

A comparison of root canal transportation and centering ability between WaveOne® Gold and Protaper Next® files, using micro-computed tomography

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A Gajoum¹, E Patel², IE Munshi³, S Tootla⁴

ABSTRACT

Aim

This study compared the transportation and centering ability of ProTaper Next (PTN) and WaveOne Gold (WOG) files in curved permanent teeth using micro-computed tomography (μ CT).

Methodology

Twenty-four molar teeth with curved roots were divided randomly into two equal groups. The root canals of one group was prepared using PTN files, and the other using WOG files. Pre-instrumentation and post-instrumentation μ CT imaging were taken for all the teeth. The dentine thickness of the pre- and the post-instrumentation cross sections was measured at eight different points at three levels: 3, 5 and 7mm from the apex, by two dentists using image analysis software. The data were analysed using one-way ANOVA, at a 5% significance level.

Results

The transportation in both groups was within the range accepted in the literature. The WOG file exhibited sig-

ACRONYMS

NiTi:	Nickel Titanium
μCT:	Micro-Computed Tomography
CBCT:	Cone-Beam Computed Tomography
PTN:	ProTaper Next
WOG:	WaveOne Gold
KV:	Kilovolt
μA:	Micro Amber
EDTA:	Ethylenediaminetetraacetic Acid

nificantly less root canal transportation compared with the PTN file ($p=0.001$). The WOG file showed a significantly ($p<0.001$) higher mean centering ratio of 0.4286 when compared to that of PTN at 0.2448.

Conclusions

Using a novel technique to measure canal transportation, this study found that the WOG and PTN systems were both suitable for preparation of curved molar root canals, but the WOG showed significantly less canal transportation and better centering ability than the PTN system.

Keywords

Centering ability, Protaper Next, root canal transportation, WaveOne Gold.

INTRODUCTION

Biomechanical preparation of the root canal should result in a tapered preparation that maintains the original path of the canal.¹ This is particularly pertinent in the apical third of curved canals because of the propensity to straighten the canal and the development of complications like, ledge formation, zipping, perforation and root canal transportation.^{2,3}

Root canal transportation and centering ability measurements have been used to compare filing systems and techniques.⁴⁻⁶ Root canal transportation is defined as "Removal of canal wall structure from the outside curve in the apical half of the root canal due to the tendency of

Author affiliations:

- Abdulrag Gajoum:** BDS, MScDent., Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Alasmarya University, Zliten, Libya.
ORCID Number: 0000-0003-4061-6291
- Ebrahim Patel:** BDS, MScDent, Department of Paediatric & Restorative Dentistry, School of Oral Health Sciences, Faculty of Health Sciences, University of the Witwatersrand, South Africa.
ORCID Number: 0000-0002-7683-4867
- Ismail E Munshi:** BSc, BCHD, MDent, Department of Oral Rehabilitation, School of Oral, Health Sciences, Faculty of Health Sciences, University of the Witwatersrand, South Africa.
- Saidah Tootla:** BCHD, MScDent, Department of Paediatric & Restorative Dentistry, School of Oral Health Sciences, Faculty of Health Sciences, University of the Witwatersrand, South Africa.
ORCID Number: 0000-0001-9014-9455

Corresponding author: Ebrahim Patel

Department of Paediatric & Restorative Dentistry, School of Oral Health Science, 7 York Road, Parktown, Johannesburg, 2193, South Africa.
Email: ebrahim.patel@wits.ac.za

Author contributions:

- Abdulrag Gajoum:** Principal author - 55%
- Ebrahim Patel:** Co-author - 15%
- Ismail E Munshi:** Co-author - 15%
- Saidah Tootla:** Co-author - 15%

files to restore themselves to their original linear shape during canal preparation; may lead to ledge formation and possible perforation".⁷

A centred root canal preparation is another way to express an ideal root canal preparation without transportation. However, it must be kept in mind that the sole use of this method is flawed as it does not account for total circumferential transportation but only transportation in certain directions. The centering ability of a file is its ability to keep centred in the canal during instrumentation and is important for ideal root canal enlargement and to avoid weakening of root canal structure.⁸ While root canal transportation is usually measured in millimetres or micrometres, centering ability is measured using a ratio of 0 to 1. A centering ratio of 1 indicates perfect centering ability whereas, a ratio closer to zero indicates that the root canal wall was unequally prepared.

