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Comparison of Shaping Ability of ProTaper Next and WaveOneGold File Systems in Curved Resin Blocks – An *In-Vitro* Experimental Study

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ABSTRACT

Objective: To compare shaping ability of ProTaper Next (PTN) & WaveOne Gold (WOG) file systems in curved resin blocks.

Methods: 68 resin blocks were divided into two groups (n = 34), shaped, photographed, and analyzed: Group 1- PTN; Group 2- WOG. Superimposition of pre- and post- instrumentation images was done using Adobe Photoshop software. Thirteen measurement points (0-12) were evaluated. Canal transportation (CT) and centering ability (CA) were measured using Image J software. The data was statistically analyzed using factorial design ANOVA, with a level of significance of <0.05.

Results: WOG showed better CA and less CT ($p < 0.05$) than PTN at middle third of simulated canal. At coronal and apical thirds, both the file systems showed comparable results ($p > 0.05$).

Conclusions: Both PTN & WOG were safe in preserving root canal anatomy. In the middle third, WOG was superior in maintaining canal anatomy than PTN.

Keywords: Centric Ability; Heat Treatment; Root Canal Shaping

Abbreviations: PTN: ProTaper Next; WOG: WaveOne Gold; CT: Canal Transportation; CA: Centering Ability

Introduction

Chemo-mechanical debridement is widely recognized as a pivotal stage in endodontic treatment, holding immense significance. Its purpose is the elimination of infected and necrotic tissue from the root canals and the establishment of smooth canal walls that enhance the ease of irrigation and obturation [1,2]. Root canal instrumentation creates a consistently tapered funnel-shaped canal, enlarging it to the greatest extent possible while preserving the original canal anatomy [2,3]. This goal becomes particularly challenging in narrow and curved canals [2,4,5]. Difficulties encountered in these cases include apical foramen transportation, formation of ledges, zips, perforations, and instrument separation [6]. These issues can impede effective disinfection of root canal space and its obturation, consequently diminishing endodontic treatment success [4,6].

The introduction of nickel-titanium (NiTi) instruments has lead a revolutionary change to root canal preparations by achieving well-tapered canals, reducing operator fatigue, and significantly decreasing shaping time [7,8]. Additionally, these instruments minimize the likelihood transportation of root canal wall while maintaining the canal original anatomical shape [7,9,10]. ProTaper Next (PTN) and WaveOne Gold (WOG) file systems have been recently developed root canal shaping systems that offer innovative approaches to canal preparation [6,11,12]. PTN (Dentsply Maillefer, Ballaigues, Switzerland) introduces an innovative system that uses multiple files and incorporates a design with a varying taper that gradually decreases and an off-centre rectangular cross-sectional shape [11,13]. These features are specifically engineered to minimize contact area with the walls of the canal, reducing instrument fatigue during use [11,14]. The PTN system consists of five instruments that has different tip sizes and tapers, namely X1 (#17/0.04), X2 (#25/0.06), X3 (#30/0.07), X4 (#40/0.06), and X5 (#50/0.06) [14,15]. Additionally, these instruments are constructed with M-Wire NiTi alloy [6,11,14].

WOG (Dentsply Mallefer, Ballaigues, Switzerland) in contrast, is comprised of a single file which operates through a reciprocating motion [16,17]. It incorporates an innovative NiTi alloy known as M-Wire with tapered variations along its working part [16,18]. Additionally, WOG utilizes an asymmetric reciprocating motion, which enhances the instrument resistance to fatigue [19,20]. Despite numerous studies conducted on PTN and WOG systems shaping ability, the findings have yielded varying results [14,21]. For example, Saeid, et al. [2] reported superior shaping ability of PTN as compared to WOG file system; while another study by Laura *et al*. [6] reported comparable clinical outcomes of WOG and PTN in terms of maintaining original canal anatomy. Owing to the contrasting evidence in literature, this study compares the canal shaping ability (centric ability & canal transportation) of PTN versus WOG systems in simulated curved resin blocks. We speculated that there is a significant difference in the shape of the simulated curved resin blocks prepared with PTN and WOG file systems.

