Apically Extruded Debris in Curved Root Canals Using the WaveOne Gold Reciprocating and Twisted File Adaptive Systems

Daiana Boijink, MSc, Débora Delai Costa, MSc, Carolina Bender Hoppe, MSc, Patrícia Maria Polli Kopper, PhD, and Fabiana Saores Grecca, PhD

Abstract

Introduction: The purpose of this study was to evaluate apical debris extrusion associated with different kinematics in curved root canals. **Methods:** Forty-five extracted mandibular molars with root curvature angles ranging between 20° and 40° and curvature radii <10 mm were randomly assigned to 3 groups (n = 15) according to the kinematics used for root canal preparation: reciprocating motion with the WaveOne Gold system (Dentsply Tulsa Dental, Tulsa, OK), rotary/reciprocating motion with the Twisted File Adaptive system (SybronEndo, Orange, CA), and the manual technique. The debris apically extruded during preparation was collected into preweighed Eppendorf tubes. The tubes were then stored in an incubator at 70°C for 5 days. The extruded debris was quantified by subtracting the preinstrumentation from the postinstrumentation weight of the Eppendorf tubes. The time required for each instrumentation procedure was recorded. Data were analyzed using 1-way analysis of variance Tukey post hoc tests (∝ = 0.05). **Results:** The WaveOne Gold reciprocating single-file system was associated with less extrusion of debris compared with hand files ($P < .05$) and the Twisted File Adaptive system ($P > .05$). The preparation time required by hand files was significantly longer than that required by the other techniques ($P < .05$). **Conclusions:** Under the conditions of this study, all of the instrumentation systems caused apical debris extrusion to some degree. The WaveOne Gold reciprocating system was associated with less debris extrusion in curved root canals compared with the manual technique and the Twisted File Adaptive system although the difference between the WaveOne Gold and Twisted File Adaptive systems was not significant. *(J Endod 2018;■:1–4)*

Key Words

Apical debris extrusion, reciprocating motion, Twisted File, WaveOne Gold

Significance

Different kinematics and a reduced number of instruments seem to have influenced the extrusion of debris favorably, thus supporting the concept of single-file preparation as beneficial to use in clinical practice.

During the chemomechanical preparation of root canals, dentin chips, remnants of pulp tissue, and bacteria can be conveyed to the apical third of the canal and extruded into the periradicular tissues (1). This may cause postoperative pain, flare-ups, and even failure of apical healing (2, 3), adversely affecting the clinical outcome of endodontic treatment.

The introduction of nickel-titanium (NiTi) files and the technological advances in the thermal treatment of alloys and kinematics have revolutionized root canal treatment (4). Although all preparation techniques produce some degree of apically extruded debris (5), the use of motor-driven instruments has been found to lead to less debris extrusion compared with hand file techniques (6). Reciprocating systems were designed with the purpose of simplifying root canal instrumentation by reducing the number of steps and files involved. The recently introduced WaveOne Gold (WOG) reciprocating system (Dentsply Tulsa Dental, Tulsa, OK) is a single-file system that applies a special thermal treatment to its instruments for improved physical properties (gold alloy technology). According to the WOG manufacturer, the tip diameters, tapers, and cross section (a parallelogram with 2 cutting edges) of the instrument were modified to provide greater file flexibility compared with that of the earlier WaveOne reciprocating system (Dentsply Tulsa Dental) (7). The WOG Primary file is 50% more resistant to cyclic fatigue than the WaveOne Primary file (8). According to Adigüzel and Capar (9), WOG instruments have proved more resistant to cyclic fatigue than WaveOne instruments and have exhibited higher resistance to torsional stress and higher flexibility compared with Twisted File Adaptive (TFA) instruments (SybronEndo, Orange, CA) (10).

The TFA NiTi system combines continuous rotation and reciprocating motion. Whenever an increase in stress is detected on the file, the Elements Motor (SybronEndo) of the system modifies the motion from continuous to reciprocating when the file is rotated up to 370° clockwise and 50° counterclockwise (11). This adaptive technology, coupled with the twisted file design that uses an R-phase treatment to increase flexibility, is designed to allow the file to adjust to intracanal torsional forces depending on the amount of pressure placed on the file (11, 12).

