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Original research

Efficiency of ProTaper Universal Retreatment, Reciproc Blue and XP-endo Shaper in the removal of a bioceramic-based root canal filling

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Purpose

This *in vitro* study aimed to assess the performance of ProTaper Universal Retreatment (PTUR), Reciproc Blue (RB), and XP-endo Shaper (XPS) system in the removal of bioceramic root canal filling.

Materials and Methods

Forty-five human single-rooted mandibular premolars were prepared up to 30/.04 and filled with Endosequence BC sealer and BC points before being assigned into three groups (n=15). The root canal fillings were removed until reaching pre-determined working length (WL) with PTUR in group 1, RB in group 2, and XPS in group 3. During the removal of the filling material, apically extruded debris was collected in pre-weighed Eppendorf tubes, and operation time was recorded with a digital chronometer. Reaching the WL and maintaining apical patency were evaluated separately. The data were statistically analyzed using Kruskal Wallis and Mann Whitney U tests.

Results

The mean amount of extruded debris was highest in the PTUR group, although all instruments caused apical extrusion of debris. The mean time for reaching WL was longest for RB and shortest for XPS, with significant differences among the groups ($p<0.05$). Although the difference was not significant ($p=0.799$), in the PTUR group the WL was reached in 93.3% of the samples, which was higher than other groups (86.7%).

Conclusion

All tested systems caused a certain amount of debris extrusion. XPS was associated with less extrusion while regaining more rapid access to the periapical area than PTUR and RB.

Keywords: *Debris extrusion, endodontic retreatment, Endosequence BC sealer, Reciproc Blue, XP-endo Shaper*

Introduction

The non-surgical retreatment is the first option after failure of initial root canal treatment (1). Regaining access to the apical foramen by removing preexisting filling materials for facilitating re-cleaning and re-shaping is one of the main goals of retreatment (2). During endodontic retreatment, obturation materials, tissue remnants, microorganisms, and irrigation solutions might extrude from the apical foramen into the periradicular tissues (3). Debris extrusion may result in postoperative pain, flare-up, and delay in recovery (4, 5). In this sense, while removing the filling materials, using an appropriate instrumentation technique to reduce the amount of apically extruded debris would be advantageous in minimizing postop-

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erative reactions (3). Among various methods advocated for removing the filling materials, Ni-Ti instruments have proven to be effective and time-saving (6-8). However, previous *in vitro* studies have shown that almost all Ni-Ti instruments and techniques used for retreatment may cause debris extrusion to some degree (3, 9-12). The amount of extruded debris could be affected by the design, kinematics, and cutting efficiency of the endodontic instruments (13).

ProTaper Universal Retreatment (PTUR; Maillefer, Dentsply Sirona, Ballaigues, Switzerland) is a well-documented NiTi rotary system specially designed for root-filling removal. PTUR system consists of D1 (30/.09), D2 (25/.08), and D3 (20/.07) instruments with a convex cross-section, variable taper, and diameters at the tip. The active tip of the D1 instrument facilitates its initial penetration into the root canal filling (8). The effectiveness, safety, and rapidness of PTUR in retreatment cases have been demonstrated in previous studies (6, 8, 14). Recently, nickel-titanium (Ni-Ti) instruments with different designs, alloying processes, and kinematics have been introduced. Depending on the technological developments, apical extrusion studies have tended to focus on root canal preparation systems with different designs, alloys, and innovative manufacturing features such as surface treatment or phase change (15). The Reciproc Blue (RB; VDW GmbH, Munich, Germany) is a new-generation reciprocating single file system presenting a similar design to Reciproc with an S-shaped cross-section and two cutting edges (16, 17). However, it is manufactured from blue thermomechanical-treated alloy, making the file more flexible and resistant to fracture (17). Although RB was initially developed for primary root canal treatment, its use for retreatment has been promoted (9, 18). XP-endo Shaper (XPS; FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) is another single file system used with continuous rotation. XPS is a minimal tapered instrument with an apical diameter of 0.30 mm and an initial taper of 1%. Through MaxWire alloy technology (FKG Dentaire SA), XPS changes into an austenite phase at body temperature, assuming a snake shape that can reach up to 4% taper (19). It is suggested as an appropriate retreatment tool when used at higher speeds (3000 rpm) (20).

