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Evaluating the apically extruded debris and irrigants in different nickel–titanium instrumentation and irrigation techniques

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Purpose: This study aims to evaluate the amount of debris and irrigant extruded apically following the use of the ProFile .04/.06 with Orifice Shapers and HERO 642 rotary instrumentation systems and manual preparation using the modified step-down technique, in combination with irrigation by an anesthetic needle, perforated needle, or passive ultrasonic irrigation (PUI).

Methods: One hundred and eighty teeth with single canals and similar morphologies were included in this study. The teeth were then divided into nine groups. In each group, instrumentation and irrigation were performed using different methods. The extruded material was collected in preweighed vials and the amount of extruded debris was calculated. The data were analyzed using Kruskal–Wallis one-way analysis of variance and Dunn's test.

Results: The amount of debris extruded apically was determined to be significantly higher with the step-down technique ($p < 0.001$) and ProFile system ($p < 0.05$) compared to the HERO 642 system. While the amount of irrigant extruded apically by perforated needle was higher than that by PUI ($p < 0.01$), compared to both methods, the anesthetic needle caused significant irrigant extrusion apically ($p < 0.001$). While a negative correlation was determined between the extruded irrigant and working length ($p < 0.01$), the irrigant was positively correlated with both minor ($p < 0.01$) and major foramen areas ($p < 0.05$) ($n = 180$).

Conclusion: HERO 642 and PUI yielded better results in terms of the parameters tested.

Keywords: Dental instruments, root canal irrigants, root canal preparation.

Introduction

Apical extrusion of debris, such as dentin chips, vital or necrotic pulp tissue fragments, microorganisms and/or their products, or remnants of root canal filling materials, during root canal preparation may lead to pain and/or swelling (1–4). Infected dentin chips plugging the apical region may impair periapical healing (5). Furthermore, extruded root canal filling materials may result in the development of a therapy-resistant foreign body giant cell granuloma (6). Currently, no combination of instrumentation and irrigation techniques has been identified to completely prevent apical extrusion of debris and irrigants (7). Therefore, to reduce the frequency and severity of complications (1–6), clinicians should choose a combination that extrudes relatively lower amounts of apical debris and irrigant, using experimental results as a guide.

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The primary factor that determines the amount of apically extruded debris is the movement pattern of the instrument rather than its manual or engine-driven application (8–10). Instrumentation techniques using rotational movement have been reported to extrude less debris apically compared to those using linear filing techniques (9–12). Among the previously examined nickel–titanium (Ni–Ti) rotary systems, ProFile instruments were found to extrude less debris apically than K-files (9,11), the hybrid technique (10), and Nitiflex (13). However, there was no statistically significant difference between ProFile instruments and the manual balanced force technique (8–10), ProTaper hand instruments (14), or several Ni–Ti rotary systems including Lightspeed (8,9), NT McXIM (8), Quantec 2000 (10), Pow-R (10), Race (13), FlexMaster (13), and HERO Shaper (15). In 2 studies, apical extrusion of debris was lower with ProFile instruments than with ProTaper (14,15), but no difference was found in another study (16). It is noteworthy that although some early studies (8–11) investigated ProFile instruments with .04 taper, recent ones (13–16) have examined .04/.06 tapers and Orifice Shapers.

Vande-Visse and Brilliant (17) reported that instrumentation of root canals without irrigation produced no collectible debris. However, apically extruded debris was obtained from all root canals when irrigation was performed during the procedure. Besides leading to debris extrusion (18–21), extrusion of the irrigant itself may cause severe periapical toxic reactions (22).

Thus, the primary aim of this study was to compare the amounts of apically extruded debris and irrigants following the use of the ProFile .04/.06 with Orifice Shapers and HERO 642 Ni–Ti rotary instrumentation systems and manual preparation with Nitiflex files using a modified Stock's step-down technique. Furthermore, we aimed to statistically evaluate the amount of extruded materials with regard to the irrigation devices used, including a dental anesthetic needle, the Hawe Max-I-Probe perforated needle, and passive ultrasonic irrigation (PUI).

Materials and Methods

Specimen Selection

Freshly extracted permanent human teeth with single roots were collected and stored in a 0.1% thymol solution. Upper and lower incisors, canines, and premolars were selected, and each tooth was placed in an individual bottle.