To date, few studies have evaluated the apical extrusion of debris in curved canals with different kinematics (13–15). Furthermore, the extrusion of apical debris in molars can be influenced by the highly variable anatomy and degree of curvature of

From the Department of Conservative Dentistry, School of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil.
Address requests for reprints to Ms Daiana Boijink, Rua Ramiro Barcelos, 2492, Porto Alegre, RS 90035-003, Brazil. E-mail address: dboijink@yahoo.com.br
0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2018.04.011

the root canals in these teeth, a feature that often increases the level of instrumentation difficulty (16, 17).

To the best of our knowledge, no study is available evaluating the influence of the WOG reciprocating system on the amount of apically extruded debris in curved canals. Thus, the aim of this *ex vivo* study was to compare the amount of apically extruded debris and instrumentation time associated with the use of the WOG reciprocating single-file system, the TFA rotary/reciprocating system, and hand files in the instrumentation of curved root canals of mandibular molars.

Materials and Methods

Sample Selection

The study protocol was approved by the Institutional Research Ethics Committee of Federal University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil (register no. 1.413.530). Forty-five extracted human mandibular molars were collected and stored in physiological saline solution until use. Inclusion criteria were teeth with mature apices, without previous endodontic treatment, and with apical patency. Radiographs of each tooth were taken to select the root specimens, and their curvature angles were measured using an image analysis program (Adobe Photoshop CS3; Adobe Systems Inc, San Jose, CA). Angles ranging between 20° and 40° (18) and radii of curvature <10 mm according to Schäfer et al's (19) method were included in the study.

Root Canal Preparation

Standard access cavities were made using round diamond burs (#1014; KG Sorensen, Barueri, SP, Brazil) at high speed and under air-water spray cooling. After irrigation with distilled water, the cervical third of the canal was enlarged using an LA Axxess bur #35.06 (SybronEndo) and a low-speed contra-angle handpiece. Apical patency of all the root canals was confirmed with a #10 K-file (Dentsply Tulsa Dental).

The specimens were mounted on a custom attachment and scanned in a micro–computed tomographic system (SkyScan 1174 v.2; Bruker-microCT, Kontich, Belgium) using 90 kV, 112 μA, and 12.8-μm voxel size parameters. The images were 3 dimensionally reconstructed with CTan software (version 1.4.32, Bruker-microCT). The apical diameter of the foramen was selected, delimited using Adobe Photoshop CS3 software (Adobe Systems Incorporated), and measured, yielding a mean diameter value of 0.09 ± 0.05 mm. The specimens were randomly assigned (http://www.random.org) to 3 experimental groups (n = 15) according to the foramen diameter and angle of curvature as follows:

1. The WOG group: the WOG Primary file (#25.07) was coupled to an endodontic motor (VDW Silver, Munich, Germany) and set to operate in the "WaveOne All" mode. The file was used with a slow, in-and-out pecking motion according to the manufacturer's instructions. This protocol was repeated until the working length (WL) was reached by the WOG #25 file. The flutes of the instrument were cleaned after 3 pecks.
2. The TFA group: the instruments were coupled to the Elements Motor; file #25.08 was used to prepare the cervical third; file #25.06 was used up to 2 mm short of the WL, and files #20.04, #25.06, and #25.08 were used up to the WL.
3. The manual technique group: instrumentation was performed with FlexoFile hand files (Dentsply Maillefer, Ballaigues, Switzerland) using the crown-down technique. The coronal third of each canal was prepared using an LA Axxess bur #35.06. Manual instrumentation started with instrument sizes 50, 45, 40, 35, 30, and 25 up to the WL using the balanced force movement. Apical stop preparations were performed with file #25.02.

