Comparison of apical debris extrusion using clockwise and counter-clockwise single-file reciprocation of rotary and reciprocating systems

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Abstract

The aim was to evaluate apical debris extrusion produced by a single-file system used in counter-clockwise reciprocation and compare it to rotary single-file systems used in clockwise rotation and clockwise reciprocation. A total of 100 first mandibular molars were divided into five groups (n=20): (1) WaveOne Gold Glider and Primary instrument in counter-clockwise reciprocation; (2) One G and One Curve file in clockwise rotation; (3) One G and One Curve file in clockwise reciprocation; (4) TruNatomy Glider and Prime instrument in clockwise rotation; and (5) TruNatomy Glider and Prime instrument in clockwise reciprocation. Apical debris extruded was measured after glide path preparation and canal preparation. WaveOne Gold displayed significantly higher amounts of apical debris extrusion in all the groups ($P < 0.05$). The lowest mean values were recorded by clockwise reciprocation groups: TruNatomy Glider, One Curve and TruNatomy Glider and Prime combined value, for glide path, canal preparation and combined mean values, respectively.

Keywords

apical debris extrusion, canal preparation, clockwise reciprocation, glide path, kinematics

Introduction

During root canal preparation dentine chips, pulp tissue remnants, micro-organisms, and irrigants may be disseminated into periapical tissues and may cause postoperative flare-ups and treatment failures (1-3). Extrusion of infected debris during instrumentation can disturb the balance between bacterial aggression and host defence, leading to development of an acute inflammatory response resulting in postoperative pain and swelling (4, 5). According to Iqbal *et al.*, flare-up rates described in the literature range from 1.3% to 20% (5). Flare-ups increase the necessity of unscheduled visits and early post-treatment pain control with non-steroidal anti-inflammatory drugs (6). These undesirable complications highlight the importance of reducing debris extrusion (5, 7).

Engine-driven canal preparation with NiTi instruments extrudes smaller amounts of bacteria and debris than does manual preparation. Consequently, lower postoperative pain incidence is noted in continuous and reciprocating NiTi engine-driven instrumentation than in manual canal preparation (8). The main concern with NiTi files and engine-driven rotation is file separation, which is mainly attributed to continuous rotation. Several studies have compared novel reciprocating systems and rotary systems. Reduced incidence of endodontic mishaps through file separation has proven to be the key advantage of reciprocal motion. Moreover, reciprocation has been shown to have adequate cutting efficiency and shaping ability and reduced transportation tendency and maintains the anatomy of the root canal system (9, 10).

WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) is a commonly used single-file reciprocating system made from gold-treated NiTi. The WaveOne Gold Glider (WOGG) (Dentsply Sirona) is a glide path file with an ISO number 15 tip diameter and a variable taper of 2% to 6%. The WaveOne Gold Primary (WOGP) shaping instrument (Dentsply Sirona) has an ogival tip ISO size 25. The first 3mm of the file has a 7% continuous taper with a progressively decreasing taper in the remainder of the file length (11). The WOGG and WOGP instrument have a parallelogram-shaped cross-section and semi-active tips.

One G (OG) (Micro-Mega, Besancon, France) is a continuous rotation single-file glide path system made of conventional NiTi alloy. OG has an ISO number 14 tip diameter with a 3% constant taper, and an asymmetric cross-section with three cutting edges throughout the shaft. One Curve (OC) endodontic file (Micro-Mega) is a single-file canal-shaping system manufactured from a novel proprietary NiTi alloy developed by Micro-Mega. OC has an ISO tip size of 25 and a constant taper of 6% at variable cross-sections, with a triangular shape at the tip of the instrument and an S-shape near the shaft (12).

TruNatomy (Dentsply Sirona) is a recently launched innovative single-file rotary system made from superflex alloy by a postmanufacturing thermal process. This new file system is intended to shape canals into a continuously tapering preparation, significantly preserving pericervical dentine. This is achieved by a regressive variable taper of the shafts. TruNatomy Glider (TNG) (Dentsply Sirona) has an ISO tip size 17, a centred cross-section parallelogram design and a taper that averages 2%. The maximum flute diameter is 0.8mm compared to the 1.1mm of all the other conventional glide path instruments. The TruNatomy Prime (TNP) shaping instrument (Dentsply Sirona) has an off-centred parallelogram cross-section, a 4% taper and an ISO number 26 tip size (13).

