Comparison of the Cleaning Efficacy of Different Final Irrigation Techniques

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Abstract

Introduction: The aim of this study was to evaluate the removal of dentin debris from artificially made grooves in standardized root canals by 6 different final irrigation techniques. **Methods:** Conventional syringe irrigation, manual dynamic activation (MDA) with tapered or nontapered gutta-percha (GP) cones, the Safety Irrigator system, continuous ultrasonic irrigation (CUI), and apical negative pressure (ANP) irrigation were tested *ex vivo* in 20 root canals with a standardized, debris-filled groove in the apical portion of one canal wall. After each irrigation procedure, the groove was photographed, and the residual amount of dentin debris was scored. **Results:** There was no significant difference between the MDA with a nontapered GP cone, the Safety Irrigator, and the ANP irrigation. These techniques produced better cleaning efficacy than syringe irrigation (P < .005) but significantly worse than the MDA with a tapered cone (P < .05). CUI was significantly better than all the other techniques tested in this study (P < .001). **Conclusions:** CUI was the most effective technique in dentin debris removal from the apical irregularities, and syringe irrigation alone was the least effective. MDA technique was more effective with a tapered GP cone than with a nontapered one. *(J Endod 2012;38:838–841)*

Key Words

Apical negative pressure, continuous ultrasonic irrigation, dentin debris, manual dynamic activation

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Debridement is the aim of and also a big challenge to endodontic treatment (1), especially in the apical portion of the root canal (2). Because of the complexity of the root canal anatomy and the limitations of instrumentation (3, 4), irrigation has gained increasing attention, and one improvement in this respect is irrigant activation that resulted in the development of various irrigation techniques or systems. Removal of the dentin debris from apical uninstrumented areas seems to be a good indication of the mechanical debridement efficacy of an irrigation system, because the flow of the irrigant directly influences the debris removal (5).

Syringe irrigation is the conventional and still widely used irrigation technique. Combinations of syringe irrigation to deliver the irrigant and various ways to activate it are applied mainly as final irrigation after root canal instrumentation is completed. There are various methods to activate the irrigant, ranging from moving gutta-percha (GP) cones up and down in the root canal (manual dynamic activation [MDA]) (6–8) to instruments energized by (ultra)sonic or laser devices (9–12).

To prevent irrigant extrusion and enhance the apical irrigation, so-called apical negative pressure (ANP) systems, such as EndoVac (Discus Dental, Culver City, CA), have been introduced (13). Its microcannula can be inserted until working length (WL), and the negative pressure will create an apical circulation of the irrigant without apical extrusion. It also seems to have a better apical debridement efficacy compared with positive pressure irrigation (13–15). The Safety Irrigator (Vista Dental, Racine, WI) has been recently introduced as a simple, "negative-pressure" endodontic irrigation device. It features a large coronal evacuation tube, enabling the irrigant aspiration from the pulp chamber simultaneously with the irrigant delivery in the root canal through a flexible needle tip. The VPro tip (Vista Dental) is an ultrasonically activated, 30-gauge irrigation needle that was recently introduced to allow simultaneous continuous irrigant delivery and ultrasonic activation, recently referred to as continuous ultrasonic irrigation (CUI) (16).

The aim of this study was to compare the mechanical cleaning efficacy of conventional syringe irrigation, MDA, the Safety Irrigator system, CUI by the VPro tip, and ANP by the EndoVac system in the removal of dentin debris from simulated irregularities located at the apical area in standardized root canals.

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 following the protocol described previously (5, 9). Briefly, the roots were embedded in resin and bisected longitudinally. The surfaces of the halves were then ground to leave only a little of the original root canal lumen. Four holes were drilled in the resin part, and the halves were reassembled by 4 self-tapping bolts through the holes. All the models were checked to see whether there was any leakage of liquid or gas apically or laterally before experiments. If there was any, rubber dam caulk would be applied to ensure that the root canal modeled a closed system.