The WL was determined by introducing a #10 K-file (Dentsply Tulsa Dental) into the canal until visible at the major diameter of the apical foramen and then subtracting 1 mm from this measurement. Patency of the canal was checked by taking a #10 K-file to the WL. The root canals were irrigated with a total volume of 10 mL distilled water using a syringe and a 29-G side-vented NaviTip irrigation needle (Ultradent, South Jordan, UT) during canal preparation. Each instrument was used to prepare only 1 canal, and a single operator performed all the procedures.

Debris Assessment

The method used for the collection of apically extruded debris during chemomechanical preparation was adapted from a previous study (20). The Eppendorf tube stoppers were separated from the tubes, and their initial weight was determined in a 10^{-5} g precision analytical balance (Sartorius, Göttingen, Germany). Three consecutive weights were obtained for each tube, and their mean value was calculated. Each tooth was inserted into the Eppendorf tube stoppers up to the cementoenamel junction. A 27-G needle was placed alongside the stopper to equalize the internal and external pressures.

After instrumentation was completed, the stopper, needle, and tooth were separated from the Eppendorf tube, and the debris adhered to the root surface was collected by washing the root with 1 mL distilled water while in the tube. The tubes were stored in an incubator at 70°C for 5 days to allow the distilled water to evaporate (21). The Eppendorf tubes containing the extruded debris were then weighed again in the same way to obtain the final mean weights of the tubes. Each tube was weighed in triplicate, and its mean weight value was calculated. The amount of extruded debris was calculated by subtracting the weight of the empty Eppendorf tube from the final weight of the assembly. An examiner blinded to all the experimental groups performed all weight measurements.

Preparation Time

The time elapsed during canal preparation was recorded using a digital timer (SportLine, Elmsford, NY) and included the total active instrumentation, instrument changes within the sequence, and irrigation procedures.

Statistical Analyses

The amount of extruded debris and the preparation time periods were statistically analyzed using SPSS software (IBM SPSS, Chicago, IL). Analysis of variance and post hoc Tukey tests were used in the analyses. The significance level adopted was 5%.

Results

The WOG reciprocating single-file system was associated with less extrusion of debris compared with the hand files (P = .036) and the TFA

TABLE 1. The Mean and Standard Deviation (SD) Values for the Amount of Apically Extruded Debris in Each Study Group (in Milligrams)

Group	Mean	SD
WOG	9.69^{A}	0.76
TFA	10.46^{AB}	0.96
MT	10.53^{B}	0.93

MT, manual technique; TFA, Twisted File Adaptive system; WOG, WaveOne Gold system.
Values for the groups marked with different superscript letters were significantly different (P < .05).

system (Table 1) although the difference between the WOG and TFA systems was not significant (P = .059). The time required to complete manual instrumentation was significantly longer than that required by the other techniques (P < .05). There was no significant difference between the WOG and TFA systems with respect to the time required for preparation (P > .05) (Table 2).

Discussion

The apical extrusion of debris during chemomechanical preparation has been reported in the literature; however, many factors affect the amount of debris extruded such as the preparation technique; kinematics; and the number, design, and size of the instruments used in each system (22). A reduction in debris extrusion is desirable to help reduce postoperative pain after root canal treatment (5).

The majority of studies found in the literature have used single-rooted teeth with relatively straight root canals. Nevertheless, high anatomic variability and differences in root canal curvature have been reported to influence the effectiveness of several NiTi engine-driven systems (5). The use of mesial roots of mandibular molars in this study represents an approximation of a laboratory experiment to the actual challenge faced by clinicians (14).

The results indicate that apical extrusion of debris occurred in all the instrumentation systems tested. However, the WOG reciprocating single-file system produced less debris extrusion than the hand files and TFA but with no statistically significant difference in relation to the latter. It is well-documented that hand files extrude more debris than reciprocating single-file or rotary systems (13, 23).

These results confirm those found by Üstün et al (22) and De Deus et al (13) for reciprocating systems, who attributed this advantage to the balanced force and pressureless mechanics provided by these systems. Moreover, the parallelogram-shaped design of the cross section of the WOG instrument with cutting edges, alternate 1-point contact, and improved alloy (M-Wire Gold) could also be linked to a low level of debris extrusion (24).

