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# Efficacy of passive ultrasonic activation and photon-initiated photoacoustic streaming on apical extruded debris of different rotary systems in curved canals

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## Abstract

**Aim:** The aim of this study was to investigate the impact of photon-initiated photoacoustic streaming (PIPS) and ultrasonic activator Ultra X (UX) on the extrusion of debris using the One Curve (OC) rotary system and the Reciproc Blue (RB) system in curved canals.

**Methodology:** Ninety extracted mandibular first molar teeth were divided into six groups (n = 15), Group (1): OC with PIPS, (2) OC with UX, (3) OC with conventional needle irrigation (CNI), (4) RB with PIPS, (5) RB with UX, and (6) RB with CNI. The irrigation activation methods were used in the final irrigation with 2.5 cc of distilled water. The apically protruded debris was collected into pre-weighed Eppendorf tubes. By deducting the tube's initial weight from the final weight, the weight of dry protruded debris was calculated. Two-way ANOVA test was used to analyze the results statistically.

**Results:** A significant difference was found among all groups ($p < 0.05$). No statistically significant difference was found among the instrumentation systems, regardless of the irrigation technique employed ($p > 0.05$). The statistically significant difference was found among the PIPS, UX, and CNI irrigation systems, regardless of the rotary systems ($p < 0.05$). CNI caused significantly less debris extrusion than the UX ultrasonic irrigation activation systems.

**Conclusion:** The UX irrigation activation system caused the highest amount of debris extrusion in curved canals. PIPS can be preferred to ultrasonic devices as irrigation activation systems.

**Keywords:** Apical debris extrusion, PIPS, laser-activated irrigation, ultrasonic activation, Reciproc Blue, One Curve

## Introduction

During chemomechanical preparation, irrigants, debris, extrusion of dentine chips vital and necrotic tissues, microorganisms, pulp tissue fragments, and their by-products may protrude from periradicular tissues, and these protruded materials may increase postoperative pain and flare-ups (1). All instrumentation methods and rotational systems are linked to the extrusion of debris, according to studies on the apical extrusion of debris. The number of instruments and kinematics may contribute to debris extrusion during root canal shaping (2-4). With the technological advances in nickel-titanium devices, significantly less protruded apical debris has been reported (5, 6). The irrigation activation methods used can also affect apically protruded debris.

The standard method of hand syringe irrigation has been found inadequate for cleaning and disinfecting the root canal wall from smear layer, debris and bacteria and their by-products from root canals due to the highly complex root canal anatomy. For this reason, various other new irrigation activation techniques such as negative pressure, sonic (<20.000 Hz), and ultrasonic irrigation (>20.000 Hz), and more recently laser-activated irrigation (LAI), have been introduced to enhance the irrigation action in order to (7). Furthermore, these activation techniques allow irrigation solution to penetrate deeper into dentinal tubules and lateral canals, increasing their penetration depth and effectively remove the smear layer and debris in the final irrigation stage and provide a good connection interface between the root canal filling and the canal walls (8).

The Ultra X ultrasonic activator (Eighteeth Medical, Changzhou City, China), with an operating frequency of 45 kHz, was recently introduced. it activates the irrigation solution through acoustic streaming, agitation, and micro-cavitation to reach difficult-to-instrument areas of the complex root canal system Although agitating irrigant with this headpiece is a type of PUI, its greater operating frequency than other ultrasonic devices may increase its efficiency for cleaning root canal system (9).

Laser-activated irrigation produces explosive vapor bubbles with a secondary cavitation effect and enhances fluid interchange and the removal of debris (8). An erbium:yttrium-aluminum-garnet (Er:YAG) laser is utilized with a photon-initiated photoacoustic streaming (PIPS) irrigation system. PIPS, a novel laser agitaion technique, involves creating peak power increases (10/20 mJ) a pulse repetition rate of 15 Hz and short microsecond pulse length (50 µs). The PIPS technology generates deep photoacoustic shock wave shock waves in an aqueous solution with minimum thermal effect with intracanal cavitation. The three-dimensional movement of irrigation solutions is accelerated by the photoacoustic shock wave (10, 11).