Methodology

This study was an *in-vitro* experimental investigation carried out at dental clinics of Aga Khan University Hospital (AKUH) in Karachi, Pakistan, following the guidelines set forth in the Declaration of Helsinki. Ethical exemption was obtained from the institutional Ethical Review Committee (ERC exemption #: 2023-9242-26474). Sample size calculation was done using the OpenEpi version 3.01 (open-source statistics for public health, www.openepi.com). Based on previous studies, the mean centric ability of ProTaper and WaveOne Gold systems were 0.095±0.012 and 0.119±0.048 respectively[6]. The sample size calculated was 34 resin blocks per group (total 68 resin blocks) with a confidence interval of 95% and a power of 80%. The samples included in the study were prefabricated standardized resin blocks comprising a single canal (length=17mm, with 10mm long straight part and 7mm long curved part; canal curvature=30°-35°). Any samples that were previously instrumented or damaged were excluded. This study included sixty-eight curved resin blocks (Endo Training Block-L, Dentsply Maillefer, Ballaigues, Switzerland). Patency of the canal was confirmed using a size 10 K-file, after which the resin blocks were allocated to one of two groups (n = 34 canals/group). Preoperative photographs of each resin block were captured using a digital camera (cannon EOS 4000D). Before taking the pictures, the blocks were filled with black ink (S. DOLLAR) to enhance their outlines and ensure standardized images.

A tripod stand was employed to maintain a consistent distance for standardized comparison purposes. For group A, PTN rotary files were utilized with a torque control motor (Dentsply Maillefer) following manufacturer's guidelines (300 rpm speed; 2.0 Ncm torque). The following instrumentation order was followed: X1 (size 17, 0.04 taper); X2 (size 25, 0.06 taper) up to the full working length. The files were used in a pecking motion with an amplitude under 3 mm and three pecks per application, as per the manufacturer's guidelines. After three in-and-out movements, the flutes of the instrument were cleared of debris. For lubrication, EDTA cream (RC prep-META BIOMED CO>LTD) was applied with each instrument. After using each rotary file, the simulated curved canal in the resin block were be flushed with distilled water. Irrigation was performed using a 27-gauge tip plastic syringe, containing 5ml of distilled water. Additionally, after the removal of each rotary instrument, canal patency was verified with 10 size K-file. For group B, WOG primary file (apical taper = 0.07, tip size = 25) was employed with WaveOne motor (Dentsply Maillefer) in the "WaveOne All" mode, using a reciprocating motion. The canals were instrumented and irrigated as for PTN group, following the manufacturer's guidelines. A single skilled operator performed the preparation of all the canals and each file was exclusively dedicated to the preparation of a single canal. Following instrumentation, red ink (S. DOLLAR) was used to fill all the canals and were subsequently photographed once more under the same identical conditions as mentioned earlier.

An Adobe software application (Adobe Photoshop Elements 7.0; Adobe Systems, San Jose, CA, USA) was utilized to superimpose all the images taken before and after instrumentation, resulting in a composite image. The composite images were overlaid with a measuring template. Using Image J software, the amount of removed resin due to instrumentation was analyzed at 13 levels/points of the root canal (apical third: 0-4 mm, middle third: 5-8 mm, coronal third: 9-12 mm) in a perpendicular manner to the canal surface and there was 1 mm spacing between each point (Figure 1). Measurements were conducted to determine the distance between the initial root canal outline and the outline after instrumentation, both on inner side (Xi) and outer side (Xo) of the root canal at 13 levels (apical third: 0-4 mm, middle third: 5-8 mm, coronal third: 9-12 mm). Furthermore, the total width of the shaped root canal (Y) was also documented. Centric ability and canal transportation were calculated using the following equations [6]:

