

Comparative Evaluation of Changes in Surface Topography of Protaper Universal and Protaper Gold NiTi Files After Root Canal Preparation in Curved Canal of Molar Teeth: An Optical Profilometry Study

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Abstract

Objective: The objective of the present in vitro study were to examine the surface topography of intact ProTaper Universal and ProTaper Gold NiTi files and to compare alterations in surface topography of these files before and after root canal preparation in severely curved canals of molar teeth.

Method: Eight ProTaper universal F2 (25/.08) and Eight ProTaper Gold F2 (25/.08) files were included in the present study. In total, (n= 64) severely curved canals of molar teeth, with curvature angles ranging between 50° and 70°, were prepared with ProTaper gold and universal (32 in each group). Quantitative and qualitative analyses of the files' surface deformation were performed by using optical profilometry before and after root canal preparation. The data were analysed with the Student t test at the 5% significant level by using SPSS 21.0 software.

Result: In the ProTaper Gold group, the qualitative evaluation revealed the presence of cracks and micro cavities after use of the file for root canal preparation, the average roughness, root mean square roughness, and peak to valley height values of the ProTaper Gold group were significantly higher than those of the ProTaper Universal group after root canal preparation ($P < .05$).

Conclusion: Within the limitations of the present study, the ProTaper gold files showed significantly higher surface alterations compared with the ProTaper universal files after the preparation of severely curved root canals.

Keywords: ProTaper; NiTi; Root Canal; Curved Canal

Introduction

The application of Nitinol to endodontics was first described in 1975 by Civjan., *et al.* [1] and in 1988 by Walia., *et al.* [2]. Nickel-Titanium instruments offer great flexibility when instrumenting curved canals thus reducing the potential for file separation and canal transportation compared to their stainless-steel predecessors [3]. The ability of a clinician to adequately negotiate the canal system is coincident with the anatomy of the root. The shape and degree of root canal curvature pose a significant limitation in successful cleaning and shaping of root canals. NiTi files systems vary

in terms of alloys used, cross-section, blade, and pitch designs taper angles and production methods. In spite of these innovations, management of teeth with curved canals remains a challenge, and the possibility of unexpected fracture of files within the canal remains a fact.

The surface topography of the NiTi files is an important factor in its mechanical behavior. Thus it is prudent to know the surface properties of intact and used NiTi files' to avoid unexpected file fractures.

In the recent past, many developments such as use of new alloys, changed production methods and thermal treatments improving the mechanical properties of NiTi files are employed to increase the safety and efficiency of NiTi files [4].

ProTaper Universal™ (PTU, Dentsply Tulsa Dental Specialities) is a NiTi rotary file manufactured with a variable taper over the length of the cutting blades, convex triangular cross sections, and non cutting tips. Later on ProTaper Gold™ (PTG, Dentsply Tulsa Dental Specialities) instruments was introduced. The PTG files have a design that features identical geometries as PTU but are more flexible and have been developed with proprietary advanced metallurgy. PTG is 300 times more fatigue resistant as compared to PTU [5].

When operating within a curved canal, the rotary instrument experiences alternating tensile and compressive stresses, which lead to deformations and breakage [6]. Many techniques including scanning electron microscope (SEM) [7] and atomic force microscope (AFM) were used to analyze the topographical properties of NiTi files [8]. The noncontact three-dimensional (3-D) optical profilometry is a widely used method in dentistry in analyzing the teeth and composite surfaces, but the method was first used by Ferreira, *et al.* [9] in examining the surface properties of NiTi files. Ferreira, *et al.* suggested the use of optical profilometry in analyzing the surface properties of endodontic files because this method makes it possible to analyze wider surfaces without destroying the files when compared with other methods such as SEM or AFM.

The aims of the present study were to examine the surface topographies of intact ProTaper Universal™ and ProTaper Gold™ NiTi rotary files and to compare alterations in the surface topographies of these files after root canal preparation of 4 severely curved mesiobuccal canals of molar teeth.

Materials and Methods

Eight ProTaper Universal™ and Eight ProTaper Gold™ NiTi files were included in the present study. By using an ISO 014 diamond round bur, all the files were marked on the shaft portion before the experiments. With the aid of these marks on the shaft, the same areas on the surfaces of the files were analyzed before and after the root canal preparation.