One Curve (OC) (Micro-Mega SA Besancon Cedex, France) rotary system was introduced in 2018 as single-file nickel-titanium systems that perform in rotary motion. OC files are manufactured from a C-wire using heat treatment and are provided with a shape-memory effect and the ability to be curved in advance. C-Wire Ni-Ti alloy improves the mechanical properties of the OC system, resulting in better blade flexibility and high fracture resistance. The changing cross-section of OC file improves cutting efficiency and centering capabilities in the apical third and increased debris removal in the middle and coronal thirds (12).

Reciproc Blue (VDW, Munich, Germany) is a novel single-file system and an update of the Reciproc system developed by a patented thermal process that results in the formation of a blue titanium oxide coating on the instrument's surface, giving the instrument its color and name (13). The dimensions and geometrical features of Reciproc Blue instruments are the same as the conventional Reciproc system, but the thermally treated shape memory alloy which modify its molecular structure has been found to provide superior flexibility and fatigue resistance when compared to the classic system (13).

To date, no studies have compared the effect of Ultra X (UX) and PIPS activation techniques on the sum of apically protruded debris. This study used a novel One Curve continuous rotating system and a reciprocation system known as Reciproc Blue in curved canals to examine the impact of various irrigation activation systems on the extrusion of debris. The null hypothesis is that there is no difference in the sum of apically extruded debris between the Reciproc Blue, One Curve rotary systems and the different irrigation activation systems.

## Materials and Methods

This study was confirmed by the ethics committee of Necmettin Erbakan University, Faculty of Dentistry (Registration No: 2020/03). Ninety mandibular first molar teeth were chosen. The 10° to 20° range represented the angles of canal curvature. The mesial roots were sectioned at the cement enamel junction with a fissure bur. Root lengths were adjusted to 13 mm to be standard. Endodontic working lengths were set to 12 mm.

### Irrigation and instrumentation procedures

Ninety extracted mandibular first molar teeth were randomly separated into six groups (n = 15). Between each file, three in-and-out movements were made using 2.5 ml distilled water. The irrigation activation methods were used in the final irrigation with 2.5 cc distilled water. The total irrigation and activation time for each tooth was 1 min, the total volume was 5 ml.

Group 1: OC+PIPS
Group 2: OC+UX
Group 3: OC+CNI
Group 4: RB+PIPS
Group 5: RB+UX
Group 6: RB+CNI

## PIPS-activated irrigation

Utilizing a 12-mm-long, 400-mm tapered quartz tip, an Er:YAG laser with a wavelength of 2.940 nm was employed. After placing the optical fiber in the coronal portion of the root canal, 2.5 ml of distilled water was flushed into the canal. When the irrigating solution in the coronal part declined, 2.5 ml distilled water was used in the final irrigation.

## UX ultrasonic irrigation

Ultra X Cordless Ultrasonic Activator activated the irrigation process at 1 mm from the WL and was applied in an up-and-down motion.

## Conventional needle irrigation

The canal was irrigated with distilled water using a 27-gauge needle. The needle was inserted into the canal and worked in an up-and-down motion.

**Group 1: OC+PIPS:** The canal was prepared with an OC file (25 .06) at a speed of 300 rpm. The above protocol was used for PIPS irrigation.

**Group 2: OC+UX:** The canal was prepared with an OC file at a speed of 300 rpm. The above protocol was used for UX irrigation.

**Group 3: OC+CNI:** The canal was prepared with an OC file at a speed of 300 rpm. The above protocol was used for CNI irrigation.

**Group 4:** RB+PIPS: Canal preparation was performed with an RB file (25 .06) at a speed of 300 rpm. The above protocol was used for PIPS irrigation.

**Group 5:** RB+UX: Canal preparation was performed with an RB file at a speed of 300 rpm. The above protocol was used for UX irrigation.

**Group 6:** RB+CNI: Canal preparation was performed with an RB file at a speed of 300 rpm. The above protocol was used for CNI irrigation.

## Debris collection

The empirical model defined by Myers and Montgomery (14) was operated to collect apically protruded debris. Separate Eppendorf tubes were used for each specimen. Electronic scales with an accuracy of $10^{-5}$ g were used to measure the weight of each tube. The measurements were taken three times, and the mean value was obtained. Each root was placed inside the Eppendorf tube. The experimental model is shown in Figure 1. The tubes were incubated at 70 °C for seven days to volatilize the protruded distilled water. The tubes were weighed three times after volatilization, and the mean weight was determined.

