Curved versus straight root canals: the benefit of activated irrigation techniques on dentin debris removal

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Objective. The aim of this study was to compare the efficacy of hydrodynamic and ultrasonic-activated irrigation to conventional syringe irrigation in removing dentin debris in straight and curved root canals.

Study design. Twelve human teeth were selected for study. The root canals of 6 single-rooted premolars with straight canals and 6 molar roots with curved canals were prepared to a size of 45 and split longitudinally. To simulate canal irregularities, 3 standardized holes were cut in 1 canal wall. The canals and holes were then covered with debris. After reassembly, 3 irrigation techniques were compared: syringe irrigation, hydrodynamic irrigation, and ultrasonic irrigation. The amount of debris that remained was evaluated microscopically and graded with a 4-score system.

Results. The hydrodynamic and ultrasonic irrigation techniques were significantly \(^{P < .001}\) more efficient as compared with syringe irrigation in both the straight and curved root canals. Ultrasonic irrigation demonstrated a higher efficiency in the straight root canals \(^{P < .01}\), whereas hydrodynamic irrigation was more efficient in the curved canals \(^{P < .01}\).

Conclusions. In the straight canals, ultrasonic irrigation was the most effective, but in the curved root canals, hydrodynamic irrigation was superior. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:529-534)

Recently, the impact of root canal irrigation has been identified as an important issue. This has been reflected in the development of new irrigation methods and an increasing number of scientific studies on this topic. Most of this research has been conducted using in vitro studies on single-rooted extracted teeth \(^{1,2}\) or artificial canals. \(^{3}\) Unfortunately, these studies do not appropriately reflect the general clinical environment. Most root canal treatments are performed on multirooted teeth, where clinicians must treat curved canals. \(^{4,5}\)

Chemo-mechanical preparation of the root canal system aims to remove microorganisms, \(^{6}\) remaining pulp tissue, and dentin debris. \(^{7}\) The root canal contains accessory canals, canal wall irregularities, and cavities. \(^{8}\) These anatomical structures are not accessible by hand or rotary instruments in many cases. \(^{9}\)

The instruments used in root canals produce dentin debris that might be pressed into existing irregularities. \(^{10}\) Dentin debris is composed of dentin chips, bacteria, and necrotic pulp tissue. Debris accumulation is a side effect of root canal instrumentation, and it may interfere with the primary objectives of root canal treatment. Complete removal of debris is essential to providing direct contact of the irrigant solution with the root canal wall and to producing adequate disinfection. \(^{10}\) Furthermore, debris-filled extensions may lead to leakage of the root canal filling. \(^{11}\)

Besides instrumentation, irrigation is the other important step in preparing root canals. The effectiveness of irrigation depends on both mechanical flushing and chemical action. With syringe irrigation, the ability to flush the root canal is limited and primarily depends on the depth and placement of the irrigation cannula. \(^{12}\) The efficiency of irrigation can be increased by activating the solution with an ultrasonic or hydrodynamic device. \(^{13}\) Passive ultrasonic irrigation, as used in the present study, is defined as the activation of rinsing solution in the root canal using an ultrasonic file without continuous flow. \(^{14}\) In combination with sodium hypochlorite, this method has been shown to be more effective than conventional hand irrigation in removing dentin debris from the root canal. \(^{1}\) The hydrodynamic irrigation system (RinsEndo, Dürr Dental, GmbH & Co KG, Bietigheim-Bissingen, Germany) is based on pressure-suction technology and has been shown in a few studies to be effective. \(^{2,15}\) A recent review concluded that irrigant agitation plays an important role in contemporary endodontics. Recently, the efficiency of different irrigation systems, including ultrasonic, hydrodynamic, and syringe irrigation, was
compared regarding their ability to remove dentin debris in straight root canals. The authors demonstrated that ultrasonic irrigation was more effective than hydrodynamic irrigation and syringe irrigation in straight canals. However, in curved root canals, the efficiency of the irrigation systems may be affected. Syringe cannula insertion to the apical region is more difficult in narrow and curved canals. Even the performance of ultrasonically activated files is reduced because of instrument restriction.16,17

Thus, the aim of this study was to compare the efficiency of 2 activated irrigation techniques for the removal of dentin debris in root canal irregularities and from the root canal wall of straight and curved root canals and to compare these techniques with conventional syringe irrigation ex vivo.