The selection process for the 180 teeth used in this study was as follows:

1- The teeth were radiographed mesiodistally and buccolingually, and the degrees of canal curvatures in both planes were determined using the Schneider method (23). The larger of the two curvature measurements was used for allocation of the groups. Following radiographic examination, the teeth that had extremely wide or calcified canals, more than one curvature or a curvature >25 degrees in one plane, or canal anatomy other than Weine's Type I (24) were discarded.

2- Similar to the method used by Beeson et al. (11), the two largest diameters of the minor and major foramina, which were perpendicular to each other, were measured using a stereomicroscope with a screw micrometer eyepiece (Reichert Inc., Nr. 315 499, Austria). Assuming they had rectangular forms, the approximate areas of the minor and major foramina of each tooth were calculated by multiplying the two measurements. Following stereomicroscopic examination, teeth with fractured root apices, more than one foramen, and immature, calcified, or resorbed foramina were discarded.

Preparation of the Experimental Setup

Dark colored, 30-cc, screw-capped glass containers (Pasabahce, Turkey) were used to collect the debris and irrigants. Plastic caps were punctured, and the teeth were fixed onto them using self-cured acrylic resin. Then, the crowns of the teeth were removed to provide a reference surface for repeatable measurement of the working length and to produce regular samples with similar root lengths. A #10 K-file (Dentsply, Maillefer) was negotiated into the root canal until its tip was visible at the apical foramen and then retracted by 1 mm to determine the working length.

A second cap was used during the weighing procedure. Empty vials with second caps were preweighed on an electronic microbalance (AT 261 DeltaRange, Mettler Toledo, Spain). Caps with teeth were vented with 20-gauge needles to equalize the air pressure between the inside and outside of the vials.

Allocation of Groups

The teeth were randomly assigned to one of the nine base groups of 20 teeth each, with each group having equal numbers of each tooth type. The same types of teeth were repeatedly exchanged between the groups, until all groups were deemed statistically similar with respect to each variable according to the Kolmogorov-Smirnov and Kruskal–Wallis tests. Since the HERO 642 system classifies canals in 3 types as easy, moderate, and difficult based on the degree of canal curvature, 2 subgroups having equal numbers of specimens with easy (0°–10°) and moderate (11°–25°) canals were allocated to HERO 642.

Instrumentation and Irrigation of the Root Canals

The ProFile .04/.06 with Orifice Shapers (Dentsply Maillefer, Swiss) and HERO 642 (Micro-Mega, France) systems were used according to the manufacturers' instructions. The instruments in both rotary systems were used in a W&H 975 AE electric handpiece (W&H Dentalwerk Bürmoos, Austria), with a speed reducing ratio of 20:1 powered by a TCM Endo electric motor (NOUVAG AG, Switzerland) at a torque setting of 3 and a constant speed of 250 rpm for ProFile and 450 rpm for HERO 642.

In the root canals instrumented using ProFile, #3 and #2 Orifice Shapers were used consecutively to shape the coronal one-third of the canal, followed by size 25 and 20 instruments with .06 taper to shape the middle one-third of the canal. A size 25 instrument with .04 taper was used to reach a distance 3 mm short of the apex. Size 20, 25, and 30 instruments with. 04 taper were used till the working length. Finally, size 20 and 25 instruments with. 06 taper were used for final shaping without an effort to reach the apex. When difficulty was encountered in reaching the desired point of the canal, a #1 Orifice Shaper and size 15 instruments with .06 and .04 tapers were included in the sequence.

In the HERO 642 group, a size 30 instrument with .06 taper was initially used to shape the coronal two-thirds or half of the canal. Then, a size 30 instrument with .04 taper was used to reach a distance 2 mm short of the apex, followed by a size 30 instrument with .02 taper to reach the apex. In moderate canals, size #25.06, 25 instruments with .06, .04, and .02 tapers were sequentially used to reach the apex. Then, instrumentation was continued using size 30 instruments with .04 and .02 tapers. When difficulty was encountered in reaching the desired point of the canal, the previous instrument was then reused. In both types of canals, a size 30 instrument with .04 taper was used as the last instrument at the working length.

