3 subgroups according to the supplementary cleaning approach.

Control group: An additional cleaning method was not used. 5ml 2.5% NaOCl solution is delivered using a syringe with 27 gauge needle.

XP-endo Finisher R: The root canals, positioned in the water bath with constant temperature 37°C, were filled with 2.5% NaOCl and the XP-endo Finisher R was activated with 7-8 mm lengthwise movements up to the WL for 1 min (800 rpm and 1 Ncm). Each instrument was used in five canals and then discarded.

PIPS technique using Er: YAG laser (PIPS): Each canal was filled with 2.5% NaOCl and the optical fibre was placed approximately 1 mm below the root canal orifice without touching the inner surface of the

canal wall and activated for 1 min (3x20 sec). When the irrigation solution in the coronal reservoir decreased, the supplemental NaOCl was applied through the root canal. Each specimen was irradiated using a 2940 nm Er: YAG laser (Fotona, Ljubljana, Slovenia), 0.3 W, 15 Hz, and 20 mJ per pulse with 300 µm diameter quartz tip. The pulse duration was 50 µs.

Finally, each root canal was irrigated with 5 ml 2.5% NaOCl in all groups.

Evaluation of residual material

To evaluate the residual filling material, the teeth were grooved buccolingually using a double-sided diamond disk and split longitudinally using an Ochsenbein chisel. Both root halves were photographed at x10 magnification using an operation microscope (Zeiss, Heidelberg, Germany). The images were transferred to a computer and analyzed by Image J program. The results were calculated by proportioning the area of residual filling materials on all root canal surfaces to the area of all root canals.

Statistical Analysis

Statistical analysis were made using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA) software program. The data were analyzed with two-way analysis of variance (ANOVA), one-way ANOVA, post hoc Tukey multiple comparison test and Independent Samples t test. P value was established at 0.05.

Results

The mean and standard deviations of the amount of residual gutta-percha are presented in Table 1. When the cleaning methods were ignored, the root canals obturated with cold lateral condensation technique have significantly less gutta-percha remnants than the root canals obturated with System B (p=0.010) after retreatment. When the obturation techniques were ignored, there was no significant difference between the subgroups in cleanliness effect (p=0.196), but XP Endo Finisher R had the lowest remnant rates.

Table 1. Intergroup and intragroup comparison of mean ± standart deviation of residual values of gutta percha

Groups	Lateral Condensation			System B		
	Mean ± SD	95% Confidence Interval		Mean ± SD	95% Confidence Interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
Control	0,168 ± 0,177 ^{ab}	0,042	0,295	0,225 ± 0,155 ^{ab}	0,115	0,338
XPEFR	0,094 ± 0,066 ^{ab}	0,047	0,141	0,170 ± 0,099 ^{ab}	0,100	0,240
PIPS	0,128 ± 0,134 ^{ab}	0,033	0,224	0,270 ± 0,125 ^{ab}	0,178	0,357
Total	0,130 ± 0,133 ^a	0,081	0,180	0,221 ± 0,130 ^b	0,172	0,270

There was no significant difference between the cleaning methods in terms of remaining gutta-percha in either cold lateral condensation technique (p=0.467) or System B filling technique (p=0.250).

No significant difference was found in the pairwise comparison of filling methods in the control group and XP-endo Finisher R group (p=0.453, p=0.058). A significant difference was only found in the pairwise comparison of filling methods in the PIPS group (p=0.027).

Discussion

Nickel-Titanium (NiTi) rotary systems are frequently used for endodontic retreatment procedures because they are safe, effective and speedy (13). One of the specially designed rotary instrumentation systems used for endodontic retreatment is the ProTaper Universal Retreatment (PTR) System. This system, whose efficacy in removal of the root canal filling material has been well documented in the literature,¹³ was used in this study. In addition, as recommended in the literature, the retreatment procedure was completed with ProTaper Next X5 (50/0.06) instrument that two size larger than enlargement size of primary preparation (30/0.07) to reduce the amount of residual obturation materials in the root canal.¹⁴

Several techniques have been used to evaluate remaining root canal filling materials on the root canal walls after non-surgical endodontic retreatment, including radiography, longitudinal sectioning before microscopic or photographic analysis, and micro-computed

tomography scanning. Similar to the previous studies^{15,16}, in this study, the roots were separated vertically to evaluate the residual root canal filling material under the operation microscope. It has been reported that this method offers advantages over other techniques due to its ease of use and the constant distance between the object and the device and provides image standardization.^{15,17} This methodology has been shown to be more effective than radiographic techniques to investigate remaining filling materials.^{15,17} In addition, Image J program, used in some previous endodontic studies, has been stated to fulfill most routine image processing and analysis needs.¹⁸ This software was used in the present study, since it is non-destructive and gives accurate results without the need for any intervention in the evaluation of remaining gutta-percha percentages.

