Comparison of forward and reverse single-file reciprocation for root canal instrumentation in curved mandibular molar canals - a Micro-CT analysis

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ABSTRACT

To compare (i) canal centering ability and transportation of Primary WaveOne Gold in combination with WaveOne Gold Glider with ProTaper Next X2 in combination with ProGlider using Micro-CT, and (ii) difference in final preparation times between these two preparation groups. Mesiobuccal canals of 50 mandibular first molars were used. Teeth were randomly divided into two preparation groups. Results were analysed using a one-way analysis of variance (ANOVA).

Apically, ProGlider/ProTaper Next X2 demonstrated better centering ratio values and lower transportation values compared to WaveOne Gold Glider/Primary WaveOne Gold ($p < .05$). No differences were found in the mean combined centering ratios and transportation values between groups ($p > .05$).

No statistically significant differences between the canal preparation times were found ($p < .06$). The combination of ProGlider / ProTaper Next X2 yields better results for transportation and centering ability apically compared to WaveOne Gold Glider in combination with Primary WaveOne Gold.

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Keywords

Centering ability, ProTaper Next, reciprocation, transportation, WaveOne Gold.

INTRODUCTION

Preparation and shaping of curved root canals can result in iatrogenic errors including but not limited to apical canal transportation, uncentered preparations, ledge formation, or perforation in curved canals.[1]

Advances in metallurgy have produced more super-elastic nickel titanium (NiTi) files that manufacturers claim are strong enough to resist the forces of torsion while maintaining enough flexibility to follow complicated root canal anatomy.[2]

In addition endodontic motors have undergone enhancement with regard to torque control and kinematics that are adjustable in several directions, which offer more effective and safer shaping of root canals.[3] Recently, the Root Pro CL (Medidenta, Las Vegas, USA) and E-Connect S (Eighteeth Medical, Changzou, China) endodontic motors were launched that allow clinicians to use rotary instruments in a forward reciprocating motion.

WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) is a reciprocating root-canal shaping system manufactured from Gold-Wire and exhibits a unique alternating off-centered parallelogram-shaped cross-section and a progressively decreasing percentage taper design.[4]

The Primary WaveOne Gold instrument (PWOG) (25/07) is 50% more resistant to cyclic fatigue, 80% more flexible and 23% more efficient than its NiTi predecessor, the conventional Primary WaveOne instrument (Dentsply Sirona) manufactured from M-Wire.[5]

ProTaper Next (Dentsply Sirona) is a rotary root-canal shaping system constructed of M-Wire NiTi, making it almost 400% more resistant to cyclic fatigue than conventional NiTi.[6] ProTaper Next (PTN) features a bilateral symmetrical rectangular cross-section, with an offset axis of rotation (except in the last 3 mm of the instrument (D0 – D3), allowing it to experience a rotational phenomenon known as precession or swagger.[7]

Contemporary single-file mechanical glide path preparation systems like the reciprocating WaveOne Gold Glider (Dentsply Sirona) and the rotating ProGlider file (Dentsply Sirona) have been introduced in recent years. The WaveOne Gold Glider (WOGG) is made from Gold-Wire while the ProGlider (PG) file is manufactured from flexible memory nickel-titanium wire (M-Wire).

Preservation of the original canal anatomy and remaining dentine thickness has been shown to improve the outcome of endodontic treatment. Micro-computed tomography (Micro-CT) has emerged as a useful analytical system that provides non-destructive and highly accurate analyses of the effects of endodontic instrumentation on root canal anatomy. Extensive information can be obtained from Micro-CT evaluation and slices can be recreated in a two- or three-dimensional plane with either simultaneous or separate assessment of internal and external structures.[8]

Reciprocating files currently available on the market are designed for use in a reverse motion. This motion employs a greater engaging counter-clockwise (CCW) angle (left-cutting) with a non-cutting disengaging clockwise (CW) angle. However, some authors suggest that reciprocating motion (RM) with a CW rotation greater than the CCW motion (forward reciprocation or right-cutting) could expand the use of conventional rotary files typically designed for continuous CW rotation.[9,10]

