



# Impact of Endodontic Instrumentation on Surface Roughness of Various Nickel-Titanium Rotary Files

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## Abstract

**Objectives** The aim of the present study was to evaluate the surface roughness (SR) of various nickel-titanium (NiTi) rotary endodontic instruments (ProTaper Next [PTN], WaveOne Gold [WOG], and ProTaper Gold [PTG]) before and after root canal instrumentation.

**Materials and Methods** For each type (PTN, WOG, and PTG), the endodontic instrumentation was performed using extracted mandibular molar teeth's curved mesial root canals (curvature: 20–40 degrees) after determining the working length. Each NiTi file was cleaned, and sterilized following preparation of four root canals and characterized for surface properties before and after endodontic instrumentation using a contact-mode three-dimensional surface profiler. The data were analyzed statistically using Statistical Package for the Social Sciences for SR parameters including average surface roughness value (Sa), root mean square roughness (Sq), and peak to valley height (Sz).

**Results** Preinstrumentation assessment revealed a significant difference for all the three SR variables ( $p < 0.05$ ) for the cutting blade and the flute area. WOG instruments showed the highest SR values ( $p = 0.000$ ). The postinstrumentation assessment revealed significant differences in SR values in the blade and the flute between the three groups ( $p < 0.05$ ), with WOG and PTG exhibiting the highest values in the blade and flute sections, respectively.

**Conclusions** The SR parameters of intact PTN, WOG, and PTG NiTi files vary and that was increased following the endodontic instrumentation.

## Keywords

- ▶ clinical endodontics
- ▶ shape memory alloy
- ▶ topography
- ▶ fatigue resistance
- ▶ root canal treatment
- ▶ profilometry

## Introduction

Root canal shaping is performed using various endodontic files and essentially required for the successful root canal treatment.<sup>1</sup> In addition to cleaning and shaping, the morphology and original curvature of root canals should be conserved during instrumentation.<sup>2</sup> The root canals' cleaning and shaping is a technique-sensitive procedure that is vulnerable to complications such as ledge formation, apical transportation, and perforations due to complex root canals anatomy, morphological

variations, and over-instrumentation.<sup>3,4</sup> The nickel-titanium (NiTi) alloy files are more flexible compared with the conventional stainless steel files resulting in an improved quality of root canal preparation and reduced chances of procedural errors.<sup>5,6</sup> A variety of systems and modifications (alloy composition, heat treatments, taper, and cross-sectional design) of NiTi rotary files has been introduced in the recent decades.<sup>7-12</sup>

During endodontic instrumentation, mechanical friction or chemical stimuli may lead to loss of surface contents (wear) and formation of surface defects such as scratches and

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microcracks.<sup>13,14</sup> Accordingly, the wear and surface topography of NiTi instruments may be affected in terms of manufacturing, compositional variations, and mechanical stresses. For example, ProTaper Next (PTN) instruments, NiTi alloy is processed thermally during fabrication to enhance flexibility and cyclical fatigue resistance.<sup>15</sup> PTN instruments have a regressive taper, a rectangular cross-section, and are designed to minimize its contact area with the root canal walls and decrease fatigue stresses while instrumenting root canals.<sup>16</sup> The WaveOne Gold (WOG) rotary files are manufactured using a heat-treated NiTi alloy (gold wire) to machine a parallelogram-shaped cross-section resulting in improved properties and clinical performance compared with the WaveOne (WO) files that are fabricated using M-wire.<sup>17,18</sup> In contrast, ProTaper Gold (PTG) instruments have a triangular cross-section, a variable progressive taper (similar to ProTaper Universal), and are known for improved flexibility and cyclic fatigue resistance.<sup>19</sup>

The surface roughness (SR) characterization of NiTi rotary files provides useful information regarding surface defects, performance, and associated limitations.<sup>20</sup> Therefore, researchers have explored a variety of techniques including scanning electron microscopy (SEM),<sup>20,21</sup> atomic force microscopy (AFM),<sup>22,23</sup> and noncontact optical profilometry to study surface morphology of endodontic files.<sup>24-26</sup> At present, there are no published reports comparing the effects of endodontic cleaning and shaping on surface nano-profiles of PTN, WOG, and PTG rotary endodontic files. Therefore, the aim of this study was to compare the surface profilometry of various NiTi rotary endodontic files (PTN, WOG, and PTG) before and after instrumentation.