In the canals instrumented using Stock's step-down technique (25) with minor modifications, size 15, 20, and 25 Nitiflex files (Dentsply Maillefer, Switzerland) were initially used with a reaming motion. Later, #1 and #2 Gates Glidden burs (Dentsply Maillefer, Switzerland) were successively used to shape the coronal two-thirds of the root canal. Nitiflex files sizes 15 through 30 were successively used to form apical seats at full working length, by using a reaming motion followed by circumferential filing motion until the apex was reached. Finally, a step-back procedure was followed by using Nitiflex files sizes 35 and 40 Nitiflex files in 1 mm increments. Recapitulation was then performed with a size 30 master apical file at the working length after each file.

In the present study, all canals were irrigated with distilled water. Two milliliters of irrigant were delivered through either a dental anesthetic syringe with a 27-gauge hypodermic needle (set inject, TIBSET AS, Turkey) or the same type of syringe with a 25-gauge safe-ended perforated needle (Hawe Max-I-Probe, Hawe Neos Dental, Switzerland) after each instrument and as a final flush over a 15 s period. PUI was performed by using a size 20 finger spreader (Dentsply Maillefer, Swiss) that was cut 15 mm from the tip and attached to an ultrasonic unit (Multipiezo, Mectron Medical Technology, Italy). The ultrasonic unit was used for 15 s after each instrument and as a final flush while its power was set to "endo" and its irrigant pump was set to grade 3, producing a flow rate of 8 ml/min. Both needles and spreader tips were placed as deep into the canal as possible without binding.

Weighing of the Debris and Irrigant

After instrumentation was completed, the external surface of each root apex was washed with 0.5 ml of distilled water into the vial to remove any possible debris remnants adhered to the surface. Each vial containing a mixture of debris and irrigant was immediately closed with its second cap. The exterior surfaces of the vials were then washed and dried. Then, the vials were weighed. The weight of the debris and the irrigant extruded through the apex was calculated by subtracting the weight of fluid used to wash the root apex (0.5469 g) from the weight of the mixture.

Millex-HV Filter Units (Millipore Corporation, USA), with a diameter of 13 mm and pore size of 0.45 µm, were numbered and placed in an incubator (Techne Hybridiser HB-1D, Techne Inc., USA) at 37 °C for 24 h and then stored under vacuum in a desiccator (Glaswerk Wertheim, Germany) containing $CaSO_4$ crystals for 48 h to evaporate the moisture and keep the weights constant. The filters were weighed at daily intervals without handling in the same order by a microbalance until three consecutive values consistent to the nearest 0.01 mg were obtained for each sample. The content of each vial was transferred to a 5-ml syringe attached to the corresponding filter using a glass funnel and filtered. Then, fresh distilled water was introduced into each vial, and the new content was filtered until the vial was completely free of debris. Filters with debris were dried and weighed as described earlier. The weight of the debris was calculated by subtracting the mean prefiltration weight of the filter from the mean postfiltration weight for each sample.

In order to prove the reliability of the methodology, 10 control filters were dried and weighed. After filtration of 10 ml of distilled water through them, they were dried and weighed again. Pre- and post-filtration weights of the control filters were found to be equal.

Statistical Analysis

Instrumentation and irrigation groups of 60 teeth each were compared in terms of the apically extruded debris and irrigants, using the Kruskal–Wallis one-way analysis of variance and Dunn's multiple comparisons tests (GraphPad Instat™). The correlations among the data on the variables of teeth, debris, and irrigants were determined by using the values of r and two-tailed p of Spearman's test (GraphPad Prism Version 3.02).

Results

The debris extruded with the step-down technique was found to be more than that with ProFile, although no significant difference was noted ($p > 0.05$). Moreover, the debris extruded with the step-down technique ($p < 0.001$) and ProFile system ($p < 0.05$) were significantly more than that with the HERO 642 system. No significant differences were also observed among the instrumentation groups in terms of irrigant extrusion ($p > 0.05$) (Table 1). While the perforated needle extruded a higher amount of irrigant compared to PUI ($p < 0.01$), the anesthetic needle caused the highest amount of irrigant extrusion ($p < 0.001$). There were no significant differences among irrigation techniques with regard to apically extruded debris ($p > 0.05$) (Table 2).

Although the extruded debris and irrigants showed positive correlation among themselves ($r = 0.3693$, $p < 0.001$) when all the teeth used in this present study were considered ($n = 180$), no correlation could be detected between extruded debris and irrigants in the ProFile group ($r = 0.2265$, $p = 0.818$, $n = 60$).

