Evaluation of the Surface Characteristics of Used and New ProTaper Instruments: An Atomic Force Microscopy Study

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Abstract

The purpose of this study was to evaluate the topography of new and used ProTaper rotary nickel-titanium (NiTi) instruments by using atomic force microscope. Four new and four used size S1, S2, F1, and F2 instruments were selected for this study. New and used instruments were analyzed on 11 points along a 3-mm section at the tip of the instrument. Quantitative measurements according to the topographic deviations (root mean square) were recorded. Data were analyzed by paired samples *t* test. Mean root mean square values for used ProTaper instruments were higher than the new ones, and the difference between them was statistically significant. The results of this study showed that used ProTaper instruments demonstrated more surface deformation and wear. *(J Endod 2007;33:1334–1337)*

Key Words

Atomic force microscopy, clinical use, NiTi rotary instruments

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Although successful root canal treatment depends on many factors, preparation is one of the most important steps because it determines the efficacy of all subsequent procedures (1). However, root canal preparation is a challenge, particularly in narrow, curved canals.

Nickel-titanium (NiTi) endodontic instruments have gained great popularity in endodontics because of their superelasticity. Since early 1990s, several such instruments have been introduced into endodontic practice. The specific design characteristics of those instruments vary, such as tip sizing, taper, cross-section helix angle, and pitch (2). A major concern with the use of NiTi engine-driven rotary instruments is fracture (3). A number of studies have been performed regarding instrument fracture (4–7). In these studies it has been reported that clinical use significantly reduced cyclic fatigue resistance of the rotary NiTi instruments. Particularly, they have been reported to undergo fracture without any warning signs, ie, a fracture can occur without any visible defects or previous deformation (8). Martins et al (9) reported that the majority of deformations on the instruments could only be observed by scanning electron microscopy (SEM) with high magnification.

ProTaper NiTi instruments (Dentsply Maillefer, Ballaigues, Switzerland) have been developed to facilitate instrumentation of difficult and severely curved canals. ProTaper instruments have varying percentage tapers over the length of cutting blades (10). According to the manufacturer, progressively tapered instrument system reduces instrument fatigue and potential for breakage.

Cracks that arise from superficial defects play a role in instrument fracture, illustrating the importance of surface quality (11). Several studies have investigated the surface quality of NiTi instruments by using SEM (8, 11–14). On the other hand, atomic force microscopy (AFM) is becoming increasingly popular in the biologic community, because it offers unique possibilities (15). In AFM, the sample surface is probed with a sharp tip attached to a flexible cantilever that deflects in z-direction as a result of the surface topography during tip scanning over the sample surface. A photodiode detects the deflection of the cantilever through a laser beam focused on and reflected from the rear of the cantilever. A computer processes the electrical differential signal of the photodiode obtained from each point of the surface and generates a feedback signal for the piezoscanner to maintain a constant force on the tip. This information is finally transferred into a topographic image of the surface (16).

The purpose of this study was to investigate the surface quality of new and used ProTaper rotary NiTi instruments by using AFM.

Materials and Methods

Total of 8 ProTaper instruments were analyzed. Four new and four used S1, S2, F1, and F2 instruments were selected for this study.

The ProTaper NiTi instruments were used in mesial canals of mandibular first molar teeth of 5 patients. Preparations were made by an expert operator. The instruments were used with X-Smart Device (Dentsply Maillefer) with 16:1 reduction rotary handpiece X-Smart Contra-angle (Dentsply Maillefer); the speed of rotation was maintained at 250 rpm. ProTaper files were used according to the manufacturer's recommendations. Briefly, the pulp chamber was filled with 2.5% sodium hypochloride (NaOCl) solution, and S1 file was taken into the canal just short of the depth. Then the canal was reirrigated, and the auxiliary SX file

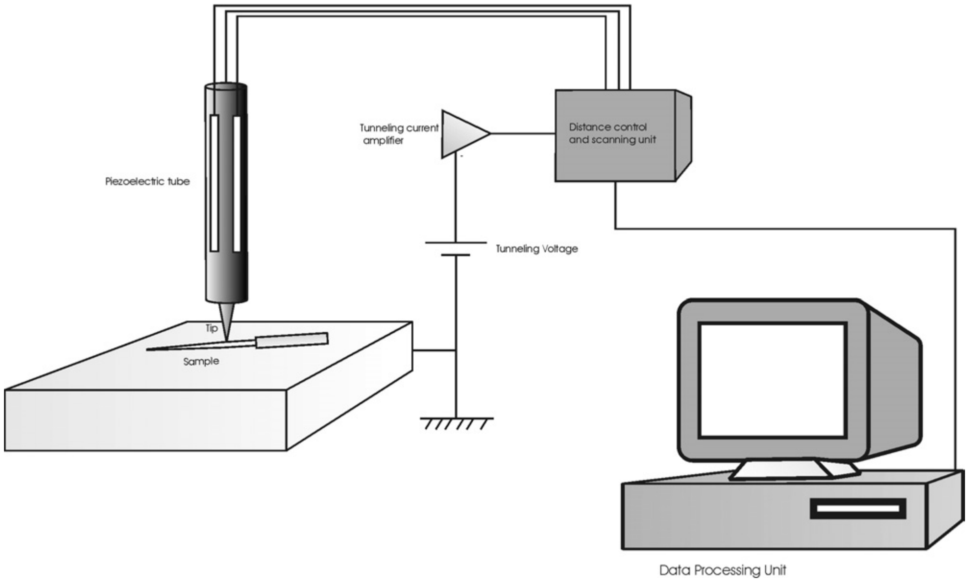

Figure 1. Schematic representation of the operating principle of VT/STM AFM.

