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ORIGINAL ARTICLE

Debris extrusion by glide-path establishing endodontic instruments with different geometries

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One G;
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Abstract *Background/purpose:* Glide-path preparation is an important step during initial endodontic procedure to reduce shaping-instrument fracture. The aim of this study was to evaluate the amount of apically extruded debris produced by glide-path preparation instruments with different geometric designs.
Materials and methods: Forty teeth extracted for periodontal reasons were randomly divided into four groups ($n = 10$). The working length was standardized at 17 mm from the apical foramen by a flattening reference point. The glide-path was created using repetitive up-and-down movement three times with one of following four selected instruments: One G, ProGlider, a size 15 ScoutRace, and a size 15 stainless-steel K-file. To collect the apically extruded debris, the customized apparatus was used, and the collected debris was stored in an incubator. The weight of the debris was measured using an analytical balance with an accuracy of 0.00001 g. The data were analyzed by one-way analysis of variance and Duncan's multiple comparison test at a significance level of 95%.
Results: The ProGlider group produced significantly less debris extrusion relative to the other groups ($P < 0.05$). The One G and ScoutRace groups showed no significant difference, but debris production was lower than that observed for the stainless-steel group ($P < 0.05$).
Conclusion: Creating the glide-path using nickel-titanium rotary files produced lower amounts of debris extrusion than using manual stainless-steel files. The progressive taper design of

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ProGlider, the center-off cross-section of One G, and the alternative-pitch design of ScoutRace may have increased the efficiencies of debris removal with minimal extrusion during glide-path preparation. Glide-path preparation using NiTi rotary files have better clinical efficiency than the manual stainless-steel file.

Introduction

In order to reduce the fracture risk of nickel-titanium (NiTi) instruments and root canal aberrations caused by instrumentation, it is recommended that a glide-path be created during the initial preparation in contemporary endodontics.[1–3] Creating a glide-path could reduce torsional stress, thereby increasing the lifespan of the rotary instrument used for canal preparation.[3] Additionally, it could help in reducing canal transportation. Prior to using reciprocating instrumentation, canal aberration could be reduced by establishing the glide-path.[4] It may also provide more confidence to the clinician for treating complex and challenging endodontic cases.[3–5]

Various NiTi rotary glide-path instrument systems, such as G-file (Micro-Mega, Besançon, France), ScoutRace (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), and PathFile (Dentsply Maillefer, Ballaigues, Switzerland), have been introduced. These systems comprise two to three sequential and multiple instruments. Recently, single glide-path files have been introduced: One G (Micro-Mega) and ProGlider (Dentsply Maillefer). While One G has an ISO 14 diameter at the D0 tip and 3% constant taper, ProGlider has an ISO 16 diameter at the D0 tip and a progressive taper.

Compared to manual glide-path preparation with stainless-steel (SS) hand files, procedures using NiTi rotary instruments are faster and maintain the original canal anatomy better, resulting in less modifications of canal curvatures and ultimately leading to fewer canal aberrations.[6] It was reported that NiTi rotary glide-path files do not produce apical transportation, even when the files repeatedly reach the apical terminus of the working length (WL) up to 10 times.[3,7] Moreover, Berutti et al[5] and Kwak et al[8] reported that glide-path preparation using rotary instruments is less sensitive to clinician expertise; under experimental conditions, an inexperienced clinician using NiTi rotary glide-path files produced a more conservative preparation than an experienced endodontist who used SS hand files.[5,8]

Extruded debris containing microorganisms, dentin particles, or necrotic pulp-tissue remnants may trigger an inflammation reaction in the periapical region and subsequent postoperative pain and swelling.[9,10] Pasqualini et al[6] reported that NiTi rotary glide-path files induced less postoperative pain relative to the SS hand files. Many studies were conducted regarding debris extrusion using the NiTi root canal-shaping instruments,[5,11–16] especially for minimizing debris extrusion during reciprocating preparation.[12,13] Berutti et al[5] specifically recommended establishing the glide-path with NiTi rotary instruments prior to using the reciprocating instruments.

However, there is no reliable evidence regarding debris extrusion during glide-path establishment by the glide-path preparation instruments. Therefore, the aim of this study was to compare the amounts of apically extruded debris produced by various glide-path-establishing instruments with different geometric designs. The null hypothesis was that there would be no significant differences among the file groups in terms of the mean weights of the apically extruded debris.