Root canal instrumentation

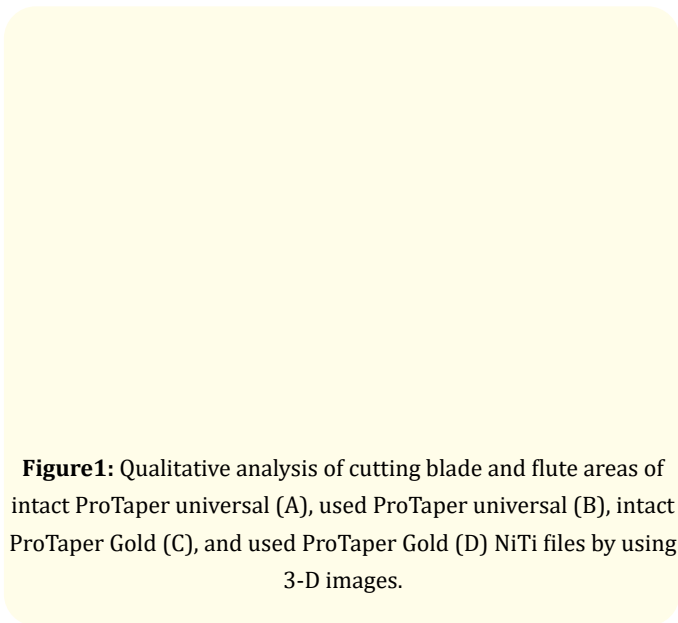
Eight ProTaper Universal™ and Eight ProTaper Gold™ files were used *in vitro* in the present study. In the tests, 64 severely curved canals of molar teeth, with angles of curvature ranging between 50° and 70°, were used. To determine the root canal curvature, mesiodistal and buccolingual radiographs were taken according to the parallel technique [10]. Only roots with a fully developed apex and no internal and external resorption were included in the present study. The working length (WL) was determined by measuring the length of #10 K-file just visible at the apical foramen. S1 file was used to prepare the coronal third of the canal. The canal was irrigated, and a size 10 K-file was used for recapitulation. Both in ProTaper Universal™ the ProTaper Gold™ group, S1 (17/02), S2 (20/04), F1 (20/07), and F2 (25/08) files were used till the WL. The preparation was completed with F2 file. PTU & PTG files were used at a constant speed of 300 rpm and 2.0 Ncm torque. Each file's use was limited to prepare 4 curved canals. After each file change, the root canals were irrigated with 1 mL 5.25% sodium hypochlorite. A total of 20 mL 5.25% sodium hypochlorite was used in each sample. After the preparation of the root canals, the instruments were thoroughly rinsed with 5 mL distilled water. The files were then dried with a soft cotton swab. The used files were ultrasonically cleaned and sterilized by exposing them to 30 psi of pressure for 4 minutes at 134°C, followed by drying for 15 minutes [11].

Surface evaluation and quantitative analysis

The ProTaper Universal 25/.08 and ProTaper Gold 25/.08 files were analyzed before and after the root canal preparation by using optical profilometry (Taylor Hobson Precision Talysurf CCI). The surface evaluation of the files was adapted from Ferreira, *et al.* [9]. The marked points on the shafts of the files were used as reference points. The scanning areas were located 3 mm coronal from the tip of each file. By using a 50 objective lens, the scanning areas were obtained from the cutting blade and the adjacent portion of the flute. The dimensions of the scanning areas were 170 X 170 mm. Three amplitude parameters were evaluated in the quantitative analysis: the average roughness (Sa), root mean square roughness (Sq), and peak to valley height (Sz).

Statistical analysis

The data was first analysed by using the Shapiro-wilk test to verify the assumption of normality. For the statistical analysis of the data, the student 't' test was performed by using SPSS 21.0 (IBM-SPSS inc.) software. The statistical significance level was set at 5%.



Results

In the ProTaper Universal™ group, the qualitative evaluation of the cutting blade and adjacent flute portion of the file showed minor surface deformation. In the ProTaper Gold™ group, the qualitative evaluation revealed the presence of cracks and micro cavities after the root canal preparation.

The mean and standard deviations of the Sa,Sq,Sz Values are shown in Table 1. The pre-use ProTaper universal™ and ProTaper Gold™ have no significant difference in between the two groups.