was used to move the coronal aspect of the canal away from furcal danger and to improve radicular access. Shaping with the auxiliary SX was continued with brushing motion until two thirds of its cutting blades were below the orifice. The canal was irrigated, and a size 10 K-file (Dentsply Maillefer) was used for recapitulation. Preparation continued with S1, S2, F1, and F2 files to working length. The preparation was completed with F2 file. The instruments were ultrasonically cleaned and sterilized in an autoclave for 18 minutes at 134°C before use on another patient and before AFM analysis after use for 5 times.

Used and new files were attached to metal holders by using a rapid-setting cyanoacrylate glue. Each sample was placed on the AFM and analyzed on 11 points along a 3-mm section at the tip of the file. AFM images were recorded by using the needle mode operation on an Omicron VT/STM AFM (Omicron NanoTechnology GmbH, Taunusstein, Germany) (Fig. 1). The measurements were carried out at room temperature and atmospheric pressure with 1 μm/s speed scan. Scanned areas were perfect squares (1 μm $\times$ 1 μm). Three-dimensional AFM images (400 $\times$ 400 lines) were processed with Scala Pro 5.0 software (Omicron NanoTechnology GmbH) and quantitative measurements according to topographic deviations (root mean square values [RMS]) were recorded. The data were statistically analyzed with paired samples *t* test.

Results

To evaluate the surface qualities of ProTaper instruments, we obtained three-dimensional AFM images of new and used instruments (Fig. 2). According to our measurements, the mean RMS values of used ProTaper instruments were higher than the mean RMS values of new ones, and the observed differences were statistically significant (Table 1). RMS values of used finishing files were significantly higher than the used shaping files ($P < .001$).

Discussion

Instruments typically fracture in 2 different ways. In one case, the instrument shows visible defects including unwinding, reverse winding, reverse winding with tightening of the spirals, or a combination of these defects. These visible defects lead to the instrument's torsional fracture or flexural fatigue. In the other case, the fracture occurs without any visible accompanying defects (3). Sattapan et al (3) evaluated defects in rotary NiTi instruments after clinical use and found no visible defects in 50.8% of the instruments. Martins et al (9) detected irregularities that were randomly distributed along the length of the instruments, and the majority of the irregularities could only be observed by SEM with high magnification.

Literature search revealed no studies comparing the surface deformations of new and used instruments through the use of AFM. The surface quality has usually been evaluated with SEM in previous studies (7, 8, 12, 14, 17, 18). Tripi et al (8) compared the defects in GT rotary instruments after use and reported significant changes before and after usage in the presence of pitting and scraping. Svec and Powers (12) evaluated ProFile instruments and observed signs of deterioration even after one use. The deterioration was of the pitting or the flaking type and was an example of surface fatigue wear. Troian et al (14) reported that spiral distortion and surface wear increased for RaCe instruments as the number of uses increased. More recently, Wei et al (7) evaluated ProTaper instruments under SEM and reported defects including surface cracks, distorted machine grooves, pitting, and microcracks. They also reported that if these instruments had been used further, separation and file breakage would have occurred. In our study, RMS values were used to obtain quantitative data, and higher RMS values of used instruments reflected surface wear, deformation, and deterioration that might lead to flexural failure.

It has been reported that the distribution of stress in the ProTaper system was more regular and uniform than in the ProFile system (19). Because of the lower and equally distributed stress, it has been reported that ProTaper instruments might be less likely to become permanently deformed but are more likely to fail as a result of fatigue of the instruments without a warning sign (17). In the present study, the deformation observed in AFM images and increased RMS values for used instruments might result in a fatigue failure without a warning sign.

The SEM has been widely used to evaluate surface characteristics of NiTi instruments and has been accepted as the most adequate method for the accurate evaluation of deformation of instruments (14). AFM has a number of advantages over SEM. One main advantage of AFM is that it can be used equally well on conducting and insulating surfaces and can be performed in ambient conditions in air and liquid as well as in a vacuum. Fragile samples are not damaged by harsh sample preparation techniques such as coating, dehydration, and exposure to vacuum, and artifacts associated with such techniques are avoided (20). In the

