ORIGINAL ARTICLE

Evaluation of surface characteristics of rotary nickel-titanium instruments produced by different manufacturing methods

U Inan, M Gurel

Department of Endodontics, Faculty of Dentistry, 19 Mayis University, Samsun, Turkey

Abstract

Background: Instrument fracture is a serious concern in endodontic practice.
Objective: The aim of this study was to investigate the surface quality of new and used rotary nickel-titanium (NiTi) instruments manufactured by the traditional grinding process and twisting methods.
Materials and Methods: Total 16 instruments of two rotary NiTi systems were used in this study. Eight Twisted Files (TF) (SybronEndo, Orange, CA, USA) and 8 Mtwo (VDW, Munich, Germany) instruments were evaluated. New and used of 4 experimental groups were evaluated using an atomic force microscopy (AFM). New and used instruments were analyzed on 3 points along a 3 mm. section at the tip of the instrument. Quantitative measurements according to the topographical deviations were recorded. The data were statistically analyzed with paired samples *t*-test and independent samples *t*-test.
Results: Mean root mean square (RMS) values for new and used TF 25.06 files were 10.70 ± 2.80 nm and 21.58 ± 6.42 nm, respectively, and the difference between them was statistically significant ($P < 0.05$). Mean RMS values for new and used Mtwo 25.06 files were 24.16 ± 9.30 nm and 39.15 ± 16.20 nm respectively, the difference between them also was statistically significant ($P < 0.05$).
Conclusion: According to the AFM analysis, instruments produced by twisting method (TF 25.06) had better surface quality than the instruments produced by traditional grinding process (Mtwo 25.06 files).

Key words: Atomic force microscopy, endodontics, fracture, nickel-titanium

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Introduction

Rotary nickel-titanium (NiTi) instruments were introduced to endodontics in 1988 to overcome the disadvantages of stainless steel instruments.[1] NiTi instruments are more flexible and more resistant to cyclic fatigue and have substantially reduced the incidence of several clinical problems such as blocks, ledges, and transportation.[2] Despite these advantages, a major concern with the use of rotary NiTi instruments is instrument fracture.[3,4] Fracture of instruments can occur with or without any visible defects of previous permanent deformation.[5]

Traditionally, rotary NiTi instruments are manufactured by a grinding process. During this manufacturing technology, a considerable amount of work-hardening takes place on the

Address for correspondence:
Dr. U Inan,
Department of Endodontics, Faculty of Dentistry,
19 Mayis University, Samsun, Turkey.
E-mail: ugurinan@omu.edu.tr

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surface; machining grooves or marks are also produced.[6] These defects on the instrument surface can act as local stress raisers that may become the origin of fatigue crack and make the instruments more vulnerable to fracture.[7] For this reason, manufacturers tried to enhance the surface smoothness of the instruments expecting to inhibit the crack initiation process and improve the fatigue resistance by using electropolishing method.[8] Furthermore, new manufacturing methods have been developed to give the instruments greater flexibility and more resistance to cyclic fatigue than those made with conventionally processed NiTi wires.[9]

Twisted Files (TF) (SybronEndo, Orange, CA, USA), were produced using a new manufacturing process. TF instruments are manufactured using a raw NiTi wire in austenite form that transforms into R-Phase by a process of heating and cooling. In the R-Phase, NiTi can be twisted and converted back to an austenite structure by heating and cooling again.[10] According to the manufacturer, TF are superior to instruments manufactured by the traditional method due to cyclic fatigue resistance, and flexibility.

Surface morphology of NiTi files has usually been investigated with scanning electron microscope (SEM).[11-13] On the other hand, atomic force microscopy (AFM) is a nondestructive practical method for evaluating endodontic file surface in a quantitative way.[14,15] By using AFM, the sample surface is probed with a small tip attached to a flexible cantilever and the tip is in constant contact with the sample. This constant contact mode has the advantage of tracking the surface topography very well even with large variations in height.[16]

The purpose of this study was to investigate the surface quality of new and used rotary NiTi instruments manufactured by the traditional grinding process and twisting methods.

Materials and Methods

In this study, a total of 8 TF (SybronEndo, Orange, CA, USA) and 8 Mtwo (VDW, Munich, Germany) instruments were evaluated. Two groups of each instrument type were analyzed: New and used of 4 experimental groups were evaluated.