The literature revealed that the type of the obturation material has a direct impact on its re-treatability (14, 18, 21). Endosequence BC sealer (Brasseler, Savannah, GA, USA) is a bioceramic-based sealer with a superior bond strength to root canal dentin (22). A recent study has also revealed that Endosequence BC sealer provides better marginal adaptation and tubular penetration depth compared to epoxy resin sealer (23). Although there are several studies regarding the retreatment of these sealers with various Ni-Ti instruments, no study compared the amount of debris extrusion of Endosequence BC obturation material after removal with PTUR, RB, and XPS files (14, 18, 21). Therefore, the purpose of this *in vitro* study is to assess the performance of Ni-Ti files with different alloys (PTUR, RB, XPS) in the removal of a bioceramic-based root canal filling regarding debris extrusion, success in regaining access to the periapical area, and operation time. The null hypothesis was that there were no differences among the systems for all analyzed variables.

Materials and Methods

Ethical approval

This research was approved by the Research Ethics Committee of the İstanbul Okan University (2021/131).

Sample size estimation

The sample size for this study was calculated using G*Power 3.1 (*Heinrich-Heine-Universität* Düsseldorf, Germany) based on a previous study with an effect size of 0.5, power-beta of 0.80, and 0.05 alpha-type error (10). The minimum sample size for each group was determined as 14 teeth to observe differences among the groups. The sample size was adjusted to 45 teeth (3 groups, n=15) by considering the possible losses.

Sample selection

Forty-five human single-rooted mandibular premolars extracted for periodontal reasons with mature apices and straight roots (less than 10°) were selected. The root canal morphologies were verified by viewing radiographs from buccolingual and mesiodistal directions. The degree of curvature was calculated according to the Schneider method (24). The teeth were examined under x40 magnification by an operating microscope (Leica M320; Leica Microsystems, Wetzlar, Germany). Only teeth with a single root canal and a single foramen were included. The teeth having cracks, previous root canal treatments, internal or external resorptions, root caries, more than one canal, and calcifications were excluded.

Sample preparation

Under the operating microscope, the working length (WL) was established as 1 mm shorter than the length where the tip of the #10 K-file (Maillefer, Dentslpy Sirona) appears at the apical foramen. To standardize the WL at 16 mm, the crowns of the teeth were separated using a diamond disk. The root canals were prepared up to 30/.04 (Endosequence; Brasseler, Germany) and were irrigated with 2 mL of 5.25% NaOCl (Cerkamed, Stalowa Wola, Poland) between each file using a 30 gauge side-vented needle (NOP Dental Needles, Spident, Korea). Apical patency was checked with #10 K-file during the root canal preparation. 5.25% NaOCl and 17% EDTA (Cerkamed) were used as the final irrigant. The root canals were filled with Endosequence BC sealer and 30/.04 BC points (Brasseler, Germany) using a single-cone technique. The quality of the obturation was confirmed by digital radiographs taken from the buccal and proximal directions. The samples were stored in an incubator (EN120, Nüve, Ankara, Türkiye) at 37°C in 100% humidity for 30 days.

A modification of the experimental design described by Myers & Montgomery (25) was used to collect the apically extruded debris and the irrigant. The Eppendorf tubes (2 mL) were labeled for each sample and weighed empty using an electronic balance (ATX 224, Shimadzu Co., Kyoto, Japan) with an accuracy of 10^{-4}. The measurements were repeated three times for each Eppendorf tube, and the average values were taken. Round holes were punched on the plastic caps of the Eppendorf tubes. The roots were inserted into these holes up to the cementoenamel junction and fixed with cyanoacrylate (Zapit, DVA Inc., Corona, CA, USA) (Fig 1a). A 27-gauge open-ended needle was immersed in each plastic cap to balance external and internal pressures. Then, setups were mounted into glass vials (Fig 1b).

