Canal Transportation and Centering Ability of WaveOne Gold in Combination with and without Different Glide Path Techniques

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Abstract

Introduction: The aim of this study was to compare centering ability and transportation values of the Primary WaveOne Gold instrument (PWOG) with or without different glide path techniques. Centering ability and transportation were also compared between the three different glide path preparation groups. **Methods:** Mesiobuccal canals of 60 extracted human mandibular molars (curvature angles between 25° and 35° and radii ≤ 10 mm) were selected and randomly divided into 4 groups with 15 canals each. Canals were negotiated to patency with a #8 K-file. Canal preparations were performed by a single operator using: pre-curved #10-15-20 stainless steel manual K-files (group KF); #10 stainless steel manual K-file followed by PathFiles #1-3 (group PF); #10 stainless steel manual K-file followed by WaveOne Gold Glider (group WOGG) and no further glide path preparation (group NG). Micro-computed tomography (micro-CT) was used to scan teeth before and after glide path preparation. The final canal preparation was done with PWOG, after which all 60 specimens were scanned again by means of micro-CT. Canal transportation and centering ratio values were determined over levels 3 mm, 5 mm and 7 mm from the root apex after glide path preparation and again after final preparation with PWOG. One-way analysis of variance (ANOVA) was used to statistically compare groups. The significance level was set at $P < 0.05$. **Results:** No statistically significant difference in the mean centering ratios was found after glide path preparation when KF, PF, and WOGG groups were compared ($P > 0.05$). Mean combined transportation values after glide path preparation were statistically significantly higher in the KF group compared to the PF and WOGG groups ($P > 0.05$). There was no statistically significant difference in the mean combined centering ratios or transportation values of the NG and three glide path groups in combination with PWOG over the three levels ($P > 0.05$). **Conclusion:** KF's demonstrated highest mean transportation values during glide path preparation. However, the PWOG instruments's performance regarding centering ability and transportation was not influenced by the different glide path/ no glide path preparation groups.

Keywords: Centering ability, transportation, micro-CT, stainless steel K-files, PathFiles, WaveOne Gold Glider, WaveOne Gold.

Introduction

Biomechanical cleaning and shaping in order to facilitate irrigation, disinfection and proper obturation is essential in eliminating apical periodontitis (1). Protecting and preserving the original canal anatomy and the position and size of the apical foramen also remain important (2). Long, thin and curved root canals remain a challenge for even the skilled clinician. These difficulties increase the risk for root perforations, apical zipping, strip perforations and apical extrusion of debris (3).

A glide path is a smooth radicular tunnel extending from the canal orifice to the radiographic canal terminus or exit (4). An effective glide path preparation has been shown to reduce torsional stresses and can increase the lifespan of a rotary instrument up to 6 times (1). Original canal curvature is also preserved when an effective glide path is prepared prior to further instrumentation (5). Manual glide path preparation with K-files (KF) has been recommended by numerous authors (1,4,6), while nickel titanium (NiTi) rotary files have been shown to be faster and produce fewer procedural accidents as a result of the superior flexibility of the files (7–9). Cantatore, Berutti and Castellucci (10) showed that PathFiles (PF) (Dentsply Sirona, Ballaigues, Switzerland) introduced in 2009 can prepare a glide path with fewer irregularities and better conservation of original canal anatomy. Contemporary single-file mechanical glide path preparation systems have been introduced in the last few years. These include rotary systems like the ProGlider (Dentsply Sirona) and One G (Micro-Mega, Besançon, France) and, more recently, reciprocating systems like the WaveOne Gold Glider (WOGG) (Dentsply Sirona). The file tip of WOGG at D0 has an ISO 0.15 tip size with a 2% taper that progressively increases up to 6% at D16. The file has a semi-active tip and a parallelogram-shaped cross-section.

The use of NiTi shaping files in a reciprocating motion is a recent innovation with manufacturers claiming increased resistance to instrument separation (11). One such system, WaveOne (Dentsply Sirona), has demonstrated increased resistance to file fracture in a number of studies (12,13). The conventional WaveOne system was manufactured from M-Wire technology whereas WaveOne Gold (Dentsply Sirona) instruments are manufactured by means of a post-manufacturing thermal process that produces a file with super-elastic NiTi metal properties. This process gives the file a gold finish with improved mechanical characteristics.