New root canal spaces were prepared by Flexofiles (Dentsply Maillefer, Ballaigues, Switzerland) to #15 and rotary System GT instruments (Dentsply Maillefer) to a WL of 15 mm, an International Organization for Standardization (ISO) size of 30, and a taper of 0.06. The apical part was further enlarged by using nickel-titanium K-files #40/.02

(Dentsply Maillefer) with a balanced-force technique. During preparation, the canals were rinsed with 2 mL of 2% NaOCl after each file, delivered by a 10-mL syringe (Terumo, Leuven, Belgium) and a 27-gauge needle (Navitip; Ultradent, South Jordan, UT).

The coronal 3 mm of the canal was enlarged by a no. 23 round bur (Dentsply Maillefer) with a diameter of 2.3 mm, simulating a pulp chamber. A standard groove of 4 mm in length, 0.5 mm deep, and 0.2 mm wide, situated at 2–6 mm from WL (11), was cut in the wall of one half of each root canal with a customized ultrasonic tip (Fig. 1*B*). 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 (17). 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 (11). 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 is sensitive, and the data are reproducible (18). A pilot study has shown that a single model could be reused up to at least 8 times without any visible defect on the surface of the canal wall. Therefore, the 20 models were used repeatedly in the 6 experimental groups, which are shown in Table 1.

Final Irrigation Procedures

Conventional Syringe Irrigation Group (Group 1). Two milliliters of irrigant (6% NaOCl) was delivered by using a 10-mL syringe with a 30-gauge needle (Navitip; Ultradent) placed 1 mm from WL in 20 seconds. This process was repeated twice, resulting in a total irrigant volume of 6 mL and a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL/sec^{-1}.

MDA Groups (Groups 2 and 3). The process was the same as for group 1, but the irrigant was also activated by moving a GP cone #40/.02 (group 2) or a tapered GP cone #30/.06 (group 3) up and down (from WL – 5 mm to WL) for 10 seconds (3 strokes/sec^{-1}) after each irrigant delivery. This sequence was repeated twice more, resulting in a total irrigant volume of 6 mL, a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL/sec^{-1}, and total irrigant activation time was 30 seconds.

Safety Irrigator Group (Group 4). Two milliliters of 6% NaOCl was delivered with the needle (30-gauge, open-ended) placed 1 mm from WL in 20 seconds. The process was repeated twice, resulting in a total irrigant volume of 6 mL and a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL/sec^{-1}.

CUI Group (Group 5). CUI was performed with the 30-gauge VPro Tip driven at power setting "yellow 4" by an ultrasonic device (Suprasson PMax; Satelec Acteon, Merignac, France) for 30 seconds with the in-plane oscillation direction toward the groove, during which the tip was moved up and down twice/second from WL – 4 mm to WL – 1 mm. This ultrasonic tip is a 30-gauge needle, enabling a continuous flow of irrigant from the tip with a simultaneous ultrasonic oscillation of the tip. This procedure resulted in a total irrigant volume of 3 mL, a total irrigant delivery time of 30 seconds with a flow rate of 0.1 mL/sec^{-1} approximately, and a total irrigant activation time of 30 seconds.

ANP, EndoVac Group (Group 6). Two milliliters of 6% NaOCl was delivered by using a 10-mL syringe with a 30-gauge needle placed WL – 1 mm in 20 seconds. Afterwards, the microcannula (#32/.00) was placed under ANP at WL for 6 seconds and then at WL – 2 mm for 6 seconds alternatively for a total of 30 seconds; simultaneously, the Master Delivery Tip (MDT) located at the orifice ensured the continuing irrigant supply. This procedure resulted in a total irrigant volume of 5 mL, a total irrigant delivery time of 50 seconds with a flow rate of 0.1 mL/sec^{-1}, and a total apical irrigation time by microcannula of 30 seconds.

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) by 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 2 calibrated examiners who were blinded to the group assignment scored each picture twice respectively.

The debris left in the groove after irrigation was scored independently by 2 calibrated dentists by using the following score system (11):

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.
3 = The complete groove is filled with debris.

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 test. The level of significance was set at $\alpha = 0.05$.

Results

The 2 investigators differed in the scoring of 5 specimens; agreement was reached after discussion (kappa > 0.90, almost perfect agreement). Before irrigation procedures, the groove score was 3 for each specimen. The results after irrigation are shown in Table 1.