## Materials and Methods

### Experimental Design and Study Groups

The present experimental study was approved by the institutional research ethics committee at the College of Dentistry, Taibah University, Madinah Al-Munawarah, Saudi Arabia (Ref: TUCDREC/20200216/MSZahaf). The NiTi rotary endodontic instruments were divided into three study groups ( $n = 5$ ) including PTN, WOG, and PTG. All NiTi rotary instruments used in the present study were manufactured by Dentsply Sirona Endodontics, Tulsa, United States. To rule out any manufacturing defects, the surfaces of all NiTi instruments were inspected using an optical microscope at 50X (Leica DM6000; Leica Microsystems, Wetzlar, Germany). All NiTi instruments were characterized for surface roughness properties before and after endodontic instrumentation.

### Root Canal Instrumentation

The root canal instrumentation was performed on extracted lower molars' curved mesial (mesiobuccal and mesiolingual) root canals (Vertucci type 1; curvature: 20–40 degrees) according to the Schneider's technique.<sup>27</sup> Briefly, each root canal was explored using stainless steel K-files (size#10; Dentsply Maillefer, Oklahoma, United States) and the working length was determined at 1 mm shorter from the apical foramen. Following the manufacturers' instructions, the root canal instrumentation was performed using sodium hypochlorite (3%: ~5 mL for each canal) as a root canal irrigant. After the preparation of four root

canals, each NiTi file was cleaned using an ultrasonic cleaner, sterilized (134°C for 4 min; pressure: 30 psi), and dehydrated. A single operator performed all the endodontic instrumentation. Four root canals were prepared using each NiTi instrument (20 canals for each group). Any root canals with pathological conditions (such as internal or external resorption, open apex) or history of endodontic treatment were excluded. In addition, any root canals other than Vertucci type 1 were also excluded.

### Surface Profilometry Analysis

The surface profilometry analysis of NiTi rotary files was performed before and after endodontic instrumentation using a contact-mode surface profiler (Dektak150; Veeco Instruments Inc., Tucson, Arizona, United States) fitted with a low-inertia stylus. Each NiTi file was mounted on a glass slide, and fixed on the sample stage. Using the inbuilt camera, the cutting blade, and adjacent flute area, 3 mm coronal from the file's tip was chosen and scanned using the fixed parameters (stylus radius 200 nm: stylus z-range 36  $\mu\text{m}$ ; and scan duration 60 sec). For each NiTi file, five distinct locations (area dimensions: 100  $\times$  100  $\mu\text{m}^2$ ) were scanned. The profilometer was operated at a constant stylus force (4 mg), which allowed the stylus to scan and analyze the alloy surface without causing any damages or deformation of the surface. The surface characterization was performed in a standard position as described previously by AlRahabi and Atta<sup>12</sup> and data were exported and saved for further analysis of SR parameters; also, SR parameters including average surface roughness value ( $S_a$ ), root mean square roughness ( $S_q$ ), and peak to valley height ( $S_z$ ) were determined (ISO 25178–2).

### Statistical Analysis

The surface profilometry data were analyzed statistically using Statistical Package for the Social Sciences software (version 22, IBM Corp., Armonk, New York, United States) with the significance value ( $p < 0.05$ ). The one-way analysis of variance (ANOVA) determined significant differences among SR parameters ( $S_a$ ,  $S_q$ , and  $S_z$ ) before and after endodontic instrumentation. The multiple comparisons between SR values for the three test groups were evaluated by post-hoc Tukey HSD test. Pair-wise comparison of SR parameters before and after the instrumentation was evaluated by paired-samples statistics. The Kolmogorov-Smirnov test was applied to analyze the normality of data.

## Results

The current study evaluated and compared the SR parameters ( $S_a$ ,  $S_q$ , and  $S_z$ ) of three endodontic NiTi instruments at their cutting blade and flute areas before and after instrumentation using a contact-mode nanoscale profilometer. Preinstrumentation assessment revealed a significant difference with one-way ANOVA for all the three SR variables ( $p < 0.05$ ) for the cutting blade and the flute between the instruments (**►Table 1**). The results showed that WOG instruments have the highest values of SR parameters at the blade as well as at the flute locations, which was statistically significant ( $p = 0.000$ ) than the groups PTN and PTG. Almost similar SR values for the cutting blade were