- Centric Ability (CA) = (Xi-Xo)/Y
- Canal Transportation (CT) = Xi-Xo

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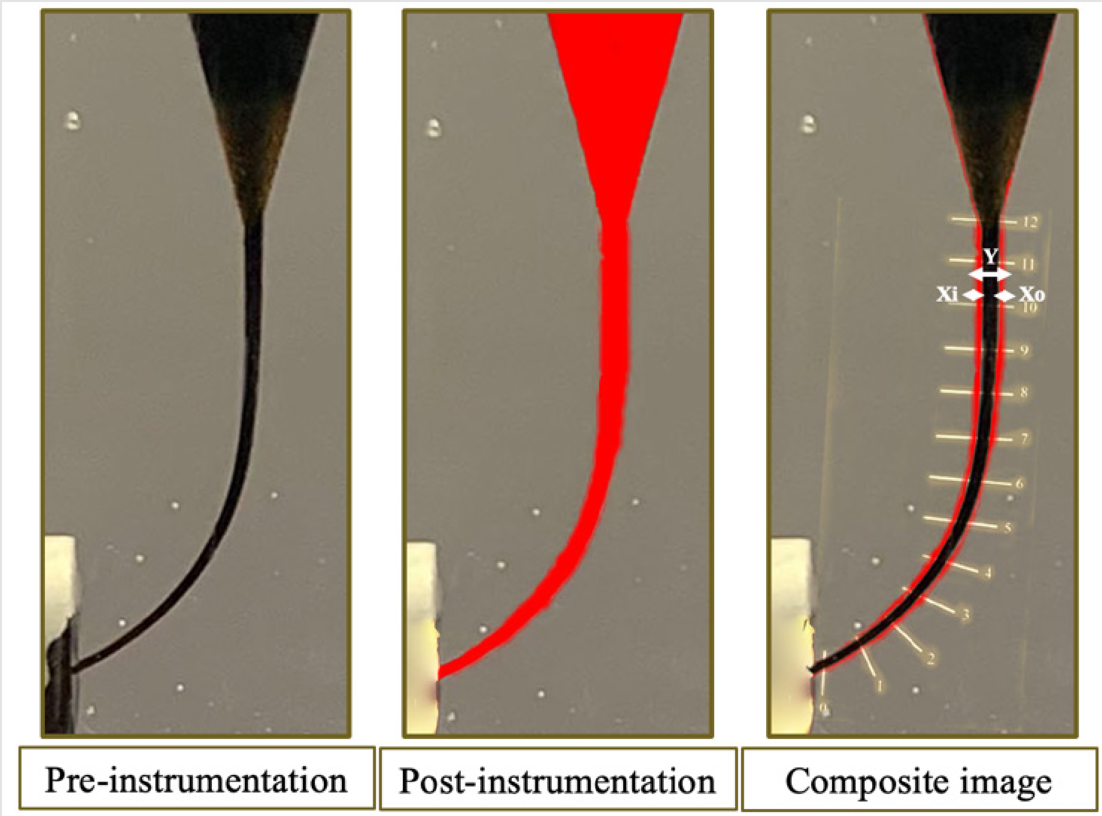

Figure 1: Image of simulated canals prepared with PTN and WOG.

Two independent examiners, blinded of the group allocation, assessed both the images taken before and after instrumentation. All the measurements were then documented on a customized proforma. Data was analysed using SPSS version 23.0. Intra-class correlation coefficient was used for assessment of intra-examiner reliability. Cohen's kappa statistics was use for inter-examiner reliability. The data distribution was analysed using the Kolmogorov-Smirnov test. Descriptive statistics, such as the mean and standard deviation, were calculated. ANOVA and factorial design ANOVA were utilized to compare the outcomes between the study groups. The significance level was set at <0.05.

Results

No instrument separation occurred while preparation of the resin blocks. Therefore, all the specimens were used for statistical analysis. In middle third of the canal (points 5, 7 and 8) WOG produced less transportation of the canal ($p < 0.05$) and maintained the canal more centric (points 5 and 8) [$p < 0.05$] than PTN (Table 2). At coronal and apical thirds, both PTN and WOG file systems demonstrated no statistically significant difference in CA and CT ($p > 0.05$) (Tables 1 & 3).

Table 1: Xi, Xo, CA and CT Mean Value, Standard Deviation, and ANOVA for Apical Third.

