

Research Article



The effect of root canal preparation on the surface roughness of WaveOne and WaveOne Gold files: atomic force microscopy study

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

Conceptualization: Özyürek T, Yılmaz K, Uslu G, Plotino G; Data curation: Plotino G; Formal analysis: Özyürek T; Funding acquisition: Özyürek T, Yılmaz K, Uslu G, Plotino G; Investigation: Plotino G; Methodology: Özyürek T, Uslu G; Project administration: Özyürek T; Resources: Özyürek T, Yılmaz K, Uslu G, Plotino G; Software: Yılmaz K; Supervision: Özyürek T, Plotino G; Validation: Plotino G; Visualization: Yılmaz K, Uslu G; Writing - original draft: Yılmaz K, Uslu G; Writing - review & editing: Özyürek T, Plotino G.

ABSTRACT

Objectives: To examine the surface topography of intact WaveOne (WO; Dentsply Sirona Endodontics) and WaveOne Gold (WOG; Dentsply Sirona Endodontics) nickel-titanium rotary files and to evaluate the presence of alterations to the surface topography after root canal preparations of severely curved root canals in molar teeth.

Materials and Methods: Forty-eight severely curved canals of extracted molar teeth were divided into 2 groups ($n = 24$ /each group). In group 1, the canals were prepared using WO and in group 2, the canals were prepared using WOG files. After the preparation of 3 root canals, instruments were subjected to atomic force microscopy analysis. Average roughness and root mean square values were chosen to investigate the surface features of endodontic files. The data was analyzed using one-way analysis of variance and *post hoc* Tamhane's tests at 5% significant level.



Results: The surface roughness values of WO and WOG files significantly changed after use in root canals ($p < 0.05$). The used WOG files exhibited higher surface roughness change when compared with the used WO files ($p < 0.05$).

Conclusions: Using WO and WOG Primary files in 3 root canals affected the surface topography of the files. After being used in root canals, the WOG files showed a higher level of surface porosity value than the WO files.

Keywords: Atomic force microscopy; Nickel-titanium; Usage; WaveOne; WaveOne Gold

INTRODUCTION

Although nickel-titanium (NiTi) files are reported to be more flexible and have better mechanical properties than stainless-steel files [1], they can fracture while being used in root canal preparations [2]. New alloys, different horizontal cross-section designs and different movements have been introduced to increase the fracture resistance of NiTi files during clinical use [3-5]. A reciprocating motion may effectively increase the cyclic fatigue life of endodontic mechanical instruments [6,7]. Besides that, NiTi alloys manufactured with specific thermal treatments have also improved the mechanical properties of endodontic files [8,9].

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The WaveOne (WO; Dentsply Sirona Endodontics, Ballaigues, Switzerland) NiTi rotary file, which was introduced in 2011, is a file system that uses a reciprocating motion for the preparation of root canals and is made of M-wire alloy. Recently, WO NiTi files were upgraded to WaveOne Gold (WOG; Dentsply Sirona Endodontics) NiTi files. The WOG files were also designed to be used with a reciprocating movement, while the geometry and dimensions of the instrument were modified. Moreover, the proprietary gold metal treatment, which offers higher flexibility than M-wire alloy, was used [10,11].

The usage of NiTi files decreases file's cyclic fatigue resistance [12,13]. Moreover, root canal preparation has been reported to cause wear and deformation of NiTi files [14,15]. To date, the surfaces of NiTi files have been examined using various methods. While a scanning electron microscope (SEM) has frequently been used for examining the surface features of NiTi files, atomic force microscopy (AFM) is also recommended to examine the topographic features of files used in endodontics. Unlike the SEM, AFM does not require any sample preparation to examine the surface topography, so that 3-dimensional (3D) surface images of the specimens can be obtained with a variety of conditions under high spatial resolution [16]. The working principle of an AFM is to probe a sample surface by using a tip connected to a flexible lever. Determining the forces in the interaction between the tip and sample surface provides qualitative and quantitative information about the sample topography [17].