Over the years, manufacturers of nickel-titanium (NiTi) file systems have introduced various changes to the metallic structure and the designs of the files in order to improve their performance. Different cross sectional and longitudinal designs were produced to minimize apical transportation and to achieve a faster and more predictable canal preparations. These improvements include changes in design, metallurgy, and even the motion which the file is driven with.

ProTaper Next (PTN) file system (Dentsply Tulsa Dental Specialties, USA) is made from M-Wire; a thermo-mechanically treated NiTi metal. PTN was introduced in 2013 and is a continuous rotation system. It contains three crystalline phases: martensite, R-phase, and austenite⁹ and has shown improved cyclic fatigue resistance in comparison with conventional NiTi alloys.¹⁰ The main characteristic of PTN files is that the centre of the file mass is offset, which is claimed to provide a number of advantages, not least of which is the ability to prepare a size of canal that would otherwise require larger and stiffer files.^{11,12} PTN files showed competitive results when compared to other file systems in some studies.^{13,14}

The WaveOne Gold (WOG) reciprocating file system (Dentsply Maillefer, Switzerland) was launched in 2015. After having established an effective glide path, a single file is required to shape the entire canal (in most cases, according to the manufacturer). The files have an off-centred parallelogram cross-section similar to PTN. WOG files have significantly greater flexibility and resistance to torsional stress compared to Reciproc (VDW, Germany) and Twisted File Adaptive (Kerr Endodontics, Glendora, Orange, CA, USA).¹⁵

Recently, methods to measure root canal transportation involving micro-computed tomography (μ CT) and cone-beam computed tomography (CBCT) have become popular.^{13,16-19} Whilst CBCT produces 3-D images, the spatial resolution is considered to be inferior to μ CT which conserves specimens and provides 3-D high resolution images.^{20,21}

The aim of this study was to compare the root canal transportation and centering ability produced by the WOG reciprocating file system and PTN filing system in root

canal treatment using μ CT scans. The study uses a novel eight points measurement technique modified from Gambill et al.⁴ to measure the amount of canal transportation at three different levels along the length of the root canal.

Material and methods

24 extracted maxillary and mandibular first molars with complete root apices were randomly divided into two groups: PTN and WOG. The mesiobuccal and distobuccal roots of maxillary first molars, and the mesiobuccal and mesiolingual root canals of mandibular first molars were used, if they had roots with separate root canals and root canal curvatures of between 20 and 40 degrees.¹³ Excluded were calcified root canals, resorbed roots/root canals, root canals which did not allow a size #8 K-file to be inserted to the major foramen and those that allowed the passive placement of a #15 K-file to within 1 mm of the major foramen. Teeth with fractured roots were also excluded as were those with any previous attempts of endodontic treatment. Ethical clearance for the use of freshly extracted teeth (which were placed immediately after extraction in a 37% formalin solution) was granted by the Human Research Ethics Committee of the University of the Witwatersrand, South Africa; certificate number M160262.

Teeth were placed in a Protrain platform (Simit Dental, supplied by Dentsply, South Africa) and access cavities of sufficient size were prepared using round diamond burs and the Endo Z bur (Dentsply Maillefer, Switzerland). The canals of selected teeth were explored with a size #10 K-file (Dentsply Maillefer, Switzerland), which was advanced passively into the canal until the tip reached the apical foramen. The working length was established while using magnification (Zeiss OPMI Pico dental microscope, 31.25X magnification), from a standardised coronal point to the anatomical apical foramen minus 1 mm. The occlusal surfaces of the teeth were ground down so that the working length of all teeth was 17 mm.

Schneider's method was used to measure the curvature of the root canal, while Pruett's method was used to measure radius of root canal curvature.^{22,23} The angle and the radius of curvature was calculated using the Digi-mizer 4 image analysis software (MedCalc Software®). There-after the teeth were embedded in an acrylic resin block 25 mm depth x 15 mm x 15 mm. Base plate wax was used to prevent the acrylic resin from entering the apical foramen. Pre-instrumentation images were taken using a Nikon Metrology XTH 225/320 LC Micro-CT scanner at a voxel size of 15 μ m, 80 kV and 95 μ A.

