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ORIGINAL ARTICLE

Effect of different laser-assisted irrigation activation techniques on apical debris extrusion

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ABSTRACT

Objective: The aim of this study was to compare apical debris extrusion when neodymium-doped yttrium aluminium garnet (Nd:YAG) lasers, erbium-doped yttrium aluminium garnet (Er:YAG) or photon-induced photoacoustic streaming (PIPS) are used for irrigation activation.

Materials and methods: A total of 60 extracted human mandibular premolar teeth have similar dimensions were included and the samples were split into four groups according to the irrigation technique ($n = 15$): conventional needle irrigation, PIPS, Er:YAG and Nd:YAG. ProTaper Universal system up to F4 was used for root canal instrumentation. Bidistilled water was used as an irrigation solution during instrumentation and irrigation activation. Apically extruded debris was collected into preweighed Eppendorf tubes during instrumentation and irrigation activation procedures. The tubes were then kept in an incubator at 70 °C for 5 days. The initial weight of the tube was subtracted from the final weight and the result was recorded as the weight of dry extruded debris. The data were evaluated statistically using a one-way ANOVA test followed by least significant difference *post hoc* test ($p < .05$).

Results: Conventional needle irrigation caused significantly less debris extrusion than laser-assisted irrigation activation groups ($p < .05$). Laser-assisted irrigation activation groups caused statistically similar debris extrusion ($p > .05$).

Conclusion: Laser-assisted irrigation activation techniques caused more debris extrusion when compared to conventional needle irrigation.

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Introduction

Root canal treatment aims disinfection of the root canals, to control infection in root canal space and to heal or prevent of pulpal and periradicular diseases [1]. To provide disinfection, mechanical preparation of the root canals and irrigation are crucial stages of root canal treatment. Irrigation of the root canals provides flushing away debris, cleaning the untouched areas of the root canals, removing the smear layer, and disinfection the canal space [2–4]. It is known that traditional needle irrigation does not sufficiently provide irrigation solutions to deliver and penetrate in the complex three-dimensional microstructure of the root canal system especially in the apical third of the canal [5]. Therefore, irrigation activation methods have been suggested to enhance the effect of irrigation solutions in the root canal system and distribution in root canal irregularities [6].

Laser-assisted irrigation has been used as an alternative method to increase the effects of root canal irrigation solutions. The mechanism of action of laser-assisted irrigation activation techniques depends on expansion and implosion of vapour bubbles at the fibre tip, thus rapid irrigation solution movement in the root canal [7,8]. In addition, pressure waves and secondary cavitation bubbles contribute to the cleaning action [9]. Different lasers such as neodymium-doped yttrium aluminium garnet (Nd:YAG) laser, erbium-doped yttrium aluminium garnet (Er:YAG) laser, erbium chromium:yttrium-scandium-gallium-garnet laser (Er,Cr:YSGG), diode laser had been used for irrigation activation [10–13].

Irrigation activation using Er:YAG laser was found successful in improving of dentinal tubule penetration of sealers, improving of bond strength of resin cements, sealers, improving of bleaching effect of hydrogen peroxide, removal of apically placed dentinal debris, smear layer, filling materials, calcium hydroxide, triple and double antibiotic pastes [14–22]. Irrigation activation using Nd:YAG laser was found successful in improving of bond strength of resin cements, sealers, removal of smear layer, filling materials [21–24].

The fact that pulp tissue, debris chips, irrigation solutions, microorganisms, and their byproducts may be extruded from the apical foramen is an undesired result of root canal preparation [25]. Postoperative complications, such as postoperative pain, periapical inflammation and thus deterioration of periapical healing may occur due to apically extruded materials [26]. In previous studies, the effect of various instrumentation and irrigation methods on the amount of apically extruded debris has been evaluated [10,11,27,28]. The aim of this study was to compare apical debris extrusion when photon-induced photoacoustic streaming (PIPS), Er:YAG, or Nd:YAG lasers are used for irrigation activation. The null

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hypothesis was that there would be no significant difference between laser-assisted irrigation activation techniques and needle irrigation in terms of apical debris extrusion.

Materials and methods

Selection of the specimens

A total of 60 extracted human mandibular premolar teeth have similar dimensions with mature apices were selected for this study. Teeth with one straight mature root and one root canal; no signs of cracks, calcification, caries, internal or external resorption were included. After the access cavities were prepared, teeth have the apical constriction larger than #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) were excluded. To determine the working length, 0.5 mm was subtracted from the length which the tip of a #10 K-file (Dentsply Maillefer) was seen at apical foramen.

Pre-instrumentation weighing of the Eppendorf tubes

Weights of empty and numbered Eppendorf tubes were determined using an electronic balance, which has an accuracy of 10^{-4} precision (Precisa XB 220 A, Precisa Instruments, Dietikon, Switzerland). The mean of three consecutive measurements was calculated and recorded as pre-instrumentation weight for each Eppendorf tube.