Materials and methods

Group classification

The instrument size was standardized to minimize the effects of different instrument tip sizes and to evaluate the effects of geometric designs and movement kinetics. Because the ProGlider and One G have ISO #16/progressive taper and #14/0.03 taper, respectively, the size nearest to them, ISO #15, was selected for the multisequential systems (ScoutRace and SS hand K-file). Therefore, four instrument systems for glide-path establishment were selected in the present study (Figure 1): Group SS, SS hand K-file group (#15/0.02 taper); Group OG, One G (#14/0.03 taper); Group PG, ProGlider (#16/progressive taper); and Group SR, ScoutRace (#15/0.02 taper).

Specimen preparation

Mandibular incisors extracted for periodontal reasons were collected and disinfected in 0.5% chloramine-T and stored in distilled water at 4°C until further use. Digital radiography systems (RVG6100; Carestream Dental LLC, Atlanta, GA, USA) were used to examine the specimens in the bucco-lingual and mesio-distal directions, and a dental operating

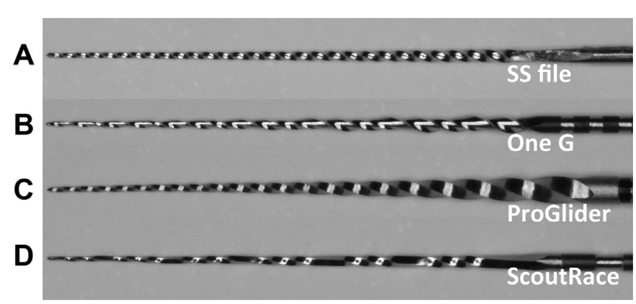

Figure 1 The files used in this study for glide-path establishment. (A) Stainless steel #15 hand K-file, (B) One G, (C) ProGlider, and (D) ScoutRace.

microscope (Zeiss Pico; Carl Zeiss MediTec, Dublin, CA, USA) was used to confirm a single canal with mature apices. Based on the radiographic and visual microscopic examinations, the teeth with complex anatomy, more than one canal and foramen, internal or external root resorption, or an immature apex were excluded. Additionally, teeth with $> 10°$ of root curvature were excluded according to the Schneider[17] method. A total of 64 extracted human mandibular incisors were involved in this criteria. The remnants of the soft tissues and the calculi on the external root surfaces were removed mechanically under a dental operating microscope.

Access cavities were prepared with high-speed tungsten-carbide #4 round (Komet Dental, Lemgo, Germany) and Endo-Z (Dentsply Maillefer, Ballaigues, Switzerland) burs. A #8 K-file (Dentsply Maillefer) was inserted into the canal to be visible at the major foramen under the microscope, and the WL was determined to be 0.5-mm short from the major foramen. Among 64 specimens, 40 teeth specimens in which the #8 K-file hardly reached the apical foramen were selected as representative root canals that needed the glide-path, and the remainder 24 specimens were discarded. The WL was adjusted to 17 mm by flattening the reference point. Furthermore, the patency of the canal was confirmed by using a #10 K-file. The teeth specimens were randomly divided into four groups ($n = 10$), and glide-path was prepared with the assigned instrument system, while the canals were filled with 1 mL of tri-distilled water.

For Group SS, the glide-path was established with SS #15 K-file by using the balanced force technique. For Groups OG, PG, and SR, continuous rotating motion was used for rotary NiTi instruments of One G, ProGlider, and ScoutRace systems, respectively. According to manufacturer instructions, the rotation speed and torque of the endodontic motor (X-smart; Dentsply Maillefer) was set at 400 rpm/2N·cm, 300 rpm/2N·cm, and 800 rpm/2N·cm for One G, ProGlider, and ScoutRace, respectively. After each file reached the full WL, the glide-path was established by using repetitive up-and-down movements three times. The cleaning, shaping, and irrigation of all the specimens were conducted under a dental operating microscope (Zeiss Pico) at $\times 10$ magnification by one trained operator.