For all teeth, the glide path was prepared using the Pro-Glider file (Dentsply Maillefer, Switzerland), according to manufacturer instructions. The X-Smart™ Plus micro-motor (Dentsply Maillefer, South Africa) was used to drive the files and adjusted for the two file systems. One group was instrumented using the primary size (25/07) WOG file according to manufacturer instructions and the other group instrumented using a PTN file X1 (017/0.04) followed by the X2 (025/0.06) file. A #10 K-file was used in both groups between every step to maintain canal patency. 10 to 12 mg of 17% EDTA (RC-Prep, Premier Dental, USA) was loaded on every rotary file to lubricate the root canal.

The individual canals were irrigated with 3 ml of 2.5% sodium hypochlorite between each rotary file. Each instrument was discarded after use in four canals, but any instrument that deformed was discarded immediately. A final irrigation with saline was applied to each root canal and a post-instrumentation μ CT image taken.

Two calibrated assessors compared the pre-and post-instrumentation images using VGSTUDIO MAX 3.0 software (Volume Graphics GmbH, Germany) by measuring the canal cross-sections. When the value between the two raters was different, the mean value of the readings was taken as a final value.

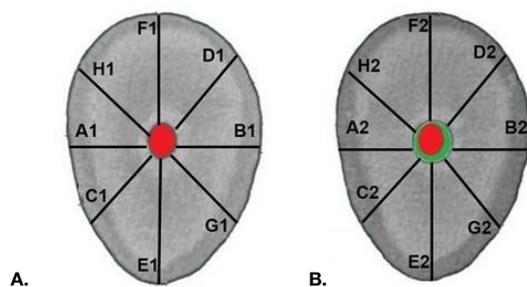


Figure 1. (A) Pre-instrumentation image and measurements taken designated A1 to H1 measured to the unprepared canal (red). (B) post-instrumentation image superimposed and the same measurements taken, designated A2 to H2, measured to the prepared canal (green).

The technique used to measure canal transportation was modified from Gambill et al.⁴ Instead of two measurements, this study used eight measurements (Fig. 1) after superimposition of pre-and post-instrumentation images. The root canal transportation and the centering ability ratio were measured in four directions as the axes A-B, C-D, E-F and G-H.

All readings were taken at each of the three levels from the apex (3, 5 and 7 mm from the root apex). The measurements along each axis were recorded and the values of opposing distances along an axis were subtracted from each other. A result of zero for the equation (e.g. $(A1-A2) - (B1-B2)$) was interpreted as no transportation. A positive value meant that the direction of canal transportation is in the direction of the first part of the equation and a negative value meant the direction of the second part of the equation.

A result of up to 0.15 mm was considered acceptable root canal transportation as most rotary NiTi instruments produce 0.15 mm or less.²⁴ A result of >0.30 mm at the apical end was unacceptable transportation²⁵ and values between 0.15 and 0.30 mm were considered borderline. In order to determine the centering ability, the ratios of the measurements along each axis were calculated, and transposed if necessary to reach a value of between 0 and 1. For example if the result of $\frac{(A1-A2)}{(B1-B2)}$ was more than 1 that meant $\frac{(B1-B2)}{(A1-A2)}$ must be used instead to obtain a value between 0 and 1. Hence the formula was a variation as necessary of the following:

$$CA = \frac{(A1-A2)}{(B1-B2)}, \frac{(C1-C2)}{(D1-D2)}, \frac{(E1-E2)}{(F1-F2)}, \frac{(G1-G2)}{(H1-H2)}$$

A result of 1 means optimal centering ability while a result of zero means no centering ability.

RESULTS

Three X2 PTN files separated during the study, with no separation recorded for the WOG files. Since separation occurred after the full working length had been reached, the three affected teeth were included in the analysis. The average curvature of the canals was 26.43° and 26.54° in the PTN group and the WOG group, respectively. The average radius of curvature in the PTN group was 5.49 mm, and in the WOG group was 5.52 mm.