In both groups, the tested amplitude parameters (Sa,Sq,Sz) increased after root canal preparation. These parameters were statistically significantly increased in the ProTaper gold group after root canal preparation (p<0.5).

Variable	ProTaper Universal				ProTaper Gold			
	Cutting Blade		Flute		Cutting Blade		Flute	
	Before	After	Before	After	Before	After	Before	After
Sa	21.93 ± 3.4 ^{ax}	34.91 ± 5.8 ^{bx}	40.19 ± 6.5 ^{ax}	53.11 ± 1.2 ^{bx}	27.14 ± 3.4 ^{ay}	41.11 ± 1.3 ^{by}	38.09 ± 1.7 ^{ay}	59.09 ± 2.9 ^{by}
Sq	32.07 ± 5.0 ^{ax}	44.11 ± 1.8 ^{bx}	53.73 ± 8.3 ^{ax}	67.11 ± 1.8 ^{bx}	36.01 ± 1.8 ^{ay}	53.72 ± 1.5 ^{by}	49.14 ± 2.5 ^{ay}	73.12 ± 3.8 ^{by}
Sz	161.5 ± 2.4 ^{ax}	181.21 ± 3.9 ^{bx}	97.57 ± 7.9 ^{ax}	119.32 ± 1.9 ^{bx}	179.0 ± 4.3 ^{ay}	201.74 ± 5.8 ^{by}	105.61 ± 1.7 ^{ay}	131.11 ± 2.1 ^{by}

Table 1: Mean and standard deviation of Sa, Sq, Sz parameters before and after use of ProTaper universal™ and ProTaper Gold™ NiTi instruments (in μm).

Different superscript letters indicate statistically significant difference at 5% level (ab for intra group comparison, xy for intergroup comparison)

Discussion

Adequate cleaning and shaping of severely curved root canal is difficult to achieve and rotary NiTi instruments are at an increased risk of fracture in canals with abrupt curvatures Therefore, use of conventional rotary NiTi instruments should be used with extreme caution.

Nickel titanium instruments are often manufactured through machining of a blank wire. This machine grinding of NiTi files leave the surface with pits, fissures, grooves and multiple cracks [12] which may act as areas of stress concentration, initiating crack formation during clinical use [13]. Sattapan., *et al.* [14]. Analysed the type of defects in 378 NiTi rotary instruments after clinical use and

observed torsional failure in 55.7% and cyclic fatigue in 44.3% of all instruments.

So the quality of both the cutting blade and flute area of NiTi files is of clinical interest [15]. Therefore examining these surfaces before and after instrumentation becomes essential to understand the changes that occur in surface topography which leads to instrument fracture [16].

The surface characteristics of NiTi instruments subjected to cyclic fatigue testing have mainly been evaluated using scanning electron microscopy (SEM) [17] or atomic force microscopy (AFM). Drawbacks attributed to SEM include the risk of sample destruction caused by the preparation process and inability to give quantitative

data. AFM can be employed to quantitatively evaluate changes in the surface topography of NiTi files [18]. However, the method requires an ultra-flat and rigid surface but endodontic files are not perfectly flat. In addition, the measurement cycles are lengthy, which increases the time and cost of investigations.

Non-contact optical profilometry has been used by Ferreira, *et al.* [19] and Uslu G., *et al.* [20] to study surface topography of NiTi files with good results.

Optical profilometry is a rapid, non destructive and noncontact surface metrology technique. An optical profiler is a type of microscope in which light from a lamp is split into two paths by a beam splitter. One path directs the light onto the surface under test; the other path directs the light to a reference mirror. Reflections from the two surfaces are recombined and projected onto an array detector. This contains information about the surface contours of the test surface.

The present study aimed to analyse the intact surface properties of ProTaper Universal™ and ProTaper Gold™ rotary file systems and the changes on the surface properties of files after severely curved root canal preparation.

According to the results obtained, the surface of intact ProTaper Gold™ files was found to be rougher than that of intact ProTaper Universal™. Though the difference between the two was not statistically different. It is known that ProTaper Universal™ and ProTaper Gold™ files have rougher surfaces because of their production processes. Tuurker, *et al.* [21] and Fatma, *et al.* [22] compared the pre-use and post-use surface topography of NiTi files and there results were also similar to our study. They reported that the intact NiTi files had irregular surface properties originating from their production procedures.