Test design

The experimental set-up described previously by Myers and Montgomery [29] was used to collect apical debris extrusion. Teeth were placed into the holes created through the stoppers of Eppendorf tubes. To prevent leakage of irrigating solution, teeth were fixed using cyanoacrylate (Pattex Super Glue; Türk Henkel, Inc., Istanbul, Turkey). The air pressure between the inside and outside of the tube was balanced using a 25-gauge open-ended needle, which was placed through stopper of Eppendorf tube. The stoppers were fitted into the Eppendorf tubes and the Eppendorf tubes were fitted into the glass vials. Rubber-dam sheets were placed on the teeth, thus the operator did not see debris extrusion.

Root canal preparation and irrigation procedures

The samples were randomly split into four groups ($n = 15$). For all groups, teeth had a statistically similar working length ($p > .05$). The mean values of the working lengths as well as standard deviation data of groups are shown in Table 1.

Root canal preparations were performed using ProTaper Universal instruments (Dentsply Maillefer) up to F4. A size 10 K-file was used as a patency file and it was used by moving passively through the terminus of the root canal (1 mm longer than working length) without enlarging the apical between each file change. When instrument reached the working length, irrigation with 2 mL bidistilled water was performed using a NaviTip irrigation needle (30-G; Ultradent Products Inc., South Jordan, UT, USA) which was placed into the canal 2 mm short of the working length.

Table 1. The mean and standard deviation (SD) values of working length data (in millimetres).

	Needle irrigation	PIPS	Er:YAG	Nd:YAG
Mean	22.76	22.7	22.73	22.76
SD	1.08	1.09	0.77	0.92

Groups

Needle irrigation group: Following the root canal instrumentation, root canal was irrigated using 1 mL bidistilled water for 10 s; gentle back and forth movement was applied during irrigation. Following 10 s of irrigation, bidistilled water was kept in the root canal for 10 s. This cycle was repeated six times. Totally, 6 mL of bidistilled water was used.

PIPS group: Following the root canal instrumentation, 1 mL bidistilled water was activated by 2940 nm Er:YAG laser (LightWalker AT, Fotona, Ljubljana, Slovenia) at 1 W, 20 Hz and 50 mJ per pulse in the very short pulse mode (VSP). A 300-μm PIPS fibre optic tip was placed in the access cavity during the irrigation activation. Following 10 s of irrigation, bidistilled water was activated for 10 s. This cycle was repeated six times. The activation was completed for a total of 60 s, using 6 mL of bidistilled water.

Er:YAG group: Following the root canal instrumentation, 1 mL bidistilled water was activated by 2940 nm Er:YAG laser (LightWalker AT) at 1 W, 20 Hz and 50 mJ per pulse in the VSP mode. A 300-μm optic fibre plain tip was placed into the apical third of the root canal and moved in apico-coronal direction with a helical movement during the irrigation activation. Following 10 s of irrigation, bidistilled water was activated for 10 s. This cycle was repeated six times. The activation was completed for a total of 60 s, using 6 mL of bidistilled water.

Nd:YAG group: Following the root canal instrumentation, 1 mL bidistilled water was activated by 1064 nm Nd:YAG laser (LightWalker AT) at 1 W, 20 Hz and 50 mJ per pulse in the VSP mode. A 320 μm optic fibre plain tip was used for irrigation activation. Rest of the procedures were performed in group Er:YAG group.

In all groups, irrigation needle was inserted into 2 mm short of working length. After the completion of the root canal instrumentation procedure, the Eppendorf tubes were removed from the vials and the apical parts of the roots were washed with 1 mL distilled water in order to put the apically extruded debris on the root apex into the Eppendorf tube.

Post-instrumentation weighing of the Eppendorf tubes and determination of the amount of the extruded debris

After the completion of the root canal preparation and irrigation procedures, the Eppendorf tubes were kept in an incubator at 70 °C until the distilled water was evaporated (for 5 days). The final weights of Eppendorf tubes were again determined using an electronic balance (Precisa XB 220 A)

Table 2. The mean and standard deviation (SD) values of the amount of extruded debris data (in grams).

	Needle irrigation	PIPS	Er:YAG	Nd:YAG
Mean	0.001386	0.00188	0.001893	0.00196
SD	0.0003642	0.0005002	0.0006616	0.0008658

three times and mean of the measurements was recorded as post-instrumentation weight. The initial weight of the tube was subtracted from the final weight and the result was noted as the weight of dry extruded debris.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software, version 20.0 for iOS (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. The working length and apical debris extrusion data were evaluated statistically using a one-way ANOVA test followed by least significant difference *post hoc* test ($p < .05$). The level of significance was set at $p < .05$.