Root canal transportation and centering ability results were normally distributed and were analysed using a one-way ANOVA, using Stata Version 13.1 (Stata Corp LP, Lakeway Drive, College Station, Texas, USA). Where there was a statistically significant difference, Tukey's multiple comparison post-hoc test was performed to show the site of the difference. A p value of <0.05 was considered statistically significant.

Canal transportation

At all levels of measurement, as well as the overall mean of all measurements, the PTN system was statistically significantly greater than the WOG system (Table 1).

The frequency and direction of root canal transportation at each measurement level is shown in Table 2. At the 3 mm and 5 mm levels, both systems caused greater canal transportation toward the outside, as compared with the inside of canal curvature. However, the opposite was true at the 7 mm sections. The PTN system had a lower range and frequency of samples with no canal transportation (4.2 to 8.3%) than the WOG filing system (8.3 to 33.3%).

Centering ability

The centering ability was significantly different ($p < 0.0001$) between the two systems, with the WOG system performing significantly better overall, and at each of the three levels (Table 3). The WOG also showed consistency between the different levels, whereas the PTN system had significant differences between the 3 mm and 7 mm levels.

DISCUSSION

The aim of this study was to compare the canal transportation and centering ability produced by a rotary file system, PTN, and a reciprocal file system, WOG, in freshly extracted permanent molars with severe canal curvature. In the present study, freshly extracted teeth were used, since they more accurately mimic the clinical situation.²⁶ μ CT scans were used to measure canal transportation and centering ability at three points along the length of the canal, representing the apical, middle and coronal thirds of the canal.

Root canal transportation

The technique that was used to measure root canal transportation was modified from the technique developed by Gambill et al.⁴ which was limited to using two measurements along a single plane. Measurement in only one direction may not be able to adequately show the geometric changes in three dimensions (3D) along the length of the

canal. This study modified Gambill's technique to enable an eight points circumferential analysis that allowed for an enhanced assessment of the mechanical action of the file systems.

Table 2 shows that transportation was observed to have occurred circumferentially, and not just in one direction. This affirms the use of the eight-point measurement technique for assessing canal transportation.

Apical canal transportation of up to 0.15 mm is acceptable and should not be greater than 0.30 mm²⁴ as it negatively affects apical sealing.²⁵ Although the results of this study show that the PTN system produced more canal transportation and poorer centering ability compared to the WOG system, the canal transportation of PTN was within the accepted range and was similar to that obtained by Silva et al.²⁷ (0.061 to 0.144 mm), Zhao et al.¹³ (0.62 mm), and Zanesco et al.¹⁴ (0.055 to 0.081 mm). The results for the WOG system in this study were superior to those reported by van der Vyfer et al.²⁸

This study also confirms the findings from previous studies that the direction of canal transportation in the 3 mm and 5 mm sections under both systems was predominantly toward the outside curvature, while in 7 mm section it was toward the inside of the curvature.^{29,30}

Centering ability

Centering ability, which indicates whether or not the den-

tine removal over the prepared area is spread evenly by the instrument. The ability of an instrument to remain centred within the natural canal path during preparation is essential for adequate enlargement without weakening the root structure.⁸ Good centering ability reduces the risk of transportation, zipping, elbow formation and other preparation errors.

The results of this study concur with the findings by Tamba et al.³¹ who demonstrated that the WaveOne (reciprocation) file (Dentsply Maillefer, Switzerland) remained better centred in the canal than the ProTaper. However, this is in contrast with McRay et al.¹⁷ who showed no significant difference between WaveOne (reciprocation) file and ProTaper Universal (continuous rotation) (Dentsply Maillefer, Switzerland). This could be because WaveOne and ProTaper Universal files have similar design, taper and size and made from the same form of NiTi alloy.

There are several possible explanations for the findings of this study. Zhao et al.¹³ recognised that the centering ability is influenced both by the design features of the instruments (size, taper, flexibility, and type of alloy) as well as the anatomy of the root canal.

The WOG filing system had superior centering ability compared with the PTN filing system, in all three sections along the length of the root canal. This may be attributed to the following factors:

1. The thermal treatment of the WOG file gives it greater

Table 1. Mean ± standard deviation of all measurement for transportation.