Cold lateral condensation technique is the most widely used technique for root canal filling worldwide. On the other hand, the studies have indicated that this technique does not ensure a successful seal of the root canals.^{19,20} Warm vertical compaction is able to create an intimate obturation with good three dimensional sealing with plasticized gutta-percha condensed into the root canals.²⁰ In this study, cold lateral condensation and system B techniques were compared for ease of removal during retreatment and a statistically significant difference was found between them, in agreement with other studies.^{21,22} More remnants were observed in the root canal walls obturated with System B technique ($p=0.01$). This may be due to the ability of System B technique to plasticize the gutta-percha and thus allow better compaction of the material into the root canal irregularities.

The issue of the present study was the efficacy of two novel supplementary cleaning approaches in removing filling materials from the root canals during retreatment. Residual filling materials were remained in all samples. This finding is in consistency with previous reports that also indicated that no retreatment technique was capable of removing entire filling material from the root canal walls^{3,23} and the need to develop additional methods.

In the study by Tavares et al.¹², XP-Endo Finisher R was shown to provide a better cleaning than R1-Clearsonic, which is an ultrasonic tip produced especially to complement cleaning during retreatment. It was stated that XP-Endo Finisher R provides a better cleaning than passive ultrasonic irrigation.⁹ Also in previous studies, it has been determined that Xp-Endo Finisher R contributes to gutta-percha removal as an additional cleaning method.^{7,11,24} In a study investigating the effectiveness of XP-endo Finisher R in the removal of mineral trioxide aggregate, bioceramic, and epoxy resin-based sealers, XP-endo Finisher R file improved removal only in the AH Plus group.²⁵ In this study, there was no significant difference between the subgroups in cleanliness effect, however the lowest amount of gutta-percha was determined in the group that received additional cleaning with XP Endo Finisher R.

The effect of PIPS technique using Er: YAG laser on smear layer removal has been investigated in many studies. It has been demonstrated that activation of NaOCl and EDTA solutions by PIPS technique using Er: YAG laser with parameters of 0.3 W, 15 Hz and 20 mJ were removed smear layer effectively.^{26,27} However, there are few studies investigating the gutta percha removal efficacy of the PIPS technique. In one of these studies, it was determined that PIPS was more effective than ultrasonic and passive ultrasonic irrigation in gutta-percha removal.²⁸ The results of this study contradict with the results of our study. On the other hand, in another study, it was stated that there was no difference between PIPS technique using Er:YAG laser and conventional needle irrigation.²⁹ In the other study, Er: YAG laser application with optic fiber plain tip after the use of rotary instruments had a significantly higher removal of filling remnants than using Er:YAG laser with PIPS fiber tip.³⁰ The results of aforementioned studies are in accordance with our study. According to the results of this study, no statistically significant difference was found between the activation with PIPS and conventional irrigation according to the amount of residual gutta-percha. In addition, there was no statistically significant difference between XP-Endo Finisher R and PIPS technique in terms of gutta percha removal. This is the first study to compare the gutta percha removal efficiency of PIPS and XP-Endo Finisher R. Therefore, there is no study to compare our results.

Conclusion

- It can be accomplished that under the limitations of this study cleanliness is more difficult in root canals obturated with System B obturation technique.
- Neither the XP-Endo Finisher R nor the PIPS technique were effective in completely removing the residual root canal filling material.
- More effective root canal cleaning techniques should continue to be investigated, as any amount of remaining debris or bacteria will be sufficient to substantially jeopardize retreatment.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu makale, sempozyum ya da kongrede sunulan bir tebliğin içeriği geliştirilerek ve kısmen değiştirilerek üretilmemiştir.

