Apical extrusion of intracanal debris and irrigant following use of various instrumentation techniques

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Objective. The purpose of this study was to compare in vitro the amount of debris and irrigant extruded apically from extracted teeth, using manual technique and crowndown pressureless technique by K3, RaCe, and FlexMaster instruments.
Study design. Sixty human single-rooted mandibular premolar teeth were randomly assigned to 4 groups, 15 teeth each. The teeth in 4 groups were instrumented until the working length with RaCe, K3, FlexMaster, and K-type stainless steel instruments respectively. Debris and irrigant extruded from the apical foramen were collected into vials and the amounts were determined. The data obtained were analyzed using Kruskal-Wallis 1-way analysis of variance and Mann-Whitney *U* tests, with $\alpha = 0.05$ as the level for statistical significance.
Results. No statistically significant difference was observed among the groups in terms of debris extrusion ($P > .05$). On the other hand, a statistically significant difference was observed between K3 and manual technique groups in terms of irrigant extrusion ($P < .05$). The difference between other groups was not statistically significant ($P > .05$).
Conclusion. Based on the results, all instrumentation techniques produced extruded debris and irrigant; however, the engine-driven nickel-titanium systems were associated with less apical extrusion and irrigant. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:257-62)**

Complete preparation of the root canal space is one of the most important stages in endodontic treatment. During preparation, irrigant and debris such as bacteria, dentin fillings, and necrotic tissue may be extruded into the periradicular region leading to periapical inflammation and postoperative flare-ups.[1] Tissue reactions following instrumentation short of the apex are milder than those reactions that follow instrumentation beyond the apex.[2] It is also known that inflammatory reactions can cause bone resorption, edema, and pain.[3] Therefore, it is logical to assume that minimizing the amount of apically extruded material should minimize postoperative reactions.

All preparation techniques and instruments have been reported to be associated with extrusion of infected debris, even when preparation is maintained short of the apical terminus.[4-12] Vande Visse and Brilliant[4] first quantified the amount of debris apically extruded during instrumentation. They found that instrumentation with irrigant produced extrusion, whereas instrumentation without irrigant produced no collectible debris. Martin and Cunningham[5] reported that less debris was extruded when the intracanal preparation was accomplished with and ultrasonic instrument. Al-Omari and Dummer[6] verified that techniques involving a linear filing motion, such as the stepback techniques, create a greater mass of debris than those involving some sort of rotational action. Reddy and Hicks[7] were the first to compare apical debris extrusion between manual instrumentation and engine-driven techniques. When comparing the mean weights of apically extruded debris, they noted that the stepback technique produced significantly more debris than the engine-driven techniques and the balanced force technique. They suggested that rotation during instrumentation, in both the engine-driven techniques and the balanced force technique, tended to pack the dentinal debris into the flutes of the instruments and directed them toward the orifice. Er et al.[10] first showed the amount of intracanal bacteria apically extruded during instrumentation using a new experimental model. Tinaz et al.[11] reported that manual instrumentation with K-files and engine-driven instrumentation with the ProFile .04 taper system perform similarly with respect to apical extrusion in teeth with varying extent of apical patency. They also found that a tendency for increased apical extrusion exists with both techniques as the diameter of the apical patency increases.

Engine-driven nickel-titanium instruments have been shown to prepare the root canal rapidly, and maintain

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the canal shape and working length with few aberrations during root canal preparation.[13-16] They are available in various designs that differ in tip and taper design, rake angles, helical angles, pitch, and presence of radial lands.

FlexMaster instruments (VDW, Munich, Germany) have been introduced to supplement the well-known engine-driven instruments with varying tapers and designs. According to the manufacturer, their unique feature is a cross-section similar to a triangle with convex sides that is presumed to increase stability, cutting efficiency, and torsional resistance. The FlexMaster instruments have flattened, noncutting tips and lack radial lands. For severely curved root canals, the FlexMaster instruments with greater taper are advocated for enlargement of the coronal and middle third following the guidelines of the manufacturer. The root canal preparation is achieved by shaping the apical portion with the 2% tapered instruments.[17] FlexMaster instruments prepared curved canals more rapidly and with only minimal straightening compared to hand instruments in a clinical study.[18]

