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Original Article

Comparison of cleaning efficiency and deformation characteristics of Twisted File and ProTaper rotary instruments

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ABSTRACT

Objective: The objective of the following study is to compare the cleaning efficiency and deformation characteristics of Twisted File (TF) and ProTaper (PT) nickel-titanium rotary instruments in root canal preparation. **Materials and Methods:** A total of 52 canals from 26 extracted maxillary first molars were randomly assigned into two groups of each including 13 mesiobuccal and 12 distobuccal (DB) canals. Two DB canals were as blank controls. After preparation with TF and PT, we recorded the preparation time and evaluate the amounts of debris and smear layer at apical, middle and coronal canals under scanning electron microscopy (SEM). Three cross-sections of canals at 3 mm, 5 mm and 7 mm from the apex foramens were scanned before and after preparation under micro-computed tomography. Changes of the cross-section area (CSA) at the three levels were calculated with Photoshop CS4. File deformation was also investigated under SEM. Two groups were statistically compared with Mann-Whitney test and independent sample *t*-test. **Results:** Less debris and smear layer were found in coronal regions of canals prepared with TF ($P = 0.006$, $P = 0.001$, respectively). TF group displayed more CSA change than PT group ($P = 0.045$) at cross-sections of 5 mm from the apex foramens and took significantly less preparation time than PT group did ($P = 9.06 \times 10^{-28}$). All five TF files without obvious micro-cracks and two out of 25 PT files with many micro-cracks showed visible unwound deformation. **Conclusion:** Neither TF nor PT achieves complete cleanliness of canal walls. Their deformation features might indicate different fracture resistance. TF single-file technique would substantially shorten the time of root canal preparation.

Key words: Cleaning efficiency, deformation, ProTaper, Twisted File

INTRODUCTION

The purpose of root canal preparation is to properly shape and thoroughly clean the canal system.[1] During the past decades, many kinds of nickel-titanium (NiTi) endodontic instruments emerge to facilitate efficient and fast root canal preparation.[2-6] Nowadays, manufacturers tend to focus on creating an instrument with sound safety and high efficiency.[7,8] Among them, ProTaper (PT; Dentsply, Ballaigues, Switzerland) System, one of the most popular ones, appears to be safe and efficient.[9-11] And recently, Twisted File (TF; SybronEndo, Orange, CA, USA), a new rotary nickel-titanium (RNT) system, has been introduced with three new design methods, namely R-phase heat treatment, manufacturing by twisting the metal and special surface conditioning.[12]

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Previous studies found that TF possessed higher resistance to cyclic fatigue and removed dentine efficiently with more uniform cutting than other NiTi files with a grinding manufacturing process.[12-15] Nevertheless, no comprehensive investigation regarding cleaning efficiency and deformation characteristics of TFs during instrumentation in molar canals was reported. The present study aims to evaluate the cleaning efficiency and cutting ability of TF and PT systems using scanning electron microscopy (SEM) and micro-computed tomography (μCT), regarding the presence of debris and smear layer on canal walls and changes of the cross-section area (CSA) after chemo-mechanical preparation and to assess the deformation features of TF and PT after application in molar canals.

MATERIALS AND METHODS

Specimen selection

The study protocol was approved by the Ethics Committee at the School of Stomatology, Wuhan University. A sample of 26 extracted human maxillary first molars was selected in the study. After removing roofs of pulp chambers, canals were negotiated to an apical size of #15 K-file. Balanced the working length and curvature (no more than 25°), 52 canals were randomly assigned into two groups of each including 13 mesiobuccal and 12 distobuccal (DB) canals. Two DB canals were as blank controls. Apical foramens of all samples were sealed with cold-cure acrylic to avoid irrigation fluid flushing out of the foramens.