**Table 1** The quantitative analysis of surface roughness parameters ( $\mu\text{m}$ ) of tested instruments before root canal instrumentation

Scanned location	NiTi instrument	Sq <sup>a</sup> Mean $\pm$ SD	Sa <sup>a</sup> Mean $\pm$ SD	Sz <sup>a</sup> Mean $\pm$ SD
Blade	PTN	6.61 $\pm$ 1.07	4.25 $\pm$ 1.02	20.80 $\pm$ 1.53
	WOG	12.95 $\pm$ 1.08	10.47 $\pm$ 1.04	49.13 $\pm$ 2.43
	PTG	5.79 $\pm$ 0.93	4.56 $\pm$ 1.04	38.83 $\pm$ 1.67
ANOVA <sup>b</sup> <i>p</i> -value		0.0000	0.0000	0.0000
Flute	PTN	0.34 $\pm$ 0.04	0.30 $\pm$ 0.03	1.56 $\pm$ 0.14
	WOG	0.62 $\pm$ 0.12	0.51 $\pm$ 0.11	2.85 $\pm$ 0.63
	PTG	0.62 $\pm$ 0.07	0.43 $\pm$ 0.15	4.09 $\pm$ 0.44
ANOVA <sup>b</sup> <i>p</i> -value		0.0000	0.0000	0.0000

Abbreviations: ANOVA, analysis of variance; NiTi, nickel titanium; PTG, ProTaper Gold; PTN, ProTaper Next; Sa, average surface roughness value; SD, standard deviation; Sq, root mean square roughness; Sz, peak to valley height; WOG, WaveOne Gold.

Note: Scanned areas dimensions: 100  $\times$  100  $\mu\text{m}^2$ .

<sup>a</sup>The Sq, Sa, Sz were measured in micrometers ( $\mu\text{m}$ ).

<sup>b</sup>The significance level ( $p \leq 0.05$ ).

noted for the PTN and PTG, which was statistically non-significant ( $p = 0.252$ ), while for the SR of the flute of the PTN and PTG, there were significant differences ( $p = 0.000$ ) between the values.

► **Table 2** describes the postinstrumentation SR parameter values for blade and flute of the three tested groups. The postinstrumentation assessment revealed significant differences in the Sq, Sa, and Sz values in the blade and flute between the three groups ( $p < 0.05$ ), with WOG and PTG exhibiting the highest values in the blade and flute section, respectively. The one-to-one comparison between the surface parameters before and after the instrumentation of all the three groups with post-hoc Tukey test is presented in ► **Table 3**. For most of the comparisons, significant differences were observed except between the PTN and PTG for the blade section before and after the instrumentation (► **Table 3**).

Paired-samples *t*-test was used for the comparison between the SR parameters (Sq, Sa, Sz) of the three tested instruments before and after the instrumentation within the same-group specimens (► **Table 4**). In the blade section for the PTN and WOG, significant differences ( $p < 0.05$ ) were noted for all the three SR parameters, while for the PTG in the blade section, only Sq parameter ( $p = 0.116$ ) was found to be nonsignificant. In the flute section for PTN, significant differences were found for all the three SR parameters, while for the WOG only Sq ( $p = 0.022$ ) and for PTG only Sa ( $p = 0.000$ ) were found to be significant. The qualitative analysis indicated enhanced SR and wear of all the NiTi instrument (PTN, WOG, and PTG) compared with the corresponding intact instruments. In addition, the NiTi instruments exhibited formation of minor surface scratches, pits, and microcavities without showing any signs of cracks or fractures (► **Fig. 1**).

## Discussion

The present study investigated the effects of endodontic instrumentation on different NiTi rotary instruments (PTN,

WOG, and PTG) by comparing the SR before and after instrumentation. The endodontic instrumentation was performed on extracted mandibular molars' curved mesial root canals (curvature: 20–40 degrees) using the NiTi files and characterized for changes in the SR by a three-dimensional (3D) surface profiler. The NiTi rotary instruments are prone to spontaneous fracture<sup>28</sup> due to their nature or presence of artifacts (such as fissures and pits) formed during the process of milling during the manufacturing.<sup>29</sup> The cold working of NiTi alloy results in the formation of work hardening areas that are prone to cracking or brittle fracture without showing any signs of ductile behavior.<sup>30</sup> The cyclic loading and unloading during instrumentation results in repeated transfiguration between the austenitic and martensitic phases thereby altering the mechanical properties such as fatigue strength.<sup>31</sup> Although the NiTi rotary instruments have excellent surface smoothness and cyclic fatigue resistance,<sup>32</sup> the stresses caused by mechanical instrumentation increase the SR, force of friction, and likelihood of instrument failure.<sup>33</sup> Therefore, understanding the effects of mechanical stresses on SR of NiTi rotary instruments may suggest useful information in terms of surface defects and clinical safety.<sup>24</sup>