The WaveOne Gold system exhibits a unique alternating off-centered parallelogram-shaped cross-section and a progressively decreasing percentage taper design (14). This design limits engagement of the file and dentine to only one or two points of contact at any given stage of canal preparation which improves the safety of the file with less taper-lock- and screw-in effect. The cross-sectional design of the file also allows for more debris extrusion during canal preparation. The Primary WaveOne Gold instrument (PWOG) (25/07) is 50% more resistant to cyclic fatigue, 80% more flexible and 23% more efficient than the conventional Primary WaveOne instrument (14,15).

Micro-CT has been shown to provide non-destructive and more accurate analyses of endodontic instrumentation than histological sections, plastic model evaluation, serial sectioning, radiographic comparisons and cone-beam computed tomography.

Extensive information can be obtained from micro-CT evaluation and slices can be recreated in a 2- or 3-dimensional plane with either simultaneous or separate assessment of internal and external structures (16,17).

The aim of this *in vitro* study was to investigate various glide path preparation instruments followed by root canal preparation with the reciprocating PWOG in curved mesiobuccal root canals of extracted human mandibular molars in order to advise the clinician on the most favorable combination (glide path technique in combination with PWOG) in order to preserve original canal anatomy best during canal shaping. Micro-CT was used to evaluate canal transportation and centering ability over the apical, mid-root, and coronal root canal levels (3 mm, 5 mm and 7 mm from the root apex). To our knowledge, no study has yet compared WOGG or PWOG for its centering ability and transportation values when used to prepare curved mandibular molar canals. The hypothesis tested for this study was that WaveOne Gold Glider would perform best when evaluating centering ability and transportation in combination with the Primary WaveOne Gold instrument when preparing curved root canals.

Materials and Methods

Selection of Teeth

Mesiobuccal canals of 60 human mandibular first molars, extracted for reasons unrelated to this study, were selected after obtaining written informed consent. Teeth were stored in distilled water at 4˚C until use. After access cavity preparation with an Endo-Access bur (Dentsply Sirona), the mesiobuccal canals were explored with a size 08 KF and canals were negotiated to patency under a surgical microscope (Zumax Medical Co., Ltd., Suzhou, China). Working length was determined by subtracting 0.5 mm from the length of the canal measured to the major apical terminus. The Schneider method (18) was used to evaluate canal curvature and only previously untreated mesiobuccal root canals with curvatures between 25 and 35 degrees and radii of equal to or less than 10 mm (19) were used. The specimens were coded and randomly divided into 4 equal experimental groups (n=15). Final canal preparation of all 60 canals was done with PWOG. In this present study, 3 levels (3,5 and 7 mm) were chosen to evaluate transportation and centering ability. These levels represent the apical, middle and coronal thirds of the roots with a high risk and incidence of iatrogenic errors. (22)

Micro-CT Analysis

Micro-CT was used to scan each tooth before instrumentation, after glide path preparation and again after final canal preparation with PWOG, using the XTH 225 ST micro-focus x-ray computed tomography system (Nikon Metrology, Leuven, Belgium) This system has a spatial resolution capability of 0.001–0.006 mm (20). Samples were placed on a stable support and a series of sequential 2-dimensional (2D) x-ray images were captured as the samples were rotated through 360°. These images were then reconstructed to generate 3-dimensional (3D) volumetric representations of each tooth. Reconstruction and visualisation of the micro-CT images was done with the use of VGSudioMax visualisation software (Volume Graphics GmbH, Heidelberg, Germany).

Glide Path Preparation

Glide path preparation was performed by a single operator in strict accordance with the manufacturer’s recommendations for each system. All rotary or reciprocating glide path files were operated by a 16:1 gear reduction hand piece powered by the X.Smart IQ (Dentsply Sirona) cordless motor. RC Prep (Premier, Pennsylvania, USA) was used as a lubricating agent and 3% sodium hypochlorite (NaOCl) as canal irrigation.

