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In Vitro Comparison of Two Ultrasonic Irrigation Needles for Dentin Debris Removal

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Abstract

Introduction: The aim of this study was to compare the removal of dentin debris from simulated canal irregularities in standardized root canals between two continuous ultrasonic-activated needles; the ProUltra® PiezoFlow (Dentsply Tulsa, OK) and the VPro® Stream clean System (Vista Dental Products, Racine, WI) when used as a final irrigation procedure.

Methods: 15 tooth models with four standard depressions in one canal wall and a standard groove in the other canal wall were reused in seven experimental groups. Ultrasonic activated irrigation was performed with the VPro and ProUltra inserted at 7, 5 and 3 mm short of Working Length (WL). Conventional irrigation was performed with the Vpro inserted at 1 mm short of WL without ultrasonic activation. The flow rate was 10ml/min for all groups. The depressions and the groove were then photographed under stereomicroscope and the amount of dentin debris in each one was scored.

Results: A significant difference was found between the seven groups in the grooves (-p-value<0.0001) and the depressions (-p-value<0.0001). The overall cleaning efficacy decreased with increasing distance between the file and the apex. The amount of debris was significantly the lowest with ProUltra 3mm short of WL and the highest in the group control.

Conclusion: Final irrigation with the ProUltra and VPro resulted in significantly less debris compared with conventional needle (-p-value<0.05). The ProUltra showed a better cleaning than the Vpro. Its effect was up to 2 mm beyond its tip contrary to the Vpro which cleaned only behind its tip.

Keywords : Passive Ultrasonic Irrigation; Conventional Irrigation; Insertion Depth; Dentinal Debris; Apical Cleaning

Abbreviations : WL: Working length, Ni-Ti: Nickel Titanium

Introduction

Syringe irrigation is the most popular irrigation technique. However, this technique produces irrigant exchange no farther than 1mm beyond the needle tip and is ineffective in flushing debris from the apical third of the canal because of the typically challenging complexity of the root canal morphology [1-3]. Recent studies have shown that Passive ultrasonic irrigation can provide an advantage over conventional irrigation in apical debridement [4-8]. In fact, dentin debris, pulp tissue, and biofilm can be removed from the root canal wall by shear stress produced by acoustic streaming of the irrigant [9].

Two recently introduced systems; the ProUltra® PiezoFlow (Dentsply, Tulsa, OK) and the VPro® Stream Clean System (Vista Dental Products), ultrasonically activate a constant flow of irrigant. Rather than activating standing sodium hypochlorite in a canal, they consist of a needle that is activated ultrasonically while the NaOCl flows through it. The irrigation needles are attached to a piezoelectronic ultrasonic unit (Suprasson® P5 Booster). The VPro differs from the ProUltra by its irrigation needle that is made of Nickel Titanium (Ni-Ti) compared with Stainless steel, the needle gauge is narrower (#30 vs #25) and the irrigant flow rate is lower (5-10 mL/min vs 15 mL/min).

By lack of information concerning the apical debridement by the two systems, the aim of this study was to compare the mechanical cleaning efficacy of these needles with conventional syringe irrigation 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 15 extracted human mandibular canines were decoronated to obtain uniform root sections of 15 mm [9]. A mesio-distal radiograph was taken to ensure the presence of a single canal in all the teeth. 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 depressions were drilled in the resin part, and the two halves were reassembled by four self-tapping bolts through the depressions.

Standardized root canals were established by K-flexofiles #15/.02 (Dentsply Maillefer, Ballaigues, Switzerland) and GT (Dentsply, Maillefer) Ni-Ti rotary instruments to a WL of 15mm, an ISO size of 30, and a taper of 0.06. The final apical enlargement was performed with the Mtwo (VDW, Munich, Germany) Ni-Ti rotary instrument #35/.04. During instrumentation, 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).

With the help of a stereomicroscope (magnification x10; Karl Kaps, SOM 22, Gmbh & Co., Wetzlar, Germany) and a round bur (H71.104.003; Komet, Lemgo, Germany) attached to a drilling machine, four standard depressions (Ø = 0.3 mm) located at 1, 2, 4, and 6 mm from the WL were drilled in the wall of one half of each root canal (Figure 1A). A standard groove with 4 mm length, 0.5 mm deep, and 0.2 mm wide, situated at 2–6mm from WL, was also drilled in the wall of the other half of each root canal with a customized ultrasonic tip. The dimension of the groove is comparable to an apical oval root canal [10] (Figure 1B).