In contrast, some results appear to confirm the hypothesis that faster mechanical preparations with a reduced number of instruments tend to force more debris through the apex. Bürklein and Schäfer (25) concluded that rotary motion was associated with less debris extrusion compared with a reciprocating single-file system. Corroborating this conclusion, Karataş et al (11) assessed the amount of debris extrusion using the TFA system with different kinematics and reported that rotary motion was associated with less debris extrusion than reciprocating motion. On the other hand, Koçak et al (21) found no difference between the reciprocating and rotary motions.

The adaptive motion concept is based on the differential stress endured by the file during instrumentation, which may depend on root canal anatomy and curvature (11). Taking this into account, special care was taken to compose groups that were as balanced as possible in terms of angle and radius of root curvature. During the instrumentation of specimens with TFA files, there was a predominance of continuous rotation, even with root angles ranging between 20° and 40° and curvature radii <10 mm. Nevertheless, instrumentation with TFA files proved more difficult in reaching the WL in curved root canals compared with the other instruments. This may be attributed to their lower flexibility and different cross section compared with WOG (10). These findings are confirmed by observing the greater standard deviation values found for TFA in the preparation time assessment.

In addition to setting a limited range for root canal curvature during specimen selection in an attempt to reduce variation, further measures were taken to ensure a reliable, nonbiased comparison of the study groups. The apical diameter was standardized at ISO #25 to prevent variation in the amount of debris extruded. When sodium hypochlorite is used as an irrigating solution, sodium crystals cannot be separated from the debris and may change the results; for this reason, bidistilled water was used (5). Moreover, the apical foramen areas were measured to further reduce bias. Previous studies did not standardize the apical foramen size, which could explain the different results concerning apical debris extrusion (26, 27). According to Tanalp and Güngör (5), standardization of the apical foramen size is an important issue and should be considered.

The instrumentation time required by the reciprocating single-file and adaptive motion systems for root canal preparation was shorter than that required by hand files. Therefore, different kinematics and a reduced number of instruments seem to have influenced the extrusion of debris favorably, thus supporting the concept of single-file preparation as beneficial to use in clinical practice.

Nonetheless, although reducing the amount of debris extruded to the periapical region is a goal sought by clinicians and manufacturers alike, the performance increment made by each individual development in technique or instrument design and properties may not have the expected clinical impact, particularly considering that the balance between microbial aggression and host defenses may be the predominant factor involved (3). However, the search for improved instruments and protocols along with the research necessary to verify it is a continuing endeavor that should be encouraged.

TABLE 2. The Mean and Standard Deviation (SD) Values for the Preparation Time in Each Study Group (in Seconds)

Group	Mean	SD
WOG	75^A	13
TFA	95^A	49
MT	160^B	10

MT, manual technique; TFA, Twisted File Adaptive system; WOG, WaveOne Gold system.
Values for the groups marked with different superscript letters were significantly different (P < .05).

Conclusions

Under the conditions of this study, all the techniques tested caused apical debris extrusion to some degree. The WOG reciprocating system was associated with less debris extrusion in curved root canals compared with the manual technique and the TFA system although the difference between WOG and TFA was not significant.

Acknowledgments

The authors deny any conflict of interests related to this study.

References

1. Kirchhoff AL, Fariniuk LF, Mello I. Apical extrusion of debris in flat-oval root canals after using different instrumentation systems. J Endod 2015;41:237–41.
2. Seltzer S, Naidorf IJ. Flare-ups in endodontics: I. Etiological factors. J Endod 1985;11:472–8.
3. Siqueira JF Jr. Microbial causes of endodontic flare-ups. Int Endod J 2003;36:453–63.
4. Shen Y, Zhou HM, Zheng YF, et al. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013;39:163–72.
5. Tanalp J, Güngör T. Apical extrusion of debris: a literature review of an inherent occurrence during root canal treatment. Int Endod J 2014;47:211–21.
6. Ferraz CC, Gomes NV, Gomes BP, et al. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. Int Endod J 2001;34:354–8.
7. Ruddle CJ. Single-file shaping technique, 2016. Available at: https://www.dentsplysirona.com/content/dam/dentsply/pim/manufacturer/Endodontics/Glide_Path__Shaping/Rotary__Reciprocating_Files/Shaping/WaveOne_Gold_Reciprocating_Files/WaveOneGold_Jan2016%20Ruddle_WPaper.pdf. Accessed January 31, 2018.