The K3 instruments (SybronEndo, West Collins, CA) are reported to have a slightly positive rake angle in combination with so-called radial land relief and asymmetrical cross-sectional design.[19] The peripheral blade relief areas are alleged to have 2 functions: (1) to increase the peripheral mass in order to increase the instruments' resistance to fracture and (2) to reduce the amount of area of the radial lands that comes in contact with the canal wall in order to reduce frictional resistance.[20]

Recently, the RaCe instruments (FKG Dentaire, La Chauxde-Fonds, Switzerland) have become available. The instrument has a triangular cross-sectional shape along its length with helical and undulated edges. This characteristic may allow the instrument to rotate inside the canal without having continuous contact with the walls, rather contact may be present only at specific points. According to the manufacturer, the alternating cutting edges reduce the phenomena of self-threading and frictional forces, and therefore minimize risk of instrument breakage.[21]

The purpose of this study was to compare in vitro the amount of debris and irrigant extruded apically from extracted teeth, using manual technique and crown-down pressureless technique by K3, RaCe, and FlexMaster instruments.

MATERIAL AND METHODS

Selection and preparation of teeth

Sixty freshly extracted human single-rooted mandibular premolar teeth with mature apices and curvature between 0 and 10 degrees were selected. All teeth were controlled with digital radiographs in buccal and proximal directions to check for a single canal. Teeth with calcification and open apices were excluded. The teeth were cleaned of debris and soft tissue remnants and were stored in physiological saline solution at $+4^{\circ}C$ until required. Endodontic access cavities were prepared (Endo Access Bur, Dentsply Maillefer, Ballaigues, Switzerland) in a high-speed handpiece and pulpal remnants were extirpated using a broach.



Fig. 1. The experimental model system used to evaluate debris and irrigant extrusion.

Test apparatus

A previously described method was used for debris and irrigant collection.[11] The experimental model system used to evaluate debris and irrigant extrusion is presented in Fig. 1. Briefly, vials with rubber stoppers were adjusted for use by using a heated instrument to create a hole through the center of each. The tooth was inserted under pressure into a rubber stopper, which was fixed to the cementoenamel junction by means of cyanoacrylate (Quickstar, Furkan Inc., Istanbul, Turkey). The apical part of the root was suspended within the vial, which acted as a collecting container for apical material evacuated through the foramen of the root. A bent 27-gauge needle was also forced alongside the rubber stopper to use as a drainage cannula, balance between the air pressure inside and outside the vials, and an electrode for the electronic working length determination during canal instrumentation. Two coats of nail varnish were applied to the external surface of all roots. The rubber stopper with the tooth was then fitted into the mouth of the vial. Glass vials were entirely filled with 0.9% saline solution. Before the experiment, a hole was created in the nail varnish that covered the apical foramen using a size 15 K-file. During this procedure, only 1 mm of instrument was extruded. In

this way a standard size of foramen and apical patency was achieved. The tooth–rubber stopper–needle unit was fitted into the mouth of the vial.

Root canal preparation

Working length determinaton in all teeth was done using an Endomaster (EMS, Nyon, Switzerland) endodontic handpiece with the electronic apex locator mode switch on. A lip clip was attached to the needle. K-files were attached to the file holder cord and placed into the root canals and advanced apically in the root canal until 1 LED was read on the console of the Endomaster. The rotary NiTi instrument groups were prepared with an Endomaster endodontic handpiece at low speed (300 rpm) and automatic reverse function mode.

A total volume of 7 mL of 2.5% NaOCl was used in each root canal for irrigation because of the different numbers of the files in groups. The irrigant was delivered by disposible plastic syringe with an attached 27-gauge stainless steel needle that had been placed down the canal until slight resistance was felt.

The instrumentation sequences used in this study were as follows:

Group 1 (RaCe group). RaCe instruments were used in a crowndown manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument. File sequences used were as follows: size .06/25 was used one half of the working length; size .04/25 was used between one half and two thirds of the working length; instruments of size .02/20, .02/25, and .02/30 were used to the working length.

Group 2 (K3 group). K3 instruments were used in a crowndown manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument. File sequences were as follows: size .06/25 was used one half of the working length; size .06/20 was used between one half and two thirds of the working length; and instruments of size .04/20, .04/25, and .04/30 were used to the working length.

Group 3 (FlexMaster group). FlexMaster instruments were used in a crowndown manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument. File sequences used were as follows: size .06/20 was used one half of the working length; size .04/30 was used two thirds of the working length; size .04/25 was used three quarters of the working length; size .04/20 was used between three quarters of the working length and working length; and instruments of size .02/20, .02/25, and .02/30 were used to the working length.