Yared[3] was the first to propose a canal preparation technique with a F2 ProTaper Universal (Dentsply Sirona) NiTi rotary instrument used in forward reciprocation. The study showed great potential in the reduction of the number of instruments, in minimising possible cross contamination and in alleviating operator anxiety of the possibility of instrument failure.[3]

In 2010, numerous authors[11-13] also confirmed that the forward reciprocating movement promoted an extended cyclic fatigue life of ProTaper Universal instruments (Dentsply Sirona) in comparison with conventional rotation. Gavini et al.[9] compared the Reciproc R25 file (VDW, Munich, Germany) in continuous rotation and forward reciprocation motion. The file group used in forward reciprocating motion fractured in 163,28 seconds, whereas the continuous rotation file group fractured in 357.56 seconds.[9]

The aim of this *in vitro* study was to investigate and compare root canal instrumentation of two single-glide path preparation and shaping system combinations used in RM in curved mesiobuccal root canals of extracted human mandibular molars: WOGG with the PWOG (in reverse reciprocation according to the manufacturer's instructions) and PG with the PTN X2 (in forward reciprocation, not used according to the manufacturer's instructions).

To our knowledge, no study has yet compared the preparation times, centering ability, and transportation values of WOGG/PWOG to PG/PTN used in RM in curved mandibular molar canals. The null hypothesis proposed is that there is no difference in preparation times and between forward and reverse reciprocating motion with regard to centering ability and canal transportation.

MATERIALS AND METHODS

Selection of teeth

Mesiobuccal canals of 50 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. The Schneider method was used to evaluate canal curvature and only previously untreated mesiobuccal root canals with curvatures between 25˚ and 35˚ and radii of equal to or less than 10 mm were used.[14]

The selected teeth were scanned (pre-instrumentation scan) using the XTH 225 ST micro-focus X-ray computed tomography system at the Micro-focus X-ray Radiography and Tomography facility (MIXRAD) at the South African Nuclear Energy Corporation (NECSA).

This system has a spatial resolution capability of 0.001 - 0.006 mm.[15] Samples were placed on a stable support and a series of sequential two-dimensional (2D) x-ray images were captured as the samples were rotated through 360°. These images were then reconstructed to generate three-dimensional (3D) volumetric representations of each tooth. Reconstruction and visualization of the Micro-CT images were done using VGStudioMax visualization software (Volume Graphics GmbH, Heidelberg, Germany).

After access cavity preparation with an Endo-Access burr (Dentsply Sirona) ensuring straight line access, the mesiobuccal canals were explored with a size 0.08 K-file (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 specimens were coded and randomly divided into two equal experimental groups for glide path preparation. A single operator performed the glide path preparation and shaping for each system.

All reciprocating and rotary files were operated by Root Pro CL (Medidenta) cordless endodontic motor. RC Prep (Premier, Pennsylvania, USA) was used as a lubricating agent and 3% sodium hypochlorite for canal irrigation. Each file was used to prepare one canal only before being discarded. Glide path preparation and shaping times were recorded with an electronic stopwatch.

WOGG/PWOG group

In each of the 25 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. Each canal in this group was enlarged using WOGG, followed by shaping with PWOG - both in a reverse RM. Reverse RM was characterized by a CCW movement of 150° and a CW movement of 30°.

PG/PTN X2 group

In each of the 25 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.

Each canal in this group was enlarged using PG, followed by shaping with the X2 PTN – both in a forward RM, not according to the manufacturer's instructions. Forward RM was characterized by a CW movement of 150° and a CCW movement of 30°.

A post-instrumentation scan was taken of each sample after final shaping. The VGStudioMax software (Volume Graphics GmbH) was used to superimpose images from the final shaping scan over the images from the pre-instrumentation scan. This allowed for assessment of the canal transportation and centering ability of the two groups. The method used by Elnaghy and Elsaka[16] was used to measure canal transportation and centering ability (Fig. 1).