To date, there is no study that compares the surface topography of WO and WOG NiTi files before and after root canal preparation. Therefore, the aims of the present study were to examine the surface topography of intact WO and WOG NiTi rotary files and to evaluate the presence of alterations to the surface topography after root canal preparations of severely curved root canals in molar teeth. The null hypotheses tested were that 1) There would be no difference between the surface topography of WO and WOG files before root canal preparation, 2) The root canal preparation would not affect the surface topographies of WO and WOG files, and 3) There would be no difference between the surface topographies of WO and WOG files after root canal preparation.

MATERIALS AND METHODS

Based on a previous study [18], a power calculation was performed using G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany) by selecting the Wilcoxon-Mann-Whitney *U* test of the *F* tests family. The alpha-type error of 0.05, a beta power of 0.95, and a ratio N_2/N_1 of 1 were also stipulated. The calculation indicated that the sample size for each group must be a minimum of 8 files. Thus, 8 WO and 8 WOG files were included in the present study. The files were examined under a stereomicroscope (Olympus BX43, Olympus Co., Tokyo, Japan) at $\times 20$ magnification to detect any defects and deformities. As none were detected, all the files were included in the study. The same areas on the surfaces of the files were analysed before and after the root canal preparation.

Root canal instrumentation

Forty-eight severely curved mesial canals of extracted lower mandibular molar teeth, with angles of curvature ranging between 50° and 70° were used [19]. To determine the root canal curvature, mesiodistal and buccolingual radiographs were taken by parallel technique. Only roots with a fully developed apex, having no internal or external resorption, were included in

the present study. The working length (WL) was determined by measuring the length of a size 10 K-file (Dentsply Sirona Endodontics) just visible at the apical foramen. The teeth in which have canals that the size 10 K-file could not reach the WL were excluded from the study.

Eight WO Primary (25/0.08) and 8 WOG Primary (25/0.07) files were used to prepare the canals. All the files were used to prepare 3 severely curved canals, according to the manufacturer recommendations, using the 'WaveOne ALL' program on a Reciproc Gold endodontic motor (VDW, Munich, Germany).

After every third pecking motion, the root canals were irrigated with 1 mL of 2.5% sodium hypochlorite, recapitulated with a size 10 K-file, and irrigated with 1 mL of 2.5% sodium hypochlorite again. A total of 20 mL of 2.5% sodium hypochlorite was used in each sample. After the preparation of the root canals, the instruments were thoroughly rinsed with 5 mL of distilled water. The files were then dried with a soft cotton swab and ultrasonically cleaned. All the procedures were performed by an endodontist with 5 years of experience.

Surface evaluation

The files used were examined under AFM (NT-MDT, NTEGRA Solaris, Moscow, Russia). A gold-doped silicon tip (40 μm) with resistivity of 0.01–0.025 $\Omega\text{-cm}$ was used in the non-contact mode. Changes in the vertical position of the silicon tip provided the height of the images and registered as bright and dark regions. A constant tip sample 'tap' was supplied by using a constant oscillation amplitude (set-point amplitude). Digital images (5 \times 5 μm in size) were obtained for each surface and recorded at a slow scan rate (1 Hz). Average roughness (Ra) and root mean square (RMS) values were selected to investigate the surface features of endodontic files. Ra and RMS values indicated changes in vertical surface topography. An increase in values meant alterations of the NiTi instruments' surfaces after root canal preparation.

Statistical analyses

The data were firstly analysed using the Shapiro-Wilk test to verify the assumption of normality. One-way analysis of variance and *post hoc* Tamhane's tests were performed to statistically analyse the data using SPSS 21.0 (IBM-SPSS Inc., Chicago, IL, USA) software. The statistical significance level was set at 5%.