Size 25.06 of new TF and Mtwo instruments were collected for the study. Furthermore, 4 sets of TF and Mtwo instruments were used to shape mandibular first molar teeth of two patients in routine clinical use. Preparations were made by an expert operator. Periapical radiograph of each tooth was taken to evaluate its anatomical condition, canal curvature, and its approximate length. The instruments were used with X-Smart Device (Dentsply Maillefer, Ballaigues, Switzerland) with 16:1 reduction rotary handpiece X-Smart contra angle; the speed of rotation was maintained at 300 rpm for Mtwo instruments and 500 rpm for TF instruments. Both rotary NiTi systems were used according to the manufacturers' recommendations.

After preparation of access cavity, root canals were negotiated with #10 K-Files (Dentsply Maillefer), and working length (WL) was determined with an apex locator (Root ZX Mini, J Morita Corp., Kyoto, Japan). The WL was also confirmed using radiography. For Mtwo rotary system, all instruments were used at the full WL starting from #10.04 to #40.04. For TF rotary NiTi system, posterior set (25.08, 25.06 and 30.06) was used. Preparation started with a #25.08 TF file which was used at 2/3 WL, and then #25.06 and #30.06 instruments were used at the full WL. 5.25% sodium hypochlorite (NaOCl) solution was used as irrigation solution between each file size.

The instruments were ultrasonically cleaned and sterilized in an autoclave for 18 min at 134°C before use on another patient and #25.06 instruments of both Mtwo and TF systems were collected for AFM analysis. Used and new files were attached to metal holders with double sided tape and each sample was placed on the AFM and analyzed on 3 points along a 3-mm section at the tip of the file. AFM images were recorded by using the contact mode operation using a SiN tip (Model NP-S) on a SPM Nanoscope IV (Veeco, Santa Barbara, CA, USA). AFM probe (curvature radius 10 nm) mounted on a three-dimensional (3D) cantilevers with force constant 35/Nm were used. Scanned areas were uniform squares (5 μm × 5 μm). 3D AFM images were processed with Nanoscope 6.13 Software(Veeco, Santa Barbara, CA, USA) and quantitative measurements according to topographic deviations (root mean square [RMS]) were collected. The data were statistically analyzed with paired samples *t*-test and independent samples *t*-test using IBM SPSS version 21 (SPSS Inc., Chicago, IL, USA).

Results

Three-dimensional AFM images of the used and new TF and Mtwo rotary NiTi files are shown in Figures 1 and 2. Mean RMS values for new and used TF 25.06 files were 10.70 ± 2.80 nm and 21.58 ± 6.42 nm, respectively, and the difference between them was statistically significant ($P < 0.05$). Mean RMS values for new

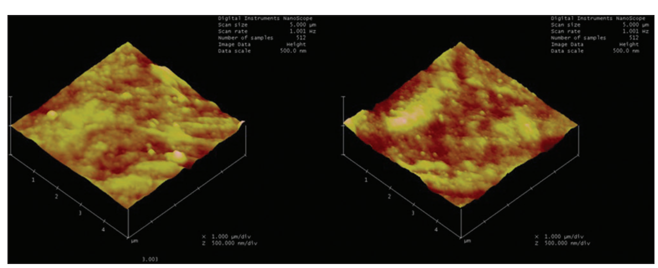

Figure 1: Three-dimensional atomic force microscopy images of new and used Twisted Files 25.06 instruments

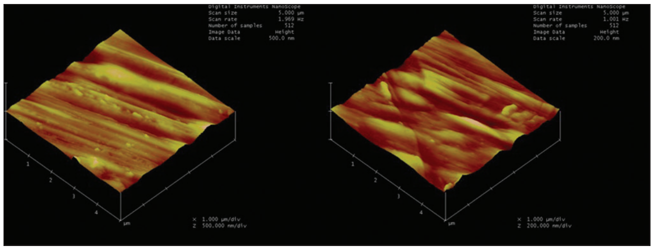

Figure 2: Three-dimensional atomic force microscopy images of new and used Mtwo 25.06 instruments

and used Mtwo 25.06 files were 24.16 ± 9.30 nm and 39.15 ± 16.20 nm, respectively, the difference between them also was statistically significant ($P < 0.05$).

