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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 six different final irrigation techniques. **Methods:** Conventional syringe irrigation, manual dynamic activation (MDA) with tapered or non-tapered gutta-percha (GP) cones, the Safety Irrigator system, passive ultrasonic irrigation (PUI) and apical negative pressure (ANP) irrigation were tested *ex vivo* in twenty 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 non-tapered GP cone, the Safety Irrigator and the ANP irrigation. These techniques produced better cleaning efficacy than syringe irrigation ($p<0.005$), but significantly worse than the MDA with a tapered cone ($p<0.05$). PUI was significantly better than all the other techniques tested in this study ($p<0.001$). **Conclusions:** PUI was the most effective technique in dentin debris removal from the apical irregularities, and syringe irrigation alone the least effective. MDA technique was more effective with a tapered GP cone than with a non-tapered one.

Introduction

Debridement is the aim of and also a big challenge to endodontic treatment (1), especially in the apical portion of the root canal (2). Due to 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 which 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).

In order to prevent irrigant extrusion and enhance the apical irrigation, so-called apical negative pressure (ANP) systems have been introduced. EndoVac is such an irrigation system and seems to have a good debridement efficacy due to a better apical irrigant delivery (13-15), but the effectiveness of the apical flow remains to be seen. The Safety Irrigator™ (Vista dental, Racine, WI, USA) has been recently introduced as a simple, "negative-pressure" irrigation device. It features a large coronal evacuation tube, enabling the irrigant delivery in the root canal and the irrigant aspiration from the pulp chamber simultaneously with this single device.

The aim of this study was to compare the mechanical cleaning efficacy of conventional syringe irrigation, MDA, the Safety Irrigator system, PUI 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 both 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 two halves were reassembled by four self-tapping bolts through the holes. All the models were checked to see if 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, Ballaigues, Switzerland) to a working length (WL) of 15 mm, an ISO size of 30, and a taper of 0.06. The apical part was further enlarged using Ni-Ti 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, USA).

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 to 6 mm from working length (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 (16). Each groove was filled with dentin debris, which was mixed with 2% NaOCl for five 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 (17). 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 six experimental groups which are shown in Table 1.

Final Irrigation procedures

Conventional Syringe Irrigation Group (Group 1). Two mL irrigant (6% NaOCl) was delivered by using a 10-mL syringe with a 30-gauge needle (Navitip, Ultradent, South Jordan, UT, USA) placed 1 mm from WL in 20 seconds. This process was repeated twice, resulting in a total irrigant volume of 6mL, and a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL sec^{-1}.
MDA Groups. Same as **Group 1**, but the irrigant was additionally activated by moving a gutta-percha (GP) cone #40/.02 (**Group 2**) or a tapered GP cone #30/.06 (**Group 3**) up and down (from WL-5mm 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 6mL, a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL sec^{-1}, and a total irrigant activation time was 30 seconds.
Safety Irrigator Group (Group 4). Two mL 6% NaOCl was delivered with the needle (30-gauge, open-ended) placed 1mm from WL in 20 seconds. The process was repeated twice resulting in a total irrigant volume of 6mL, and a total irrigant delivery time of 60 seconds with a flow rate of 0.1 mL sec^{-1}.
PUI Group (Group 5). PUI was performed with the 30-gauge VPro™ Tip (Vista dental, Racine, WI, USA) 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 towards the groove, during which the tip was moved up and down twice/sec from WL-4mm to WL-1mm. 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 mL 6% NaOCl was delivered by using a 10-mL syringe with a 30-gauge needle placed WL-1mm in 20 seconds. Afterwards, the micro-cannula (#32/.00) was placed under ANP at WL for 6 seconds and then at WL-2mm 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 5mL, 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 micro-cannula 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) 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 that were blinded to the group assignment scored each picture twice respectively.

The debris left in the groove after irrigation was scored independently by 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; 3: the complete groove is filled with debris (11). The percentage of inter agreement 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 inter-observer agreement was very high (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.

There was a significant difference between the experimental groups ($p<0.001$). There was no significant difference between the MDA with a non-tapered GP cone, the Safety Irrigator and ANP irrigation by EndoVac system. These techniques resulted in better cleaning efficacy than conventional syringe irrigation ($p<0.005$), but significantly worse than the MDA with a tapered cone ($p<0.05$). PUI by the ultrasonic system was significantly better than all the others tested in this study ($p<0.001$).

Discussion

Since the irrigant volume and fluid flow dynamics are important factors that affect canal debridement (18), we tried to standardize (if applicable) the volume, the flow rate and the activation time in all the experimental groups as much as possible. The results confirmed that activation of the irrigant, either manually or ultrasonically, enhances the removal of dentin debris from the apical irregularities, either manually or ultrasonically.