Results

All the techniques tested were associated with extrusion of some debris from the apical foramen. Table 2 shows the mean values of the amount of apically extruded debris, as well as the standard deviation data for each group. Conventional needle irrigation caused significantly less debris extrusion than laser-assisted irrigation activation groups ($p < .05$). Laser-assisted irrigation activation groups caused statistically similar debris extrusion ($p > .05$).

Discussion

Chemomechanical preparation is a crucial step to perform a successful root canal treatment. Mechanical preparation and irrigation solutions play a key role in providing debridement and removing vital and necrotic tissue, debris, and microorganisms from the root canal system [30]. Different irrigant activation techniques have been suggested to enhance the effects of irrigation solutions. Laser-assisted irrigation is one of the irrigant activation techniques. This study aimed to compare apical debris extrusion when PIPS, Er:YAG, or Nd:YAG lasers are used for irrigation activation. No significant differences were found among laser-assisted irrigation activation groups ($p > .05$). Conventional needle irrigation caused significantly less debris extrusion than laser-assisted irrigation activation groups ($p < .05$). Therefore, the null hypothesis was rejected.

Although irrigation activation with different methods was advised for debriding and decontamination of the root canal system, according to the results of this study, laser-assisted irrigation activation techniques caused more debris extrusion than conventional needle irrigation method. This difference among groups may be caused by the fact that laser activation of the irrigation solution provides shock waves and cavitation effect in the root canal [31] and this mechanism creates high pressure that can enhance to delivery of the irrigants to three-dimensional complexity of the root canal and facilitate cleaning of the root canal system [32]. Hence, more debris extrusion in laser-assisted irrigation activation groups could be explained by more aggressive irrigation because of the high pressure. On the contrary, it has been reported that laser-assisted irrigation activation removed more debris from the root canal than conventional needle irrigation [21,33,34]. Another explanation of the result of this study could be the higher concentration of debris in the extruded irrigation solution than conventional needle irrigation. Although there are many studies relating to the effect of different file systems on apical debris extrusion, studies relating to the effect of the irrigation activation techniques are limited. Kuştarci and Er [10] reported that laser-assisted irrigation using Er,Cr:YSGG laser significantly affects the amount of debris extrusion. Arslan and Kuştarcı [11] reported that PIPS activation caused significantly more extrusion debris than no activation. The results of these studies are in harmonious with the result of this study.

There are many studies compare laser-assisted irrigation techniques in terms of different effects. However, studies compare three laser-assisted irrigation activation techniques used in this study are limited. Keleş et al. [22] showed that using laser-assisted irrigation activation techniques enhanced the removal of filling material and using Er:YAG laser showed more efficient than using PIPS or Nd:YAG laser. Akyuz Ekim and Erdemir [35] reported that using Er:YAG laser or PIPS or Nd:YAG laser improved push-out bond strength of fibre post. Kamalak et al. [12] demonstrated that using Er:YAG laser or PIPS or Nd:YAG laser after removal of root canal filling did not decrease fracture resistance of endodontically retreated roots.

The absence of periapical resistance to extrusion by the surrounding structure could increase irrigation solution and debris extrusion. The experimental set-up used in this study did not include the simulation of periapical tissues. It is known that in clinical conditions some factors such as periapical tissues and bone might decrease the amount of extrusion by providing resistance [28]. The fact that periapical tissues were not simulated is a limitation of this study.

Campello et al. [36] compared the first file to bind and cone-beam computed tomographic measurements in terms of initial apical canal diameter determination and micro-computed tomographic measurements were used as the gold standard. Campello et al. [36] reported that the first file to bind did not show the exact diameter and cone-beam computed tomographic measurements were more successful in determining the initial apical diameter. In this study, the initial apical size of teeth was determined by the first file to bind and this is another limitation of the study.

In some of debris extrusion studies, crowns of teeth were removed to standardize the length of the roots [27,37]. In this study, teeth with similar lengths were selected. This is more proper in terms of reflecting clinical conditions. In addition, a reservoir is required for irrigation solution to apply PIPS. Access cavity provides a reservoir for irrigation solution. Teeth have statistically similar length were used in this study.

Since sodium hypochlorite and other irrigation solutions involve particulate matter, they tend to crystallize and this might change the amount of the apically extruded debris and affect the results [25,38]. To obtain more accurate measurements, in this study bidistilled water was used for irrigation during instrumentation and also final irrigation. After each instrument, root canals were irrigated using 2 mL bidistilled water. Totally, 12 mL bidistilled water was used during instrumentation. As final irrigation, 6 mL bidistilled water was used.

Conclusion

All irrigation activation techniques extruded debris apically. Within the limitations of this study, laser-assisted irrigation activation techniques caused more debris extrusion when compared to conventional needle irrigation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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