Short Communication

Root canal debridement by negative pressure irrigation, ultrasonically activated irrigation and their combination

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Abstract: Despite scientific evidence that root canal debridement is the cornerstone for successful treatment, the effectiveness of a combination of delivery and activation systems in cleaning root canals remains unknown. This study is the first to demonstrate the remaining pulp tissue in root canals after irrigation with various techniques such as positive pressure syringe-and-needle irrigation, ultrasonic activation, negative pressure irrigation and ultrasonic activation after negative pressure irrigation. The results showed that negative pressure irrigation alone and its combination with ultrasonic activation resulted in significantly superior effectiveness than positive pressure irrigation and ultrasonic activation alone in the apical-third of root canals.

Keywords: debridement, negative pressure, remaining pulp tissue, syringe irrigation, ultrasonic activation

Introduction

Root canal debridement is achieved by a combination of mechanical instrumentation and irrigation. While mechanical instrumentation removes necrotic pulp tissue, infected dentin and microbial biofilms, it also creates space to irrigate, mediate and fill the root canal system. The pivotal role of irrigation in debriding root canals, especially in those areas left untouched by mechanical instrumentation is well established [1,2]. Irrigants are delivered into the canal using a syringe and a needle. However, optimal irrigant exchange to the critical apical third is impeded mainly due to the vapor lock effect [3]. Consequently, several delivery strategies have been suggested in order to improve the effectiveness of irrigation.

Irrigant delivery throughout the length of the root canal system may be achieved by negative pressure irrigation [4]. Here, the irrigant is delivered to the pulp chamber and drawn to the working length by suction, then eventually evacuated by a cannula, thereby maintaining a constant replenishment of fresh irrigant [5]. EndoVac (Kerr Corporation, Orange, CA, USA), a negative pressure irrigation system, is more effective than needle irrigation in delivering irrigants to the working length [4], achieving superior debridement in the apical region and removing biofilms. With scientific evidence that the root canal system consists of several aberrant anatomies, agitation/activation strategies, such as ultrasonically activated irrigation (UAI) [2], have been proposed to enhance the penetration of the irrigant into these areas. Indeed, UAI was demonstrated to have a greater microbial reduction in vitro compared to other approaches [6]; nonetheless evidence in this regard is still conflicting [5].

Critically, there is no evidence regarding the effectiveness of root canal debridement by a combination of negative pressure irrigation and UAI. The aim of this study was to compare root canal cleanliness by measuring the remaining pulp tissue after final irrigation with syringe irrigation, UAI, negative pressure irrigation and UAI after negative pressure irrigation. The null hypothesis was that there is no significant difference in root canal cleanliness between the experimental groups in all root-thirds (coronal, middle, apical).

Material and Methods

Specimen selection

Recently extracted non-carious human premolars, extracted for orthodontic reasons, were used in this study (approved by the University of Hong Kong/Hospital Authority Hong Kong West Cluster Institutional Review Board; UW17-153). Informed consent was obtained from all patients. Pulp sensibility test was performed prior to extraction to confirm normal pulp status; afterwards, teeth were stored in formalin. All teeth were scanned using a micro-computed tomographic scanner (SkyScan 1172; Bruker microCT, Kontich, Belgium) and only teeth with a single canal were included in the study. A total of 60 specimens were selected for the study with 12 of them being used as a negative control group. In the control group, no canal preparation was performed.

Canal preparation and irrigation

A closed apical system was created, and root canals were instrumented to size 40, 0.04 with K3XF files (SybronEndo, Orange, CA, USA) with 5 mL of 3% sodium hypochlorite (NaOCl) as the irrigant, delivered using a syringe with a 30-G Luer-Lock Tip (Becton, Dickinson and Company, Franklin Lakes, NJ, USA) placed passively in the canal without binding, 2 mm short of working length. Patency filing was performed with a size 10 K-file. Canals were then irrigated with 2 mL of distilled water and dried with absorbent paper points. Then the specimens were randomly allocated to four groups (n = 12) according to the final irrigation protocol as shown below.

