An Evaluation of the Effect of Pulsed Ultrasound on the Cleaning Efficacy of Passive Ultrasonic Irrigation

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Abstract

Introduction: Multiple activations of the irrigant by using pulsed ultrasound may enhance the removal of dentin debris because of repeated acceleration of the irrigant. The aim of this study was to evaluate the effect of pulsed ultrasound on passive ultrasonic irrigation (PUI) in its ability to remove artificially placed dentin debris from a simulated apical oval extension within standardized root canals. **Methods:** Each of 20 *in vitro* root canal models with a standard groove in the apical portion of one canal wall filled with dentin debris received PUI repeatedly, either without pulsation (group1) or with pulsation (730 milliseconds on/100 milliseconds off in group 2, 400 milliseconds on/400 milliseconds off in group 3, and 100 milliseconds on/670 milliseconds off in group 4), corresponding to duty cycles of 100%, 88%, 50%, and 13%, respectively. After each irrigation procedure, the amount of dentin debris in the groove was evaluated by taking photographs of the groove and scoring. The irrigation procedures were also visualized *in vitro* using high-speed imaging performed in glass root canal models. **Results:** The debris score was significantly lower only in group 3 (p = 0.023). The *in vitro* visualization showed increased streaming and cavitation during the start-up phase of each pulse. **Conclusions:** PUI with a pulsation pattern of 400 milliseconds on/400 milliseconds off and a duty cycle of 50% is more effective in removing dentin debris from a simulated apical oval extension in standardized root canals than continuous ultrasonic activation. Duty cycles of 13% and 88% showed no difference compared with continuous oscillation. *(J Endod 2010;36:1887–1891)*

Key Words

Dentin debris, passive ultrasonic irrigation, pulsation, pulsed ultrasound

After the completion of a standard root canal preparation, the debridement of the root canal is, however, by far complete, leaving large untouched areas that may harbor tissue or dentin debris, microbes, and their byproducts (1–7). The root canal system has better access for cleaning by an irrigant after finishing the instrumentation, and irrigation has a better possibility for cleaning the space beyond the prepared canal (8). Therefore, a final rinse after the completion of the preparation is an essential part of root canal debridement.

It has been realized in recent years that irrigation dynamics play an important role in the cleaning process (9–11). The use of a file in conjunction with an (ultra)sonic device that activates the irrigant has been proposed for the final rinsing step to enhance the cleaning of the root canal through streaming and cavitation (12–15).

Laser-activated irrigation has been shown to be more effective in removing dentine debris from the apical part of the root canal than passive ultrasonic irrigation (PUI) (16). This improvement in cleaning efficacy may be associated with the fact that the irrigant becomes accelerated at every laser pulse (16). Similarly, the acoustic streaming of the irrigant introduced by the ultrasonic activation may also be enhanced by repeated activations after introducing ultrasound pulsations into the system. Each activation causes an acceleration of the irrigant, and the governing fluid physics laws link acceleration to force. In addition, pulsed ultrasound has a direct effect on acoustic cavitation in a liquid (17–19). Therefore, this study looks into the enhancement of the cleaning efficacy of PUI by pulsed ultrasound under the hypothesis that PUI with pulsation is more effective than without pulsation within 10 seconds.

Materials and Methods

Dentin Debris Removal Model

Straight roots from 20 extracted human maxillary canines were decoronated to obtain uniform root sections of 15 mm. The roots were embedded in self-curing resin (GC Ostron 100; GC Europe, Leuven, Belgium) and then bisected longitudinally through the canal in mesiodistal direction with a saw microtome (Leica Microsystems SP1600, Wetzlar, Germany). The surfaces of both halves were ground successively with 240-, P400- and 600-grit sandpaper, resulting in smooth surfaces on which only little of the original root canal lumen was left. Four holes were drilled in the resin part, and the two halves were reassembled by four self-tapping bolts through the holes (9). All the models were checked for any leakage of liquid or gas apically or laterally before experiments; if there was any, rubber dam caulk was applied to ensure the root canal space of the model was a closed system.

New root canals were prepared by K-files #15/.02 (Dentsply Maillefer, Ballaigues, Switzerland) and HERO 642 (MicroMega, Besançon, France) nickel-titanium rotary

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instruments to a working length of 15 mm, ISO size 30, and taper of 0.06, resulting in standardized root canals. During preparation, the canals were rinsed with 1 mL of 2% NaOCl after each file delivered by a 10-mL syringe (Terumo, Leuven, Belgium) and a 30-G needle (Navitip; Ultradent, South Jordan, UT).