The broad aim of this *ex-vivo* study was to compare apical debris extrusion created with single-file systems designed for continuous rotation when used in clockwise (CW) rotation and CW reciprocation. Debris extrusion with a single-file system in counter-clockwise (CCW) reciprocation was also evaluated and compared to above mentioned groups. Although previous studies have been conducted to assess the influence of kinematics in canal preparation, this study was designed to investigate debris extrusion of both glide path and canal preparation independently. The null hypothesis tested is that there will be no significant differences among the different groups in terms of the mean weights of the apically extruded debris.

Materials and methods

Specimen selection and preparation

One hundred extracted mandibular first molars with curved mesiobuccal canals with closed apices were selected from a group of 150 teeth. Pre-operative radiographs were taken and the GNU Image Manipulation Program 2.10.12 (GIMP Development Team) was used to digitally calculate Schneider's angle root curvature (14). Samples with visible canals on pre-operative radiographs and canal curvatures between 25° and 35° were used (15). After access, working length was determined by subtracting 0.5mm from the length of the canal measured to the apical terminus under 10 times magnification. Mesial roots were separated from distal roots and crowns were sectioned off and removed to flatten the reference point and standardise the working length to 18mm. The specimens were randomly divided into five equal experimental groups (n = 20) and coded.

Glide path and canal preparation

Glide path and root canal preparation was performed by a single operator in accordance with the manufacturer's recommendations for each system except in the two groups, group 3 and 5, where the kinematics were altered. Before root canal instrumentation a precurved size 10 K-File was negotiated to working length to ensure canal patency and a reproducible glide path.

Control group 1

WOGG and WOGP (Dentsply Sirona) files were used in CCW/reverse reciprocation with an X-Smart endodontic motor (Dentsply Sirona) set to engage at 150° CCW and disengage at 30° CW.

Test group 2

OG and OC (Micro-Mega) files were used in continuous rotation with an X-Smart endodontic motor (Dentsply Sirona) set at 350rpm and 1.2Ncm torque.

Test group 3

OG and OC files were tested in a CW reciprocating motion. Program 4 on the RootPro CL endodontic motor (MediDenta, Las Vegas, USA) was selected for 150° CW and 30° CCW rotation, permitting forward reciprocation.

Test group 4

TNG and TNP (Dentsply Sirona) instruments were used in continuous rotation with an X-Smart endodontic motor (Dentsply Sirona) set at 500rpm and 1.5Ncm torque.

Test group 5

TNG and TNP instruments were tested in a CW reciprocating motion. Program 4 on the RootPro CL endodontic motor (MediDenta) was selected for 150° CW and 30° CCW rotation, permitting forward reciprocation.

Mean values of glide path preparation and final canal instrumentation of the same tooth were merged to get a combined value for the entire instrumentation process of a selected file system.

Debris collection and measurement

A modified experimental model described by Myers & Montgomery was used for debris collection (16). All five groups were evaluated in the amount of apically extruded debris produced from the apical foramen during glide path preparation and after final canal instrumentation of the same tooth. The collection apparatus consists of a small glass vial with lid which functions as a container that collects debris; a big glass vial that acts as a carrier into which the small glass vial is placed to prevent outer surface contamination; a 23-gauge needle placed through the lid to permit internal and external air pressure balance; a rubber dam sheet to cover and isolate the assembled apparatus; and a mesial root for instrumentation. The collection vials were handled with gloved hands and tweezers to avoid any contamination of the outer surface that could influence the weight. Collection vials were placed through a U-electrode ioniser (Mettler Toledo, Greifensee, Switzerland) immediately before weighing to remove electrostatic charge and avoid distortion of the weighing results. The lidless vials were weighed prior to and after instrumentation using a six-decimal XP6 micro balance (Mettler Toledo).