System	Level of measurement from the apex			p-values	Mean
	3mm	5mm	7mm		
PTN	0.0621 ± 0.0454	0.0956 ± 0.0753	0.1306 ± 0.9935	p < 0.0001	0.0961 ± 0.0813
WOG	0.0229 ± 0.0240	0.0566 ± 0.0451	0.0931 ± 0.0922	p < 0.0001	0.0575 ± 0.0671
p-values	p < 0.0001	p < 0.0001	p = 0.0073	-	p < 0.001

Table 2. Frequency and direction of root canal transportation at each measurement level of the root canal.

Level	Axis	PTN						WOG					
		Outside		Inside		None		Outside		Inside		None	
3 mm	A – B	19	(79.2%)	4	(16.7%)	1	(4.2%)	12	(50.0%)	4	(16.7%)	8	(33.3%)
	C – D	21	(87.5%)	3	(12.5%)	-	-	14	(58.3%)	6	(25.0%)	4	(16.7%)
	E – F*	16	(66.7%)	8	(33.3%)	-	-	5	(20.8%)	15	(62.5%)	4	(16.7%)
	H – G	11	(45.8%)	11	(45.8%)	2	(8.3%)	12	(50.0%)	7	(29.2%)	5	(20.8%)
5 mm	A – B	20	(83.3%)	4	(16.7%)	-	-	15	(62.5%)	9	(37.5%)	-	-
	C – D	15	(62.5%)	8	(33.3%)	1	(4.2%)	12	(50.0%)	12	(50.0%)	-	-
	E – F*	10	(4.7%)	13	(54.2%)	1	(4.2%)	4	(16.7%)	12	(50.0%)	8	(33.3%)
	H – G	17	(70.8%)	6	(25.0%)	1	(4.2%)	15	(62.5%)	7	(29.2%)	2	(8.3%)
7 mm	A – B	4	(16.7%)	20	(83.3%)	-	-	2	(8.3%)	15	(62.5%)	7	(29.2%)
	C – D	3	(12.5%)	21	(87.5%)	-	-	11	(45.8%)	11	(45.8%)	2	(8.3%)
	E – F*	7	(29.2%)	16	(66.7%)	1	(4.2%)	13	(54.2%)	8	(33.3%)	3	(12.5%)
	H – G	9	(37.5%)	14	(58.3%)	1	(4.2%)	3	(12.5%)	13	(54.2%)	8	(33.3%)

N.B: The E – F (marked with an asterisk *) direction is considered to be neutral. Column labelled none indicates zero transportation.

Table 3. Mean ± standard deviation of all measurement for centering ability.

System	Level of measurement from the apex			p-values	Mean
	3mm	5mm	7mm		
PTN	0.1858 ± 0.2389a	0.2538 ± 0.2986	0.2947 ± 0.2913b	p = 0.0241	0.2448 ± 0.2802
WOG	0.4074 ± 0.3442	0.4302 ± 0.3381	0.4481 ± 0.2938	p = 0.6873	0.4286 ± 0.3254
p-values	p < 0.0001	p = 0.0002	p = 0.0004	-	p < 0.001

^{a,b} Within a row, means without a common superscript differ at P < 0.05. Data are shown as mean ± SD. All the p-values written in bold mean that the values are significantly different.

flexibility, allowing the file to follow the root canal anatomy without considerable resistance, and confirms the findings of Elsaka et al.¹⁵ that the WOG file had significantly greater flexibility and resistance to torsional stress compared to Reciproc and Twisted File Adaptive.

2. The use of a single file requires the gradual introduction of the file to the working length, whereby the file reaches the full working length after the coronal part is partially prepared.
3. The kinematics of the instruments was originally thought to play a role in canal transportation, and reciprocal motion was thought to make the file more centred.³² However, a review of the instrumentation kinematics of engine driven NiTi instruments showed conflicting results on the effect of reciprocating instruments on canal transportation.³³ They attribute the conflicting results to different instruments and methodologies of the respective studies.

