Cutting Efficiency of Twisted versus Machined Nickel-Titanium Endodontic Files

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Abstract

Introduction: The purpose of this study was to compare the efficacy of the cutting ability of two different instruments, concerning changes in the dentin thickness removed and root canal volume, by using multislice computed tomography scanning. **Methods:** Thirty single-rooted mandibular premolars were divided into two equal groups according to the preparation system used: the twisted file (TF) and ProTaper (Dentsply Maillefer, Ballaigues, Swizerland). Dentin thickness along the whole length of the root canal and canal volume were measured before and after instrumentation by using multislice computed tomography scanning and image analysis software. **Results:** ProTaper removed significantly more dentin from the mesiodistal and buccolingual directions of the root canal than the TF ($P < .05$). No significant difference was recorded for the changes in root canal volume between the two systems ($P > .05$). **Conclusions:** The TF system was found to cut dentin efficiently with more uniform cutting than ProTaper system. *(J Endod 2011;37:1143–1146)*

Key Words

Dentin thickness, multislice computed tomography scanning, root canal volume

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The main objective of root canal instrumentation is to shape and clean the root canal system effectively while maintaining the original configuration of the canal (1). It also aims to create a tapered funnel preparation with increasing the diameter from the endpoint to the orifice to facilitate effective irrigation and a three-dimensional (3D) obturation of the root canal space (2).

Over the last 22 years since the introduction of the first rotary nickel-titanium (RNT) instrument, manufacturers have centered their concern on a desire to obtain both safety and cutting efficiency in the same instrument. Although previous file systems have enabled easier, faster, more predictable, and efficient canal preparation (3–5), they were generally either safe or they cut well, but they did not tend to do both (6).

RNT safety and efficiency are collectively determined by the design of the file, the manner in which the file is used, and the method of manufacturing (7). Recently, a completely different manufacturing process has been evolved to introduce the third generation of RNT instruments into the endodontic market: the twisted file (TF) with R-phase technology. The TF has three new design methods of manufacturing, namely R-phase heat treatment, twisting of the metal, and special surface conditioning (deoxidation). These processes significantly increase the instrument resistance to fracture (8, 9), provide greater flexibility, and maintain the sharpness of the flutes (10).

Several publications discussed aspects of root canal preparations using plastic blocks (4, 11). While having the advantage of standardized dimensions, plastic blocks lack the material qualities of human dentin. Other *in vitro* approaches used cross-sections of human root canal at various levels to directly view the shape and position of the root canal (12), radiographic imaging (13), and longitudinal cleavage of the teeth (14). Recently, the use of computed tomography (CT) scanning has been suggested for evaluation of root canal preparation with good results; it allows detailed 3D observation of their forms and shapes and measures the amount of dentin removed from the root canal walls (15, 16). More recently, multislice computed tomography (MSCT), the latest innovation in CT technology, has evolved as a promising tool in endodontic research that could provide high-resolution 3D imaging (17). It has been advocated for the comparison of preinstrumentation and postinstrumentation images (18, 19).

However, the root canal shaping ability of the TF has been evaluated (20) but not yet its efficacy of cutting ability. Thus, the aim of this study was to evaluate and compare the cutting efficiency of TF and ProTaper nickle-titanium (NiTi) rotary instruments (Dentsply Maillefer, Ballaigues, Swizerland) using MSCT regarding changes in root canal volume and the amount of remaining dentin thickness.

Materials and Methods

Specimen Preparation

Thirty freshly extracted single-rooted mandibular premolars with less than 15° deviation from the long axis (21) were used in this study. All teeth were cleaned from soft-tissue fragments and calcified debris by scaling and stored in 10% formalin solution. Teeth were decoronated, and roots were adjusted to a standardized root length of 14 mm using a high-speed diamond bur under water coolant. A #15 K-type file (Dentsply, Maillefer, Baillaiges, Switzerland) was introduced into each root canal to ensure patency, and the working length of each canal was determined by observing the tip of the file protruding through the apical foramen and subtracting 1 mm from this recorded length. Teeth with apical diameters larger than size #20 were excluded from the study. Teeth were randomly divided into two equal experimental groups (n = 15 each) according to the

TABLE 1. Mean and Standard Deviation (SD) of Dentin Thickness Removed for Both Groups in the Mesiodistal and Buccolingual Directions