RESULTS

The mean and standard deviations of the Ra and RMS values of the files are shown in **Table 1**. The lowest Ra and RMS values were observed in intact WO and WOG files. The statistical analyses showed that there was no significant difference in surface roughness values between intact WO and WOG files. The surface roughness values of WO and WOG files statistically changed after use in root canals ($p < 0.05$). The used WOG files exhibited higher surface

Table 1. Means and standard deviations of root mean square (RMS) and average roughness (Ra) of intact and used WaveOne and WaveOne Gold files

Variables	WaveOne		WaveOne Gold		p value
	Intact	Used	Intact	Used	
RMS	47.46 \pm 5.69 ^a	68.40 \pm 9.57 ^b	46.39 \pm 6.55 ^a	93.40 \pm 13.11 ^c	< 0.05
Ra	39.03 \pm 5.46 ^a	60.55 \pm 7.87 ^b	35.63 \pm 3.85 ^a	74.24 \pm 11.13 ^c	< 0.05

Different superscript letters indicate statistically significance difference at 5% level.

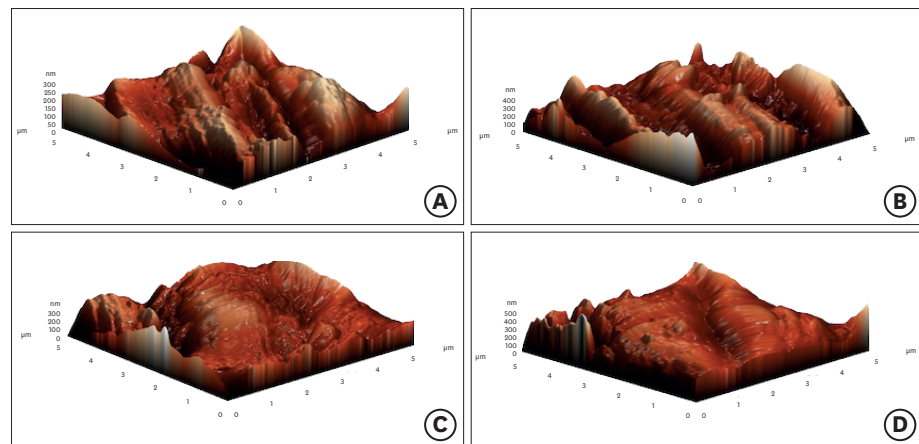


Figure 1. Three-dimensional atomic force microscopy (AFM) image of WaveOne and WaveOne Gold instruments. (A) Intact WaveOne; (B) intact WaveOne Gold; (C) used WaveOne; (D) used WaveOne Gold.

roughness change when compared with the used WO files ($p < 0.05$). The 3D images of intact and used WO and WOG Primary files are shown in **Figure 1**. The images show an increase in the surface roughness of the files after use.

DISCUSSION

The inspection of files is not considered a reliable method for assessing used files since NiTi rotary files may fracture during clinic use, within the limits of elasticity, and without any prior permanent deformation sign [20,21]. It has been shown that invisible surficial defects and cracks play a significant role in instrument fractures [22]. It is also known that surface porosity of NiTi rotary files may cause fractures during clinic use, especially in curved canals [23]. Understanding surficial feature changes of files after their use in root canals greatly informs about the clinical uses of these files.

Both SEMs and AFMs have been widely used to examine changes in the surface features of rotary files after their use [24-26]. SEMs provide 2D topographic images of samples, making quantitative examination impossible. However, AFMs offer 3D images, making it possible to obtain quantitative data [27]. For this reason, an AFM was used in the present study to perform both qualitative and quantitative analyses of the surface features of the used files.

In previous similar studies, both artificial canals made by acrylic teeth and canals of permanent teeth were used [22,24,28]. The use of artificial canals might be preferred to minimize variation caused by natural teeth and to ensure standardization of root canal diameter, length, and curvature in terms of angle and radius [29]. On the other hand, the hardness values of artificial canals made of acrylic are not the same as those natural teeth [30]. It has also been reported that heat preparation may cause acrylic material to melt and accumulate in grooves [31]. Care has been taken visually and radiographically to standardize the teeth to be used so that they do not have any anomalies, but the 2 extracted natural teeth never be identical and have differences in regard to the calcification, hardness, and other features [32]. Nevertheless, in the present study, the use of root canals of natural teeth was preferred to better represent clinic conditions. The determination of root canals curvature was based on Kosti *et al.*'s study [19].