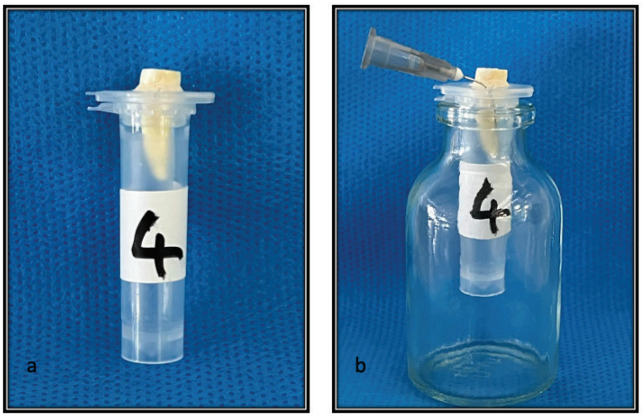

Figure 1. *The representative experimental setup. a) The root canals fixed to Eppendorf tubes b) The setup mounted into a glass vial.*

Removal of the filling material

The teeth were randomly divided into three groups (n=15):

Group 1: The root canal fillings were removed using Protaper Universal Retreatment files D1 for the coronal third, D2 for the middle third, and D3 until the WL was achieved. The instruments were operated with a X-Smart Plus endomotor (Maillefer, Dentsply Sirona), at a speed of 250 rpm with 2 Ncm torque for D1 and D2; 1.5 Ncm for D3 files. The instruments were used in a crown-down manner with a brushing action and lateral pressing movements.

Group 2: The gutta-percha in the coronal thirds (3 mm) were removed using a no. 2 Gates Glidden drill (Mani Inc., Tochigi, Japan) (18). Then, the rest of the root canal filling was removed with RB files (25/.08) operated at "Reciproc All" mode of the X-Smart Plus until the WL was achieved. The instruments were used in the root canal with slight apical pressure in three back and forth movements.

Group 3: The gutta-percha in the coronal thirds (3 mm) were removed using a no. 2 Gates Glidden drill (9). The remaining root canal fillings were removed with the XPS files till the WL was achieved. The instruments were operated on an Elements motor (Kerr-SybronEndo, Glendora, CA, USA) at a speed of 3000 rpm and 1 Ncm torque as suggested for gutta-percha removal with slow pecking motions (9, 20).

After each withdrawal, the flutes of the instruments were cleaned off with a gauze immersed into NaOCl, and the root canals were irrigated with 2 mL distilled water. The removal of root canal filling was terminated after reaching WL smoothly, and no residual filling material was observed on the last instrument or in the irrigation solution. Since this study was not intended to compare reinstrumentation procedures, after reaching WL, no further canal refinement was performed (14).

During the removal process, all glass vials were filled with warm water heated up to 37°C, both to mimic physiological conditions and let the phase change of XPS. The glass vials were covered with aluminum foil to prevent the operator from being affected by the experimental conditions and any contamination. All root canal instrumentations were performed by a single operator experienced in the tested systems, with 15 years of practice in endodontics. Each set of instruments to remove the filling materials was used only once and discarded.

Study variables

Three parameters were evaluated; success in regaining access to the periapical area, the amount of extruded debris, and the operation time.

Success in regaining access to the periapical area: Reaching the working length and maintaining the apical patency were evaluated separately. During the removal of gutta-percha, in case the instruments could not go deeper after three extra strokes, reaching the WL was deemed as not achieved. After confirmed by operating microscope and digital radiographs, the teeth that the WL could be reached and that the patency was maintained were regarded as successful. The cases where the WL cannot be reached, patency could not be maintained, or complications occurred were considered unsuccessful.

Apical debris extrusion: After reaching WL, final irrigation was performed with 2 mL of distilled water. The Eppendorf tubes were separated from the vials, and the caps were removed. The apical root thirds were washed with 1 mL of distilled water to collect the extruded debris around the external root apex. The teeth that WL could not be reached were not included in the debris extrusion evaluation.The Eppendorf tubes were then transferred into the incubator and stored at 70°C for five days to evaporate the distilled water (10). After evaporation, the tubes were weighed three times with the same electronic balance. The average of the measurements was recorded as the final weight value. The net extruded dry debris was calculated by subtracting the initial weight from the final weight of the tubes. All measurements were completed by a second observer who was blind to the operation parameters.