Bu çalışma, yüksek lisans ya da doktora tezi esas alınarak hazırlanmamıştır.

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

This article is not the version of a presentation.

This article has not been prepared on the basis of a master's/ doctoral thesis.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı - ithenticate

Etik Bildirim / Ethical statement

ethic.selcukdentaljournal@hotmail.com

Telif Hakkı & Lisans / Copyright & License

Yazarlar dergide yayınlanan çalışmalarının telif hakkına sahiptirler ve çalışmalarını CC BY-NC 4.0 lisansı altında yayımlanmaktadır.

Finansman / Grant Support

Yazarlar bu çalışma için finansal destek almadığını beyan etmiştir. | The authors declared that this study has received no financial support.

Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: AT (%50), AE (%50)
Veri Toplanması | Data Acquisition: GAD (%30), DH (%40), GE (%30)
Veri Analizi | Data Analysis: AT (%100)
Makalenin Yazımı | Writing up: GAD (%70), AE (%30)
Makale Gönderimi ve Revizyonu | Submission and Revision: GAD (%100)

REFERENCES

- Ng YL, Mann V, and Gulabivala K, A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. *Int Endod J.* 2011;44(7):610-625.
- Khedmat S, Azari A, Shamshiri AR, Fadae M, Fakhar HB. Efficacy of ProTaper and Mtwo Retreatment Files in Removal of Gutta-percha and GuttaFlow from Root Canals. *Iran Endod J.* 2016;11(3):184-187.
- Zuolo AS, Mello Jr JE, Cunha RS, Zuolo ML, Bueno CES. Efficacy of reciprocating and rotary techniques for removing filling material during root canal retreatment. *Int Endod J.* 2013;46(10):947-53.
- Pinto de Oliveira D, Vicente Baroni Barbizam J, Trope M, Teixeira FB. Comparison between gutta-percha and resilon removal using two different techniques in endodontic retreatment. *J Endod.* 2006;32(4):362-4.
- Alves FR, Marceliano-Alves MF, Sousa JCN, Silveira SB, Provenzano JC, Siqueira Jr, JF. Removal of root canal fillings in curved canals using either reciprocating single-or rotary multi-instrument systems and a supplementary step with the XP-Endo Finisher. *J Endod.* 2016;42(7):1114-1119.
- Cavenago BC, Ordinola-Zapata R, Duarte MAH, del Carpio-Perochena AE, Villas-Boas MH, Marciano MA, Moraes IG. Efficacy of xylene and passive ultrasonic irrigation on remaining root filling material during retreatment of anatomically complex teeth. *Int Endod J.* 2014;47:1078-1083.
- Volponi A, Pelegrine RA, Kato AS, Stringheta CP, Lopes RT, de Sá Silva AS, da Silveira Bueno CE. Micro-computed Tomographic Assessment of Supplementary Cleaning Techniques for Removing Bioceramic Sealer and Gutta-percha in Oval Canals. *J Endod.* 2020;46(12):1901-1906.
- Aksel H, Küçükkaya Eren S, Askerbeyli Örs S, Serper A, Ocak M, Çelik, HH. Micro-CT evaluation of the removal of root fillings using the ProTaper Universal Retreatment system supplemented by the XP-Endo Finisher file. *Int Endod J.* 2019;52(7):1070-1076.
- De-Deus G, Belladonna FG, Zuolo AS, Cavalcante DM, Carvalhal JCA, Simões-Carvalho M, Silva EJNL. XP-endo Finisher R instrument optimizes the removal of root filling remnants in oval-shaped canals. *Int Endod J.* 2019;52(6):899-907.
- Karamifar K, Mehraza N, Pardis P, Saghiri MA. Cleanliness of canal walls following gutta-percha removal with hand files, RaCe and RaCe plus XP-Endo finisher instruments: a photographic in vitro analysis. *Iran Endod J.* 2017;12(2):242.
- Machado AG, Guilherme BPS, Provenzano JC, Marceliano-Alves MF, Gonçalves LS, Siqueira Jr JF, Neves MAS. Effects of preparation with the self-adjusting file, TRUS hape 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;52(5):709-715.