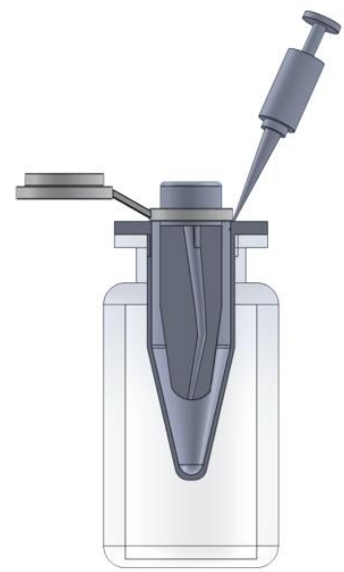

Figure 1. A schematic illustration of the experimental model.

## Statistical analysis

Analyses were performed by using SPSS software (IBM SPSS Statistics version 21, IBM Inc., Armonk, NY, USA). Two-Way ANOVA test was used. 0.05 was used as the significant level.

# Results

The standard deviation and median values of the weighed apically protruded debris of each test group are presented in Table 1. Significant differences were found among the all test groups ($p$ = 0,026). However, a statistically significant difference was not demonstrated between the OC and RB rotary systems regardless of the irrigation systems ($p$ = 0.578). Statistically significant difference was found among the PIPS, UX, CNI irrigation systems regardless of the rotary systems ($p$ = 0,026). CNI created significantly less debris extrusion than the than the UX ultrasonic irrigation activation systems. CNI created less apical debris extrusion than PIPS but there was no statistically difference between PIPS irrigation activation systems. Although there was a statistically insignificant difference between PIPS and UX, PIPS produced less apical debris extrusion (by weight) than UX.

Table 1. The Mean and Standard Deviation (SD) values for the amount of apically extruded debris in each study group (in milligrams)

| | Reciproc Blue | | | One Curve | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|
| | CNI | PIPS | UX | CNI | PIPS | UX | CNI | PIPS | UX |
| Mean | 0.0002467 | 0.0005700 | 0.0004633 | 0.0002800 | 0.0002667 | 0.0006000 | 0.0002633[a] | 0.0004183[ab] | 0.0005317[b] |
| SD | 0.00018465 | 0.00042586 | 0.00044979 | 0.00027242 | 0.00020325 | 0.00056821 | 0.00022929 | 0.00036234 | 0.00050829 |

* Values with the same superscript letter are not statistically different.

## Discussion

In this study, the weight of protruded debris was appraised and compared for root canal preparation using the OC and RB rotary systems with the PIPS, UX, and CNI irrigation systems. We compared the apically protruded debris of two newly developed file systems with different designs, heat treatments, and kinematics. To the best of our knowledge, these studies did not report the sum of apically protruded debris when PIPS and UX were used after the OC and RB rotary systems. The findings show that all rotary systems and irrigation systems resulted in the apical extrusion of debris, consistent with previous studies (15-18). Rejecting the null hypothesis.

Studies on apical debris extrusion have utilized single and straight roots (19, 20). In the present study, the mesial roots of mandibular molars with curvature between 10° and 20° were chosen because the preparation of the curved canals can be associated with the protruding material on the greater sum than the straight canals (21-23). The well-known debris-picking technique developed by Myers and Montgomery was applied in the current study (14), which was suggested by Tanalp and Gungor to provide normalization of all groups (24).

Although sodium hypochlorite (NaOCl) as an irrigation solution would give a more accurate representation of clinical situations, NaOCl was not used as an irrigant during the evaluation of the apically extruded debris in this study. Nevertheless, distilled water was utilized as an irrigant due to the importance of meticulous measurements, to minimize any potential weight gain due to NaOCl crystal formation after the drying procedure, which might affect the accuracy of the post-instrumentation weight data (25).