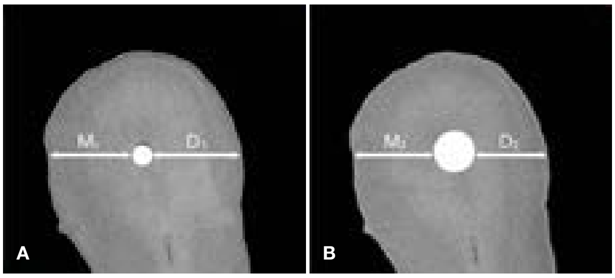

Figure 1. Cone-beam computed tomographic images indicating (A) pre- and (B) post- instrumentation measurements for determining canal transportation and centering ratio.

Centering ratio and canal transportation were measured at three different lengths from the anatomical apex of the mesiobuccal canals roots. In this 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.[16] A cross-section at levels 3 mm, 5 mm and 7 mm was evaluated using the following equations:[17]

Canal transportation = (M1-M2) – (D1-D2)
Canal-centering ratio= (M1-M2)/(D1-D2) or (D1-D2)/(M1-M2).

Where:
M1: Shortest distance from the mesial margin of tooth measured to the mesial margin of uninstrumented canal.
M2: Shortest distance from 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, whereas transportation was measured in millimetres. A transportation value closest to 0 indicated no transportation. The higher the value the greater the transportation.[17]

Statistical analysis

Mean and standard deviations for centering ability, canal transportation, and canal preparation times 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) and statistical significance was set at $p<.05$.

RESULTS

Canal Transportation and Centering Ratio

Tables 1 and 2 show the mean and standard deviation values of the centering ability ratios and canal transportation at the three different levels for the different groups, respectively. PG/PTN X2 demonstrated a statistically sig

Table 1. Statistical Analysis of Mean Centering Ratio Values for the Tested Group.

System	Apical		Midroot		Coronal		Combined	
	Mean ± SD	Min–Max	*Mean ± SD*	Min–Max	*Mean ± SD*	Min–Max	*Mean ± SD*	Min–Max
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
WOGG/PWOG	$0.36^{a} \pm 0.30$	0.035 – 1.100	$0.45^{a} \pm 0.29$	0.031 – 0.952	$0.35^{a} \pm 0.26$	0.063 – 0.921	$0.40^{a} \pm 0.27$	0.029 – 1.100
PG/PTN X2	$0.62^{b} \pm 0.33$	0.072 – 0.993	$0.48^{a} \pm 0.22$	0.106 – 0.898	$0.31^{a} \pm 0.21$	0.021 – 0.750	$0.48^{a} \pm 0.28$	0.021 – 0.993
P value	.0189		.470		.459		.120	

Mean values with the same superscript letters were not statistically different at $p<.05$ using the ANOVA test.

Table 2. Statistical Analysis of Mean Transportation (mm) for the Tested Groups.

System	Apical		Midroot		Coronal		Combined	
	Mean ± SD	Min–Max	*Mean ± SD*	Min–Max	*Mean ± SD*	Min–Max	*Mean ± SD*	Min–Max
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
WOGG/PWOG	$0.132^{a} \pm 0.061$	0.032 – 0.211	$0.098^{a} \pm 0.056$	0.015 – 0.287	$0.201^{a} \pm 0.168$	0.006 – 0.956	$0.14^{a} \pm 0.13$	0.006 – 0.956
PG/PTN X2	$0.067^{b} \pm 0.068$	0.001 – 0.229	$0.225^{a} \pm 0.364$	0.0 15 – 1.080	$0.264^{a} \pm 0.276$	0.035 – 1.356	$0.19^{a} \pm 0.28$	0.001 – 1.356
P value	.0129		.1176		.3294		.210	

Mean values with the same superscript letters were not statistically different at $p<.05$ using the ANOVA test.

nificantly better centering ratio value than WOGG/PWOG ($p<.05$) at the apical level. At the midroot and coronal levels, there was no statistically significant difference between the centering ratio values of the two groups ($p>.05$). After shaping, PG/PTN X2 demonstrated a statistically significantly lower apical canal transportation value ($p<.05$). At the midroot and coronal levels, there was no statistically significant difference between the transportation values of the two groups ($p>.05$). No statistically significant difference was found in the mean combined centering ratios and transportation values of the two groups ($p>.05$).