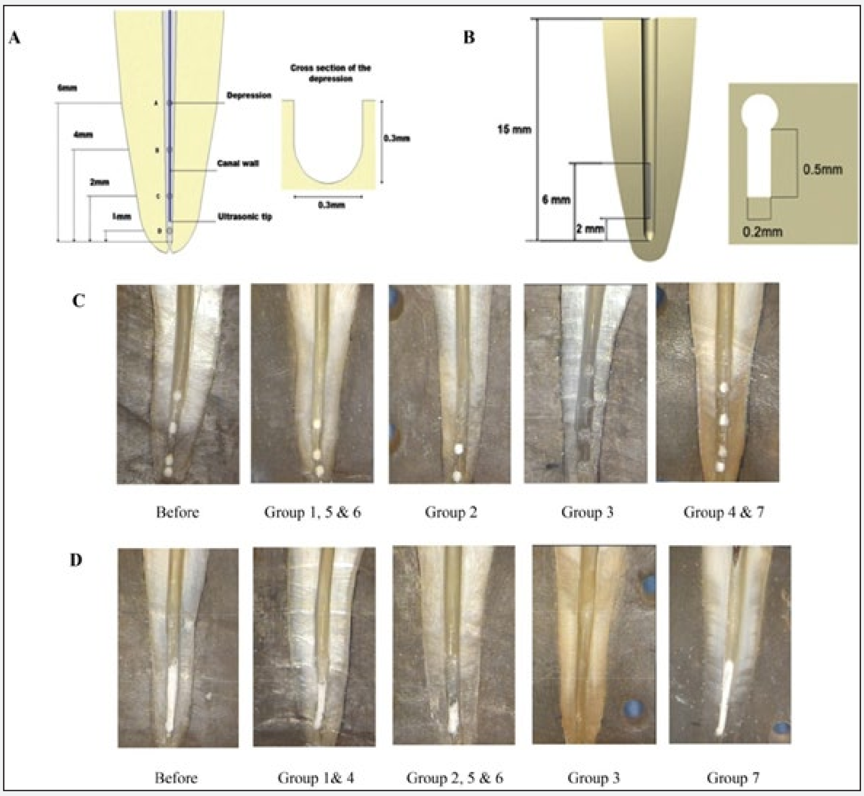

Figure 1: Schematic drawings of the depressions on one canal wall (A) and the grooves on the other canal wall (B) and their typical images (C and D) before and after different irrigation procedures.

Each depression and groove was filled with dentin debris, which was mixed with 2% NaOCl for 5 minutes in order to simulate a situation in which dentin debris accumulates in uninstrumented canal extensions [7,8]. These models were 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 [11]. The 15 models were used repeatedly in the seven experimental groups [9].

Irrigation Procedures and Experimental Groups

Groups 1, 2 and 3 were irrigated using ProUltra. Groups 4, 5 and 6 were irrigated using Vpro. A 10mL syringe containing 2% NaOCl was attached to the luer-lock connection on both needles. The inactive needles were placed into the canal, and the solution was delivered. Once irrigant filled the canal, the ultrasonic unit was activated with the power set to level 5. Maintaining a continuous irrigation flow, the ProUltra was gently inserted respectively to groups 1, 2 and 3 to 7, 5 and 3 mm short of WL and the Vpro was inserted respectively to groups 4, 5 and 6 to 7, 5 and 3 mm short of WL. Upon activation, the needles were moved up and down in a consistent straight-line path from the canal entrance to the length required. Group 7 was irrigated using Vpro placed 1mm short of WL without being activated by ultrasound. The flow rate was 10ml/min for 1 minute for all the groups.

Image Evaluation and statistical analyses

Before and after each irrigation procedure (Figure 1C & 1D), the samples were evaluated by direct observation of images recorded under the dental operating stereomicroscope.

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Pictures were taken with a digital camera (Axio cam, Carl Zeiss). The orientation of all samples was standardized in relation to the recording microscope to produce similar images for all groups. The sequence of all the pictures was randomized.

The debris removal from each depression and groove after each irrigation procedure was scored independently and blindly by two trained, standardized and calibrated endodontists. The depressions were scoredas "0" if the depression was clean with only few particles and "1" if it was not completely clean. The outcome was assessed in each bloc at each of the 4 levels of depressions. The grooves were scored independently by using the following score system: "0" if the groove is empty; "1" if less than half is filled with debris; "2" if more than half is filled with debris and "3" if the complete groove is filled with debris. When the two evaluators differed in the scoring, an agreement was reached after discussion.