The specimen roots were secured into the collection vial lids in a manner that allowed the apex to remain free in the air. Each lid with the mounted root and needle was attached to its collection glass vial which was placed in a carrier vial. Manual exploration of the mesiobuccal canal was done with a precurved 10 K-File (Dentsply Sirona). Throughout engine-driven instrumentation the canals were irrigated with 2ml of distilled water. After instrumentation was complete the apex was washed with 1ml distilled water into the vial to collect the debris adhered to the apical root surface. The collection glass vials were then placed in a standard incubator drying oven (Binder, Tuttlingen, Germany) at 140°C for five hours, to evaporate the distilled water before weighing the dry extruded debris (17). Once removed from the incubator the vials were capped and placed in a non-vacuum Pyrex desiccator (SciLabware, Staffordshire, United Kingdom) to maintain moisture control.

Data was recorded in a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, Washington) and verified. Calculation of the net collected extruded debris was undertaken by subtracting the collection vial's pre-instrumentation weight from the gross post-instrumentation weight. Five consecutive weights were obtained in milligrams (mg), the lowest and highest weights were discarded and the mean value of three weights determined. Mean values of glide path preparation and final canal instrumentation of the same tooth were merged to get a combined value for the entire instrumentation process of a selected file system.

Apical debris extrusion values were compared between the five groups by a one-way ANOVA (parametric distributions). For comparison of two sets of related samples, the Student's t-Test (parametric distributions) or the Wilcoxon Signed Rank Test (non-parametric distributions) were used. Statistical significance was set at $P < .05$.

Results

All the groups tested caused extrusion of debris from the apical foramen. The mean values of instrumentation debris (mg) collected are presented in Table 1.

Glide path preparation apical debris extrusion

The highest mean debris extrusion value was observed with WOGG. There was a statistically significant difference between the WOGG group and all other groups ($P < 0.05$). Although not statistically significant, OG and TNG CW rotation glide path groups produced more apical debris extrusion than the OG and TNG CW reciprocation groups.

Canal preparation apical debris extrusion

The highest mean debris extrusion value was observed in the WOGP group. There was a statistically significant difference between the values of the mean apical debris extrusion between the WOGP and the OC CW rotation, OC CW reciprocation, and TNP CW reciprocation groups ($P < 0.05$). The OC CW rotation and TNP CW reciprocation groups produced the same results, and the lowest mean debris extrusion value was recorded by the OC CW reciprocation group.

Combined apical debris extrusion of glide path and canal preparation

The highest combined mean debris extrusion value was observed with the WOGG/WOGP group and a statistically significant difference compared to all other groups was noted (P <

0.05). Among the groups employed in CW rotation, comparable combined debris extrusion means were observed in the OG/OC and TNG/TNP groups. The lowest combined mean debris extrusion value was recorded by the CW reciprocation TNG/TNP group.

Comparison of apical debris extrusion between glide path and canal preparation

Glide path preparation resulted in less apical debris extrusion than did canal preparation in all the groups. A statistically significant difference between glide path and canal preparation debris extrusion was only observed in the TruNatomy groups (CW rotation ($P = 0.02$) and CW reciprocation ($P = 0.04$)).

Comparison of apical debris extrusion between CW rotation and CW reciprocation

CW reciprocation groups performed more favourably than the CW rotation groups in terms of apical debris extrusion. However, there was no statistically significant difference between the groups ($P > 0.05$). The lowest mean debris extrusion value amongst all the groups was recorded by the TNG group used in CW reciprocation.

Discussion

Reducing apical debris extrusion can decrease postoperative pain and inflammation (3-5). This study assessed the impact of rotary alternatives on overall apical debris extrusion and evaluated the influence on kinematics of two stages of canal instrumentation, glide path and canal preparation by weighing the collected post-instrumentation debris.

Glide path preparation groups produced less apical debris than the canal preparation groups. A possible explanation for the results attained for debris volume can be correlated with the different design features of the instruments, including cross-sectional area and taper size, with a resulting difference in file metal volume between the smaller glide path file and larger canal-shaping file. Hence, increased canal volume due to greater file taper and cross-sectional diameter is likely to result in greater debris production during canal shaping.