Root canal instrumentation

Each tooth was mounted in a special device and loaded under μCT (μCT-50; Scanco Medical, Bassersdorf, Switzerland). The data of cross-sections of each canal at intervals of 25 μm were scanned. Then all specimens were unloaded and ready for root canal preparation. Being negotiated to apical size of #15 K-file and curvature ≤25°, the selected canals can be easily prepared to a #25 master apical diameter and hence we selected the single-file technique with 0.08/25 TF in TF group[8,16] and PT F2 as the finishing file in PT group in accordance with the recommendation procedures of the manufacturers.[17] Each file was applied in a total of five canals. A total of five TF files were used to prepare the 25 canals in TF group and 25 PT files were used to prepare the 25 canals in PT group for each canal with S1, Sx, S2, F1, F2 respectively. All files were used in a 16:1 gear reduction handpiece at a consistent rotation of 300 rpm. During instrumentation, the root canal was irrigated with 2 mL 2.5% NaOCl after each file insertion. Preparation time was recorded as the first RNT file got into the canal until the instrumentation finished. After instrumentation, each canal was rinsed in the same time duration with 10 mL 2.5% NaOCl, followed by 10 mL 17% ethylenediaminetetraacetic acid (EDTA). Then, the canal was flushed with 5 mL distilled water to cease chemical reaction and to remove residual irrigating agents. One operator finished all preparation. The used TF and PT files were then examined for deformation under SEM (FEI Sirion, Eindhoven, Netherlands).

Image analysis

After preparation, each tooth was scanned under μCT as that before preparation. We selected images of cross-sections before and after preparation at 3 mm (apical), 5 mm (middle) and 7 mm (coronal) from the apex foramen from μCT data and calculated CSA at the three levels with Photoshop CS4 (Adobe, San Jose, CA, USA). Subtracting the pre-operative value from the corresponding post-operative value equals change of CSA.

Next, each experimental root was longitudinally split into two half roots and prepared for SEM examination by the method described previously.[17] Due to the damage during splitting roots, only 16 half roots in each group were used for SEM evaluation. Examination was separately carried out by two trained operators who were blind to experimental groups. Cleanliness of canal wall in each specimen was evaluated in apical, middle and coronal canal, which correspond to the region between 1 mm to 3 mm/3 mm to 5 mm/5 mm to 7 mm from the foramen respectively. The three regions of all specimens were observed under SEM. Eight fields at ×1000 magnification were randomly chosen in each region. The five-step scoring systems[17,18] with score 1 indicating the best and score 5 representing the worst were used for evaluating the debris and smear layer on dentine walls. The score of one region was the average value of the eight selected fields.

Statistical analysis

Two groups were statistically compared by Mann-Whitney test for scores of debris and smear layer and by independent sample *t*-test for changes of CSA and preparation time. The significance level was set at $P \leq 0.05$.

RESULTS

Completely cleaned root canals were not found. The blank control canals behaved just as expected with amounts of debris and smear layers and a score of 5 (figures not shown). TF group showed statistically lower scores than PT group in coronal canals (debris scores, $P = 0.006$; smear layers scores, $P = 0.001$). Usually, more effective cleaning was observed in coronal and middle canals in the two groups. The results of debris and smear layer scores are summarized in Table 1. TF group displays more CSA change (354.0 ± 159.5 pixels) than PT group (269.8 ± 128.8 pixels) at middle canal levels ($P = 0.045$) [Table 2]. Representative appearances under SEM and μCT are showed in Figures 1 and 2.

TF instruments took significantly less preparation time (46.0 ± 26.5 s) than PT files did (252 ± 36.2 s) ($P = 9.06 \times 10^{-28}$). All 5 TF files showed visible unwound deformation [Figure 3a]. Among 25 PT files, only two files presented visible deformation. Under SEM, metal fiber fracture presented on the cutting edge of one TF file [Figure 3b]. There were no obvious micro-cracks on the rest part of this file or on the other four TF files except machining scratches paralleling to the file longitudinal axis [Figure 3c]. Many micro-cracks perpendicular to the direction of the longitudinal axis of files showed on the surfaces of the two deformed PT files and some other PT with no visible deformation, indicating the trend of file separation [Figure 3d].

