Efficacy of Ultrasonic *versus* Laser-activated Irrigation to Remove Artificially Placed Dentin Debris Plugs

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Abstract

Introduction: The study assessed the efficacy of laser activated irrigation (LAI) with Erbium: Yttrium Aluminum Garnet (Er:YAG) and Erbium Chromium: Yttrium Scandium Gallium Garnet (Er,Cr:YSGG) wavelengths as compared with passive ultrasonic irrigation (PUI). Previously proposed irrigation times were used for LAI (4× 5 seconds) and the intermittent flush technique (3× 20 seconds). **Methods:** We used a split root model with an artificial root canal wall groove. Roots were prepared to an apical size # 40 with ProFiles 0.06 (Dentsply Maillefer, Baillaigues, Switzerland). Five groups of 20 straight canine roots were evaluated as follows: Group 1: hand irrigation for 20 s with 2.5% NaOCl (CI); Group 2: PUI performed once for 20 s with the #20 Irrisafe (Satelec Acteon group, Merignac, France) (PUI 1); Group 3: PUI for 3x 20 s with the Irrisafe (PUI 2); Group 4: LAI with the Er,Cr:YSGG laser and Z2 (200 μm) Endolase tip (Biolase, San Clemente, USA) at 75 mJ for 4x 5 s (LAI 1); Group 5: LAI with the Er:YAG laser (HoYa Versawave, Cortaboeuf, France) and a 200 μm endodontic fiber at 75 mJ for 4x 5 s (LAI 2). Images from the groove were taken before and after irrigation. The quantity of dentin debris in the groove after the experimental protocols was evaluated. **Results:** Statistically significant differences ($p < 0.05$) were found between CI and all other groups and between PUI 1 and the other groups. **Conclusion:** LAI techniques using erbium lasers (Er:YAG or Er,Cr:YSGG) for 20 seconds (4× 5 seconds) are as efficient as PUI with the intermittent flush technique (3× 20 seconds). *(J Endod 2010;36:1580–1583)*

Key Words

Irrigation, laser, root canal, ultrasound

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Effective endodontic treatment requires the combination of physical and chemical agents to eradicate soft-tissue debris, smear layer, and microorganisms because buildup of debris in the root canal system makes effective cleaning and disinfection impossible. The use of lasers at different wavelengths has been proposed to supplement conventional endodontic cleaning procedures (1–4). A considerable limitation, however, is the unidirectional emission of the laser beam, which makes it difficult to access the entire root canal wall with the laser. The laser fiber must be moved repeatedly in a spiraling motion along the root canal walls in order to maximize the area exposed to the laser beam, but even this is not completely efficient and the entire root canal wall will not be exposed to the laser beam (2, 4). Alternative approaches such as side-firing tips have limited use because of their size (4) or require further investigation before clinical application (5, 6).

Laser-activated irrigation (LAI) with an erbium laser has been introduced as a method for activating the irrigant (5–10). The effect is based on cavitation; in water, activation of the laser at subablative settings may result in the formation of large elliptical vapor bubbles, which expand and implode. These vapor bubbles may cause a volumetric expansion of 1,600 times the original volume, which increases pressure and drives fluid out of the canal. When the bubble implodes after 100 to 200 microseconds, an underpressure develops and sucks fluid back into the canal, inducing secondary cavitation effects. Therefore, the laser works as a fluid pump. Another technique, passive ultrasonic irrigation (PUI), is also based on the principle of cavitation and acoustic streaming (11). The ultrasonic activation of irrigants therefore plays a pivotal role in contemporary endodontics (12, 13).

The removal of dentin debris from the root canal using LAI has been investigated in only two studies (10, 11). Both studies, de Moor et al (10) with an Er,Cr:YSGG laser (2,780 nm) and de Groot et al (11) with an Er:YAG laser (2,940 nm), have shown that LAI is significantly more effective in removing dentin debris from the apical part of the root canal than PUI or hand irrigation when the irrigant was activated for 20 seconds. It remains unknown (1) whether the use of PUI for more than 20 seconds (3× 20 seconds according to van der Sluis et al [14]) is as effective as 20 seconds of LAI , and (2) whether there is a difference between the efficacy of LAI performed with an Er:YAG laser or Er,Cr:YSGG laser (both erbium lasers, with different wavelengths, 2,780 nm and 2,940 nm, respectively). Therefore, the aim of the present study was to evaluate *ex vivo* the removal of artificially placed dentin debris in standardized root canals by (1) active hand irrigation for 20 seconds, (2) PUI with an Er:YAG or Er,Cr:YSGG laser, and (3) LAI for 20 seconds and 3 × 20 seconds.