Group A (SNI), syringe-and-needle irrigation using a syringe with 30-G Luer-Lock Tip (Becton, Dickinson and Company) placed passively in the canal, 2 mm short of working length. Irrigant was delivered through short vertical strokes of 2-3 mm, at a rate of 100 strokes/min. The irrigation sequence was 8 mL of 3% NaOCl over 1 min, followed by 10 s of 1.3 mL 17% EDTA and 30 s of 4 mL 3% NaOCl.

Group B (UAI), ultrasonic activation with a size #25 IRRI S ultrasonic tip (VDW, Munich, Germany), with the tip placed 2 mm short of the working length with short vertical strokes as mentioned above. With an activation time of 20 s each, a total of four cycles was performed. During and after every cycle, the canals were irrigated with 3% NaOCl (1.0 mL/min). The total volume of irrigation in this step was standardized to 8 mL. This was followed by 10 s ultrasonic activation of 1.3 mL 17% EDTA and 2 cycles of 15 s activation of a total of 4 mL 3% NaOCl.

Group C (EP), negative pressure irrigation with EndoVac Pure. The irrigant flow rate was set at high flow mode (8 mL/min). The macrocannula was first used to perform a cycle of ‘macroirrigation’ for 30 s with 4 mL 3% NaOCl. Afterwards, 3 cycles of ‘microirrigation’ were performed with 8 mL 3% NaOCl for 1 min, 1.3 mL 17% EDTA for 10 s and 4 mL 3% NaOCl for 30 s.

Group D (EP + UAI), Negative pressure irrigation with EndoVac Pure followed by ultrasonic activation as described above. After each irrigation protocol, 2 mL of distilled water was used as a final rinse and the canals were dried with absorbent paper points (Dentsply Sirona Endodontics, York, PA, USA). Then, the specimens were subjected to histological analysis as follows.
Histological analysis
Specimens were fixed with 10% buffered formalin for 48 h and demineralized in a mixture of 10 wt% hydrochloric acid and 5 wt% EDTA for 1-2 weeks. After rinsing with water and dehydration, proof of demineralization was obtained radiographically [2]. Specimens were rinsed thoroughly with tap water for 24 h and dehydrated. Five-micron-thick serial sections were obtained from the coronal, middle and apical regions of each tooth with a rotary microtome (Leica RM 2155; Leica Biosystems Nussloch GmbH, Nussloch, Germany). A random section was selected for each root third. The sections were mounted on glass slides and stained with hematoxylin-eosin stain.

The stained sections were visualized using a digital microscope (Nikon Eclipse LV100POL; Nikon Instruments Inc., Kawasaki, Japan); the digital images obtained were processed with image analysis software (NIS Elements AR 3.10; Nikon Instruments Inc.).

Data presentation and statistical analysis
After checking data distribution, pairwise comparisons across groups by each root third and the whole specimen were made with the Kruskal-Wallis and post-hoc Dunn’s tests with Bonferroni correction. Intra-group analysis was used to compare variations in RPT values throughout the root-thirds. All P values were two-tailed, and values of P < 0.05 were considered statistically significant (STATA IC, version 16.1, Statacorp LP, TX, USA).

Results
Descriptive statistics of RPT values are presented (Table 1) as median with Interquartile Range (IQR) and minimum-maximum values. Representative histological images for each group are shown in Fig. 1. The control group housed a median (IQR) RPT of 0.887 (0.765-0.943). All four test groups showed significantly less RPT than the control group in all three root-thirds (P < 0.05). RPT was significantly greater in Group A (SNI) compared to the other groups, while Group D (EP + UAI) showed the least median RPT amongst all test groups (0.0119); in turn, the latter presented statistically significant differences when compared to groups A (P = 0.000) and B (UAI) (P = 0.000), but not Group C (EP) (P = 0.649).