Noncontact 3D optical profilometry has analyzed the surface characteristics qualitatively and quantitatively.<sup>34,35</sup> In case of NiTi instruments, typical metallic properties of metal such as shiny surface and optical properties interfere with the optical scanning therefore affecting the accuracy of data.<sup>36</sup> The present study evaluated the changes in surface topographies of NiTi rotary files by a stylus profilometry technique through the low-force contact mode and characterized the sensitive surfaces nondestructively.<sup>37</sup> In addition, stylus profiler has a nanoscale vertical and lateral resolution ( $\sim 0.5$  nm and 100 nm), respectively,<sup>38</sup> making it a suitable technique for surface characterization.

In the current study, preinstrumentation assessment revealed a significant difference in the three SR variables ( $p < 0.05$ ) of the cutting blade and the flute between the NiTi instruments. The highest values of SR parameters were

**Table 2** The quantitative analysis of surface roughness parameters ( $\mu\text{m}$ ) of tested instruments following root canal instrumentation

Scanned location	NiTi instrument	Sq <sup>a</sup> Mean $\pm$ SD	Sa <sup>a</sup> Mean $\pm$ SD	Sz <sup>a</sup> Mean $\pm$ SD
Blade	PTN	7.07 $\pm$ 1.06	5.60 $\pm$ 0.72	29.25 $\pm$ 10.40
	WOG	13.82 $\pm$ 1.00	12.24 $\pm$ 1.54	55.82 $\pm$ 4.91
	PTG	6.35 $\pm$ 0.52	4.60 $\pm$ 1.03	39.94 $\pm$ 1.78
ANOVA <sup>b</sup> <i>p</i> -value		0.000	0.000	0.000
Flute	PTN	0.53 $\pm$ 0.05	0.44 $\pm$ 0.05	2.57 $\pm$ 0.21
	WOG	0.77 $\pm$ 0.06	0.66 $\pm$ 0.06	3.38 $\pm$ 0.46
	PTG	0.71 $\pm$ 0.09	0.65 $\pm$ 0.11	4.18 $\pm$ 0.42
ANOVA <sup>b</sup> <i>p</i> -value		0.005	0.001	0.000

Abbreviations: ANOVA, analysis of variance; NiTi, nickel titanium; PTG, ProTaper Gold; PTN, ProTaper Next; Sa, average surface roughness value; SD, standard deviation; Sq, root mean square roughness; Sz, peak to valley height; WOG, WaveOne Gold.

<sup>a</sup>The Sq, Sa, Sz were measured in micrometers ( $\mu\text{m}$ ).

<sup>b</sup>The significance level ( $p \leq 0.05$ ).

**Table 3** Multiple comparisons of the surface roughness parameters of blade and flute area among the tested groups before and after instrumentation

Time	Dependent variable	Group comparisons	Sig. <sup>a</sup> Sq ( $\mu\text{m}$ )	Sig. <sup>a</sup> Sa ( $\mu\text{m}$ )	Sig. <sup>a</sup> Sz ( $\mu\text{m}$ )
Before Instrumentation	Blade	PTN vs WOG	0.000	0.000	0.000
		PTN vs PTG	0.252	0.867	0.000
		WOG vs PTG	0.000	0.000	0.000
	Flute	PTN vs WOG	0.000	0.710	0.000
		PTN vs PTG	0.000	0.000	0.000
		WOG vs PTG	0.001	0.000	0.001
After Instrumentation	Blade	PTN vs WOG	0.000	0.000	0.000
		PTN vs PTG	0.285	0.113	0.012
		WOG vs PTG	0.000	0.000	0.000
	Flute	PTN vs WOG	0.169	0.293	0.485
		PTN vs PTG	0.003	0.001	0.000
		WOG vs PTG	0.177	0.029	0.000

Abbreviations: PTG, ProTaper Gold; PTN, ProTaper Next; Sa, average surface roughness value; Sq, root mean square roughness; Sz, peak to valley height; WOG, WaveOne Gold.