Material and Methods

Sample Selection and Preparation

For the setup of this study, an experimental root canal model described by Lee et al (15) was used (Fig. 1). One hundred maxillary canines with straight roots were selected. These roots were mounted and prepared as described in de Moor et al (9). After verification of the location of the apical foramen with an ISO size 15 file through the apical foramen, the teeth were decapitated at 19 mm of the location of the apical foramen with a diamond disc (Horico, Berlin, Germany). The coronal 3 mm of the canals were enlarged by a round bur with a diameter of 2.3 mm (Komet, Düsseldorf, Germany, 340.202.001.001.023, American size 8) and simulating the

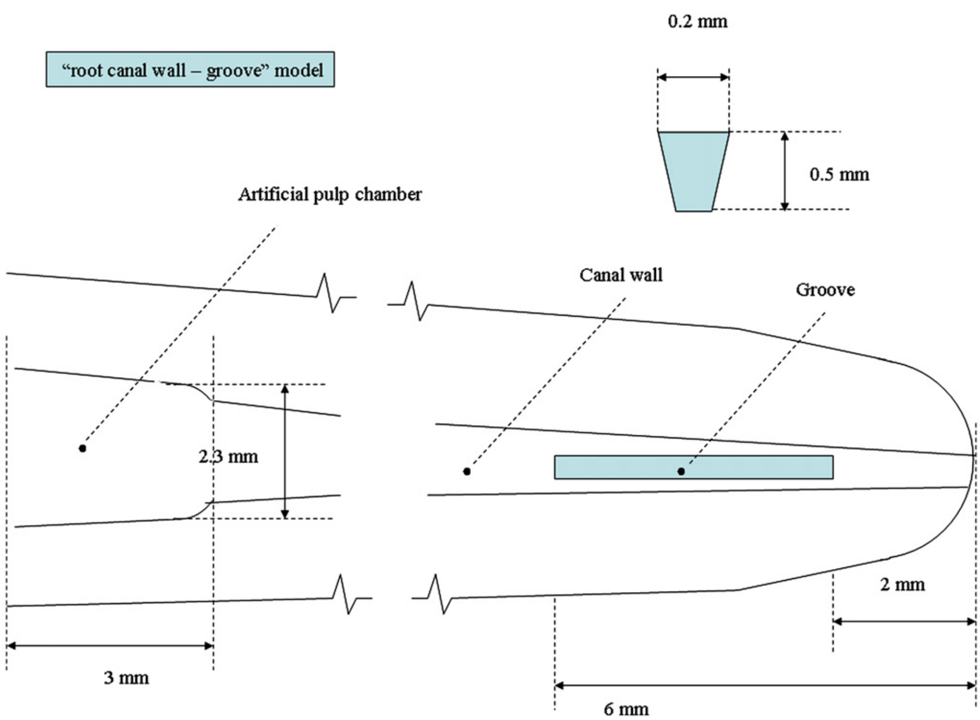

Figure 1. A schematic representation of the specimen preparation. On one half of the instrumented root canal, a groove was cut 2 to 6 mm from the apex. In the coronal 3 mm, an artificial pulp chamber was prepared over a length of 3 mm (diameter = 2.3 mm). (This figure is available in color online at www.aae.org/joe/.)

pulp chamber (Fig. 1). The root canals were then instrumented with the ProFile system (Dentsply Maillefer, Ballaigues, Switzerland) until size 40, taper 0.06 (master apical file) 1 mm short of the apical foramen (working length). The standardization of the root canal outline was checked; pictures of the canals (3,040 × 2,040 pix) were taken, and the diameter of 10 randomly chosen models was measured at 2, 6, and 10 mm from the apical end of the canal using image analysis software (Sigmascan Pro Image Analysis Version 5.0; SPSS Inc., Chicago, IL) (9). After instrumentation, the roots were longitudinally split through the canal. A standard groove 4 mm in length, 0.2 mm in width, and 0.5 mm in depth was cut in one canal wall 2 to 6 mm from the apex; the dimension of the groove is comparable to an apical oval root canal (15). Each groove was filled with dentin debris that had been mixed for 5 minutes with 2% NaOCl to simulate a situation in which dentin debris accumulates in uninstrumented canal extensions during root canal preparation. This model was introduced to standardize the root canal anatomy and the amount of dentin debris present in the root canal before the irrigation procedure, and it was intended to increase the reliability of the evaluation of dentin debris removal. The methodology is sensitive, and the data are reproducible (14). So, a total of 100 blocks with root canal–prepared roots and plugged root canal wall grooves were used for the experiment and randomly divided in five groups of 20.