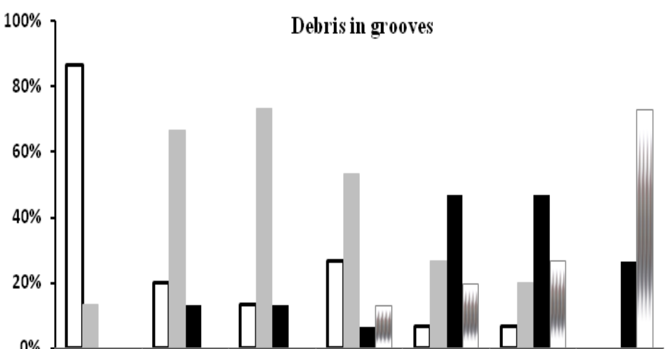
Statistical analyses were performed by a software program (SPSS for Windows, Version 18.0, Chicago, IL). The level of significance was set at α = 0.05. The Kendall's tau-b and Fisher Exact tests were conducted for comparison between distances and groups respectively.

Results

Grooves

The results are presented in Chart 1. The amount of debris was significantly the lowest with ProUltra3mm and the highest in the control group (-p-value<0.0001).

Chart 1: Percentages of grooves containing debris in each group



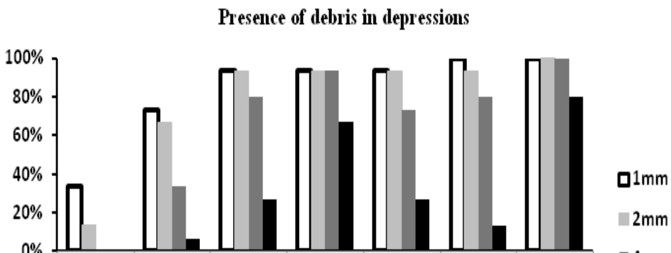
	ProUltra 3mm	Vpro 5mm	Vpro 3mm	ProUltra 5mm	ProUltra 7mm	Vpro 7mm	Control
0	86.7%	20.0%	13.3%	26.7%	6.7%	6.7%	0.0%
1	13.3%	66.7%	73.3%	53.3%	26.7%	20.0%	0.0%
2	0.0%	13.3%	13.3%	6.7%	46.7%	46.7%	26.7%
3	0.0%	0.0%	0.0%	13.3%	20.0%	26.7%	73.3%

Depressions

Comparisons between depressions in each group: With ProUltra 7mm, the percentage of depression with debris was significantly lower at 6mm from foramen (26.7%) (-p-value<0.0001). With ProUltra 5mm, it was significantly lower at 6mm from foramen (6.7%) followed by 4mm depressions (33.3%) (-p-value<0.0001). With ProUltra 3mm, it was significantly lower at 6 and 4mm from foramen (0%), followed by the distance 2mm (13.3%) and higher at 1mm from foramen (33.3%) (-p-value=0.013). With Vpro 7mm, no significant difference was found between 1, 2, 4 and 6mm (-p-value=0.062). With Vpro 5mm, it was significantly lower at 6mm (26.7%) (-p-value<0.0001). With Vpro 3mm, it was significantly lower at 6mm (13.3%) (-p-value<0.0001). With control group, it was significantly lower at 6mm (80%) (-p-value=0.027).

Comparison between the groups: The results are presented in Chart 2 Percentage of depressions without debris was significantly the highest with ProUltra 3mm and the lowest in control group (-p-value<0.0001).

Chart 2: Percentage of depressions containing debris in each group.



	ProUltra 3mm	ProUltra 5mm	ProUltra 7mm	Vpro 7mm	Vpro 5mm	Vpro 3mm	Control
1mm	33.3%	73.3%	93.3%	93.3%	93.3%	100.0%	100.0%
2mm	13.3%	66.7%	93.3%	93.3%	93.3%	93.3%	100.0%
4mm	0.0%	33.3%	80.0%	93.3%	73.3%	80.0%	100.0%
6mm	0.0%	6.7%	26.7%	66.7%	26.7%	13.3%	80.0%

Discussion

The results of this study were in agreement with others [12-15] which showed that the VPro and the ProUltra allowed better apical debridement compared with conventional syringe. It is generally admitted, that the mechanical cleaning is attributed to the flow velocity [16,17]. Indeed, when using the 30G needle, the flow velocity at the tip of the needle is expressed by the formula [18]:

$$V_1 = \frac{Q}{\pi r^2} \qquad (1)$$

Where Q is the flow rate, R is the radius of the needle.