Fig. 2. Appearance of salt deposit and dry debris in a vial.

Group 4 (manual technique group). K-file instruments were used in a stepback manner and preparation was performed with rotational forces. K-files were used first with a quarter clockwise rotation followed by a pull-back motion and used repeatedly until reaching the working length. Apical preparation was continued up to size 30 and after completion of this stage the stepback technique was used with a reduction of 1 mm for each file until size 45.

Extruded irrigant was collected from the needle into a disposible plastic insulin syringe. The volume of the collected irrigant was determined via 0.1-mL increment measure supplied on the syringe. After determining the volume of the extruded irrigant, the rubber stopper–tooth–needle unit was removed along the collecting vial and volume of the extruded irrigant was added to the vials. Vials were stored at 37°C for 15 days to evaporate the fluid. After 15 days salt deposits and dry debris with vials were weighed to 10^{-5} precision (Fig. 2). The vials were cleaned with distilled water and dried and entirely filled with 0.9% saline solution and the rubber stopper–tooth–needle unit was fitted into the mouth of

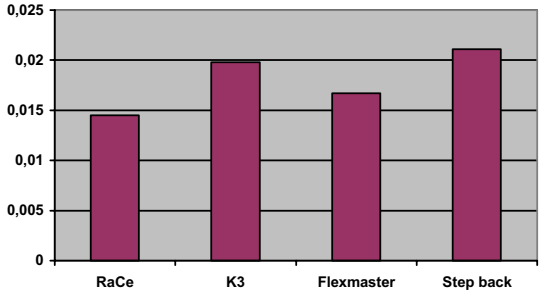


Fig. 3. The amount of extruded debris with manual instrumentation and with engine-driven instrumentation techniques.

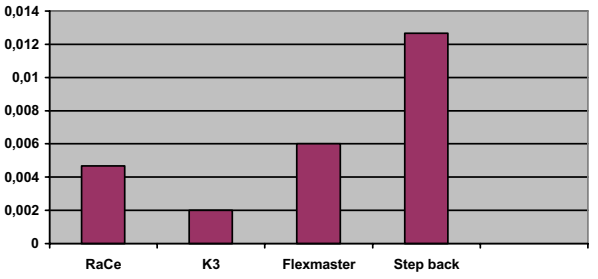


Fig. 4. The amount of extruded irrigant with manual instrumentation and with engine-driven instrumentation techniques.

the saline-filled vial. Excess saline solution was drained out through the needle and then the rubber stopper unit was removed. The determined volume of collected irrigant from that end of the preparation was added the vials and the vials were stored at 37°C for 15 days to evaporate the fluid again. Salt deposits and vials were weighted to 10^{-5} precision. Mean first weights were compared with the mean second weights and the difference was recorded as the weight of the extruded debris.

Statistical analysis

Statistical tests were performed using SPSS (Version 9.0, SPSS Inc., Chicago, IL). Data were analyzed statistically using Kruskal-Wallis 1-way analysis of variance and Mann-Whitney *U* tests. The level of statistical significance was set at $P = .05$.

RESULTS

Data regarding the weight of debris and volume of irrigant extruded are presented in Figs. 3 and 4 respectively. The results indicated that all instruments tested caused a measurable apical extrusion of debris and irrigant. No statistically significant difference was observed among all groups in terms of debris extrusion ($P > .05$). Most apical debris extruded was seen in the manual technique group and least in the RaCe group.

A statistically significant difference was observed between K3 and manual technique groups in terms of irrigant extrusion ($P < .05$). The difference between other groups was not statistically significant ($P > .05$). Most apical irrigant extruded was seen in the manual technique group and least in the K3 group.

DISCUSSION

The main objective of the present study was to assess the apical extrusion of dentin debris and irrigant as a result of canal shaping by different preparation techniques and instruments. In this study, mandibular premolar teeth were carefully selected according to tooth type, canal size, working length, and canal curvature. The teeth were digitally radiographed from clinical and proximal views to ensure that they had single canals and orifices. In previous studies, Reddy and Hicks[7] used single-rooted mandibular premolar teeth, Myers and Montgomery[22] used single-rooted maxillary lateral incisors and mandibular premolars, Ferraz et al.[8] used maxillary and mandibular central and lateral incisors with single canals, and Lambrianidis et al.[23] used maxillary central and lateral incisors.