Irrigation Protocols

Five irrigation protocols were investigated: conventional irrigation (CI) with 2.5% sodium hypochlorite (NaOCl), two protocols using PUI, and two protocols using LAI. In group 1 (n = 20), hand irrigation with 4 mL 2.5% NaOCl was performed with a 10-mL syringe (Terumo, Leuven, Belgium) and a 27-G endodontic needle (Monoject; Sherwood Medical, St Louis, MO). For 20 seconds, the needle was inserted 1 mm short of the working length and moved slowly over a distance of 4 mm up and down in the apical half of the root canal. The flow rate was approximately 0.3 mL/s, and the total irrigant volume was 6 mL. In group 2 (n = 20) (PUI 1), a stainless steel noncutting wire (#20) (Irrisafe, Satelec Acteongroup) was used driven by an ultrasonic device (Suprasson Pmax Newtron; Satelec, Acteongroup, Mérignac, France) at power setting "blue 4" (frequency 30 KHz, displacement amplitude about 30 μm according to the manufacturer) for 20 seconds. The tip of the Irrisafe was kept 1 mm from the apical stop. After this procedure, the canal was flushed with 2 mL 2.5% NaOCl with a syringe and a 27-G endodontic needle (Monoject). In group 3 (n = 20) (PUI 2), the same protocol as in group 2 was performed but with a 3× 20 seconds activation of the irrigant. The irrigant was flushed out and renewed after each activation cycle. In group 4 (n = 20) (LAI 1), the NaOCl was activated by laser irradiation (Er,Cr:YSGG laser; Waterlase Millenium, Biolase, San Clemente, CA) using an endodontic fiber (Z2, Endolase Tip, Biolase) with a diameter of 200 μm and 25-mm length, with pulse energies of 75 mJ at 20 Hz. The fiber was kept 5 mm away from the most apical preparation and then kept stationary for 5 seconds. A mark was put on the fiber with a black marker at 13 mm in order to position it in the root canal at this depth. This protocol was repeated four times, without removing the tip from the root canal. At the end of this procedure, the canal was flushed with 2 mL 2.5% NaOCl using a syringe with a endodontic needle. In group 5 (n = 20) (LAI 2), the same protocol as in group 4 was followed but with an Er:YAG laser (HoYa Versawave, Cortaboeuf, France) and a 200-μm endodontic fiber at 75 mJ. The irrigant was also activated for 4× 5 seconds. After irrigation, the canals were carefully dried with paper points (size 35).

Evaluation of Dentin Debris Removal

After unlocking the two halves, the amount of remaining debris in the artificial grooves was evaluated. Digital images of the groove were taken before and after irrigation at 40× magnification. These images were scored by two dentists who were unaware of the irrigation techniques used. Scores were assigned based on the following system: 0: the groove is empty, 1: less than half of the groove is filled with dentin debris, 2: more than half of the groove is filled with dentin debris, and 3: the groove is completely filled with dentin debris.

Statistical Analysis

The interrater agreement was determined (Cohen kappa), and data were initially analyzed using explorative data analysis. Chi-square tests were performed to determine whether the observed frequencies (counts) markedly differ from the frequencies expected by chance. A correction for multiple testing was performed using the Holm procedure, a variant of the Bonferroni adjustment. It is a step-down procedure in that one starts with the most extreme (ie, the smallest) p value and continues with less extreme p values in the successive rejection decisions. Because of this adjustment, the level of significance was set between $\alpha < 0.05$ and $\alpha < 0.005$.

Results

Table 1 shows the debris scores after irrigation with the five different techniques. Highly significant differences were found between CI and both PUI and LAI protocols ($p < 0.001$). Statistically significant differences were also observed between PUI 1 and both groups of LAI, LAI 1 and LAI 2 ($p < 0.001$). The Cohen kappa coefficient of interrater agreement was 0.85.

Discussion

The model chosen for this study on the effectiveness of irrigation in removing dentin debris in artificial irregularities and extensions allows the comparison of the presence of debris before and after irrigation. In most studies, the amount of debris is evaluated only after preparation and irrigation. Furthermore, these studies did not report how much debris was present before irrigation and are therefore unable to establish the extent of removal using the different irrigation procedures. In the present study, the groove cut in the root canal wall is made in order to simulate uninstrumented extensions in the apical half. Canines were used because they have wide canals (16, 17), and, hence, the root can be more easily split in the mesiodistal direction.

The generation of shockwaves by dental lasers inside root canals can play an important role in smear layer removal (5–10). Similarly, smear layer removal can be achieved when water is activated in root canals using erbium lasers (Er,Cr:YSGG or Er:YAG) (6, 9, 10), causing the formation of vapor bubbles that expand and implode (5, 7, 8, 10). This was also shown in the present study. Apparently, there is no difference in the efficacy of both wavelengths in terms of smear layer removal at the settings used in this study.