A standard groove of 4 mm in length, 0.5-mm deep, and 0.2-mm wide situated at 2 to 6 mm from the working length (20), was cut in the wall of one half of each root canal with a customized ultrasonic tip. A periodontal probe with an adapted 0.2-mm wide tip was used to verify the dimension of each groove during and after preparation. The dimension of the groove is comparable to an apical oval root canal (21). Each groove was filled with dentin debris, which was mixed with 2% NaOCl for 5 minutes, to simulate a situation in which dentin debris accumulates in uninstrumented canal extensions (20). This model was introduced to standardize the root canal space and the amount of dentin debris present in the root canal before the irrigation procedure to increase the reliability of the dentin debris removal evaluation. The methodology has been shown to be sensitive, and the data are reproducible (22). A pilot study has shown that a single model could be reused at least 8 times without any visible defect on the surface of the canal wall. Therefore the 20 models were used repeatedly in the five experimental groups which are shown in Table 1.

Irrigation Procedure

Specimens in all the experimental groups were rinsed with 2 mL of irrigant (2% NaOCl) using 10-mL syringes with 30-G needles (Navitip) placed 1 mm from the working length, and the flow rate was approximately 5 mL/min. Then, the irrigant was activated by an ultrasonic file #20/.00 (IrriSafe; Acteon, Merignac, France) for 10 seconds without (group 1) or with (groups 2-4) pulsed ultrasound (Table 1). All the experimental specimens received 2 mL of irrigant, which was delivered again by a syringe as the final flush.

Every attempt was made to keep the file centered in the canal to minimize contact with the canal walls (passive activation). The file was driven at power setting "yellow 4" by a piezoelectronic unit (Suprasson PMax; Satelec Acteon, Merignac, France) of which the footswitch was replaced by a customized pulse generator to be able to oscillate the file with pulsation.

Image Evaluation and Statistical Analyses

Before and after each irrigation procedure, the root halves were separated, and the grooves were viewed through a stereomicroscope (Stemi SV6; Carl Zeiss, Göttingen, Germany) using a cold light source (KL 2500 LCD, Carl Zeiss). Controls verified that no debris had fallen out of the groove during the assembly or disassembly process. Pictures were taken with a digital camera (Axio Cam, Carl Zeiss). The sequence of all the pictures was randomized, and two calibrated examiners were blind to the group assignment.

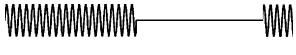
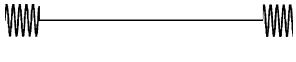
The debris left in the groove after irrigation was scored independently by the two calibrated dentists using the following score system: 0: the groove is empty, 1: less than half of the groove is filled with debris, 2: more than half of the groove is filled with debris, and 3: the complete groove is filled with debris (20). The percentage of interagreement should be more than 95%; if this percentage was lower than 95%, a consensus had to be reached. The differences in debris scores between the groups were analyzed by means of the Kruskal-Wallis test and the Mann-Whitney U test. The level of significance was set at $\alpha = 0.05$.

High-speed Imaging Experiments

An optical setup was constructed in order to visualize the effect of pulsed ultrasonic activation in the two glass models of the root canal. Both models contain straight root canals of length 10 mm, an apical diameter of 0.30 mm, and a taper of approximately 0.06. One model had no side canals; the Irrisafe file (#20/.00) was positioned at 3 mm from the apex. The other model had one side canal with a diameter of 0.2 mm located at 2.0 mm from the apex; the Irrisafe file was positioned at 1 mm from the apex. The file was driven in both models under the same conditions as the *in vitro* experiments. The root canals were filled with 5% NaOCl, to which small hollow glass spheres (mean diameter, 11 μm; Sphericel, Potters Industries, South Yorkshire, UK) were added in order to track the fluid movement.

A zoom microscope with 1.25× to 20× magnification was used (BX-FM; Olympus, Tokyo, Japan) for magnification. The root canal was illuminated in bright field by a continuous-wave light source (ILP-1, Olympus). Imaging was performed using a high-speed camera (HPV-1; Shimadzu Corp, Kyoto, Japan) at a frame rate of 25,000 frames per second.

TABLE 1. Experimental Groups and the Number of Specimens at Each Score Rank after the Irrigation Procedure

Group (N = 20)	Pulse intervals	Schematic representation (1 second)	Duty cycle (%)*	Score†			
				0 (%)	1 (%)	2 (%)	3 (%)
1	None		100	8 (40)	11 (55)	1 (5)	0 (0)
2	730 ms on/100 ms off		88	9 (45)	8 (40)	2 (10)	1 (5)
3	400 ms on/400 ms off		50	15 (75)	5 (25)	0 (0)	0 (0)
4	100 ms on/670 ms off		13	11 (55)	5 (25)	4 (20)	0 (0)
5 (control)	None		0	0 (0)	0 (0)	0 (0)	20 (100)

*Duty cycle = length of the pulse divided by the total time of one cycle.

†Score 0, the groove is empty; score 1, less than half of the groove is filled with debris; score 2, more than half of the groove is filled with debris; score 3, the complete groove is filled with debris.