	Group 1 TF		Group 2 ProTaper			Group 1 TF		Group 2 ProTaper		
	Mesiodistal					Buccolingual				
Group direction	Mean	SD	Mean	SD	*P* value	Mean	SD	Mean	SD	*P* value
Apical	0.064	0.021	0.084[c]	0.030	.172	0.081	0.027	0.089	0.011	.524
Middle	0.077	0.030	0.120[b]	0.037	.034*	0.071	0.034	0.134	0.053	.021*
Cervical	0.090	0.043	0.167[a]	0.060	.017*	0.091	0.036	0.090	0.063	.959
Total	0.244	0.062	0.371	0.095	.012*	0.244	0.067	0.326	0.072	.048*
P value	.357		.005*			.462		.153		

Means with different letters indicate a statistically significantly difference between different levels of the same group according to the Tukey test.

*Significant between the two groups at $P \leq .05$.

instrument used to prepare the canals: group 1, TF (SybronEndo, Orange, CA) and group 2, ProTaper system. Both TF and ProTaper instruments were used in a 16:1 gear reduction handpiece at a consistent rotation of 300 rpm. Preparation was completed in a crown-down manner according to each manufacturer's instructions, and the final apical preparation was set to a size 30 for both groups. One set of instruments was used for the preparation of five canals and then discarded. After the use of each instrument, the root canal was irrigated with 2.0 mL of 2.5% NaOCl solution followed by 2.0 mL of 17% EDTA solution (Ultradent Products Inc, South Jordan, UT).

Image Analysis

The roots were scanned both before and after instrumentation by using a multidetector CT scanner (Somatom Sensation 16 CT scanner; Siemens LTD, Berlin, Germany). The teeth were aligned with the buccal surface in the anteroposterior position (19), with each tooth being scanned at 50-μm intervals for a total of approximately 240 cross-section CT views. For the purposes of this study, a total of 14 cut planes for each root were reconstructed from the voxel model, and various parameters were evaluated.

Measurement of Dentin Thickness

The distances from canal wall to the root surface were measured every 1 mm, from 2 to 13 from the apex, and at the mesiodistal and buccolingual directions of each root by image analysis software (syngo CT softwareVB20; Siemens, Berlin, Germany). Thereafter, the average thickness of each four successive cut planes from the apex was calculated for each direction separately to represent the apical, middle, and coronal thirds, respectively; the cut planes were viewed with fixed window width and window center to standardize the measurements.

Measurement of Root Canal Volume

The volume of prepared root canals was analyzed by using the volumetry method by tracing the canal outline at the different 14 horizontal cut planes; then, the volume of dentin removed was automatically calculated by subtracting the uninstrumented canal volume from the instrumented one.

Statistical Analysis

Data were presented as mean and standard deviation values. The Student *t* test was used to compare the two groups. The paired *t* test was used to compare the mesiodistal and buccolingual direction. The repeated measures analysis of variance was used to compare the three segments. The Tukey post hoc test was used for pair-wise comparison between the means when the analysis of variance test is significant. The significance level was set at $P \leq .05$.

Results

Dentin Thickness

Results showed that there were statistically significant differences of dentin thickness removed between the two groups for the coronal and middle thirds of root canals in the mesiodistal direction with the ProTaper system showing a higher performance. For the apical third, no significant differences occurred. In the buccolingual direction, only at the middle third, the ProTaper group showed a statistically significantly higher mean amount of removed dentin than the TF group (Table 1).

As regards to the three levels of comparison, in the TF group, there was no statistically significant difference in either the mesiodistal or the buccolingual directions. In the ProTaper group, there was also no statistically significant difference in the buccolingual direction, whereas a statistically significant difference in the mesiodistal direction between the three levels was reported (Table 1).

Concerning the comparison between the mesiodistal and buccolingual directions, the only difference recorded was in the coronal third of the ProTaper group where the amount of removed dentin in the mesiodistal direction showed a statistically significant higher value than the buccolingual direction (Table 2).

TABLE 2. Comparison between the Mesiodistal and Buccolingual Direction for the Amount of Dentin Thickness Removed

	Group 1 TF					Group 2 ProTaper				
	Mesiodistal		Buccolingual			Mesiodistal		Buccolingual		
Group direction	Mean	SD	Mean	SD	*P* value	Mean	SD	Mean	SD	*P* value
Apical	0.064	0.021	0.081	0.027	.337	0.084	0.030	0.089	0.011	.751
Middle	0.077	0.030	0.071	0.034	.742	0.120	0.037	0.134	0.053	.502
Cervical	0.090	0.043	0.091	0.036	.953	0.167	0.060	0.090	0.063	.005*
Total	0.244	0.062	0.244	0.067	1.000	0.371	0.095	0.326	0.072	.223

SD, standard deviation.