- Tavares SJ, Gomes CC, Marceliano-Alves MF, Guimaraes LC, Provenzano JC, Amoroso-Silva P, Alves FR. Supplementing filling material removal with XP-Endo Finisher R or R1-Clearsonic ultrasonic insert during retreatment of oval canals from contralateral teeth. *Aust Endod J.* 2021;47(2):188-194.
- Rödiger T, Reicherts P, Konietzschke F, Dullin C, Hahn W, Hülsmann M. Efficacy of reciprocating and rotary NiTi instruments for retreatment of curved root canals assessed by micro-CT. *Int Endod J.* 2014;47:942-948.
- Rödiger T, Hausdörfer T, Konietzschke F, Dulin C, Hahn W, Hülsmann M. Efficacy of D-RaCe and ProTaper Universal Retreatment NiTi instruments and hand files in removing gutta-percha from curved root canals: a micro-computed tomography study. *Int Endod J.* 2012;45:580-9.
- 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):1381-4.
- Taşdemir T, Yildirim T, Çelik D. Comparative study of removal of current endodontic fillings. *J Endod.* 2008;34(3):326-9.
- De Carvalho Maciel A, Zaccaro Scelza M. Efficacy of automated versus hand instrumentation during root canal retreatment: an ex vivo study. *Int Endod J.* 2006;39(10):779-84.
- Saghiri MA, Karamifar K, Mehrvazfar P, Asgar K, Gutmann JL, Lotfi M, Garcia-Godoy F. The efficacy of foam cleaners in removing debris from two endodontic instruments. *Quintessence Int.* 2012;43(9):811-7.
- Schafer E and Olthoff G. Effect of three different sealers on the sealing ability of both thermafil obturators and cold laterally compacted Gutta-Percha. *J Endod.* 2002;28(9):638-642.
- Peng L, Ye L, Tan H, Zhou X. Outcome of root canal obturation by warm gutta-percha versus cold lateral condensation: a meta-analysis. *J Endod.* 2007;33(2):106-9.
- Ma J, Al-Ashaw AJ, Shen Y, Gao Y, Yang Y, Zhang C, Haapasalo M. Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from oval root canals: A Micro-computed tomography study. *J Endod.* 2012;38(11):1516-1520.
- Athkuri S, Mandava J, Chalasani U, Ravi RC, Munagapati VK, Chennareddy AR. Effect of different obturating techniques and sealers on the removal of filling materials during endodontic retreatment. *J Conserv Dent.* 2019;22(6):578.
- de Siqueira Zuolo A, Zuolo ML, da Silveira Bueno CE, 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;42(2):315-9.
- Silva EJNL, Belladonna FG, Zuolo AS, Rodrigues E, Ehrhardt IC, Souza EM, De-Deus G. Effectiveness of XP-endo Finisher and XP-endo Finisher R in removing root filling remnants: a micro-CT study. *Int Endod J.* 2018;51(1):86-91.
- Kontogiannis TG, Kerezoudis NP, Kozyrakis K, Farmakis ET. Removal ability of MTA-, bioceramic-, and resin-based sealers from obturated root canals, following XP-endo® Finisher R file: An ex vivo study. *Saudi Endod J.* 2019;9(1):8.
- Ayranci LB, Arslan H, Akcay M, Capar ID, Gok T, Saygili G. Effectiveness of laser-assisted irrigation and passive ultrasonic irrigation techniques on smear layer removal in middle and apical thirds. *Scanning.* 2016;38:121-127.
- Ozbay, Yagiz, and Ali Erdemir. Effect of several laser systems on removal of smear layer with a variety of irrigation solutions. *Microsc Res Tech.* 2018;81(10):1214-1222.
- 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.* 2016.34(1):3-10.
- Dönmez Özkan H, Kaval ME, Özkan G, Yiğit Özer S. Efficacy of Two Different Nickel-Titanium Rotary Systems in Retreatment Procedure With or Without Laser-Activated Irrigation: An In Vitro Study. *Photomed Laser Surg.* 2019;37(8):495-499
- Keleş A, Arslan H, Kamalak A, Akçay M, Sousa-Neto MD, Versiani MA. Removal of filling materials from oval-shaped canals using laser irradiation: a micro-computed tomographic study. *J Endod.* 2015;41.2:219-224