The representative sample images (Fig. 2) depict the typical axial canal changes after canal preparation with WOGG/PWOG, and PG/PTN X2 in forward reciprocation. In every representative figure, the black outline represents the original canal shape and red indicates the effect of root canal preparation. No instrument fracture was observed in any of the test group.

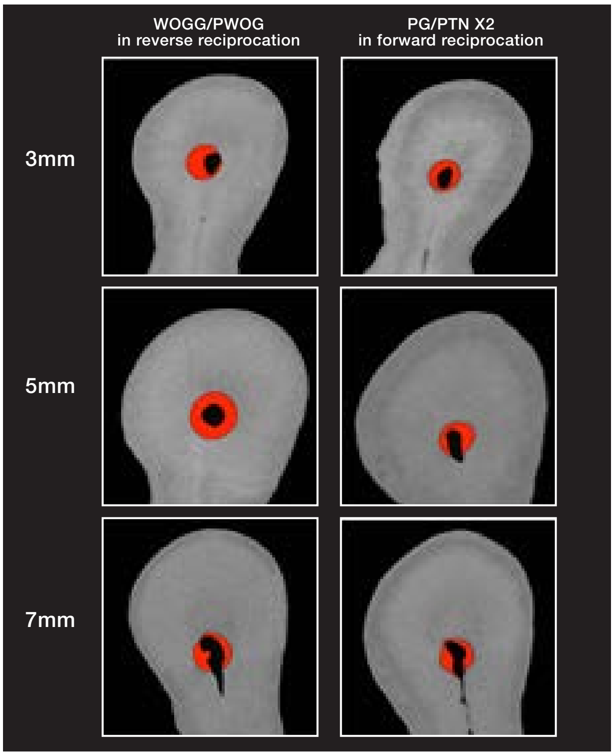

Figure 2. Pre-instrumentation and post-root canal preparation Micro-CT images with red markings showing the effect of root canal preparation and points of measurement used to determine canal transportation and centering ratio.

Canal preparation times

Table 3 depicts the mean and standard deviation values of the mean canal preparation times for the different groups. There was no statistically significant difference between the canal preparation times for the two groups ($p<.06$).

Table 3. Statistical Analysis of Mean Canal Preparation Times for the Tested Groups

System	*Mean ± SD*	Min–Max
	Mean	SD
WOGG/PWOG	48.69a ± 7.97	36.65 – 61.65
PG/PTN X2	42.98a ± 10.15	27.21 – 64.66
P value	.06	

Mean values with the same superscript letters were not statistically different at $p<.05$ using the ANOVA test.

DISCUSSION

The two single-glide path/shaping groups used in this study displayed significant centering and transportation differences only at the apical level. At this level PG/PTN X2 displayed statistically significantly lower mean canal transportation and better centering ability values than WOGG/PWOG. The endodontic files included in this study have different cross-sections, diameters, tapers, alloy types, and tip designs and were used in either a reverse or forward reciprocating motion.

Several studies have shown that instruments with greater flexibility produce more centered preparations.[18,19] The flexibility of an endodontic instrument is influenced by the composition and thermo-mechanical treatment of the metallic alloy, the size of the instrument, and its cross-sectional design.[20,21]

Instruments like WOGG/PWOG, which are manufactured from Gold-Wire super-metal, are said to possess improved metallurgic properties and therefore increased flexibility when compared to instruments made from conventional NiTi and M-Wire, like PG and PTN.[22] The study by Uygun et al.[22] found that ProTaper Gold files (Dentsply Sirona) had higher cyclic fatigue resistance owing to their flexibility compared to the NiTi ProTaper Universal (PTU)(Dentsply Sirona) and M-Wire PTN files at all levels examined.