It was shown recently that manual agitation of the irrigant significantly improved the irrigant penetration in the root canal (19). This improvement can be both longitudinally (coronal-apical) and laterally. Also, the gentle pumping with short vertical strokes (MDA) resulted in the frequent mixing of the canal content, which improved the irrigant renewal (8, 20). 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, 21, 22) only evaluated the effectiveness of MDA by using a tapered GP cone. Interestingly, our result showed a tapered GP cone (#30/.06) had significantly better cleaning efficacy than a non-tapered GP cone (#40/.02). The difference between the two was the space between the cone and the root canal wall (reflux space). Since the root canal model used in the study was #30/.06 with the apical enlargement of #40/.02, the reflux space of the tapered cone was bigger than that of the non-tapered cone only within the 2mm from the WL, and smaller in the rest of the root canal. The reflux space is essential to allow the irrigating solution to flow up and down along the cone (21). Both Parente et al. (22) and Susin et al. (23) hypothesized that the irrigant displacement is hindered by the relatively close adaptation between the GP cone and the canal wall, with the debris settling back into the canal system after removal of the GP cone. On the contrary, based on our results, a thinner layer of fluid between the tapered GP cone and the root canal wall will give a higher fluid velocity and may therefore result in a more effective hydrodynamic effect. Furthermore, the tapered GP cone could not closely adapt to the irregularities, oval extensions (represented by the groove in our study) after root canal preparation, allowing the dentin debris to become loose and removable in these areas under the force of the irrigant flow. However, the flow in the reflux space remains to be clarified in future studies.

The Safety Irrigator system could be considered as a conventional needle-and-syringe assembly plus an evacuation tube, which then actually is a positive pressure system. Compared with the ordinary aspiration system connected to the high volume suction unit, the evacuation tube is situated around the coronal part of the needle. This feature together with the extremely flexible needle might enhance the reverse flow of the irrigant and the flow in the apical third, and consequently the flush-out effect.

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 support the findings from a recent study by de Gregorio et al.(24). Though the amount of the irrigant delivered into the root canal was relatively equivalent (5mL), the actual volume of the apical irrigant circulation was probably insufficient. It's 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 measured was actually delivered by the MDT at the orifice, and the amount that actually passed through the micro-cannula at WL was unknown which should essentially be responsible for the cleaning efficacy in the apical portion. The amount of irrigant circulating through the micro-cannula measured in our pilot study turned out to be only 1.2mL min-1. This was in accordance with the study of Brunson (25) who showed that the irrigant volume aspirated by the micro-cannula was 1.6 ±0.26 mL min-1 with the same apical enlargement of #40/.02. Desai and Himel (26) however showed in their study that 51%-54% of the irrigant circulates through the micro-cannula with the apical size of #50/.04, approximately 3.5mL min-1. This discrepancy probably is due to the apical size, since the bigger the size and taper of the root canal the higher volume aspirated from the apical root canal (25). In addition, a difference in the negative pressure applied to the micro-cannula may 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 may require more time than given in this study to achieve better debridement efficiency. It also may be expected that ANP is more effective if the active streaming at the apical portion is improved.

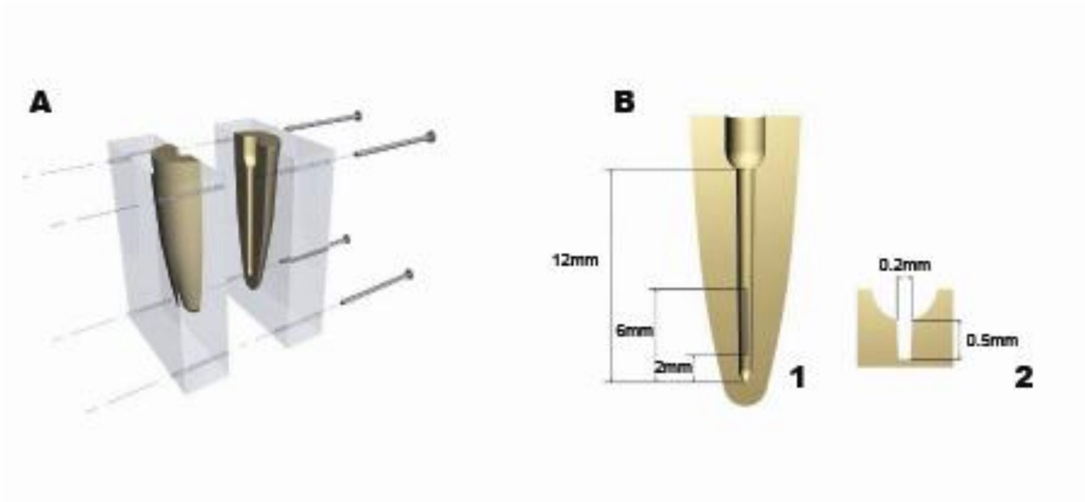
The VPro™ Tip was used in the PUI group and its premium cleaning performance was in accordance to previously published studies (11, 12, 17, 27). There are some variations among PUI technique due to the different ways to deliver the irrigant. Delivering the irrigant by syringe followed by activating the irrigant ultrasonically was more effective than the continuous delivery of the irrigant through the handpiece (28) in the pulp chamber due to the more effective apical flow by syringe irrigation. VPro™ tip however is a 30-gauge needle, enabling the continuous delivery of the irrigant into the apical part of the canal simultaneously with the ultrasonic activation of the irrigant. Burleson et al. tested a similar system in vivo with a 25-gauge needle and showed a very good cleaning efficacy, especially on the isthmus debridement (27). With the smaller size of the needle, the ultrasonic system applied in current study allows better apical penetration of the needle and the irrigant without the need for a larger apical preparation.

Table 1. Experimental groups and the number of specimens at each score rank after irrigation procedure

		Score			
Group (*n*=20)	**Irrigation Techniques**	**0**	**1**	**2**	**3**
1 (control)	Syringe	0 (0%)	0 (0%)	0 (0%)	20 (100%)
2	MDA Non-taper 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%)

Score 0: the groove is empty; score1: 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.

Figure. 1 Schematic representations of the standardized root canal model (A), its groove (B1) and cross section (B2).



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