There was a positive correlation between areas of minor and major foramina ($r = 0.551$, $p < 0.001$, $n = 180$). A negative correlation was found between extruded irrigants and working length ($r = -0.2045$, $p < 0.01$), whereas positive correlations were determined between extruded irrigants and the areas of both minor ($r = 0.2124$, $p < 0.01$) and major foramina ($r = 0.1601$, $p < 0.05$) ($n = 180$).

Table 1. Weights (mean and standard deviation) of the extruded debris and the irrigant in the instrumentation groups (n = 60)

Group	Debris (mg)	Irrigant (g)
ProFile	$0.29^a \pm 0.39$	$2.85^a \pm 4.06$
HERO 642	$0.13^b \pm 0.13$	$1.54^a \pm 1.97$
Step-down	$0.65^a \pm 0.75$	$2.23^a \pm 3.78$

[a, b, c]Means followed by the different letters are significantly different (p< .05).

Table 2. Weights (mean and standard deviation) of the extruded debris and the irrigant in the irrigation groups (n = 60)

Group	Debris (mg)	Irrigant (g)
Anesthetic N	$0.34^a \pm 0.54$	$4.89^a \pm 4.52$
Perforated N	$0.24^a \pm 0.31$	$1.42^b \pm 1.80$
PUI	$0.48^a \pm 0.68$	$0.32^c \pm 0.55$

[a, b, c]Means followed by the different letters are significantly different (p< .05).
N: Needle; PUI: Passive ultrasonic irrigation.

Discussion

In previous studies using a glass vial as a component of the experimental setup, a smaller vial (8,11,26), a centrifuge tube (10), or an aluminum crown (27) was located in the vial as a collecting container or a second component. Then, the vial was capped using a rubber stopper, and the tooth was securely inserted into a hole prepared in the stopper. In the present study, similar to a previous study (15), we used only Eppendorf tubes as a single-component assembly; the teeth were then fixed to the plastic caps of the glass vials using self-cured acrylic resin, and extruded material was collected into these vials. Second components, similar to those mentioned above, were not used in the vial. A needle was then inserted into the cap to equalize the pressure inside the vial with the outside pressure. The content of the vial was transferred to a syringe using a glass funnel and filtered via a Millex-HV filter attached to the syringe. This was similar to the methodology used in another study (28), in which a filter column suction system was used. In this method, the closed-filter system enabled us to calculate the weights of the extruded debris more accurately by preventing accidental scattering of the debris during the experimental procedures.

The present study revealed that there was a significant difference in the amount of debris extruded apically between the 2 rotary systems. The significantly lower amounts of debris extruded by the HERO 642 system (0.13 mg) compared to that by the ProFile system (0.29 mg) might be attributed to the relatively lesser number of instruments in its sequence and the differences in the cross-sectional configuration of the files in both systems. However, in another study (15), no significant difference was observed between ProFile (0.56 mg) and HERO Shaper (0.94 mg), although HERO Shaper was noted to extrude more debris. The authors hypothesize that the risk might be associated with the speed of the system, with faster systems causing increased apical extrusion. Both types of HERO instruments have triple-helix cross sections, but the Shaper file has a longer pitch (29). Comparing the results of the two studies, it can be speculated that the HERO instrument with a shorter pitch might cause less extrusion of debris (30). Alani and Al-Huwaizi (31) compared two reciprocating single file systems (WaveOne Gold, Reciproc blue) with two continuous rotation file systems (ProTaper Gold, 2Shape) using ProTaper Universal as the control. Their results showed that the amount of apical extrusion was the least with 2Shape and the most with ProTaper Universal. The authors attributed this difference to the higher number of files used in ProTaper Universal, which might be a contributing factor to the increased debris extrusion observed during instrumentation, which is consistent with the observation in this present study. Recently, there is a tendency to utilize the lowest possible number of instruments for the treatment, with single file systems being used more frequently. Uslu et al. (32) compared three single file systems — Reciproc Blue, Hyflex EDM, and XP-Endo Shaper — and found that XP-Endo Shaper caused the least amount of extrusion. Thus, different design characteristics and movement kinematics also account for the differences in results obtained with different systems.

Some studies reported that ProFile instruments produced 0.03 (11), 0.30 (13), 0.46 (9), 0.56 (15), 0.58 (14), and 1.10 (8) mg of apically extruded debris. In the present study, the ProFile .04/.06 with Orifice Shapers group produced 0.29 mg of debris. The differences in the results might be due to the variety in instrumentation and irrigation techniques, operators, instruments used for verifying canal patency, and the anatomical characteristics of the experimental teeth.