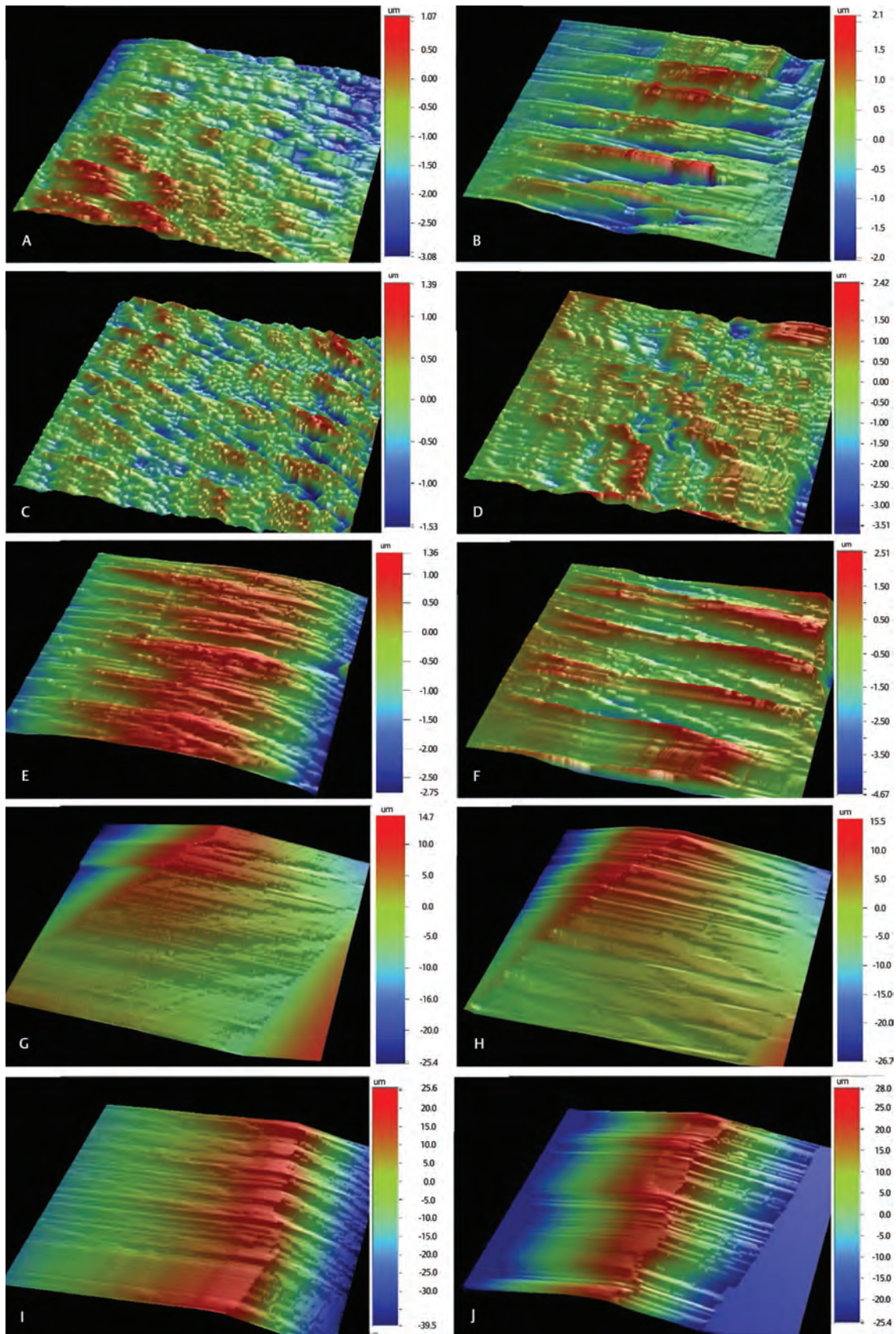
<sup>a</sup>Multiple comparisons by post-hoc Tukey HSD test ( $p \leq 0.05$ ).