Operation time: For each sample, the time to reach WL was recorded with a digital chronometer (Loyka C809, Akyol Trade Co., İstanbul, Türkiye), excluding the time required for changing the instruments, cleaning the flutes, and irrigation.

Statistical analysis

Statistical analysis was performed with SPSS 23.0 (IBM SPSS Inc., Armonk, NY, USA) software. The conformity of the data to normal distribution was checked by Skewness, Kurtosis, and Shapiro Wilk tests. Kruskal Wallis tests were used to compare multiple groups, and Mann- Whitney U tests were used for paired comparisons. The Chi-square test was used in the evaluation of categorical data. The statistical significance was set at $p < 0.05$.

Results

All instruments were associated with apical extrusion of debris. There was a statistically significant difference be-

Table 1. *The mean and standard deviation (SD) values of the apically extruded debris in grams .*

Instrument type	Apically extruded debris	*p*-value
ProTaper Universal	0.0007±0.0003[b]	**0.013***
Reciproc Blue	0.0005±0.0005[ab]	
XP-endo Shaper	0.0004±0.0005[a]	

**Values with the same letters were not statistically different*

Table 2. *The mean and standard deviation values of the operation time in seconds.*

Instrument type	Operation time	*p*-value
ProTaper Universal	36.26 ± 7.44[a]	**0.000***
Reciproc Blue	115 ± 50.35[b]	
XP-endo Shaper	21.26±7.05[c]	

**Values with different letters were statistically different*

tween the instrument type and the amount of extruded debris (p=0.013) (Table 1). The mean amount of extruded debris was highest in the PTUR group. However, the difference was only significant between PTUR and XPS groups (p=0.005).

There was also a statistically significant difference between the retreatment instrument and the operation time (p=0.000) (Table 2). The mean time required for reaching WL was the longest for RB, while it was the shortest for XPS. The differences were statistically significant among the groups (p=0.000).

WL was reached in 40 out of a total of 45 samples, while it could not be reached in 5 samples. In the PTUR group, the WL was reached 93.3% (n=14). This rate was 86.7% (n=13) for RB and XPS groups. There was no significant difference among the groups regarding reaching WL (p=0.799). Apical patency could not be regained in 60% (n=9), 46.7% (n=7), and 53.3% (n=8) of the samples for PTUR, RB and XPS groups, respectively. However, the difference was not significant (p=0.765).

Discussion

The current *in vitro* study investigated for the first time the performance of PTUR and two heat treatment NiTi instruments RB and XPS, for extruded debris amount, regaining access ability to the periapical area and the operation time during the removal of bioceramic-based root canal filling. The multifile system (PTUR) and one of the single-file systems (XPS) were operated in continuous rotation, whereas the other was used in a reciprocating motion (RB).

The results revealed that all systems led to some degree of debris extrusion, which is consistent with the results of previous studies reporting varying degrees of apical debris extrusion during retreatment with different file systems, operated both in continuous rotation or reciprocation motion (9-11, 18, 20, 26). There was a statistically significant difference in the amount of extruded debris and the time required to reach WL among the currently tested systems (p>0.05). However, the difference was insignificant in regaining the periapical access. Therefore, the null hypothesis was partially accepted. The amount of apically extruded debris is directly related to the instruments' tip size, taper, kinematics, and preparation techniques (27). There are limited studies comparing reciprocating and rotating instruments on the amount of apically extruded debris when used for endodontic retreatment. Lu *et al.* (12) reported that Reciproc resulted in more apical debris extrusion than the Mtwo. However, in most of the studies, Reciproc was associated with less debris extrusion when compared with a conventional rotary retreatment system, PTUR (11, 26, 28). Our results were consistent with the latter studies, although we used RB. Indeed, the only difference between RB and Reciproc instruments, which have the same cross-section design, tip size, and taper, is the manufacturing process (10, 18).

On the other hand, XPS resulted in less debris extrusion than PTUR and RB. Although both are single-file systems, the finding that RB produces more apical debris than XPS complies with the previous study findings, which have tested these systems in shaping and retreatment procedures (9, 29). Although XPS has a bigger final apical diameter (30/.04) at the tip, the greater and variable taper of the RB instrument (25/.08) could be speculated as the possible reason for more debris extrusion. Moreover, the slender design, small mass, and expanding feature of XPS may have contributed less extrusion by providing sufficient space for debris escape (30).