MATERIAL AND METHODS

Tooth preparation

Twelve human teeth, 6 single-rooted premolars with a straight root canal and 6 curved molar roots, were selected. The root canal curvatures were measured according to Schneider’s method18 and ranged from 17° (moderate) to 27° (severe) (mean, 21.2°). The teeth were decoronated to access the canals. The working length was determined by inserting a size 10 stainless steel file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until the tip of the file was visible at the apical foramen. The canals were flared to an apical size of 45 using a crown-down technique with ProTaper (Dentsply Maillefer) and Flexofiles (Dentsply Maillefer). After the use of each instrument was completed, the root canal was irrigated with 2 mL of 1% sodium hypochlorite solution (NaOCl) using a syringe and a 30-gauge needle. Two grooves were cut along the axis of each root using a diamond disk, and the teeth were split longitudinally into halves using a chisel. To simulate uninstrumented canal irregularities, 3 standard depressions were cut into the inner canal wall of one root half with a round bur that measured 0.3 mm in diameter and 0.5 mm in depth. The depressions were cut 2, 4, and 6 mm from the apex, as described by Lee et al.1 Dentin debris was produced by mixing dentin shavings from other teeth with 1% NaOCl. This dentin debris mixture was placed into the depressions and in the root canal. The halves of each tooth were then reassembled and fixed using impression material (Coltoflax, Coltène Whaledent, Altstätten, Switzerland) to prevent apical extrusion.19 Irrigation was performed immediately after reassembling the teeth halves and impression material was hardened to prevent drying-out of the roots. To standardize the experimental conditions and to minimize individual variations in root canal morphology, all 12 teeth were used for every group.

Accurate cleaning with a microbrush (Microbrush Plus, Microbrush International, Grafton, WI, USA) was performed using a microscope at magnifications of ×20 between the experimental settings.

Irrigation

Three irrigation techniques were compared using a standardized volume of 6 mL of 1% NaOCl for each group. The cannula was inserted 1 mm short of the working length, except in the hydrodynamic group. No movement of the irrigation needle was performed. Standardization of movements is challenging and may have an impact on the results.

❖ Group 1: Each canal was syringe-irrigated with a 30-gauge side-vented irrigation cannula (Max-I-Probe, Maillefer, Ballaigues, Switzerland) that was placed 1 mm short of the working length.

❖ Group 2: NaOCl was activated using a hydrodynamic device (RinsEndo,) based on pressure-suction technology. Sixty-five microliters of irrigant solution oscillating at 1.6 Hz was transmitted using the corresponding cannula into the root canal. According to the manufacturer’s instructions, introduction of the needle tip was limited to the coronal third (3 mm from the root canal orifice) of the root canal.

❖ Group 3: Ultrasonic irrigation was performed passively (passive ultrasonic irrigation [PUI]). The root canal was filled with NaOCl, and then the solution was activated with a smooth wire (Endo Soft Instrument, EMS, Nyon, Switzerland) for 20 seconds at 1 mm short of the working length. Finally, it was flushed with 2 mL of NaOCl using a syringe. This procedure was repeated 2 times for a total of 60 seconds of ultrasonic activation and 6 mL of NaOCl.

Quantification of remaining debris in the root canal

After irrigation, the root halves were separated, and images of the canal walls were taken with a digital camera (Leica QWin, Wetzlar, Germany) connected to a microscope (Leica, Wetzlar, Germany). The images were evaluated at magnifications of ×8 and ×20 by 2 independent examiners to quantify the amount of dentin debris present. The scoring system described by Lee et al.1 was applied for the depressions to evaluate the amount of remaining debris. Additionally, a similar scoring system was set for the root canal wall. A lower score suggests a superior degree of debris removal.

❖ Canal wall

➢ Score 0: the entire root canal wall is free of debris.
Score 1: less than half of the root canal wall is covered with debris.

Score 2: half or more of the root canal wall is covered with debris.

Score 3: the entire root canal wall is covered with debris.