In the present study, both ProTaper Universal™ and ProTaper Gold™ showed statistically significant increase in surface roughness values after root canal preparation. But the surface of used ProTaper Gold™ files was found to be statistically significantly rougher than that of used ProTaper Universal™, Inan, *et al.* [18] used AFM in examining the surface properties of ProTaper Universal™ NiTi rotary files before and after clinical use. Results of study done by Inan, *et al.* [18] showed that Universal files had higher level of surface deformation and abrasion, and the surface roughness value of used files increased.

In the ProTaper gold group, qualitative evaluation revealed the presence of cracks and micro cavities after the preparation. It can be said that heat treatment of the alloy in PTG instruments may predispose the instruments to plastic deformation and disruption of cutting edges during use, reducing its cutting ability. This finding corroborates previous literature that showed plastic deformation of instruments after clinical use as a result of the thermal pre-treatment of the alloy [23].

Ferreira, *et al.* [9] qualitatively and quantitatively examined the changes in cutting blades and grooves of Wave One files after use in resin blocks. They reported deformations on cutting blades and grooves of files and increase in their surface roughness values after use in artificial canal.

Several factors could have a substantial effect on the topographical properties of NiTi rotary instruments including cross-sectional design, chemical composition of the alloy and thermo mechanical process applied during manufacturing [24].

Although the PTG and PTU have similar cross section design, PTG has torsional value of $(2.77 \pm 0.21 \text{ N.cm})$ and PTU has value of $(3.51 \pm 0.27 \text{ N.cm})$ respectively. PTG had a significantly lower torsional resistance than PTU [25]. It could be attributed to the 2-stage transformation behaviour and the high Af temperatures from which PTG is produced; as this material has greater flexibility [26,27] with an elastic modulus lower than that of the austenitic phase [14]. Consequently, it could be supposed that the martensitic NiTi wire allows a greater amount of deformation at a similar torque than austenitic NiTi alloy [14].

It has been reported that the average root dentine micro hardness is 67 VHN [28]. Accordingly, the hardness of PTG and PTU instruments should be appropriate (approximately 5 times harder than dentine) for shaping and cleaning canal walls. PTG have a Vickers harness no. of $290.85 \pm 19.30\text{VHN}$ whereas PTU has a Vickers harness no. of $331.45 \pm 11.43\text{VHN}$. PTG instruments are significantly softer than PTU. PTU had higher VHN values compared with PTG [15]. High surface micro hardness indicates improvement in the cutting efficiency and wear resistance of NiTi rotary instruments. PTG has less resistance to torsional stress and micro hardness compared with PTU. This decreased micro hardness of PTG Files indicates they will have less resistance to wear and tear and thus will show higher surface deformations as compared to PTU [29].

It has been reported that the PTG instruments revealed 2-stage transformation behaviour (austenite [A]-Rphase-martensite [M]) and also have high Af temperatures due to heat treatment [17]. The martensitic transformation occurs due to a single-stage transformation (A-M) or a 2-stage transformation (A-R-M) depending on the thermo mechanical treatments [30] The 1-stage transformation (A-M) happens in Ni-rich NiTi alloys, whilst 2-stage transformation (A-R-M) happens after additional heat treatment. The heat treatment forms finely dispersed Ti₃Ni₄ precipitates in the austenitic matrix [20]. Consequently, the R phase is formed in preference to martensite due to the presence of Ti₃Ni₄ fine particles. However, the alloy needs additional cooling to form martensite, and hence, martensitic transformation occurs in 2 steps (A-R-M) [20]. In addition, it has been reported that the PTG instruments have high Af temperatures.

The crack propagation mechanism in martensitic phase presents a large number of highly branched cracks that propagate very slowly because the energy absorbing crystalline structure provides a damping effect. So the surface of PTG instrument showed more no of cracks. Whereas the austenitic NiTi exhibits fewer surface crack nucleation sites and crack propagation is much rapid. So it correlates with our study where ProTaper Universal showed less no of surface cracks when compared to ProTaper Gold

Conclusion

Within the limitations of the present study, the ProTaper Gold files showed a significantly higher level of surface deformation compared with the ProTaper Universal files after preparation of severely curved root canals. Hence heat treatment of this PTG file may have increased its cyclic fatigue resistance as reported by various studies but heat treatment could not show any significant difference in preventing surface topography changes.

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