In the coronal third, SNI had significantly higher RPT (0.0486 [0.0421-0.0571]) than UAI, EP and EP + UAI (P = 0.000). None of the other pairwise comparisons showed significant differences (P > 0.05). In the middle third, EP + UAI showed significantly lower RPT (0.0117 [0.0059-0.0202]) than SNI (P = 0.000) and UAI (P = 0.000), but not EP (P = 0.151). On the other hand, EP alone (group C) showed significantly lower RPT (0.0214 [0.0135-0.0312]) than SNI (P = 0.000) and UAI (P = 0.013). In the apical third, UAI (P = 0.008), EP (P = 0.000) and EP + UAI (P = 0.000)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Median (interquartile range) and minimum-maximum (min-max) values of remaining pulp tissue (%) for each test group across all root regions.</th>
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<tbody>
<tr>
<td>Group</td>
<td>Overall Median (IQR)</td>
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<td>---------</td>
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<tr>
<td>Group A</td>
<td>(syringe and needle irrigation)</td>
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<tr>
<td>Group B</td>
<td>(ultrasonically activated irrigation)</td>
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<tr>
<td>Group C</td>
<td>(EndoVac Pure)</td>
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<tr>
<td>Group D</td>
<td>(ultrasonically activated irrigation + EndoVac Pure)</td>
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</table>

For each column, values that share the same superscript lower-case letter were not significantly different at the 5% level.
showed statistically significant lower RPT values than SNI. UAI showed statistically significant higher RPT than EP ($P = 0.005$) and EP + UAI ($P = 0.0005$). However, there were no significant differences between EP + UAI and EP ($P = 1.000$) in the apical third.

**Discussion**

To the best of the authors’ knowledge, this is the first study to directly demonstrate the efficacy of root canal debridement of ultrasonic activation after negative pressure irrigation by measuring RPT. In this study, negative pressure irrigation and ultrasonic activation after negative pressure removed significantly more tissues in all root-thirds compared to syringe irrigation. Irrigant flow can only advance to 1 mm apical to the needle tip in syringe irrigation, making irrigant delivery to the working length unpredictable and inefficient [2]. The superior cleaning efficacy of negative pressure irrigation may be attributed to the superior irrigant flow, preventing fluid stagnation, and continuous replenishment of NaOCl throughout the irrigation process. Indeed, a previous study demonstrated that negative pressure irrigation improves the penetration of irrigants up to working length and the combination of negative pressure irrigation and ultrasonic activation further improved irrigant penetration into lateral canals [7].

Ultrasonic activation achieved significantly cleaner canals than syringe irrigation in the coronal and apical thirds, which agrees with the results of Lee et al. [2], where significantly higher root canal cleanliness was reported for the former than the latter, even with minimal canal preparation (20/0.04). In the present study, ultrasonic activation showed significantly less tissue removal than both groups involving negative pressure irrigation in the middle and apical third. This is in agreement with a recent study where negative pressure irrigation demonstrated the highest cleaning ability in the apical region and ultrasonic was less effective in debris removal at 1 and 3 mm from the apex [8].

This study shows that ultrasonic activation of negative pressure irrigation was significantly better than ultrasonic followed by syringe irrigation in the middle and apical third. This is a clinically critical finding since current protocols only apply ultrasonics after syringe irrigation, resulting in unclear and conflicting evidence concerning the efficacy of ultrasonics [5,6]. The primary outcome of this study was the amount of RPT following different irrigant agitation techniques. This is a commonly used surrogate outcome measure for the healing of apical periodontitis [2,9]. Further ex vivo and clinical prospective studies are needed in order to better define the ability of different irrigant agitation protocols to disinfect the root canal system, as well as their ability to influence the healing of apical periodontitis and reduce the incidence of post-treatment apical periodontitis.

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**Conflict of interest**

The authors declare that they have no conflict of interest.

**References**