*Significant at $P \leq .05$.

Root Canal Volume

There was no statistically significant difference between the two groups for the mean percentage of change in volume.

Discussion

Acquiring a continuously tapered funnel-shaped root canal with adequate volume is a prerequisite to allow effective irrigation and obturation for the root canal system. In the current study, we used MSCT at a 50-μm resolution, which provided a practical and nondestructive technique for the assessment of canal morphology before and after shaping (22). In the CT imaging system, by changing the viewing parameters, it was possible to show images with more or less tooth density and detail. Once the images have been digitized, there are infinite ways in which they can be manipulated and viewed (23). MSCT image-analysis software allowed the accurate evaluation of any changes in dentin thickness and root canal volume without complicating procedures.

Various studies investigated the efficiency of NiTi rotary instruments for the preparation of root canals. TF technology was recently developed to enhance superelasticity and provide superior mechanical properties. Therefore, in the present study, a comparison between instruments produced by a new manufacturing process, the twisting method (TF), versus a well-known and studied instrument produced with the traditional NiTi grinding process, ProTaper, was performed to evaluate their efficacy of cutting ability.

The cutting ability of root canal instruments is a complex interrelationship of different parameters such as the cross-sectional design, which seems to be a decisive parameter (24), chip-removal capacity, helical and rake angle, metallurgical properties, and surface treatment of the instruments (25). In the present study, ProTaper showed a greater amount of removed dentin than TF especially for the middle and coronal thirds in the mesiodistal direction and for the middle third in the buccolingual direction.

The greater cutting ability of ProTaper in the middle and coronal parts has been confirmed by other investigations (23, 26–28). Also, in curved canals, it was reported that ProTaper removes more tooth structure than TF (20). This could probably be related to the sharp cutting edges of the convex triangular cross-sectional design of ProTaper instruments and a flute design that combines multiple tapers within the shaft up to 19%, whereas TF instruments used in this study had a constant taper of a maximum 8%. The absence of a statistically significant difference at the apical third between both groups could be attributed to the noncutting modified safety tip of the ProTaper and TF instruments, the decreasing taper of ProTaper finishing files, and the standardization of the apical diameter size.

Comparing the coronal, middle, and apical thirds, there was a statistical significance for the amount of dentin material removed in the mesiodistal direction using ProTaper instruments. This might be attributed to the progressive taper sequence of the shaping files from tip to coronal (26), which with the sharp triangular cross-sectional design could lead to aggressive cutting (29). This effect was significantly different compared with TF in which there was no statistically significant difference in the mesiodistal direction at all levels, indicating more even and uniform removal of dentin with TF instruments, which might be explained by the high flexibility (20) and the surface deoxidation of these files (10).

With regard to the comparison of mesiodistal and buccolingual directions, only the cervical thirds of the roots instrumented with the ProTaper files showed a statistically significant larger amount of removed dentin in the mesiodistal than the buccolingual direction. This may be, in addition to the larger cross-section of the ProTaper file and its aggressive cutting, explained by the oval outline cross-section of the root canal in a buccolingual direction of mandibular premolar teeth used in this study. This outline is more pronounced in the coronal and midroot regions and decreases towards the apex, where the outline is almost round (30). It is difficult to achieve a complete mechanical debridement of the root canal system (31), mainly because of the geometric dissymmetry between the root canal and preparation instruments, which in most cases do not coincide with each other (32–34).

Root canal instrumentation resulted in significant gains in canal volume with no apparent difference between the two systems investigated, signifying more even and uniform removal of dentin structure when using TF system. This finding is in agreement with earlier studies that reported no significant differences between different RNT instruments investigated (35, 36).

Conclusion

Under the circumstances of this study, it can be concluded that the non-ISO progressive taper in the ProTaper system shows a higher cutting ability with selective areas of cutting. The TF removes dentin more evenly all over the length of the root canal, which clarifies the non-statistically significant difference in changes in root canal volume for the two NiTi rotary systems evaluated.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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