Xi	Group		0 (mm)	1 (mm)	2 (mm)	3 (mm)	4 (mm)
	PTN	Mean ± SD	0.089 ± 0.034	0.124 ± 0.108	0.129 ± 0.048	0.144 ± 0.048	0.149 ± 0.062
	WOG		0.102 ± 0.042	0.111 ± 0.040	0.164 ± 0.184	0.131 ± 0.056	0.157 ± 0.049
Xo							
	PTN	Mean ± SD	0.086 ± 0.047	0.089 ± 0.028	0.126 ± 0.048	0.128 ± 0.047	0.158 ± 0.179
	WOG		0.086 ± 0.052	0.103 ± 0.048	0.107 ± 0.048	0.114 ± 0.044	0.141 ± 0.047
CA							
	PTN	Mean ± SD	0.007 ± 0.242	0.109 ± 0.356	0.011 ± 0.116	0.047 ± 0.127	-0.029 ± 0.444
	WOG		0.069 ± 0.241	0.037 ± 0.197	0.192 ± 0.649	0.048 ± 0.146	0.036 ± 0.107
ANOVA		*p*-value	0.300	0.301	0.113	0.972	0.403
CT							
	PTN	Mean ± SD	0.003 ± 0.056	0.035 ± 0.109	0.002 ± 0.041	0.016 ± 0.047	-0.009 ± 0.183
	WOG		0.016 ± 0.055	0.008 ± 0. 051	0.057 ± 0.188	0.017 ± 0.052	0.016 ± 0.048
ANOVA		*p*-value	0.343	0.202	0.104	0.891	0.430

Table 2: Xi, Xo, CA and CT Mean Value, Standard Deviation, and ANOVA for Middle Third.

Xi	Group		5 (mm)	6 (mm)	7 (mm)	8 (mm)
	PTN	Mean ± SD	0.170 ± 0.057	0.159 ± 0.036	0.169 ± 0.051	0.149 ± 0.077
	WOG		0.156 ± 0.051	0.152± 0.035	0.152 ± 0.045	0.156 ± 0.051
Xo						
	PTN	Mean ± SD	0.147 ± 0.045	0.136 ± 0.044	0.150 ± 0.53	0.113 ± 0.058
	WOG		0.184 ± 0.055	0.142 ± 0.508	0.130 ± 0.033	0.147 ± 0.055
CA						
	PTN	Mean ± SD	0.097 ± 0.131	0.049 ± 0.113	0.038 ± 0.101	0.087 ± 0.134
	WOG		0.235 ± 0.087	0.014 ± 0.081	0.048 ± 0.108	0.024 ± 0.087
ANOVA		*p*-value	0.08*	0.142	0.679	0.024*
CT						
	PTN	Mean ± SD	0.041 ± 0.051	0.023 ± 0.056	0.186 ± 0.052	0.087 ± 0.134
	WOG		0.009 ± 0.037	0.005 ± 0.037	0.134 ± 0.188	0.009 ± 0.038
ANOVA		*p*-value	0.005*	0.128	0.001*	0.017*

Note: *Sign indicates statistical significance.

Table 3: Xi, Xo, CA and CT Mean Value, Standard Deviation, and ANOVA for Coronal Third.

Xi	Group		9 (mm)	10 (mm)	11 (mm)	12 (mm)
	PTN	Mean ± SD	0.152 ± 0.058	0.202 ± 0.051	0.188 ± 0.066	0.193 ± 0.064
	WOG		0.1633 ± 0.065	0.182± 0.055	0.166 ± 0.057	0.179± 0.067
Xo						
	PTN	Mean ± SD	0.171± 0.053	0.168 ± 0.046	0.168 ± 0.049	0.177 ± 0.052
	WOG		0.184 ± 0.062	0.167 ± 0.046	0.162 ± 0.058	0.175 ± 0.055
CA						
	PTN	Mean ± SD	-0.304 ± 0.135	0.576 ± 0.089	0.032 ± 0.125	0.021 ± 0.097
	WOG		-0.378 ± 0.157	0.028 ± 0.094	0.008 ± 0.151	0.012 ± 0.138
ANOVA		*p*-value	0.834	0.182	0.475	0.747
CT						
	PTN	Mean ± SD	-0.185 ± 0.074	0.034 ± 0.055	0.020 ± 0.081	0.017 ± 0.063
	WOG		-0.021 ± 0.085	0.015 ± 0.050	0.004 ± 0.089	0.005 ± 0.079
ANOVA		*p*-value	0.909	0.149	0.425	0.513