8. Webber J. Shaping canals with confidence: WaveOne Gold single-file reciprocating system. Roots 2015;1:34–40.
9. Adigüzel M, Capar ID. Comparison of cyclic fatigue resistance of WaveOne and WaveOne Gold Small, Primary, and Large instruments. J Endod 2017;43:623–7.
10. Elsaka SE, Elnaghy AM, Badr AE. Torsional and bending resistance of WaveOne Gold, Reciproc and Twisted File Adaptive instruments. Int Endod J 2017;50:1077–83.
11. Karataş E, Arslan H, Kirici DÖ, et al. Quantitative evaluation of apically extruded debris with Twisted File Adaptive instruments in straight root canals: reciprocation with different angles, adaptive motion and continuous rotation. Int Endod J 2016;49:382–5.
12. Gambarini G, Testarelli L, De Luca M, et al. The influence of three different instrumentation techniques on the incidence of postoperative pain after endodontic treatment. Ann Stomatol (Roma) 2013;4:152–5.
13. De-Deus G, Neves E, Silva EJ, et al. Apically extruded dentin debris by reciprocating single-file and multi-file rotary system. Clin Oral Investig 2015;19:357–61.
14. Topçuoğlu HS, Düzgün S, Akpek F, et al. Influence of a glide path on apical extrusion of debris during preparation using single-file systems in curved canals. Int Endod J 2016;49:599–603.
15. Koçak MM, Çiçek E, Koçak S, et al. Comparison of Protaper Next and Hyflex instruments on apical debris extrusion in curved canals. Int Endod J 2016;49:996–1000.
16. Berutti E, Fedon G. Thickness of cementum/dentin in mesial roots of mandibular first molars. J Endod 1992;18:545–8.
17. Saber SE, Nagy MM, Schäfer E. Comparative evaluation of the shaping ability of WaveOne, Reciproc and OneShape single-file systems in severely curved root canals of extracted teeth. Int Endod J 2015;48:109–14.
18. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg. Oral Med Oral Pathol 1971;32:271–5.
19. Schäfer E, Diez C, Hoppe W, Tepel J. Roentgenographic investigation of frequency and degree of canal curvatures in human permanent teeth. J Endod 2002;28:211–6.
20. Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filling and Canal Master techniques. J Endod 1991;17:275–9.
21. Koçak S, Koçak MM, Sağlam BC, et al. Apical extrusion of debris using self-adjusting file, reciprocating single-file, and 2 rotary instrumentation systems. J Endod 2013;39:1278–80.
22. Üstün Y, Çanakçi BC, Dinçer AN, et al. Evaluation of apically extruded debris associated with several Ni–Ti systems. Int Endod J 2015;48:701–4.
23. Toyoğlu M, Altunbaş D. Influence of different kinematics on apical extrusion of irrigant and debris during canal preparation using K3XF instruments. J Endod 2017;43:1565–8.
24. Özyürek T. Cyclic fatigue resistance of Reciproc, WaveOne and WaveOne Gold nickel-titanium instruments. J Endod 2016;42:1536–9.
25. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. J Endod 2012;38:850–2.
26. Arslan H, Doğanay E, Alsancak M, et al. Comparison of apically extruded debris after root canal instrumentation using Reciproc (®) instruments with various kinematics. Int Endod J 2016;49:307–10.
27. Capar ID, Arslan H, Akcay M, Ertas H. An *in vitro* comparison of apically extruded debris and instrumentation times with Protaper Universal, Protaper Next, Twisted File Adaptive, and Hyflex instruments. J Endod 2014;40:1638–41.