DISCUSSION

Cleaning root canals involves enlarging of the canal by instruments and flushing with irrigant solution.[19] In the present study, the agent, volume and procedures for irrigation were standardized for both experimental groups. Efforts were made to prepare all canals to the same apical diameter of 0.25 mm and a similar taper of 8% to reduce, if not eliminate thoroughly, the influence of many confounding factors on cleaning efficacy of different instruments. It is obvious for the two groups that apical canals possess the highest debris and smear layer scores and the cleaning efficiency is gradually

Table 1: Summary of debris/smear layer scores in both groups

Regions	Apical				Middle				Coronal			
Mean scores	1-2	2-3	3-4	4-5	1-2	2-3	3-4	4-5	1-2	2-3	3-4	4-5
Groups												
TF	10 (3)	5 (3)	0 (7)	1 (3)	12 (0)	3 (10)	1 (5)	0 (1)	14 (0)	2 (13)	0 (3)	0 (0)
PT	7 (0)	7 (2)	1 (12)	1 (2)	7 (0)	6 (5)	2 (10)	1 (1)	7 (0)	4 (5)	3 (10)	2 (1)
P value for each region		0.291 (0.605)				0.071 (0.143)				0.006 (0.001)*		

Listed is the number of canal areas evaluated as debris/smear layer scores 1-5 (16 half roots per group, data of smear layer scores presented in parentheses). Score 1-2 indicates the best and score 4-5 indicates the worst result. *Statistically significant difference between the two groups. TF: Twisted file, PT: ProTaper

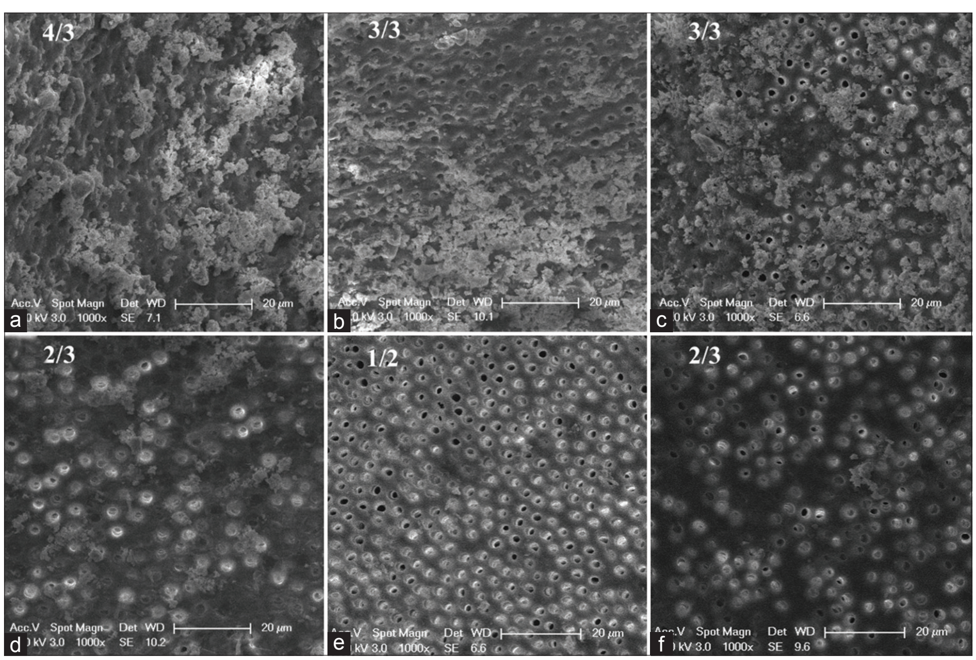

Figure 1: Typical appearance of prepared canal walls under scanning electron microscopy (a) Twisted File (TF), apical; (b) ProTaper (PT), apical; (c) TF, middle; (d) PT, middle; (e) TF, coronal; (f) PT, coronal. Numbers in figure mean debris score (left) and smear layer score (right)