Debris collection

To evaluate the collection of apically extruded debris, an apparatus with minor modifications of the Myers and Montgomery[18] experimental model was used (Figure 2). The cover plates were separated from a polyethylene cap, and the initial weight of the cap was measured using an analytical balance (ER-182A; A&D company, Tokyo, Japan) with an accuracy of 10^{-5} g. Each tube was weighed six times under controlled conditions (temperature: 19°C; humidity: 20%), and the mean value was calculated. A hole was created on each cover plate, each tooth was fixed around the cementoenamel junction, and a 27-gauge needle was placed alongside the cover plate. The needle insertion balanced the air pressure between the inside and outside of the cover plates. Furthermore, each cover plate was reassembled with the polyethylene cap, and the polyethylene caps were fitted into the glass bottles (Figure 2). Since all of the polyethylene caps were opaque,

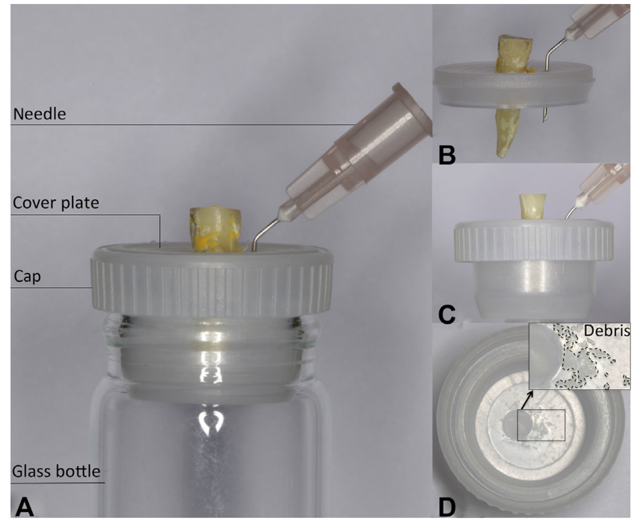

Figure 2 (A) The apparatus used for the collection of apically extruded debris. (B) Cover-plate assembly consisting of the cover plate, tooth, and 27-gauge needle. (C) Combination of polyethylene cap with cover-plate assembly. (D) Collected debris (*) in the polyethylene cap.

the operator possibly could not see the root apex during instrumentation (Figure 2A).

After instrumentation was complete, the cover-plate assembly was separated from the polyethylene cap, and the root surface adjacent to the apical foramen was washed with 1 mL tri-distilled water in the cap to collect the debris adhered to the apical-root surface (Figure 2D). The ethylene tubes were then incubated at 70°C for 5 days to evaporate the distilled water before weighing the extruded debris. Weights were calculated in the blinded condition to the group assignment. The ethylene tubes were weighed using the same analytical balance under the same conditions (temperature, 19°C; humidity, 20%).

The Kolmogorov-Smirnov test was conducted to evaluate the assumption of normal distributions. The data were analyzed using the one-way analysis of variance test, followed by Duncan's multiple comparison test at a significance level of 95% using SPSS software (version 22 for Mac; IBM Corp., Somers, NY, USA).

Results

The measured weights of extruded debris are presented in Table 1. The Group PG produced significantly less debris extrusion as compared with the other groups ($P < 0.05$). The Groups OG and SR showed no significant differences; however, their values were lower than Group SS, which produced the maximum amounts ($P < 0.05$).

Discussion

The main objectives of root canal preparation are to clean and shape the root canal system, while maintaining the original canal configuration.[19] Due to NiTi rotary instruments, these objectives have been achieved in a

Table 1 Mean and standard deviation values of debris weights (mg) from the tested groups.

Debris extrusion	SS file	One G	ProGlider	ScoutRace
Mean	0.177[c]	0.118[b]	0.061[a]	0.117[b]
SD	0.078	0.041	0.036	0.068

[a,b,c] Significant difference between groups ($P < 0.05$).
SD = standard deviation.

majority of cases;[20,21] however, in the early stages of root canal preparation, these instruments are prone to torsional fractures due to close contact with the canal walls and bindings in the root canals.[22,23] To reduce the risk of torsional fractures, a glide-path is highly recommended in contemporary endodontics. By glide-path establishment and coronal enlargement, NiTi rotary instruments could be used safely by preventing torsional fracture of the instruments and shaping aberrations.[1–3,7,24–26]

Postoperative pain and swelling are mainly associated with preparation procedures, and involve the host immune response against extruded debris containing microorganisms, over-instrumentation, or obturating material.[9,10] During root canal preparation and irrigation, intra-canal contents are forced to extrude as debris, such as dentin particles, necrotic pulp-tissue remnants, or microorganisms,[9,10] which may trigger inflammatory reactions in the periapical region. By establishing a glide-path prior to root canal preparation, debris extrusion can be decreased and postoperative pain reduced.[27]

Recently, convenient and highly efficient NiTi rotary instruments for glide-path preparation were introduced. While the G-file and PathFile systems are multisequence instruments that use two and three files, respectively, the recently introduced ProGlider and One G are single-instrument glide-path file systems. Since their tips are close to the size of ISO #15, a file with an ISO #15 tip size for a multisequence system and a SS hand file were included in the present study for fair evaluation. While the ScoutRace and One G have constant taper (ScoutRace: 0.02 taper; One G: 0.03 taper), ProGlider has a progressive pitch and taper. The results from this study presented the effects of taper and pitch length on the amounts of extruded debris beyond the apical foramen.