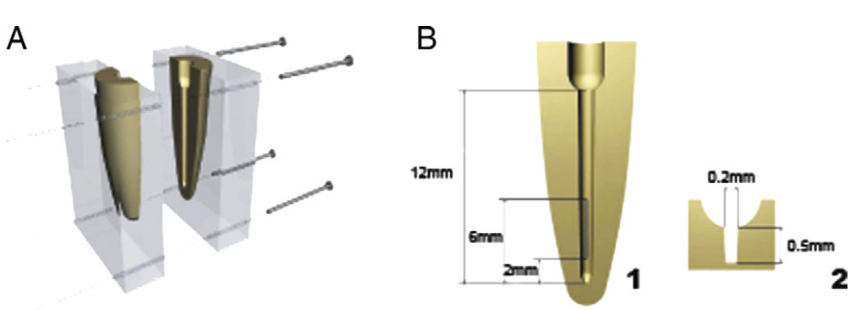

Figure 1. Schematic representations of the standardized root canal model (*A*), its groove (*B*1) and cross section (*B*2).

TABLE 1. Experimental Groups and Number of Specimens at Each Score Rank after Different Irrigation Techniques

Group (n = 20)	Irrigation techniques	Score 0	Score 1	Score 2	Score 3
1 (control)	Syringe	0 (0%)	0 (0%)	0 (0%)	20 (100%)
2	MDA nontapered GP	0 (0%)	1 (5%)	9 (45%)	10 (50%)
3	MDA tapered GP	1 (5%)	10 (50%)	9 (45%)	0 (0%)
4	Safety Irrigator	1 (5%)	6 (30%)	4 (20%)	9 (45%)
5	PUI	11 (55%)	9 (45%)	0 (0%)	0 (0%)
6	ANP	0 (0%)	0 (0%)	7 (35%)	13 (65%)

There was a significant difference between the experimental groups ($P < .001$). There was no significant difference between the MDA with a nontapered GP cone, the Safety Irrigator, and ANP irrigation by EndoVac system. These techniques resulted in better cleaning efficacy than conventional syringe irrigation ($P < .005$) but significantly worse than the MDA with a tapered cone ($P < .05$). CUI by the ultrasonic system was significantly better than all the others tested in this study ($P < .001$).

Discussion

All the irrigation techniques basically involve the irrigant delivery with or without irrigant activation. Irrigant activation can enhance the irrigant to disperse in the root canal system (19) and improve mechanical cleaning of the root canal by effective fluid flow dynamics (20). We standardized the activation time to compare these irrigation systems in mechanical cleaning efficacy by irrigant activation. The results of this study confirmed that activation of the irrigant enhances the removal of dentin debris from oval extensions either manually or ultrasonically. Irrigant volume is related to the flow rate, which influences irrigant delivery, refreshment, and mechanical effect on the root canal wall. Because the flow rate was standardized, the mechanical effect during the irrigant delivery was expected to be similar. Therefore, we accepted slight differences in the irrigant volumes used in the different groups. Furthermore, the results confirmed that in this research setup, the slight differences in volume were not influential because the group with the smallest volume performed the best because of the more energetic flow in this group.

It was shown recently that manual agitation of the irrigant significantly improved the irrigant penetration in the root canal (21). This improvement can be both longitudinal (coronal-apical) and lateral. Also, the gentle pumping with short vertical strokes during MDA resulted in the frequent mixing of the canal content, which improved the irrigant renewal (8, 22). It can be postulated that either the improvement of the irrigant penetration or the renewal (refreshment) is induced by an enhanced flow in the apical portion, which would be responsible for the improved debridement efficacy shown in our results and other studies (7, 8).