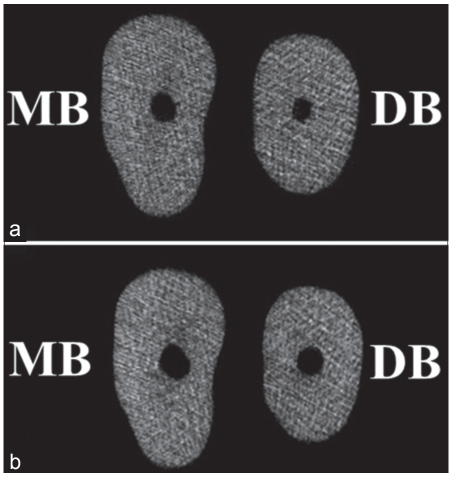

Figure 2: Micro-computed tomography images of canal cross-sections at 5 mm from the apex. (a) Before preparation: area of mesiobuccal (MB) canal, 700 pixels; area of distobuccal (DB) canal, 392 pixels. (b) After preparation: MB, Twisted File preparation, 901 pixels; DB, ProTaper preparation, 717 pixels

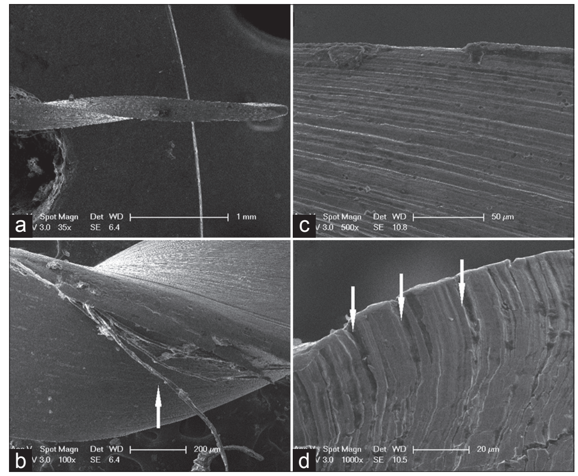

Figure 3: Representative appearance of used files under scanning electron microscopy (a) mild unwound tip of a Twisted File (TF); (b) metal fiber fracture (arrow) on one TF file; (c) surface of one used TF file; (d) micro-cracks (arrows) on one used ProTaper file

Table 2: Changes of CSA in both groups (mean±SD, pixels)

Canal levels	PT group (*N*=25)	TF group (*N*=25)	*P* value
Apical	187.3±87.4	169.0±95.7	0.484
Middle	269.8±128.8	354.0±159.5	0.045*
Coronal	422.1±292.5	422.2±259.4	0.999

*Statistically significant difference between the two groups at $P \leq 0.05$. SD: Standard deviation, CSA: Cross-section area, TF: Twisted file, PT: ProTaper

better as canals close to coronal regions, which is in agreement with previous findings that the apical third was the area with more debris under SEM observation.[20] Debris and smear layer scores showed no statistical difference in apical and middle canals, but presented significance in coronal canals with TF group possessing lower scores.

Copious irrigation is the decisive factor for cleaning efficiency of the prepared root canals. The irrigants NaOCl and EDTA were effective for the removal of debris and smear layer.[21,22] The apical and middle canal in the present study is the area 0-4 mm away from working length, which mostly belongs to the apical third of the canal. Previous studies demonstrated that it is difficult for irrigants to completely get to the apical third of canals during instrumentation.[23] Apical and middle canals in the present study would not get sufficient irrigation and subsequently obtain high scores and no statistical difference between the two groups. However, compared to apical and middle canals, coronal canals with relatively larger volume would get a sufficient mechanical flushing and consequently the difference of debris and smear layer scores should be resulted from the different instrumentation techniques, which involving in two aspects including instrument design and operating technique.[24]