This study is in agreement with previous studies that the Primary size of WOG file has a high cyclic fatigue resistance compared to other Ni-Ti files,^{34,35} and recommends the use of the WOG Primary or smaller size file in severely curved root canals to attain superior shaping and centering ability, and to avoid file fracture.

A limitation of this study was that larger sizes of the WOG files were not tested. Caution must be taken when extrapolating these results to the larger file sizes, as they would differ in flexibility. Further studies are needed to evaluate the root shaping ability of the larger sizes of WOG files due to their differing flexibility.

CONCLUSIONS

The WOG and PTN systems were both suitable for preparation of molar root canals with severe curvature, but the WOG showed significantly less canal transportation and better centering ability than the PTN system. This study recommends the use of a novel technique to measure root canal transportation. This technique enables an improved eight point circumferential analysis of the prepared canals.

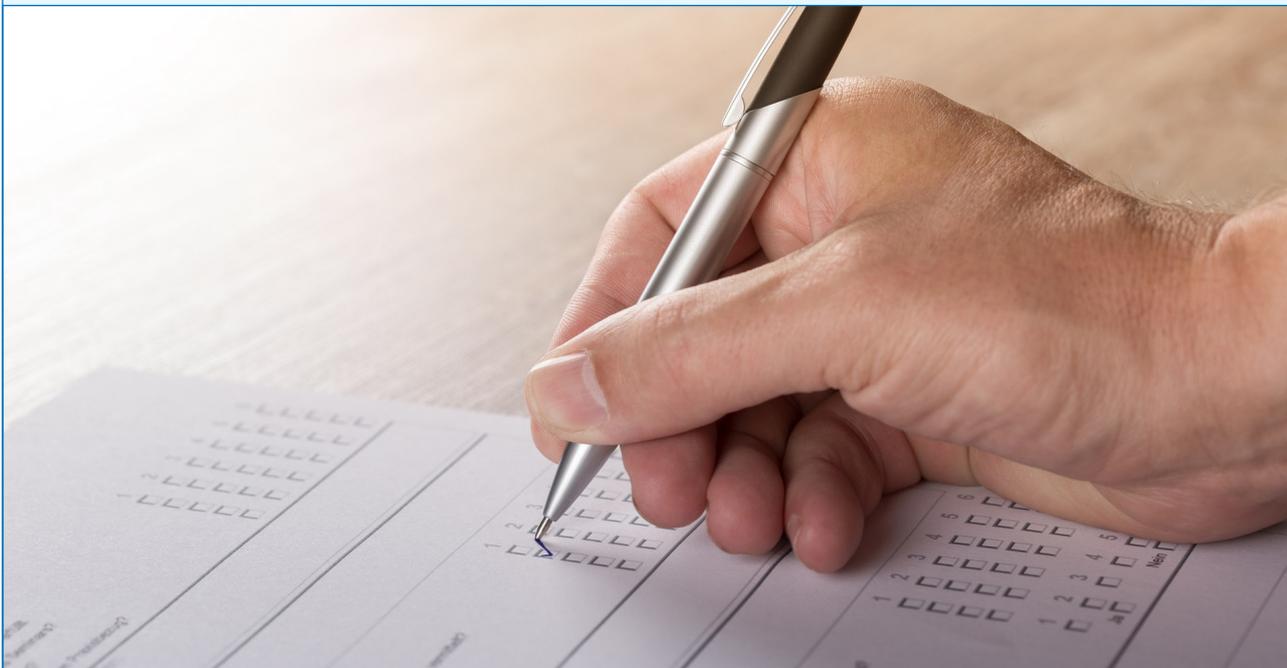
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The Continuous Professional Development (CPD) section provides for twenty general questions and five ethics questions. The section provides members with a valuable source of CPD points whilst also achieving the objective of CPD, to assure continuing education. The importance of continuing professional development should not be underestimated, it is a career-long obligation for practicing professionals.



Online CPD in 6 Easy Steps

1. Go to the SADA website www.sada.co.za.
2. Log into the 'member only' section with your unique SADA username and password.
3. Select the CPD navigation tab.
4. Select the questionnaire that you wish to complete.
5. Enter your multiple choice answers. Please note that you have two attempts to obtain at least 70%.
6. View and print your CPD certificate.