In the present study however, significantly more favourable transportation and centering values were observed in the apical region following use of the M-Wire glide path/shaping group. Other design features like the final shaping size might also explain these results. Tip sizes of the shaping files used in this study were 25/07 for PWOG and 25/06 for PTN X2.[22]

The cross-sectional design of WaveOne Gold, modified from the design of its predecessor, WaveOne (Dentsply Sirona), is also said to increase its flexibility.[23] Results obtained here might be due to the file design of PG and PTN X2, which manufacturers claim reduces contact between these files and the dentine walls. The parallelogram-shaped cross-sectional design of PWOG is said to limit 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 design features and the swaggering movement of PTN used in CR reportedly present the following advantages: reduction in taper-lock, screw-in effect and stress on the file, and minimal risk of instrument fracture because of the reduced amount of contact between the instrument blades and the dentine walls; increased cutting efficiency and range; and activation of the irrigation solution in the canal, moving the solution into canal irregularities thereby cleaning areas that are not touched by the instrument.[24,25]

The motion in which the PG and PTN X2 files were used in this study might also have contributed to the results displayed in the apical region. The file taper, design, cross-section, and/or metallurgy of these two files might lend itself to forward RM. Reciprocation of NiTi systems with fewer instruments was introduced to simplify and shorten the root-canal shaping procedure and to reduce instrument fatigue.[3]

RM is typically described as a non-continuous rotation, originally with a movement towards the cutting direction of the instrument (CCW), followed by a minor rotation in the release direction (CW).[26] RM has been extensively evaluated for its effect on instrument longevity, shaping ability, and accumulation or extrusion of debris.[27]

The incidence of instrument separation and deformations of reciprocating files has been reported as considerably low, even less than that reported for rotary instruments.[28] Various studies have examined the potential application of RM of rotary systems. Rotary instruments are produced to cut in CR but the use of these instruments in a forward RM have been evaluated using CW rotation greater than the CCW rotation.[3,9]

A study by Paque, Zehnder and De Deus[29] showed that in terms of root canal curvature, a single F2 PTU file used in RM is as efficient as the conventional PTU full-sequence technique in CR in root canals of extracted human mandibular molars. These results contrast with those of Franco et al.,[30] who showed that Flex Master (VDW) NiTi instruments, designed for use in CR, shaped simulated canals more uniformly resulting in improved centering- when used in RM, compared with the same instruments used in a CR movement.

Similarly, Giuliani et al.[10] compared the shaping effects of WaveOne and PTU files used in RM and CR in s-shaped simulated canals. The authors found that at every level examined the full sequence of PTU files used in CR removed a significantly greater amount of resin than in the other groups of their study. It was concluded that the full-sequence PTU used in a RM exhibited better shaping effects than full-sequence PTU used in a CR motion and WaveOne used in RM.

The authors claimed that this technique offers the advantage of reaching the working length with a more gradual and centered enlargement, progressing from small to large tapers without forcing the file apically. Giuliani et al.[10] attribute the superior performance of the files used in RM to the increased contact area between the instruments and the canal walls, which permits equal canal enlargement on the inner and outer aspects of the curvature.

In this study, the canal shaping abilities of WOGG/PWOG, a reverse reciprocating Gold-Wire file system, and PG/PTN X2, a conventional rotary NiTi M-Wire file used in a forward RM, were analyzed using Micro-CT imaging. The time taken to prepare the canals was similar for the two groups, but the combination of PG and PTN X2 in forward RM yielded significantly better results for both transportation and centering ability at the apical level.

The results of this study suggest that PG/PTN X2 may be used in a forward reciprocating motion. However, further research and clinical studies will be necessary to validate this concept.

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