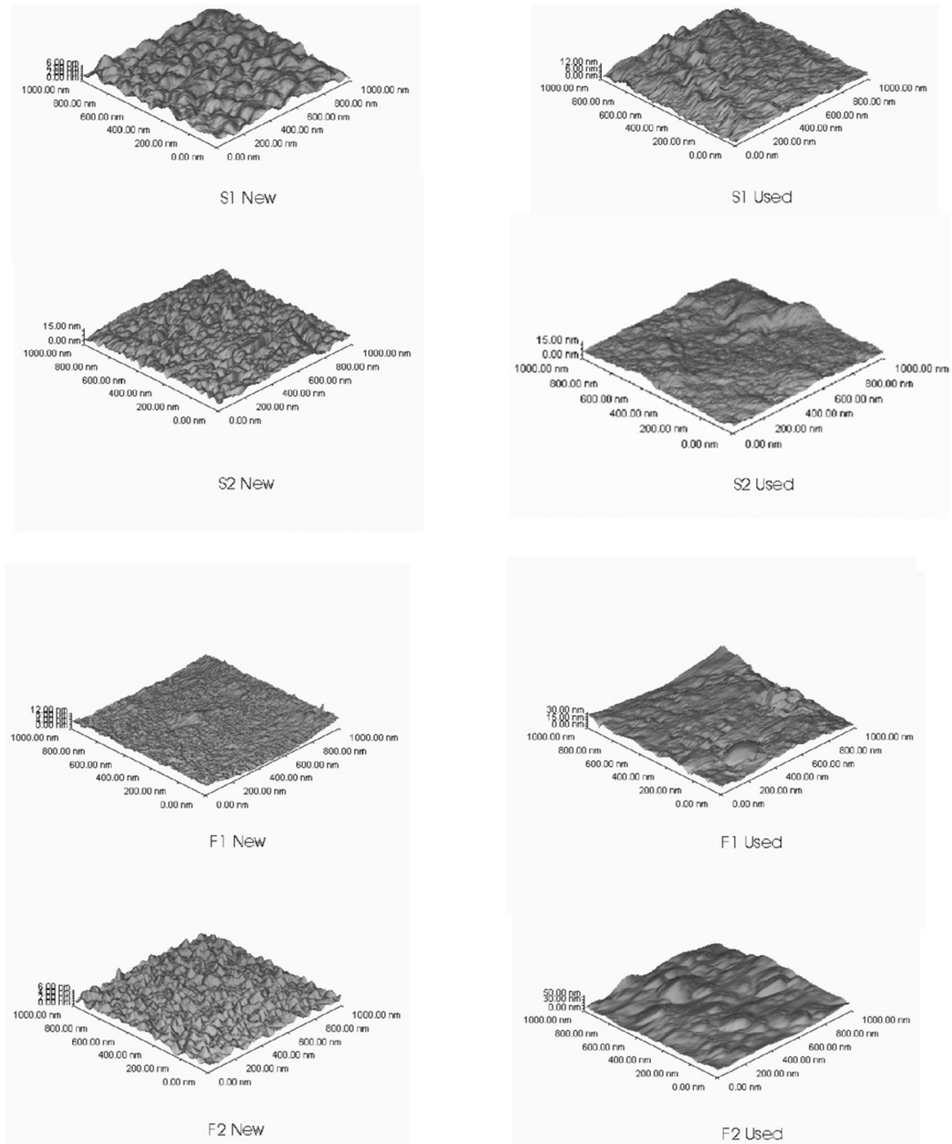

Figure 2. Three-dimensional AFM images of new and used ProTaper S1, S2, F1, and F2 instruments.

present study, we thus evaluated the surface quality of ProTaper instruments by using AFM.

The NiTi instruments are machined rather than twisted, and this can result in an increase of surface irregularities (21). Alapati et al (11) observed surface flaws arising from the manufacturing process of ProFile instruments. Martins et al (9) reported irregularities such as metal flash and deep milling marks on new ProFile instruments. Valois et al (22) compared stainless steel hand files, NiTi hand files, and rotary NiTi files by using AFM and observed higher RMS values in GT rotary and Quantec instruments. The authors also emphasized taper effect on instrument topography. In their study GT rotary files were 0.08 taper and Quantec files were 0.04 taper, whereas hand files were 0.02 taper, and rotary NiTi instruments showed higher RMS values. In an SEM study, Tripi et al (8) reported that SEM micrographs of instruments with different tapers indicated that large instruments were more subject to wear. In ProTaper system, both S1 and S2 instruments have an increasing taper over the whole working range. S1 has a taper of 2% from D1 to 11% at D14, and S2 has a 4% taper from D1 to 11.5% at D14. The F1 and F2 instruments have 7% and 8% tapers at the first 3 mm, respectively. These results correlate well with our results. In our study, the RMS values of used finishing files were higher than those of the shaping files.

In conclusion, AFM is a nondestructive, practical method for evaluating endodontic file surface in a quantitative way. The RMS values of used NiTi files were significantly higher than new ones, indicating surface deterioration. The deterioration rate was much higher in finishing files than shaping files.

TABLE 1. Mean RMS Values (nm) for the Experimental Groups

File	S1	S2	F1	F2
New: mean, SD	0.85, 0.57	1.98, 0.34	1.61, 0.62	1.46, 0.45
Used: mean, SD	1.26, 0.30	2.95, 1.13	5.09, 2.24	7.29, 0.88
P value	$<.01$	$<.05$	$<.001$	$<.001$

SD, standard deviation.

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