KF group:

In each of the 15 canals, an initial reproducible glide path was prepared using pre-curved size 0.10, 0.15 and 0.20 stainless steel KFs. A final reproducible glide path to an ISO size 0.20 was confirmed when the stainless steel size 0.20 KF could be placed at working length, pulled backwards for 4 mm and pushed back with light finger pressure to full working length without any interference or obstruction.

PF group

In each of the 15 canals, a pre-curved stainless steel size 0.10 KF was negotiated to working length with increasing amplitudes of 1–3 mm to ensure an initial manually reproducible glide path. PFs no.1-3 were used in a rotary motion to enlarge each canal in this group.

WOGG group

In each of the 15 canals a pre-curved stainless steel size 0.10 KF was negotiated to working length with increasing amplitudes of 1–3 mm to ensure an initial manually reproducible glide path. WOGG was then used in a reciprocating motion to enlarge each canal in this group.

NG group: No glide path preparation (n=15)

No further glide path preparation.

Each file in all of the glide path preparation groups was used only once. After glide path preparation, all 60 canals were shaped and prepared using PWOG reciprocating files up to working length according to the manufacturer's instructions, using the X.Smart IQ cordless motor. Throughout the instrumentation process RC Prep was used as a lubricant and 5 ml of 3% NaOCl was used as irrigation solution.

The mean canal transportation and centering ratio values were recorded and compared at 3 mm, 5 mm and 7 mm from the anatomical root apex of the tooth. The pre-op micro-CT measurements and micro-CT measurements after glide path and final canal preparation with PWOG were used to evaluate centering ability and canal transportation (Fig. 1).

Canal transportation = (M1-M2) – (D1-D2)

Canal centering ratio = (M1-M2)/(D1-D2) where (D1-D2 > M1-M2) or

(D1-D2)/(M1-M2) where (M1-M1) > (D1-D2)

Where:

M1: Shortest distance from the mesial margin of tooth measured to the mesial margin of uninstrumented canal.

M2: Shortest distance from the mesial margin of tooth measured to the mesial margin of the instrumented canal.

D1: Shortest distance from the distal margin of tooth measured to the distal margin of the uninstrumented canal.

D2: Shortest distance from the distal margin of tooth measured to the distal margin of the instrumented canal.

A value/ratio closest to 1 indicated perfect centering ability while transportation was measured in millimetres. A transportation value closest to 0 indicated no transportation. The higher the value the greater the transportation (21).

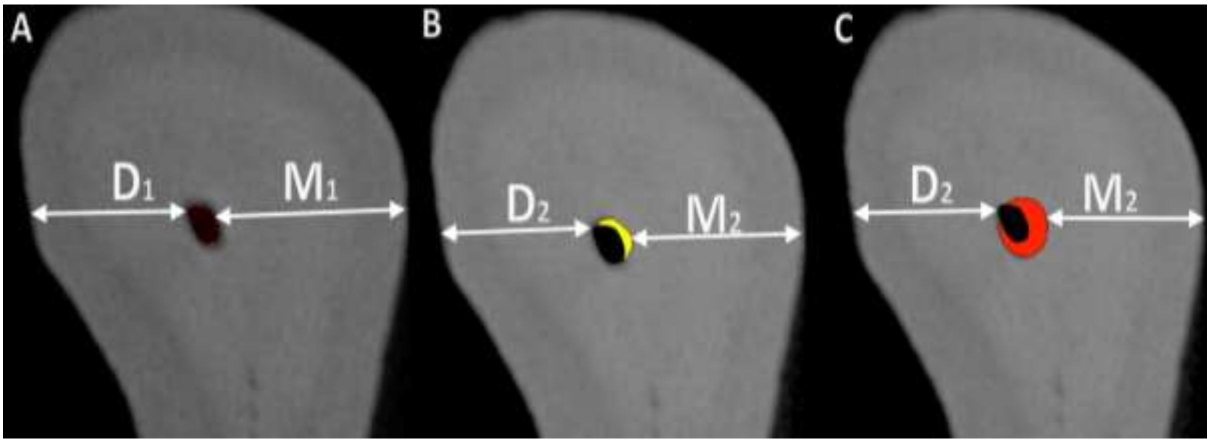

Figure 1: (a) Pre-instrumentation; (b) post glide path preparation micro-CT images with yellow markings showing the effect of glide path preparation and points of measurements used for determination of canal transportation and centering ratio; (c) post canal shaping micro-CT images with red markings showing the effect of canal preparation and points of measurements used for determination of canal transportation and centering ratio.