**Table 4** Pair-wise comparison of surface roughness parameters before and after the instrumentation by paired-samples t-test

Location	NiTi instrument	Comparison of SR values before and after instrumentation <sup>a</sup>		
		Sq	Sa	Sz
Blade	PTN	0.012	0.031	0.051
	WOG	0.001	0.000	0.000
	PTG	0.116	0.049	0.008
Flute	PTN	0.006	0.036	0.001
	WOG	0.022	0.351	0.222
	PTG	0.006	0.036	0.001

Abbreviations: NiTi, nickel titanium; PTG, ProTaper Gold; PTN, ProTaper Next; Sa, average surface roughness value; Sq, root mean square roughness; SR, surface roughness; Sz, peak to valley height; WOG, WaveOne Gold.

<sup>a</sup>The comparison is significant at the  $p \leq 0.05$  level.



**Fig. 1** Qualitatively analysis demonstrating the impact of root canal instrumentation on surface topography of various nickel titanium instruments: (A) ProTaper Next (PTN [flute]) before instrumentation; (B) PTN (flute) after instrumentation; (C) WaveOne Gold (WOG [flute]) before instrumentation; (D) WOG (flute) after instrumentation; (E) ProTaper Gold (PTG [flute]) before instrumentation; (F) PTG (flute) after instrumentation; (G) PTN (blade) before instrumentation; (H) PTN (blade) after instrumentation; (I) WOG (blade) before instrumentation; (J) WOG (blade) after instrumentation.

recorded for WOG instruments for both cutting blade and flute areas. The differences in the SR values for the cutting blade of PTN and PTG were statistically insignificant. These findings are similar to a recent study<sup>12</sup> that reported higher SR of intact WO and WOG instruments compared with the Reciproc blue instruments. The SEM analysis of Reciproc and WO instruments' cutting blade also revealed presence of various irregularities on their surface before instrumentation.<sup>20</sup> Such differences in the preinstrumentation SR are associated with variable material properties' (such as hardness, strength) processing and finishing methods used by manufacturers during the fabrication of endodontic instruments.<sup>12</sup> For instance, heat treatment used during the manufacturing of certain endodontic instruments (such as WOG) may affect the NiTi surface properties. Firstov et al<sup>39</sup> reported the surface characterization of NiTi following heat treatment using various techniques including SEM, X-ray diffraction, thermogravimetry, X-ray photoelectron, and Raman spectroscopies. Additionally, the thermal processing (600–800°C) alters the surface characteristics of NiTi leading to a rougher or even porous surface.<sup>39</sup> The manufacturing of WOG files involves heating the alloy followed by gradual cooling down; <sup>40</sup> such heat treatments may affect the surface characteristics during instrumentation. The surface porosity of NiTi instrumentation may initiate the crack initiation and ultimately lead to the file fracture.<sup>41</sup> The AFM analysis of WOG showed a noticeable surface porosity following endodontic instrumentation making them prone to failure.<sup>42</sup> In addition, such properties may be due to compositional changes as the addition of gold to NiTi alloys reduces surface hardness and affects the associated properties.<sup>43</sup> Although WOG files are commonly used,<sup>42</sup> the potential changes in their surface characteristics following instrumentation cannot be overlooked.

In addition to the heat treatment, cold working of instruments (such as grinding, hammering) also affects the microstructure of the alloy by residual stresses in crystal grains and formation of various surface artifacts such as folds and pits.<sup>44</sup> The manufacturing of endodontic instruments by machining involves grinding of the alloy to get the desired shape and taper. The formation of surface features such as grooves and pits is unavoidable during grinding and machining of NiTi instruments.<sup>32</sup> The SR of the NiTi instruments particularly the cutting blade influences various mechanical properties related to the clinical performance during the endodontic instrumentation. By increasing the SR, friction between instrument and tooth increases, hence compromising the cutting efficiency, cyclic fatigue strength, and safety.<sup>32,33</sup> Therefore, such surface defects may potentially lead to the formation of stress concentration areas, crack propagation, and fracture during the clinical use.<sup>44,45</sup> The machining grooves and pits that are potential areas for stress concentration can be reduced by electropolishing of rotary file surfaces.<sup>44</sup>

In the present study, the postinstrumentation assessment revealed significant differences in the SR values of all instruments compared with the preinstrumentation SR. The highest SR values in the blade and flute sections were observed for WOG and PTG, respectively. A similar study by AlRahabi and