The ability of rotary instruments to remove dentine and debris during shaping is obviously connected to the flute and cross-sectional design of the file.[5,25,26] TF and PT files possess similar design in following aspects, such as continuously changing pitches and helical angles, the flute width and depth becoming larger moving from the tip to the handpiece end of the file and non-landed triangular cross-section designs with positive rake angles.[27,28] So in the present study, the different operating technique plays a dominant role for cleanliness difference in coronal canals. For TF group with a single-file technique, canal preparation was generally completed in three times' repeated insertions or so. In contrast, in order to finish the entire preparation in PT group, five PT files were individually used several times in each canal. As a result, PT files rubbed on canal walls more often than TF did, producing thicker smear layers. With the times of file insertion increasing, more debris will be produced and compacted more tightly along dentine walls and then difficult to be flushed out of the canal. Hence the single-file technique could be the main reason for cleaner canal walls in TF group. The present results indicated that, when similar preparation efficacy can be achieved with different instruments, selecting single file technique would more contribute to the cleaning of the root canal system.

CSAs of canals are changed after root canal preparation. In our study, TF group displayed more change of CSA at cross-sections 5 mm from the apex ($P < 0.05$). The

TF #25/0.08 file and PT F2 file have the same taper and size within 3 mm from the file tip. Theoretically, they will engage the same volume of dentine at apical canal within 3 mm working length. Since PT files have variable tapers, the diameters of TF are greater than PT between 4 and 8 mm from the file tip, then TF #25/0.08 file will engage more dentine than PT F2 does. The CSA difference at cross-sections of middle canals should be resulted from the dimensional difference between these two file systems. Usually, more change of CSA means more cutting ability of instruments. The results imply TF could possess higher cutting ability than PT. Therefore, when using the instruments such as TF during the root canal preparation, the performer should have rich experiences and be very cautious to avoid unexpected overcutting canal wall.

In the present study, instrumentation with TF was significantly faster than preparation with PT system. The single TF needs only several repeated insertions to finish the canal preparation, whereas five files of PT were used several times respectively and subsequently were time-consuming. In clinical practice, this difference is very significant. With the help of TF single-file technique, we don't have to spend time to change from one instrument to the other. Therefore, clinical application of TF would substantially save the operation time of root canal preparation.

RNT endodontic instruments have exhibited greater flexibility and more resistance to separation than stainless steel files.[29] However, separation via cyclic and torsional fatigue is still possible for NiTi instruments.[30-32] Increasing the resistance to separation has become a focus in RNT instrument design. Consistent with previous findings,[28,33] all TF files being unwound in the present study indicates that TF possess lower torsional resistance, compared with PT with only two unwound out of 25 files. However, there were no obvious micro-cracks on surfaces of the unwound TFs except one file presented three metal fibers fracture along the blade edge. Nevertheless, SEM inspection showed many micro-cracks on surfaces of the unwound two PT files and some other PT with no visible deformation. These cracks were perpendicular to the long axis of the file and parallel to the direction of machining scratches on the surfaces, which could be the origin of the prospective file fracture.

A single file technique showed benefits in term of cleanliness and operating time, but shaping canal with only one file could lead to mechanical overstress to the file especially in some molar canals. As observed in the present study, all five TF exhibited unwound deformation which might indicate an overstress. Overstress to a file will increase the potential risk of breakage. Since TFs are made by a twisting method other than a traditional grinding process, therefore overstress on them would firstly cause unwound deformation. On one hand, the deformation will increase the possibility of file fracture; while on the other hand, easily detected deformation would be strength allowing instruments to be discarded before breakage and then help to prevent file separation in clinical practice. Visible unwound deformation without obvious micro-cracks on TF and invisible micro-cracks on deformed or no deformed PT files indicated TF and PT possess different fracture resistance.

Although further laboratory experiments and clinical trials are needed to verify the results in the present study, however, within the limitations of this study, neither TF files nor PT system achieve complete cleanliness of root canal walls. The results suggested that clinical application of TF would substantially shorten the operation time of root canal preparation. Deformation characteristic of TF and PT indicates their different fracture resistance.

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