When evaluating conventional glide path kinematics, the lowest amount of apical debris extrusion was observed in the TNG CW rotation group compared to the WOGG CCW reciprocation and OG CW rotation group. This could be attributed to the smallest taper and minimal flute diameter of the TNG compared to other glide path instruments chosen for this study.

Gunes & Yeter compared the amount of apically extruded debris after using different glide path files prior to preparing mesial canals of mandibular first molars with the WOGP instrument (18). Their study showed that creating a glide path with OG files prior to root canal preparation with the WOGP instrument caused the smallest amount of debris extrusion. Of the glide path instruments selected for this study, OG has an extra active cutting edge, which is likely to make it more aggressive and thus generate more debris than the TNG. This design variation can be identified as factor contributing to differing results in the two studies.

Ha *et al.* investigated the effect of different geometries of ProGlider (Dentsply Sirona), OG and ScoutRace (FKG, Dentaire) glide path files on apical debris extrusion. The ProGlider group produced significantly less debris extrusion than the other groups. The authors believe that in the initial stages of glide path instrumentation the ProGlider file shaves more dentine in the coronal part due to its progressive taper, allowing greater debris removal from the widened coronal third of the root canal (19).

Pedullà *et al.* investigated the cutting efficiency of rotary and reciprocating glide path files – HyFlex EDM glidepath file (Coltene/Whaledent, Altstätten, Switzerland), OG, R-Pilot (VDW, Munich, Germany) and WOGG – at different cutting inclinations. The reciprocating R-Pilot and WOGG files had greater cutting ability than the rotary HyFlex EDM glidepath file and OG files (20). Taking this into consideration, it can be anticipated that instruments with improved cutting ability will remove more dentine and create more dentinal debris. In agreement with these findings, in this study the WOGG group produced the greatest amount of debris extrusion of all the groups.

In groups used in accordance with manufacturer's instructions, the lowest mean canal preparation extrusion value was recorded by the OC CW rotation group when compared to the WOGP CCW reciprocation and TNP CW rotation groups. The OC file has a variable triangular shape at the tip of the instrument and an S-shape near the shaft. These findings could indicate that the S-shape cross-section in the coronal part of the file allows greater removal of debris in the coronal direction due to larger intracanal space, and the increased flute depth that facilitates coronal debris expulsion.

Keleş *et al.* assessed the effect of different instrument systems on the amount of apically extruded debris. The lowest amount of debris was obtained in the Reciproc (VDW), Reciproc blue (VDW), and ProTaper Next (Dentsply Sirona) groups and there were no significant differences among them. The WaveOne (Dentsply Sirona), WaveOne Gold, and One Shape (Micro-Mega) groups extruded significantly more debris than the Reciproc and ProTaper Next groups (21).

In this study, combined values were obtained by adding debris values measured for glide path instruments and corresponding canal-shaping instruments to analyse debris extrusion of the entire instrumentation process of a selected single-file system. The OG/OC CW rotation group generated the least amount of apical debris extrusion compared to groups used according to manufacturer's recommendations. Both the glide path and canal preparation files of this group have a constant taper and a triangular off-centred cross-section. These findings can be correlated with the regressive taper design of TruNatomy instruments, which create narrower canal preparations. Although smaller amounts of debris are generated, dentinal debris elimination may be limited.

When comparing apical debris extrusion between glide path and canal preparation groups, only the TruNatomy groups (CW rotation and CW reciprocation) showed a statistically significant difference between the mean values ($P < 0.05$). The difference in apical debris extrusion between the glide path and canal-shaping file of the TruNatomy system can also be attributed to the regressive taper design.

There is an inconsistency in the results available in literature on the effect of reciprocating motion on debris extrusion (17, 22). The use of rotary instruments intended to cut in full-circle CW rotation has been previously assessed in CW reciprocation by Yared, Gavini *et al.*, Giuliani *et al.* and Espir *et al.* (23-26). The advantage of reciprocating movement is that it promotes safe use of instruments by reducing torsional stress and incidence of instrument fracture (9, 10, 23). In contrast to reciprocating instruments, all continuous rotation systems are designed to cut in a CW direction. The rotary instrument flutes may neither cut nor infiltrate the canal walls if one tries to use CW cutting instruments in CCW reciprocating motion. Reciprocating motion with a CW rotation angle greater than the CCW rotation angle could allow the use of a larger number of conventional rotary systems in forward reciprocation (26).