Depressions

Score 0: the entire depressions are free of debris.

Score 1: less than half of the depressions are filled with debris.

Score 2: half or more of the depressions are filled with debris.

Score 3: the entire depressions are filled with debris.

The scoring system was first explained to the examiners (2 dentists with 3 years of clinical and scientific experience), and then they were trained and calibrated by an associate professor using example images for each score. Interexaminer agreement was calculated using weighted and unweighted kappa scores.

The images of the specimens were assessed independently on a computer screen (Dell, Austin, TX, 48.3-cm LCD monitor). The digital images were randomized and unlabeled when they were presented to the blinded reviewers. Each examiner assigned 1 score for the root canal wall and 1 score for the depressions of each specimen (Fig. 1).

Statistical analysis

To compare localizations and methods within the canal morphologies, a nonparametric method was chosen, and scores were ranked using the midrank method. Subsequently, a linear mixed-effects regression model with fixed factors, including “localization,” “method,” “examiner,” “morphology,” and a random factor “subject” was performed on the ranks. Results were reported as P values for the given comparisons of interest. A P value less than .05 was considered significant. Analysis was done using the statistical software R, version 2.11.1 (Vienna, Austria).

RESULTS

No effects of examiner were found (P = .48), κ (95% CI) = 0.73 (0.60-0.86); therefore, this factor was discarded from the regression model. Frequency distributions of the scores that were assigned by the 2 investigators were subdivided into canal morphology (type) and localization (loc) of the debris. These data are shown in Fig. 2, A-D.

The following comparisons were of interest and showed statistically significant effects:

Debris removal using syringe irrigation achieved significantly lower scores (P < .03) in the root canal wall group as compared with the depression group. The activated irrigation techniques (hydrodynamic and ultrasonic irrigation) showed no significant differences (P = .1561, P = .7112) between the groups. Hydrodynamic and ultrasonic irrigation in the straight canals showed a high effectiveness in removing dentin debris from the root canal wall and the depressions.

The activated irrigation systems differed significantly (P < .0001, P < .0001) from the syringe irrigation system. For the ultrasonic group, complete debris removal was observed in all cases for the straight canals (score of 0). The hydrodynamic group achieved higher scores than the ultrasonic irrigation group and differed significantly.
for the removal of debris from the root canal walls \((P < .001)\) and the depressions \((P < .01)\).

In the curved root canals, the activated irrigation techniques also removed more debris than the syringe irrigation system. Hydrodynamic irrigation differed significantly from syringe irrigation \((P < .0001)\). Ultrasonic irrigation showed a lower efficacy in the curved canals than in the straight canals and showed no statistical difference \((P = .0528)\) from syringe irrigation. Hydrodynamic irrigation was more effective in the curved canals; it significantly reduced the amount of debris on the root canal walls \((P < .001)\) and in the depressions \((P < .01)\) when compared with the ultrasonic group.

**DISCUSSION**

The aim of this study was to evaluate the efficacy of 2 activated irrigation techniques and 1 nonactivated technique regarding the removal of dentin debris. Under the current study conditions, passive ultrasonic irrigation was superior to hydrodynamic irrigation in the straight canals, whereas the hydrodynamic group achieved better scores for debris removal in the curved canals.

The experimental setup was based on the model of Lee et al.,\(^1\) who investigated the effectiveness of ultrasonic and syringe irrigation systems on dentin debris removal. This model with artificially created depressions simulates uninstrumented root canal areas filled with debris. These depressions are standardized and can...
be filled with a reproducible amount of debris. In a clinical situation, debris-filled root canal extensions or isthmi are a challenge to be cleaned. The teeth were embedded in a putty impression material, which represents a closed system. The fluid behavior in the apical region of this model may have influenced the irrigation performance. Adequate irrigant replacement is prevented in a closed system because of a “dead-water zone” in the apical region. This is also the case for debris removal with a side-vented cannula and, thus, it may have no impact on activated irrigation methods.19

In the study of Lee et al.,1 significantly more dentin debris was removed by ultrasonic irrigation than by syringe irrigation; however, this study was limited to straight root canals, and no hydrodynamic methods were investigated. A recent study analyzed hydrodynamic irrigation in a similar experimental setup.5 The results demonstrated that ultrasonic irrigation is superior to both syringe and hydrodynamic irrigation for removing debris. Unfortunately, this study was also limited to studying only straight canals. The results from these studies on dentin debris removal in straight canals were similar to the findings in the present study.