Each tooth was assessed for the weight of debris and volume of irrigant extruded apically using the method of Tinaz et al.[11] This method was a modification of the technique used by Ferraz et al.[8] for debris collection. The vials were filled with saline solution as an electrolyte to ensure the functioning of the apex locator. The 27-gauge needle that functioned as an air vent in previous debris extrusion studies functioned as a drain to reflect the amount of the extruded irrigant.

It must be emphasized that the results of this study should not be directly extrapolated to the clinical situation. No attempt has been made to simulate the presence of vital pulp or periapical tissues, an in vivo model may give different result, as the periapical tissues may serve as a natural barrier, inhibiting debris extrusion. Results may also differ because of positive and negative pressure at the apex[24] and with normal or pathological periapical tissues. Furthermore, this study was limited to teeth with mature root morphology. The observed results should not be generalized to teeth with immature root development and open apicies.

In this study, the canal working length was 1 mm short of the apical foramen and working length measurements were completed with the Endomaster electronic apex-locating handpiece with "autoreverse function mode." Martin and Cunningham[5] demonstrated greater debris extrusion when canals were instrumented at a length where the file was observed to just protrude

through the apical foramen versus 1 mm short of the apical foramen. Myers and Montgomery[22] clearly showed that a working lenght 1 mm short of canal length contributed to significantly less debris extrusion. Beeson et al.[25] reported that, when the instrumentation was performed to the apical foramen, significantly more debris was forced apically than when instrumentation was 1 mm short.

Irrigation is a necessary and important phase of cleansing the canal. The irrigant functions as a lavage and flush, a solvent, a disinfectant, and a lubricant within the canal.[5] Vande Visse and Brilliant[4] used 5 mL of the irrigant, 5.25% NaOCl, per treatment of canal and concluded that, although irrigation was necessary, it led to extrusion. This pushing of material from the canal into periapical tissue has been confirmed in vivo. In this study, all root canals were irrigated with 7 mL of 2.5% NaOCI solution via an endodontic syringe with a 27-gauge blunt needle that had been placed down the canal until slight resistance was felt.

According to Brown et al.[26] there was a significantly greater volume of extruded NaOCl with deep penetration of the irrigant compared with a reservoir technique. This may be because of different pressures being exerted apically within the root canals. When hand filing is continued, the file act as a plunger in a cylinder causing hydrastatic pressure sufficient to force the irrigant beyond the apex. Abou-Rass and Piccinino[27] reported that deep delivery of the irrigation solution into root canals results in more effective removal of debris. The disadvantage of this method of delivery may be an insreased apical extrusion. The reservoir technique seems to reduce the beneficial effect of the irrigation solution by not allowing deep penetration of the irrigant to the critical apical third of the tooth. However, apical extrusion of the irrigant is minimized.

In our study, using engine-driven nickel-titanium instruments for the crowndown technique extruded less debris and irrigant than K-files for the stepback technique. Early flaring of the coronal part of the preparation may improve instrument control during preparation of the apical third of the canal,[28] and also because of the rotatory motion, which tends to direct debris toward the orifice, avoiding its compactation in the root canal.[25] In the stepback technique, the reason for more apical extrusion of debris is that the file acting in the apical one third acts as a piston that tends to push the debris through the foramen and less space is available to flush it out coronally.

Zarrabi et al.[29] compared ProFile, RaCe, and FlexMaster instruments with the stepback technique and reported that the stepback technique extruded greater debris than rotary instruments. Ferraz et al.[8] reported that the ProFile instruments induced less extruded debris and irrigant than manual technique. Also, Azar and Ebrahimi[9] reported that ProTaper and ProFile rotary instruments extruded less debris and irrigant than the stepback technique. Our results were similar to previous studies that showed that engine-driven instruments extruded less debris and irrigant than manual technique.

In this study, compared with previous studies, very small amounts of debris and irrigant extrusion were observed. This may be a result of the total amount of irrigant, apical preparation enlargement size, and working length used in our study. Also, this study found that no statistically significant difference exists between manual and engine-driven instrumentations. The reason for the different results may be because the other studies employed a push-pull motion (linear motion) when using K-files.[30,31] In our study K-files were used with rotational forces.

Based on the results, all instrumentation techniques produced extruded debris and irrigant; however, the engine-driven nickel-titanium systems were associated with less apical extrusion and irrigant.

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