In this study, the same instruments were used in both CW rotation and CW reciprocation when investigating the influence of kinematics to exclude the influence of the instrument design on apical debris formation. Although the CCW reciprocating WOGG/WOGP group gave the highest apical debris extrusion values, the OG/OC and TNG/TNP groups used in CW reciprocation extruded less apical debris than when used in continuous rotation for glide path and canal preparation.

Karataş *et al.* evaluated the influence of different movement kinematics on apical debris extrusion using Twisted File Adaptive (SybronEndo, Orange, CA, USA) instruments. According to their findings, when the reciprocation range increased apical debris extrusion decreased. The decreased reciprocation range in the 90° CW–30° CCW group created more debris extrusion. The authors believe that the increased reciprocation range in the 150° CW–30° CCW group could have resulted in less extrusion because more debris was transported coronally by the file acting as a screw conveyor due to the enlarged reciprocation range (27).

In a study by Toyoğlu & Altunbaş, K3XF instruments extruded more debris when used in reciprocating motion (150° CW–30° CCW) compared to continuous rotation. However, the difference was not statistically significant (28). In contrast, Arslan *et al.* reported that Reciproc instruments tested in a 150° CCW–30° CW reciprocating motion extruded significantly less debris apically than in continuous rotation, which coincides with the current findings (29). It is apparent from the results obtained in this study and the contradicting literature available that reciprocating motion alone does not generate more apical debris.

The results of this *ex-vivo* study should be interpreted with caution because of the absence of natural barriers and back pressure created by pulp tissue and apical periodontal tissues. If simulation were to be provided it could not be standardised. Hence, no attempt was made to mimic the resistance provided by periapical tissues (7).

It is valid to state that apical debris extrusion is a result of multiple factors that contribute to its formation and elimination from the canal. Apart from kinematics, numerous elements such as preflaring and instrument design – including shaft volume, cross-section, taper and flute depth – need to be considered when analysing the complex aetiology of debris extrusion.

The null hypothesis states that there will be no significant differences among the different glide path and canal preparation techniques in terms of the mean weights of the apically extruded debris and is therefore rejected.

These results suggest that endodontic files designed for continuous rotation can safely be used in clockwise reciprocation and might aid in the reduction of debris extrusion, subsequently limiting irritation to peripapical tissues. Diligent selection of instruments and the utilization of alternative rotary kinematics in a clinical setting could possibly contribute to a lower incidence of flare-ups.

Within the limitations of this study, the findings demonstrate that all canal preparation instruments extrude debris, irrespective of kinematics used. The WaveOne Gold groups yielded the highest mean debris extrusion value in glide path, canal preparation and the combined mean values. Glide path preparation groups produced less apical debris than the canal preparation groups and showed a significant difference in the TruNatomy system. Although not statistically significant, CW reciprocation groups extruded less debris than the CW rotation groups.

Table 1. Apical debris extrusion values (mg) for the different groups (mean ± standard deviation)

Groups	**Glide path preparation**	**Canal preparation**	**Combined mean value**
WOGG/WOGP CCW reciprocation	0.78 ± 0.44	0.84^{b} ± 0.60	1.62 ± 0.83
OG/OC CW rotation	0.49^{a} ± 0.23	0.54^{a} ± 0.43	1.03^{a} ± 0.51
OG/OC CW reciprocation	0.42^{a} ± 0.26	0.53^{a} ± 0.30	0.95^{a} ± 0.46
TNG/TNP CW rotation	0.40^{a} ± 0.27	0.64^{ab} ± 0.34	1.04^{a} ± 0.42
TNG/TNP CW reciprocation	0.39^{a} ± 0.20	0.54^{a} ± 0.25	0.93^{a} ± 0.27

† Mean values with the same superscript letters were not statistically different at $P < 0.05$.

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