We also compared the topographic irregularities of new and used Mtwo 25.06 and TF 25.06 files. According to the RMS values, new TF 25.06 files had better surface quality than the Mtwo 25.06 files and the difference was statistically significant ($P < 0.05$). RMS values of used Mtwo 25.06 files were much higher than the TF 25.06 files (39.15 nm vs. 21.58 nm) which mean that used Mtwo files showed more deterioration.

Discussion

Instrument separation is a serious concern in endodontics. While stainless-steel instruments usually show deformations before separation, fracture of NiTi instruments can occur without any signs of previous permanent deformation.[11,17] In this study, the authors aimed to evaluate the surface quality of new and used rotary NiTi instruments produced by different manufacturing methods and the null hypothesis of the study was that there was no difference in the surface characteristics of the instruments made from conventional NiTi and R-Phase NiTi alloy.

Instrument design and their structural characteristics have a definite influence on the susceptibility of instrument fracture.[18-20] As a result of this, manufacturers tried to improve physical and mechanical properties of the instruments by modifications in cross-sectional designs, instrument tip design, helix angle and dimensions of the instrument center.[21] Furthermore, new manufacturing techniques like R-Phase technology have been developed to improve the surface quality of the NiTi instruments.[22] It was claimed that the manufacturing process can significantly improve fracture resistance by reducing surface defects.[7,9]

Tripi *et al.*,[11] compared the defects in GT rotary instruments before and after usage and reported that there were metal strips and debris on new instruments. Significant changes were observed before and after usage in the presence of surface defects such as pitting, scraping, and debris. Kuhn *et al.*,[18] observed a high incidence of surface defects (especially machining marks) on the instruments and concluded that was an important factor on instrument fracture. Alapati *et al.*,[13] also reported the presence of surface defects and flaws on the instruments after usage and there were adheration of tooth structure deposits to the instruments. These results were consistent with our results, and in our study new instruments showed better surface quality than the used ones for both NiTi systems.

Scanning electron microscope has been widely used to compare the surface characteristics of new and used NiTi instruments previously.[11-13] In the last decade, AFM was introduced to endodontics to provide quantitative and qualitative data about the topography of endodontic materials.[14,15,23-26] In AFM, a small tip coupled to a cantilever acts as a probe to scan the sample surface and this process produce a 3D image of the surface.[24] The great advantage of AFM is that no sample preparation such as fixation, dehydration, and coating is necessary as in SEM. AFM operates in various environments as well in air as in liquid and also no vacuum environment is needed.[16] Some recent studies recommended AFM for the evaluation of NiTi instrument surfaces.[14,15,27] However, there are some disadvantages of AFM such as slow scan speed which results in small sample sizes when compared with SEM analysis.

Literature review revealed only a few studies comparing the surface quality of rotary NiTi instruments using AFM.[14,24,26] Inan *et al.*,[14] compared the surface quality of new and used ProTaper files and found that used instruments showed more surface deformation and wear. Yamazaki-Arasaki *et al.*,[24] compared 4 brands of rotary NiTi instruments and reported that TF instruments showed the less wear when compared with K3, BioRaCe, and ProTaper. This was expected as the analyzed instruments were used 12 times which were far more than the recommended number of use. Our results were in accordance with these studies in which used files showed much more deterioration.

We also compared the surface quality of new TF and Mtwo instruments and found that mean RMS values of TF instruments were significantly less than unused Mtwo instruments which means that TF instruments had a better surface quality. This might be a result of R-Phase technology in which instruments were twisted rather than machined. Chianello *et al.*,[28] compared the surface quality of 5 brands of new rotary NiTi instruments with SEM and reported that all instruments showed a few types of surface defects. Currently, there is only one AFM study comparing the surface quality of TF instruments, reporting that TF instruments had better surface quality than the conventional NiTi instruments (K3 and ProTaper).[24]

Conclusion

The results of the present study showed that instruments produced by R-Phase technology (TF) had better surface quality than the conventionally machined instruments. TF instruments also presented less deterioration than Mtwo instruments after clinical use.

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Conflicts of interest

There are no conflicts of interest.

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