With respect to the amount of the extruded debris detected in the step-down technique, the results of the present study were in accordance with those of the previous studies, which evaluated manual crown-down preparation (9,10,12). Linear filing techniques were reported to produce significantly more apical debris than rotary systems (9–11). In the present study, the step-down technique produced more apical debris than both the rotary systems used, but the differences were significant for only HERO 642. Utilization of the reaming motion up to the desired point of the root canal before the circumferential filing in the technique results in reduction of the apical extrusion of the debris, and this might be the reason why no statistically significant difference was detected with ProFile.

Varying results were obtained in studies investigating the weight of the apically extruded irrigant (8,10,11). Hinrichs et al. (8) reported that when 18 ml of solution was used with a 27-gauge perforated needle, 2.644 g and 1.864 g of irrigants were extruded with the ProFile .04 Taper Series 29 and balanced force techniques, respectively. These results are consistent with those of this present study, wherein 2.85 g and 2.23 g of irrigants were extruded with ProFile. 04/.06 with Orifice Shapers and the step-down technique, respectively.

Previous studies reported that open-ended needles extruded more irrigants than closed-ended needles (33) or PUI (34). In this study, the highest and lowest amounts of apical extrusion of irrigants were observed with anesthetic needles and PUI, respectively. In PUI, the solution might have lost its speed and direction until reaching the foramen, reducing the extrusion of the irrigant, whereas in the anesthetic needle irrigation, the direct striking of foramen by the irrigant might have increased the extrusion. Peeters et al. (35) compared irrigant extrusion in laser-activated and ultrasonic irrigation techniques using a mixture of radiopaque contrast medium and concluded that the absence of radiopaque contrast medium from the periapical tissues in all cases indicated the safety of both techniques. This result is consistent with the results of the present study. Sharma et al. (36) demonstrated that positive pressure and PUI protocols were associated with significantly less extrusion in the position simulating the maxillary arch compared to the control group. On the other hand, negative pressure performed better than positive pressure and PUI protocols irrespective of the maxillary or mandibular arch. No differentiation was made in terms of the tooth position in the dental arch in the present study.

Some studies concluded that irrigation techniques had an effect on debris extrusion patterns (19–21). Yeter et al. (21) reported that open-ended needles were associated with significantly more debris extrusion compared to two-sided ones. Karatas et al. (20) reported that PUI extruded more debris than the needle technique, with no significant difference, and that the non-activated self-adjusting file system extruded less debris than both techniques. In terms of the amount of extruded debris, the results of the present study were similar to that of Uzunoglu et al. (37), who used open-ended or perforated needles. Both studies detected no significant difference among the irrigation techniques in terms of the amount of debris extruded. However, the PUI group extruded the least amount of irrigant and, at the same time, caused more debris extrusion compared to other methods, even though the difference was not statistically significant. This may be contradictory to the presence of a positive correlation between the extruded debris and the irrigant. However, in PUI, the irrigant advances from the canal orifice to the apex and carries all debris in the canal apically. On the other hand, in the needle techniques, the tip of the needle is placed as far into the canal as possible; therefore, only the debris located in the area between the tip of the needle and the foramen can be extruded. In addition, ultrasonic energy might have led to apical precipitation of the debris.

Psimma et al. (33) concluded that needle insertion depth had a significant effect on the amount of irrigant extruded. Similarly, a negative correlation was detected between the extruded irrigant and the working length in the present study. As the tip of the needle or spreader is placed farther from the foramen, the working length increases. Williams et al. (38) reported that there was no correlation between the extruded irrigant and the foramen area in primary teeth. In contrast, positive correlations were observed between the extruded irrigant and both minor and major foramen areas in the present study.

Conclusion

Ni–Ti rotary instrument systems, such as HERO 642, which make use of relatively few instruments, can reduce the frequency and severity of complications such as pain, swelling, and delayed healing of periapical lesions by reducing the amount of debris extruded apically. The clinical use of PUI, which extruded the least amount of irrigant apically among the techniques tested in the present study, can be recommended to avoid the toxic reactions to irrigants.

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Ethical Approval: This study was reviewed and approved as a doctoral thesis (no. 111498) by an advisory board appointed by Health Sciences Institute, Istanbul University, as an adequate ethical requirement at the time of its inception (1996).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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