The method of instrumentation (18) and the design of instrument (26) have an impact on the total amount of protruded debris. Some of the most important features of RB have an S-shaped width, two cutting edges, and a non-cutting tip (13). OC instruments include varied cross-sections along the blade for improved cutting effectiveness and centering (12). The most important factor in apically protruded debris is the number of files used (27, 28). Both file systems used in the present study are a single system used for shaping the root canal. According to our results, no statistically significant difference was observed between the OC (rotary) and RB (reciprocating) rotary systems regardless of the irrigation systems. Similarly, there was no noticeable difference in debris extrusion between single-file rotary and reciprocating systems, according to Kocak et al. (29) and Küçükyilmaz et al (30). In our study, although the RB files had a greater taper (25/0.08) than the OC (25/0.06), the sum of protruded debris was the same. This result may explain the constant different irrigation activation methods enforced during instrumentation, which could have been defined to prevent debris accumulation and reduce the effect of taper size on the sum of protruded debris (21).

In the present study, CNI, PIPS, and UX, which are irrigation activation methods, were used along with OC and RB rotary systems. CNI is the most widely used irrigation method that ensures needle depth and irrigant volume control (31). However, previous studies have speculated that CNI is generally deficient in achieving these targets (32). Irrigation activation methods have become popular in overcoming the disadvantages of the CNI system (33). The most important purpose of irrigation activation methods is to clean the root canal system more effectively by increasing the distribution of the irrigation solution within the root canal (8, 34). The results of our study show that statistically significant difference was found among the PIPS, UX, CNI irrigation systems regardless of the rotary systems. In the present study CNI created less apical debris extrusion but there was no statistical difference between the PIPS irrigation systems. On the other hand, Arslan and Kuştarcı demonstrated that PIPS activation was related to considerably higher extrusion debris in curved canals with various rotating systems as compared to CNI irrigation (35). The opposition between these results may be explained by the different apical enlargement, apical stop, continuous or final irrigation protocol, type of irrigation activation system, choice of teeth and variables connected with operators (18, 36).

The PIPS method uses a particular Er:YAG laser, a conical and stripped tip, and subablative parameters to activate frequently used endodontic irrigant solutions such as NaOCl, distilled water, and ethylenediaminetetraacetic acid (EDTA). When subablative energy (20 mJ at 15 Hz) is given with super short pulses (50 μs length), photoacoustic and photomechanical effects are induced, resulting in the creation of intense fluid streaming inside the root canal. PIPS has been proven in previous research to be more successful than syringe, sonic, and ultrasonic irrigation for removing the smear layer [34, 37]. A recent study indicated the good ability of PIPS activation of 17% EDTA during a 40-second cycle on smear layer removal, with no thermal effects or dentin surface damages [38].

The total amount of debris extruded in the study's UX ultrasonic system was much higher than when the CNI was used. UX ultrasonic system is activated the irrigation solution through acoustic flow, agitation and dilution by micro-cavitation. This three-dimensional motion may describe the UX created significantly higher sum of apical debris extrusion than CNI. In our study PIPS caused (by weight) less apical debris extrusion than UX but there was no statistically significant difference between the PIPS and UX. PIPS irrigation activation system the fiber end of the laser was used only in the pulp chamber without moving into the root apex (37, 39) whereas UX is activated in the root canals and the working length. According to research by Boutsioukis et al. the amount of apical debris extrusion increased as irrigation procedures were carried out closer to the working length (40). This factor might explain why PIPS in our study experienced less apical debris extrusion than Ultra X.

## Conclusion

Choosing a root canal shaping method and system that extrudes the least amount of apical debris enhances the success rate of endodontic treatment. The UX ultrasonic activator caused the highest sum of debris extrusion in curved canals. PIPS can be preferred to ultrasonic devices as irrigation activation systems. Although there was no significant difference between the OC and RB rotary systems, OC caused less apical debris (by weight) extrusion. The use of the OC rotary system is recommended instead of the reciprocating file.

## Disclosures

**Ethical Approval:** Ethics committee approval was received for this study from Necmettin Erbakan University, Faculty of Dentistry, Research Ethics Committee, Research Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2020/03).

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Conception – M.A.; Design – M.A., D.A.B., C.Z.; Supervision – C.Z.; Materials – M.A., D.A.B.; Data Collection and/or Processing – M.A., D.A.B., C.Z.; Analysis and/or Interpretation – M.A., C.Z.; Literature Review – M.A., D.A.B.; Writer –M.A.; Critical Review – M.A., C.Z.

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