The efficiency of ultrasonic action might be limited in small canals as well as in curved root canals owing to inherent resonance behavior.23,24 Touching the canal wall is inevitable, and it reduces the ultrasonic action. Caron et al.25 published one of the first studies reporting on the adverse role of canal curvature. The results showed a benefit for sonic activation of the solution as compared with no activation. However, a large standard deviation was observed in their results. The authors suggested that this was caused by difficulties in the standardization of experimental conditions in a complex anatomy. Furthermore, this large standard deviation may be attributed to the random division of the teeth; in other words, a large variety of teeth existed with different root canal morphologies among the studied groups.

In the present study, the efficiency of different irrigation techniques was compared in straight and curved canals. The same teeth were used for every group to standardize the experimental conditions, as the irrigation procedures in group 1 and 2 did not damage the root canal wall. In addition, the variation of the root canal morphology was the same for every group. In contrast to the present study, Caron et al.25 used a smaller irrigation volume (3 mL) and a large taper (10%). In many studies, a higher final irrigation volume (5 to 10 mL) has been recommended.26-28 Although irrigation in root canals with a greater taper has revealed better efficiency,24,29,30 this wider taper may be dangerous in curved canals because of the risk of procedural errors.31

Hydrodynamic irrigation might function as an alternative to ultrasonic irrigation, but only a few studies have evaluated the effectiveness of hydrodynamic irrigation with RinsEndo. McGill et al.15 compared hydrodynamic irrigation (RinsEndo) and static syringe irrigation on root canals that were covered with stained collagen. They found that hydrodynamic irrigation was more effective than static syringe irrigation. The third method used in this study was manual dynamic irrigation, which was performed using a gutta-percha point and a total of 200 push-pull strokes; the results showed even cleaner root canal walls as compared with the other 2 methods. However, manual dynamic irrigation does not seem practical in a clinical setting, especially for teeth with multiple root canals. Rödig et al.2 compared ultrasonic irrigation, hydrodynamic irrigation (RinsEndo), and syringe irrigation for debris removal, reporting a decreasing efficacy in the following order: ultrasonic irrigation, hydrodynamic irrigation, syringe irrigation. These results agree with the results of the present study for straight canals. In a study by Caron et al.,25 the efficiency of hydrodynamic (RinsEndo), manual dynamic, and sonic irrigation (EndoActivator; Advanced Endodontics, Santa Barbara, CA) in curved canals was evaluated; however, this study focused on smear layer removal. They found that hydrodynamic irrigation was less effective than manual dynamic irrigation and sonic activation. The authors argued that the time frame in their study may have not been long enough for a system like RinsEndo to appropriately remove debris.

According to the manufacturer’s recommendations, the RinsEndo cannula tip should not be inserted past the coronal third of the root canal. Hydrodynamic activation can reach the apical third despite the coronal position of the cannula. However, this could not be corroborated in a previous study that found that a cannula placement that was closer to the working length resulted in better collagen removal.15 Despite the coronal position of the cannula in the present study, hydrodynamic irrigation yielded the best results in curved root canals. In contrast, the ultrasonic file and needle tip used in the syringe irrigation should be placed 1 mm short of the working length for efficient irrigant flow in the apical part of the root canal.32 The morphology of the root canal or an inadequate cannula size may avoid penetration of the irrigation needle into the apical part of the root canal. The coronal positioning of the RinsEndo cannula was independent of the root canal morphology, which may be an advantage in small curved canals. Apical extrusion was reported to occur more frequently when the cannula was inserted into the canal at the greatest depth possible.33
CONCLUSIONS
Activated irrigation techniques were more effective than syringe irrigation in removing dentin debris in straight and curved root canals. However, in a curved canal, hydrodynamic irrigation showed better cleaning efficacy as compared with syringe and ultrasonic irrigation and might be recommended in such cases.

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REFERENCES