The three-dimensional images obtained before instrumentation, after glide path preparation and again after final canal preparation with PWOG were reconstructed and interpreted.

Statistical Analysis

Mean and standard deviations for centering ability and canal transportation were determined for each group and One-way analysis of variance (ANOVA) was used to statistically compare groups .Centering ratio and transportation values showed parametric distributions. Statistical procedures were performed on SAS Release 9.3 (SAS Institute Inc, Cary, NC) running under Microsoft Windows (Microsoft Corp, Redmond, WA) for a personal computer and statistical significance was set at $P < .05$

Results

Tables 1 and 2 show the mean and standard deviations values of the canal transportation and centering ability ratios at the three different levels for the different glide path groups and after canal preparation with PWOG. Stainless steel KFs were found to transport the canal statistically significantly more compared to the PFs and WOGG during glide path preparation ($P < .05$). There was no statistically significant difference between the different glide path preparation groups when mean centering ratio values were evaluated and compared between the different groups ($P > .05$). No statistically significant difference was found in the mean combined centering ratios and transportation values of the various glide path groups in combination with PWOG ($P > .05$)

Table 1: Statistical Analysis of Mean Transportation (mm) and Centering Ratios Values After Glide Path Preparation (n=15)

Level	Assessment	KF	PF	WOGG
3 mm	Centering Ratio	($0.45^{a} \pm 0.31$)	($0.38^{a} \pm 0.35$)	($0.30^{a} \pm 0.24$)
3 mm	Transportation	($0.10^{a} \pm 0.07$)	($0.06^{ab} \pm 0.07$)	($0.03^{b} \pm 0.04$)
5 mm	Centering Ratio	($0.32^{a} \pm 0.20$)	($0.47^{ab} \pm 0.27$)	($0.51^{b} \pm 0.30$)
5 mm	Transportation	($0.07^{a} \pm 0.07$)	($0.04^{a} \pm 0.04$)	($0.05^{a} \pm 0.05$)
7 mm	Centering Ratio	($0.30^{a} \pm 0.24$)	($0.47^{a} \pm 0.37$)	($0.25^{a} \pm 0.23$)
7 mm	Transportation	($0.14^{a} \pm 0.15$)	($0.04^{b} \pm$ 0.0.4)	($0.09^{ab} \pm 0.18$)
Combined Values	Centering Ratio	($0.35^{a} \pm 0.26$)	($0.45^{a} \pm 0.32$)	($0.35^{a} \pm 0.27$)
Combined Values	Transportation	($0.10^{b} \pm 0.11$)	($0.048^{a} \pm 0.05$)	($0.059^{a} \pm 0.11$)

Mean values with the same superscript letters were not statistically different at $P < .05$.

Table 2: Statistical Analysis of Mean Transportation (mm) and Centering Ratios Values After Final Preparation with PWOG (n=15)

Level	Assessment	KF	PF	WOGG	NG
3 mm	Centering Ratio	($0.44^a \pm 0.28$)	($0.26^a \pm 0.23$)	($0.37^a \pm 0.31$)	($0.33^a \pm 0.26$)
3 mm	Transportation	($0.14^a \pm 0.09$)	($0.14^a \pm 0.13$)	($0.12^a \pm 0.07$)	($0.13^a \pm 0.08$)
5 mm	Centering Ratio	($0.45^{ab} \pm 0.27$)	($0.55^a \pm 0.28$)	($0.35^b \pm 0.25$)	($0.50^{ab} \pm 0.30$)
5 mm	Transportation	($0.08^a \pm 0.07$)	($0.07^a \pm 0.05$)	($0.10^a \pm 0.07$)	($0.15^a \pm 0.16$)
7 mm	Centering Ratio	($0.34^a \pm 0.29$)	($0.36^a \pm 0.28$)	($0.34^a \pm 0.25$)	($0.29^a \pm 0.25$)
7 mm	Transportation	($0.19^a \pm 0.18$)	($0.17^a \pm 0.12$)	($0.22^a \pm 0.19$)	($0.22^a \pm 0.11$)
Combined Values	Centering Ratio	($0.41^a \pm 0.28$)	($0.39^a \pm 0.29$)	($0.35^a \pm 0.26$)	($0.38^a \pm 0.28$)
Combined Values	Transportation	($0.14^a \pm 0.13$)	($0.13^a \pm 0.11$)	($0.15^a \pm 0.13$)	($0.17^a \pm 0.13$)

Mean values with the same superscript letters were not statistically different at $P < .05$.