The manufacturer of WO and WOG files recommends the files to be single used. Single-use of the file does not mean that the file would only be used in a single canal; a single-use file can be used in a molar tooth having 3–4 canals. For this reason, based on the root canal preparation of a molar tooth, each of the files tested were used in 3 canals. Although different results were obtained in studies carried out on the effects of sodium hypochlorite (NaOCl) solution on files [33], the preparation of root canals is not possible without this component. For this reason, in the present study, NaOCl was used in the irrigation of root canals.

According to the results obtained from the present study, no difference was found in the surface porosity values of unused WO and WOG files. For this reason, the first hypothesis of present study was accepted. Ra and RMS values of unused files indicated that they have surface irregularities originating from production. These results are like those reported in studies suggesting that the production of NiTi files causes surface irregularities, grinding grooves, cavities, and cracks on the file [17,25,34].

Pirani *et al.* [35] analysed Reciproc (VDW) and WO files after use in 3 canals, and reported an increase in surface porosity values in the apical segments of the files. Similarly, Inan *et al.* [24] reported an increase in surface porosity values, measured using an AFM, of ProTaper Universal files (Dentsply Sirona Endodontics) that were used in mandibular molar teeth 5 times. Fatma and Ozgur [28] used an AFM to examine the surface porosity values of WO Primary, Reciproc R25, and ProTaper Universal F2 files that were used in one artificial canal, and reported an increase in surface porosity values of WO files. Türker *et al.* [25] also reported an increase in surface porosity values of WO files used in 3 canals. After using the files in artificial canals, Ferreira *et al.* [34] reported an increase of surface porosity values of WO Primary files using a 3D profilometer. Similarly, in the present study, significant increases were observed in the surface porosity values of WO and WOG files after their use in the root canal preparation of 3 severely curved root canals in molars. For this reason, the second hypothesis of the present study was rejected.

When the files used in the present study were compared after the preparation, WOG files were found to have higher RMS and Ra values than WO files. For this reason, the third hypothesis of the present study was also rejected. The higher level of surface porosity observed in the WOG files after use suggests that the files are more prone to the deterioration of surface features than the WO files. It has been known that changes in the surface porosity of NiTi rotary files are important for crack initiation which can lead to file breakage [23]; Although WOG files have been shown to have superior mechanical properties in comparison to WO files [11,36-38], the differences in the surface topography of the used files, found in the present study, cannot be ignored. These differences might be related to the different metal alloys, confirming the tendency for the gold metal treatment to make the file surface 'softer', an observation already reported in a previous study [39].

In addition, irrigating solutions can also cause increase in surface roughness of NiTi rotary files. Surface treatments which improve the NiTi file surface topography [40] and titanium oxide layer (TiO₂) can improve the NiTi files corrosion behavior [41]. In a study that compares changes in the surface roughness of the conventional and M-wire NiTi files after immersion in irrigating solutions, M-wire instruments were reported to be more resistant to NaOCl action than conventional NiTi files [18]. This difference was attributed to the difference in type of alloy and production process rather than the NaOCl itself. It was reported by the authors that the resistance of the M-wire files to wear may be due to the

higher wear resistance and surface stiffness of M-wire. WOG files are manufactured with a gold heat treatment procedure, which is executed manually by heating the file and then cooling slowly, in contrast to the premanufacturing heat treatment of WO files (M-wire) [38]. This different production process may affect the surface characteristics of the NiTi files in a different manner. The changes in the TiO₂ layer on the surface by production process and resulting changes in the surface properties of the files should be examined by elemental analysis, which may explain the result of the present study in more detail.

CONCLUSIONS

Within the limitations of the present study, using WO and WOG Primary files in 3 root canals affected the surface topography of the files. After being used in root canals, the WOG files showed higher level of surface porosity values than the WO files.

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