Here, mandibular incisors for which the #8 K-file barely reached the apical foramen were selected, and the #10 K-file was used prior to using four glide-path-establishing files as manufacturers usually recommend. These steps in the method were important to compare the file systems fairly. To mimic clinical situations and exclude the potential effect of different WLs on debris removal, the incisal edge or occlusal surface of each tooth was flattened using a diamond bur as a reference point. Furthermore, the WL was adjusted to 17 mm in order to standardize the shaping depth and the irrigation penetration. Although the physical backpressure provided by the periapical tissues could not be simulated, the generally accepted method of Myers and Montgomery[18] allowed a comparison of the file systems. Tri-distilled water was used as an irrigation solution to avoid potential chemical reactions, and side-vented needles were used in all the groups, because they extruded less irrigant periapically as compared with regular open-ended needles.[11] Since the analytical balance is very sensitive to vibrations and humidity, the measurements were carried out in an enclosed area under controlled conditions to avoid serious errors.

Other methods that could be used are a cube-shaped pieces of flower-arrangement foam mimicking periapical tissue,[11] real-time determination of extrusion volumes using a point-conductivity-probes,[28] and the evaluation of neuropeptide expression.[29] Despite some inherent drawbacks of the methodology proposed by Myers and Montgomery,[18] it was selected as the means to calculate debris, because it is practical and allows comparison between the amounts of debris extruded by each file.

In this study, rotary NiTi glide-path systems produced less apical extrusion as compared with manual instrumentation using a SS file. The results can be explained by differences in the instrument geometric designs and movement kinematics between systems.[29] Therefore, the null hypothesis was rejected. Similar to previous studies, rotary NiTi instrumentation showed less apical extrusion as compared to hand instrumentation.[30–32] The SS instruments extruded much more debris relative to all other instruments used in this study, which may be explained by the stiffness and push–pull motion with minimal rotation.[33] Among the rotary NiTi systems, ProGlider produced the lowest amount of debris extrusion, which might be associated with the design features of ProGlider, including a variable taper from 0.020 to 0.085, while it had the largest diameter at D0 among all the others. In the early stage of glide-path preparation, the coronal part of the ProGlider file would have shaved the dentin, resulting in major debris removal from the coronal third of the root canal. That is a similar positive effect as that of the crown-down preparation concept using an instrument with a larger taper. In practice, ProGlider may effectively flush the debris during irrigation, as well as instrumentation procedures, through the wider coronal canal space. Similarly, the One G and ScoutRace showed less debris extrusion relative to the SS file. The debris trapped in the apical part of the NiTi file would be lifted efficiently in the coronal direction during rotation. Specifically, the center-off design, as well as the 0.03 taper of One G, may have been an advantage in removing debris in a better coronal way. The alternative cutting edge with mixed pitch length of the ScoutRace might also have had a positive effect on debris removal from the long-pitch length.

Glide-path preparation is an adjunctive procedure prior to the main instrumentation. Much more debris would be extruded during the main shaping procedure as compared to during the glide-path-preparation procedure; however, the effect of small glide-path instruments would be hidden by shaping instruments with bigger sizes. Pasqualini et al[6] compared the postoperative pain clinically after manual and mechanical glide-path by randomized clinical trials, and observed that the methodological difference of glide-path preparation prior to the main instrumentation resulted in significantly decreased postoperative pain. This result might correlate with the amount of debris extrusion. Therefore, this study focused on debris extrusion during the glide-path-preparation procedure only. Although the amount of debris would be very low, the initially extruded debris may contain higher toxicity as compared with debris extruded later by the shaping instrument.[9,10,34] Thus, debris extrusion during glide-path preparation would be clinically important, as well. Further studies may describe clinical effects from glide-path-preparation procedures and potential effects of debris extrusion.

Our results indicated that creating the glide-path using NiTi rotary files produced lower amounts of debris extrusion relative to the SS hand file. The progressive taper design of ProGlider, the center-off cross-section of One G, and the alternative-pitch design of ScoutRace may have increased the efficiencies of debris removal with minimal extrusion during glide-path preparation.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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