The failure in establishing WL and/or patency may compromise the success of retreatment by impeding proper chemo-mechanical cleaning of the apical root canal that may harbour bacteria (31). Furthermore, apical patency preservation was associated with less postoperative pain (32). The WL was regained in 93.3% of the samples in the PTUR and 86.7% of the samples in the RB and XPS groups. However, regardless of the system used, apical patency could not be maintained in 46.7-60% of the cases. The effect of sealers on the retreatability of the root canals was shown in previous studies (14, 18, 21, 31). Endosequence BC sealer was speculated as difficult to retreat, due to its hardness upon setting and chemical-bond formation with dentin (22, 31). Previous studies have also demonstrated the difference between the regaining WL and patency rates in the root canals filled with Endosequence BC sealer (21, 31). Hess *et al.* (31) reported that WL could be restored in all samples contrary to our results, but patency was only achieved in 80%. In another study evaluating the retreatability of Endosequence BC sealer, Oltra *et al.* (21) established WL in 93% of the samples consistent with our results. However, the patency was regained in only 14%. The numerical differences between the studies may be attributed to the different instruments used for retreatment.

The removal of the filling material in the root canals filled with Endosequence BC sealer was demonstrated to be more time-consuming than those of AH Plus (18, 31). Regardless of the filling technique (lateral condensation or single cone), Endosequence BC sealer has provided better marginal adaptation and penetrated deeper into the dentinal tubules than AH Plus in all root segments (coronal, middle, and apical) (23). The effort required to regain access to the apical area may also affect the mean retreatment time of the Endosequence BC filling (18). According to our results, the mean time required to reach WL was the longest in the RB group (115 ± 50.35 s), followed by the PTUR (36.26 ± 7.44 s) and XPS (21.26 ± 7.05 s). The differences were significant among the groups (p=0.000).

Regarding the duration of retreatment, Özyürek *et al.* (33) found PTUR faster than Reciproc, in alignment with our findings. In the PTUR system, the active tip of the D1 instrument provides better penetration into the root canal filling, which may allow other instruments to reach the WL length more easily and faster (8). Since no previous studies have tested XPS for the retreatment of bioceramic-based filling material, a direct comparison of the results could not be performed. However, in line with our findings, XPS was shown to retreat the root canals obturated with warm vertical compaction faster than other tested Ni-Ti instruments and perform the retreatment in 60% less time than RB (9, 20). The improved efficiency of XPS could be attributed to the interesting tip design with six cutting edges and a booster tip and the plasticization of the gutta-percha at higher speeds (6, 20, 34).

On the other hand, RB files may be unlikely to penetrate bioceramic root canal filling because of the blue thermal treatment, which has been demonstrated to improve the flexibility and reduce the microhardness of the Reciproc instruments (17). Furthermore, a recent study reported that the retreatment of Endosequence BC with RB required 144 seconds, which might be time-consuming (18). The recorded time in that study was more prolonged than ours (115 s), probably due to the time taken for further refinement of the root canals. However, in the current study, the root canals were not re-shaped after reaching WL as it was not intended to compare the re-instrumentation procedures.

The extruded debris was collected with a slight modification of the method proposed by Myers & Montgomery (25). With this modification, the collection apparatus has become more practical and functional to be used as a warm bath required for the phase change of XPS. The main limitation of the present *in vitro* model is the lack of simulating physical back pressure provided by periapical tissues, which may restrict the extruded debris to some extent (3, 25). Regarding the shortcomings of *in vitro* design with no periapical pressure, Myers and Montgomery (25) pointed to reassessing the apical dentinal plug because of the potential benefits of reducing the amount of apically extruded debris. Several methods have been suggested to simulate periapical tissue resistance, including floral foam and agar gel (12, 35). However, these methods also have several disadvantages, such as the absorption of irrigants and debris by the foam and the difficulty in defining a factual agar gel thickness to mimic the size of the apical lesion (12, 35).