Atta<sup>12</sup> compared the SR of various NiTi instruments (Reciproc blue, Reciproc, WO, and WOG) before and after instrumentation. The results of the current study are in line with AlRahabi and Atta<sup>12</sup> as both studies reported an increase in the SR values following endodontic instrumentation. In addition, Özyürek et al<sup>42</sup> used AFM to compare the surface topography of WOG and WO and reported comparatively higher surface porosity values in WOG following instrumentation. Various factors that contributed to increasing the NiTi instruments' SR during endodontic working included mechanical or torsional stresses, friction with tooth structure, and chemical corrosion caused by root canal irrigators. For example, the canal enlargement prior to NiTi instrumentation reduces torsional stresses<sup>46</sup> thereby reducing the associated instrument wear and likelihood of crack formation. In the present study, to mimic the clinical conditions, a glide path was created by a stainless steel K-file (size#10) to reduce torsional stresses on NiTi instruments. In addition, NiTi instrumentation was performed using sodium hypochlorite irrigator (3%: ~5 mL for each canal). Irrigating solutions affect the surface and enhance the SR of NiTi instruments.<sup>42</sup> Fayyad and Mahran<sup>47</sup> used AFM to investigate the effects of immersing NiTi in different irrigating solutions. It was reported that 5.25% sodium hypochlorite increased the SR of various NiTi instruments.<sup>47</sup> The corrosion resistance of NiTi instruments can be enhanced by various surface treatments such as coating a layer of titanium oxide.<sup>48</sup> The qualitative analysis of intact instruments showed minor surface grooves (→ Fig. 1A, C, E, G, I) even before endodontic instrumentation. The formation of surface features such as grooves and pits is attributed to machining and grinding of NiTi instruments while yielding desired shape and taper. Therefore, the formation of surface features on NiTi endodontic instruments is unavoidable.<sup>32</sup> In addition, the qualitative analysis confirmed an increase in the SR and wear of all NiTi instrument following root canal instrumentation mainly due to the formation of pits and microcavities. However, there was no evidence of crack formation or crack propagation in any of the NiTi instruments due to their better cyclic fatigue resistance. The PTN and PTG instruments are manufactured by micro-milling and getting heat treatment.<sup>49</sup> The sizes and tapers of PTG are similar to that of ProTaper Universal; however, the flexibility and cyclic fatigue resistance are improved corresponding to the Gold thermal treatment.<sup>16</sup> The PTN instruments having martensitic phase at room temperature<sup>50</sup> are flexible and better resistant to fatigue fracture.<sup>51</sup> Although these findings suggested the safety of using NiTi instruments for the root canal instrumentation of up to four canals, varying factors such as torque, canal curvature, angulation, and mechanical stress may have a different outcome.

The present study is the first one to compare the profilometry of PTN, WOG, and PTG rotary instruments at the microscale. It was observed that using NiTi files for the instrumentation of up to four root canals produced no remarkable grooves or cracks on their surface. There are certain limitations; the present study used a contact-mode stylus profiler (stylus diameter of 400 nm); thus, the stylus cannot accurately scan any fine grooves that are less than 400 nm. Therefore, further investigations using advanced research techniques such as AFM or white-light

interferometry would provide additional information about SR at a nanoscale. In terms of endodontics prospective, although the endodontic instrumentation was simulated using natural teeth and irrigation solutions, factors such as inadequate access and angle of instrumentation may alter the mechanical stresses on NiTi instruments. Clinically, the root canals may have a wide range of morphological variations in terms of canal configuration<sup>52</sup> that may influence the mechanical stresses during instrumentation and surface wear. The present study investigated the effects of endodontic instrumentation on NiTi files while using molars of specific curvature (20–40 degrees) under extra-oral access. The effects of endodontic instrumentation in terms of surface chemistry of NiTi files were not addressed in this study. The elemental analysis may provide useful information regarding changes in the NiTi surface chemistry in response to exposure to irrigators and mechanical stresses. Therefore, future *in vitro* and clinical studies investigating a wide range of mentioned variable affecting the endodontic instrumentation are required to validate the findings reported in the present study.

## Conclusions

The surface profilometry revealed variations in the SR parameters of intact PTN, WOG, and PTG NiTi files. Although the SR of all NiTi files investigated in the present study was increased following the endodontic instrumentation of four root canals, there were no signs of any fracture or visible defect formation advocating their safe use.

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### Conflicts of Interest

None declared.

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