The representative sample images (Figure 2) depict the typical axial canal changes after canal preparation with PWOG in combination with the four different glide path groups. In every representative figure the *black* outline represents the original canal shape; *yellow* shows the effect of glide path preparation and *red* the effect of root canal preparation with PWOG.

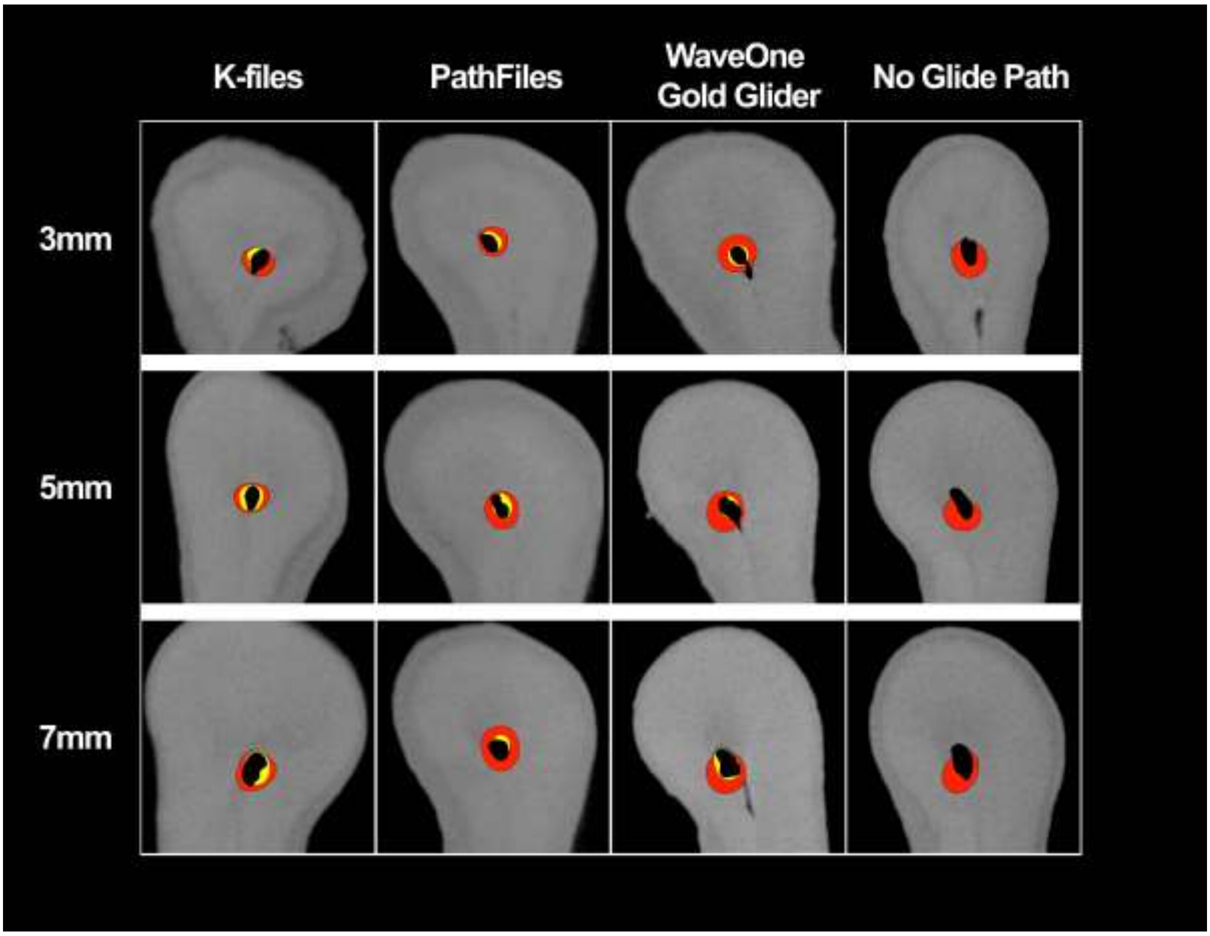

Figure 2: Typical axial canal changes after canal preparation at the different levels with PWOG in combination with the 4 different glide path groups.