Previous studies (7, 8, 23, 24) only evaluated the effectiveness of MDA by using one size and tapered GP cone. Interestingly, our results showed that the adaptation of the GP cone to the root canal wall had an influence on the cleaning efficacy. This adaptation is related to the space between the cone and the root canal wall, the reflux space. Because the dimension of the root canal model used in this study was #30/.06 with an apical enlargement of #40/.02, the reflux space of the #30/.06 tapered cone was overall smaller than the #40/.02 nontapered cone, with the exception of the 2 mm coronal from WL. The reflux space is essential to allow the irrigant to flow along the cone (23) and induce hydrodynamic forces on the dentin debris to be removed. A thinner layer of fluid between the tapered GP cone and the root canal wall could result in a more effective hydrodynamic effect. On the contrary, both Parente et al (24) and Susin et al (25) hypothesized that the irrigant displacement could be hindered by a relatively close adaptation of the GP cone to the canal wall, resulting in the debris settling back into the canal system after removal of the GP cone. The size of the debris particles could also play a role. Because the dimension of the root canal was perfectly standardized in this study, the #30/.06 tapered GP cone really adapted perfectly to the root canal wall, with the only exception of the groove where the debris was placed. This special situation could also be the reason for its effective performance. The flow in the reflux space remains to be clarified by future studies.

The Safety Irrigator system could be considered as a conventional syringe irrigation system plus an evacuation tube. Compared with the aspiration tube normally used in the clinic, the evacuation tube is situated around the coronal part of the irrigation needle, enabling hand-free suction directly from the pulp chamber. Therefore, theoretically it is more a positive pressure system with suction of irrigant from the pulp chamber. The reason for its better cleaning efficacy than syringe irrigation could be due to the evacuation tube together with the extremely flexible needle, which might enhance the reverse flow of the irrigant and consequently the flush-out effect. However, more clarification is needed.

The prominent feature of ANP is that it allows an apical irrigant circulation until WL with little risk of irrigant extrusion (13, 26). Our results indicated its limited activation of the irrigant in the apical noninstrumented areas and supported the findings from a recent study by de Gregorio et al (27). Although the amount of the irrigant delivered into the root canal was relatively equivalent (5 mL), the actual volume of the apical irrigant circulation was probably insufficient. It has been suggested that ANP delivers the irrigant more efficiently in the apical areas of the root canals than syringe irrigation (13). However, the total amount of the irrigant volume measured in that study was actually delivered by the MDT at the orifice, and the amount that actually passed through the microcannula at WL was unknown, which should essentially be responsible for the cleaning efficacy in the apical portion. The amount of irrigant circulating through the microcannula measured in our pilot study turned out to be only 1.2 mL/min^{-1}. This was in accordance with the study of Brunson et al (28), who showed that the irrigant volume aspirated by the microcannula was 1.6 ± 0.26 mL/min^{-1} with the same apical enlargement of #40/.02. However, Desai and Himel (26) showed in their study that 51%–54% of the irrigant circulates through the microcannula with the apical size of #50/.04, approximately 3.5 mL/min^{-1}. This discrepancy probably is due to the apical size, because the bigger the size and taper of the root canal are, the higher is the volume aspirated from the apical root canal (28). In addition, a difference in the negative pressure applied to the microcannula might cause a difference in the volume of irrigant flowing through the apical root canal; however, this pressure was not specified in any of the ANP studies. Furthermore, ANP might require more time than given in this study to achieve better debridement efficiency. It also might be expected that ANP is more effective if the active streaming at the apical portion is improved.

Both the VPro Tip and the ProUltra PiezoFlow (Tulsa Dental Specialties, Tulsa, OK) belong to the CUI system; the former has a 30-gauge needle, and the latter has a 25-gauge needle. In contrast to passive ultrasonic irrigation (PUI) with an intermittent flush, during CUI the irrigant is applied in the root canal with a continuous flow through the ultrasonically activated needle. In the dentin debris model used in this study, the results of CUI were comparable with those of PUI testing done in previous studies (20, 29) by using the same model. In the study of Castelo-Baz et al (16), CUI was equally effective as PUI in the placement of irrigant in the apical root canal but more effective in the irrigant placement in lateral canals. Why this difference was found is not known. The combination of the continuous flow and the simultaneous irrigant activation could have a typical influence on the irrigant streaming.

Conclusions

CUI was the most effective technique in dentin debris removal from the apical irregularities, and syringe irrigation alone was the least effective. MDA technique was more effective with a tapered GP cone than with a nontapered one.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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