Discussion

Preserving the root canal's original anatomy and avoiding irregularities in the canal wall lead to enhanced antimicrobial action and sealing ability, [22] as well as a decreased risk of compromising the structural integrity of the tooth [20]. The PTN and WOG file systems are both widely used in endodontics, but studies suggest differences in their performance. This study involved comparing the mean values of centric ability and canal transportation for PTN and WOG at three levels: apical (0-4 mm), middle (5-8 mm), and coronal (9-11mm) thirds from the anatomical apex of simulated resin block. This study reported statistically significant difference in the middle third for CA and CT between PTN and WOG, with the latter resulting in better CA and less CT than PTN at levels 5,8 and 5,7,8 respectively. However, both the file systems had comparable results for CA and CT at coronal and apical thirds. Hence, the null hypothesis was partially rejected. The possible explanation for WOG file system in maintaining the integrity of the original canal anatomy, arises from the association of three primary factors: the reciprocating motion, the file's cross-sectional design, and the type of alloy used [23,24]. The use of a single file in a reciprocating motion for achieving sufficient shaping of the root canal has been investigated in previous studies [24]. When the instrument encounters the wall of the canal, its counter clockwise rotation disengages it, encouraging a safer application of single-file instruments in curved canals [24].

Additionally, continuous rotational movement tends to move the center of the preparation in a clockwise direction. In contrast, a more symmetrical movement, such as reciprocating motion where the instruments cut in both directions, is expected to mitigate this tendency [25]. PTN features an eccentric rectangular cross-sectional design, facilitating debris removal in a coronal direction. This design creates additional space around the instrument's flutes, enhancing cutting efficiency by ensuring continuous contact of the instrument blades with the adjacent dentin walls. In contrast, WOG instruments possess an alternating eccentric parallelogram-shaped cross-sectional design with two 85° cutting edges, restricting to 1 or 2 contact points between the file and dentin at any given cross-section. This modified cross-sectional design of WOG, derived from its predecessor, is purported to enhance its flexibility. Both PTN and WOG are made of an M-wire alloy, but an additional heat treatment converts M-wire to Gold-wire in WOG which further increases its flexibility and thereby reduces the risk of canal aberrations [26]. Our results partly agree with those by Peet J, et al. [21] in which PTN and WOG had similar centric ability, but PTN demonstrated significantly more canal transportation than WOG. Similar results were reported by Eliasz, et al. [27]. whereby WOG re-

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sulted in less canal transportation than PTN in extracted human teeth. In contrast, Troiano, et al. [28] reported PTN to have better centered the canals than WOG which they reported to be due to different methodologies and models being used in their study.

The present study utilized simulated resin blocks which enables the standardization of the degree, location, radius of curvature, and width of root canals. Preoperative and postoperative root canal outlines can be superimposed through digital microphotographs, digital measurements can be analyzed and any deviations at various points in the root canals can be assessed. This model enables high level of standardization and reproducibility in the experimental design. However, resin blocks allow only a two-dimensional analysis of the shaping ability as opposed to radiographic three-dimensional analysis of extracted human teeth [29]. Also, one of the major disadvantage of resin blocks is that it differ from natural teeth in terms of hardness. Dentin, found in natural teeth, is harder than the resin used in simulated canals, leading to variations in the formation of debris during instrumentation and heat generation which might cause instrument binding in the canal wall. As a result, the process of instrumenting natural teeth may not mirror that of resin blocks. Furthermore, natural teeth typically exhibit more intricate anatomy compared to the patent single canal structure in resin blocks [30]. In clinical settings, clinicians often encounter root canal systems that are more complex than the straightforward single canal portrayed in resin blocks [29].

Conclusion

Within the limitations of the present study WOG resulted in superior preservation of the original canal anatomy, exhibiting fewer alterations to the canal curvature when compared to the PTN. Additional research is necessary to determine whether the improved performance of the instrument can be attributed to the reciprocating motion, variable section design, alloy type and treatment or a combination of these factors.

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