When the needle is ultrasonically activated, a second velocity component (V_2) is added to (V_1) due to the vibration of the needle. It is expressed by the formula [18]:

$$V_2 = \frac{\omega \varepsilon_0^2}{R} \qquad (2)$$

Where $\omega = 2\Pi f$ (f is the oscillation frequency), ε_0 is the oscillation amplitude and R is the needle radius. V_2 is responsible for acoustic turbulence and acoustic cavitation and has a value greater than V_1 [2]. These acoustic turbulences cause shear stresses on the canal walls that will remove debris dentin [15]. These shear stresses are directly proportional to the flow Velocity (V) according to the formula [17]:

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$$\tau = \eta \frac{v}{ä} \quad (3)$$

Where η is the kinematic viscosity of the liquid, V the streaming velocity and the boundary layer thickness? And since the velocity flow with ultrasonic activation is greater than without activation, the shear stress will be higher [14]. In fact, Verhaagen et al. [18] showed that the shear stresses per unit area are about $1N/m^2$ for the conventional needle and $10N/m^2$ when the needle is ultrasonically activated resulting in a better mechanical cleaning of the root canal walls.

Concerning the grooves, there was a significant difference between the seven groups (-p-value<0.0001). The ProUltra 3mm short of WL was able in 86.7% of the cases to eliminate completely the debris compared to 13.3% for the Vpro 3mm short of WL. But, the study of Jiang et al. [15] showed that 55% of the grooves were clean with the Vpro. This difference in results could be probably due to the insertion depth of the needle that is 1mm short of WL in their study compared to 3mm short of WL in ours. In the groove, the ProUltra showed a better cleaning efficiency. It was clear that the needles cleanse behind their tip but not clear how much do they cleanse ahead of them.

The position of the depression allowed us to calculate the efficiency of the needle to clean ahead of its tip. There was a significant difference between the seven groups (-p-value<0.0001). The ProUltra 7mm short of WL was able in most of the cases to clean 1 mm beyond its tip. The ProUltra 5mm short of WL was able to clean 1 mm beyond and behind its tip. The ProUltra 3mm short of WL was able in most of the cases to clean all the depressions, so the needle has cleaned 3mm above and 2mm beyond its tip. This is in agreement with the study of Castelo-Baz et al [12]. The reason why the ProUltra at 3mm short of WL was better than the other levels of insertion could be explained by the formula:

$$Q = VxS \quad (4)$$

Where Q is the flow rate, V is the velocity flow and S is the canal section. For a constant flow rate, V and S are inversely proportional. The closer we get to WL, the narrower is the canal, therefore V increases leading to a better apical debridement.

With the Vpro 7mm short of WL, no depression was cleaned. The Vpro 5mm short of WL was able to clean in most of the cases 1mm behind its tip. The Vpro 3mm short of WL was able in most of the cases to clean only the depression at 6mm short of WL. This means that this instrument works probably behind its tip. Our results correlate with those of Curtis et al. [13].

This difference in results between the Vpro and ProUltra in depressions and grooves, where the ProUltra has a better apical debridement at different levels, can be explained by equation [16]. In fact, when the radius of the needle (R) increases, the flow velocity decreases. This means that the 30G needle should clean more than the 25G needle. But other than the radius of the file, the amplitude of oscillation also affects the velocity. Observations of Verhaagen et al. [18] have shown that the amplitude of oscillation has increased with the increasing diameter of the needle. Thus, at a frequency ($\omega = 2\Pi f$) set at 30 kHz in dentistry and since the velocity is directly proportional to the square of the amplitude (ε_0), and inversely proportional to the radius of the needle, the effect of the amplitude on the velocity will be much greater. For this 25G needle cleaned more that 30G needle.

Our study, using only straight canals has shown fracture of the Vpro (8/12). A previous study [19] also found that these needles fracture easily during ultrasonic activation. According to Al-Jadaa et al. [19], this is explained by the generated heat inside the metal upon activation, a fact that limits their usability in the clinic.

Conclusion

Through this work the ProUltra and Vpro allowed a better apical debridement compared with conventional irrigation. But the ProUltra 3mm short of WL, showed the most satisfactory results in the elimination of dentinal debris. The latter is able to clean 2mm beyond and 3mm behind its tip. On the contrary, the VPro was able to clean only behind its tip.

The cleaning efficacy of the 25G needle was observed in large straight canals where the needle reached freely the depth required. But further studies are needed to investigate the effectiveness of this needle in curved canals where the contact with canal walls is certain altering the acoustic micro streaming and cavitations.

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