Furthermore, no valid method is still known for reproducing an optimal simulation of periapical tissues (18). Therefore, no additional modifications have been made to simulate periapical resistance in the present experimental setup (11, 13). During the removal of gutta-percha, irrigation was performed with distilled water as the crystals of sodium hypochlorite cannot be separated from debris and compromise the reliability of the results (36).

Notably, this study only examined the quantitative debris extrusion. As the weight of the debris increases, the severity of the inflammatory reaction of periapical tissues is expected to increase. However, the severity of the reaction has been reported to be related to not only the amount of debris but also the type and virulence of the bacteria and the host tissue resistance (37). It may not be meaningful to report only the quantity without taking into account the composition of the extruded material and other biologic aspects of the periapical irritation (15). Therefore, from a clinical perspective, further research including the biological factors is needed to better understand whether the differences among the tested systems are clinically relevant.

Conclusion

Within the limitations of this study, it can be concluded that all tested systems caused a certain amount of debris extrusion. XPS was associated with less extrusion than PTUR and RB, while regaining more rapid access to the periapical area.

Türkçe özet: *ProTaper Universal Retretament, Reciproc Blue ve XP-endo Shaper Sistemlerin Biyoseramik Esaslı Kök Kanalı Dolgusunun Uzaklaştırılmasındaki Etkinliği. Amaç: Bu in vitro çalışmada, biyoseramik kök kanalı dolgusunun uzaklaştırılması sırasında Protaper Universal Retreatment (PTUR), Reciproc Blue (RB) ve XP-endo Shaper (XPS) sistemlerinin apikal debris çıkışı, periapikal alana erişmedeki başarı ve operasyon süresi açısından performanslarının değerlendirilmesi amaçlanmıştır. Gereç ve yöntem: 45 adet tek köklü alt küçük azı dişi 30/.04'e kadar şekillendirildikten sonra Endosequence BC sealer ve BC güta-perkalar ile doldurularak 3 gruba ayrıldı (n=15). Kök kanalı dolguları, 1. grupta PTUR, 2. grupta RB ve 3. grupta XPS kullanılarak çalışma uzunluğuna (ÇU) ulaşana kadar çıkarıldı. Operasyon süresi dijital kronometre ile kaydedildi. ÇU'na ulaşma ve apikal açıklığın korunması ayrı ayrı değerlendirildi. Veriler, Kruskal Wallis ve Mann Whitney U testleri kullanılarak istatistiksel olarak analiz edildi. Bulgular: Tüm aletler apikal debris çıkışına neden olmasına rağmen, en yüksek ortalama debris çıkışı PTUR grubundaydı. ÇU'na ulaşmak için gereken ortalama süre en uzun RB grubunda, en kısa XPS grubunda kaydedildi ve gruplar arasındaki fark istatistiksel olarak anlamlıydı (p=0,000). Diğer gruplar (%86,7) ile arasındaki fark anlamlı olmasa da (p=0,799), PTUR grubunda ÇU'na ulaşma oranı daha yüksekti (%93,3). Sonuç: Test edilen tüm sistemler belirli miktarlarda debris çıkışına neden oldu. XPS; PTUR ve RB'ye kıyasla periapikal alana anlamlı derecede daha hızlı erişim sağlarken daha az debris çıkardı. Anahtar Kelimeler: Debris çıkışı, endodontik tedavi tekrarı, Endosequence BC sealer, Reciproc Blue, XP-endo Shaper*

Ethics Committee Approval: The study protocol has been approved by the İstanbul Okan University Research Ethics Committee (Protocol: 2021/131).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: EC, RSG, GAD, GK, ESK participated in designing the study. EC, RSG, GAD participated in generating the data for the study. EC, RSG, GK participated in gathering the data for the study. EC, RSG, GAD, GK, ESK participated in the analysis of the data. EC, RSG wrote the majority of the original draft of the paper. EC, RSG participated in writing the paper. EC, RSG, ESK have had access to all of the raw data of the study. EC, RSG have reviewed the pertinent raw data on which the results and conclusions of this study are based. EC, RSG, GAD, GK, ESK have approved the final version of this paper. EC guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors had no conflict of interest to declare.

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