Discussion

This is the first study on curved canals in extracted human molars to compare the centering ability and canal transportation of stainless steel KFs, PFs and WOGG in combination with PWOG. No comparative data regarding centering ability and canal transportation for WOGG and PWOG were found in the literature.

PFs performed the most favourably when mean centering ability ratios over the apical, midroot and coronal levels were compared after glide path preparation. However, there was no statistically significant difference in the mean centering ratios after glide path preparation when KFs, PFs and WOGG were compared ($P > .05$). At level 5 mm from the root apex WOGG performed statistically significantly more favourably than KFs in terms of centering ability with glide path preparation ($P < .05$). This might be attributed to the relative stiffness of the stainless steel KF's compared to the super-elastic NiTi metal properties of the WOGG that demonstrates increased flexibility.

The mean combined transportation values over the apical, midroot and cononal levels after glide path preparation were statistically significantly higher in the KF preparation groups compared to the PF and WOGG groups ($P < .05$). Several studies demonstrated NiTi files to cause significantly less transportation than manual KFs (7,22,23).

The second part of the present study examined the centering ability and transportation of PWOG after the different glide path preparation techniques and without any glide path preparation. There was no statistically significant difference in the mean combined centering ratios or transportation values of the various glide path groups in combination with PWOG over the apical, midroot and coronal levels ($P > .05$). Although not statistically significant, the highest mean transportation values were seen in the group where no glide path was prepared prior to final canal preparation with PWOG. These results suggest that the performance of PWOG might be enhanced by the creation of a glide path prior to final shaping with the PWOG instrument. Similarly, a study by de Carvalho et al (24) found no statistically significant difference between various glide path groups in combination with a single-file reciprocating system. This outcome corroborates findings from other similar studies (25,26). Although not statistically significant, Elnaghy and Elsaka (22) also reported that highest transportation values were seen in the groups where no glide path was prepared before final canal instrumentation. According to Wu et al (27), transportation greater than 0.3 mm may have a negative effect on the apical seal. It could therefore be argued that in terms of transportation none of the groups performed with any clinically significant implication in terms of reduced apical seal. No instrument fractures were recorded when the PWOG instrument was used in combination with the NG group. It was however observed that the PWOG instrument required more cutting cycles in order to reach full working length in the NG groups compared to the other glide path preparation groups.

A reduction in preparation time and a reduced number of failures related to instrumentation contribute to the growing popularity and clinical acceptability of single-file endodontic systems (28). A study by Kirchhoff et al (29) reported significantly faster glide path preparation for the single file ProGlider compared to PFs. In a study by Paleker and Van der Vyver (30), glide path preparation times of KFs, G-files and ProGlider were compared with similar results. In a recent study the single-file WOGG showed significantly faster glide path preparation times compared to KFs and PFs when used in combination with the Primary WaveOne Gold instrument. Final canal preparation was slowest where no glide path preparation was done before final instrumentation with the PWOG file (31).

In conclusion, although KF's resulted in highest transportation values with glide path preparation, centering ability and canal transportation with the Primary WaveOne Gold instrument was not influenced by the different glide path/ no glide path techniques. The increased resistance to cyclic fatigue as well as the enhanced flexibility of WOGG with its improved heat treated gold metal alloy, together with the convenience of a single-file system with the added benefit of reduced preparation time, might make WOGG/ PWOG the preferred combination of choice for preparation of curved canals.

It is important to note that only centering ability and transportation were evaluated in this study and other benefits of glide path preparation should not be overlooked. For safe, efficient, and predictable results, glide path preparation prior to shaping is therefore still recommended.

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