The present study is the first to compare the effects of Er:YAG and Er,Cr:YSGG wavelengths on laser-induced cavitation for smear layer removal. Both wavelengths have a good absorption in water and sodium hypochlorite (18). The laser light is used here at subablative settings, which does not damage the root canal wall and hence the formation of ledges is avoided (2, 4). The fiber is also inserted centrally in the root canal without contact with the root canal wall and kept stationary during emission. Also, no spiral motion is made in the irrigant, which is needed when the laser fiber is used in the conventional way and when the whole root canal wall has to be exposed directly to the laser light. In this respect, the risk of ledge creation appeared to be greater with Er:YAG than with Er,Cr:YSGG (4, 19). Care must be taken, however, when using the laser fibers in the root canal, as apical extrusion of the irrigant after laser activation has been described at the present power settings (6). A previous study by George et al (6) showed that there was twice as much dye penetration through the apical constriction with the fiber tip at 4 mm than at 5 mm. Therefore, a distance of 5 mm from the apical stop to the fiber tip was used for the present evaluation. All apical stops were also controlled under magnification 40× (Pico Opmi, Zeiss) by two dentists and no damage or widening of the unprepared last 1 mm up (from the apical stop to the outer surface of the root) was seen. These findings confirm the findings of our previous study (9).

Another interesting finding is that the intermittent flush technique (PUI 2) was as effective as both LAI protocols (12). Therefore, within the confines of the present study (removal of debris from a root canal wall groove), the use of an expensive laser device to obtain comparable results is not necessary. In the study by de Groot et al (10), however, more efficacy was attributed to LAI with an Er:YAG laser because of the formation of secondary cavitation bubbles. The fluid flow associated with such an inertial collapse, combined with acoustic streaming resulting from the oscillations of smaller bubbles, was thought to explain the cleaning efficacy of LAI. The secondary cavitation bubbles allowed better cleaning of the root canal wall because they are excited by the bubble collapse of the consecutive laser pulse. Hence, new research should be focused not only on the removal of debris from the root canal wall but also on the cleanliness of the entire root canal, especially in the apical third, and the debridement of anastomes and isthmuses. In addition, the Er:YAG used at subablative settings is also efficient in removing biofilms, even those with *Escherichia faecalis* (19). Thus, the combination of cavitation and direct interaction with the biofilm, with the possibility of sight firing (6) and overcoming the limitations of a straight forwarded

TABLE 1. Dentin Debris Scores After Conventional Irrigation With 2.5% NaOCl, Passive Ultrasonic Irrigation, Er:YAG Laser–Activated Irrigation, and Er,Cr:YSGG Laser–Activated Irrigation

	Debris scores (%)				
Irrigation technique	0	1	2	3	*N* (total)
CI*			5 (25)	15 (75)	20
PUI 1*, †	6 (30)	7 (35)	7(35)		20
PUI 2*, †	12 (60)	6 (30)	2 (10)		20
LAI 1*, †	15 (75)	5 (25)			20
LAI 2*, †	16 (80)	4 (20)			20

Debris scores: 0: the groove is empty, 1: less than half of the groove is filled with dentin debris, 2: more than half of the groove is filled with dentin debris, 3: the groove is completely filled with dentin debris. CI, conventional hand irrigation during 20 seconds with 2.5% NaOCl; PUI 1, PUI during 20 s with the #20 Irrisafe (Satelec Acteon Group, Merignac, France); PUI 2, PUI during 3× 20 seconds with the Irrisafe; LAI 1, LAI with the Er,Cr:YSGG laser and Z2 (200 μm) Endolase tip (Biolase, San Clemente, CA) at 75 mJ during 4× 5 seconds; LAI 2, LAI with the Er:YAG laser (HoYa Versawave, Cortaboeuf, France) and a 200-μm endodontic fiber at 75 mJ during 4× 5 seconds.

*Statistically significant differences between groups: CI-PUI 1, CI-PUI 2, CI-LAI 1, and CI-LAI 2 ($p < 0.001$).

†Statistically significant differences between groups: PUI 1-LAI 1 and PUI 1-LAI 2 ($p < 0.001$).

laser beam (4), might finally result in an added value for erbium lasers in root canal treatment when used at subablative settings (20).

Conclusion

LAI techniques with erbium lasers (Er:YAG or Er,Cr:YSGG) for 20 seconds (4× 5 seconds) are as efficient as passive ultrasonic irrigation with the intermittent flush technique (3× 20 seconds).

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