Comparison of Influence of Different Manufacturing Methods on the Cleaning Efficiency of Rotary Nickel–Titanium Files

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KEY WORDS smear layer; dentinal debris; rotary instrument; scanning electron microscopy

ABSTRACT The purpose of this study was to evaluate and compare cleaning effectiveness of TwistedFile, GT series X, Revo-S, RaCe, Mtwo, and ProTaper Universal rotary files in curved canals. Seventy mesiobuccal canals of extracted human first maxillary molars were divided into seven groups of 10 samples each. Canals were prepared with six nickel–titanium (NiTi) rotary systems and manual K-Flexofile. Irrigation was performed with 2 mL 2.5% NaOCl solution after each file, and 5 mL 2.5% NaOCl was used for the final flush. After the roots were split longitudinally, the presence of debris and smear layer was visualized using scanning electron microscopic photomicrographs taken at coronal, middle, and apical third. Mean scores for debris and the smear layer were calculated and statistically analyzed for significance between groups using the Kruskal–Wallis nonparametric analysis of variance ($P < 0.05$) and Mann–Whitney U test ($P < 0.001$). There was no significant difference among the groups in terms of debris and smear layer scores ($P > 0.05$). Without considering the preparation method used, while no statistically significant difference was found between the coronal third and the middle third ($P > 0.05$), higher amount of debris and smear layer were found in apical third ($P = 0.001$). The new generation of NiTi rotary files including the Twisted File and GT Series X presented similar cleaning effectiveness compared with traditionally ground NiTi rotary files. *Microsc. Res. Tech. 76:231–236, 2013.* © 2012 Wiley Periodicals, Inc.

INTRODUCTION

The purpose of endodontic treatment is to provide the required environment to preserve healthy periapical tissues or to heal diseased apical periodontium. For this purpose, chemomechanic instrumentation of root canals including completely emptying root canal content and removing debris and smear layer formed in that period may directly affect the success of endodontic treatment. Although sufficient cleaning and shaping are quite difficult especially in narrow, curved, or oval canals, dentine should be removed from all canal walls as equally as possible, without weakening the root structure, and at the same time, canal disinfection should be carried out using antibacterial irrigation solutions (Ahlquist et al., 2001; Carvalho et al., 1999; Peters et al., 2001a; Siqueira et al., 1997).

In studies investigating the cleaning ability of endodontic instruments, scanning electron microscopy (SEM) and micro-computed tomography (CT) are currently used for assessment of debris removing ability from root canals. In various in vitro studies in which SEM is used after preparation with nickel–titanium (NiTi) rotary files or stainless steel hand files, the debris remnants were seen in root canal walls in many methods (Schafer and Lohmann, 2002; Schafer and Schlingemann, 2003). Furthermore, in the study of Peters et al. (2003) carried out with upper molars using micro-CT, rotary files were shown not to touch the mesiobuccal (MB), distobuccal (DB), and palatinal canal walls at 43%, 33%, and 49%, respectively. These findings indicate that endodontic files have limited ability to clean the root canals, especially the apical third (Paque et al., 2005; Schafer and Vlassis, 2004; Tan and Messer, 2002; Wu and Wesselink, 1995).

Recently, the M-wire NiTi material, which is suggested to be more flexible than the 55-nitinol and more resistant to cyclic fatigue and with more cutting efficiency, has been produced. The first rotary file system generated from this material was GT Series X (Larsen et al., 2009). Another progress in the production of NiTi rotary files is TwistedFile system produced with plastic deformation via R-phase heat application and bolt contortion. The files belonging to this system have been claimed to be more flexible and more resistant to cyclic fatigue, to proceed in the center of the canal, especially in curved canals, and to have minimized canal transportation (Gergi et al., 2010). The new materials and methods used in the production of NiTi rotary files may contribute to the development of root canal preparation; however, the number of studies investigating these new materials and methods comparatively is limited.

To comparatively analyze the residual debris amount and the smear layer with SEM after root canal preparations performed by using GT Series X

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and Twisted File systems produced by innovative manufacturing methods, to Revo-S, RaCe, Mtwo and ProTaper Universal systems manufactured directly from conventional nitinol, and to stainless steel K-Flexofile instruments.

MATERIALS AND METHODS

The maxillary first permanent molars which had completed apical maturation, continued from the MB root canal access to the apical foramen and at a maximum #15 K-Flexofile file (Denstply, Tulsa Dental Specialties, Tulsa, OK) pinched in the apical narrowing site and extracted due to periodontal or prosthetic reasons, were used. A total of 70 MB root canals with a root curvature angle of 30°–40° and a root curvature radius of 4–9 mm were included in the study. Following the preparation of the access cavity with Endo Z drills (Denstply, Tulsa Dental Specialties, Tulsa, OK), ISO #10 K-file (Denstply, Tulsa Dental Specialties, Tulsa, OK) was proceeded into root canal until its tip was observed in the apical foramen. The working length was determined by subtracting 1 mm from the length at the time the file was first seen.

Apical preparation was completed with the files measuring 30/0.06 using the instrument order offered by the manufacturer in Group 1 (TwistedFile; SybronEndo Orange, CA), Group 2 (GT Series X; Denstply, Tulsa Dental Specialties, Tulsa, OK), Group 3 (Revo-S; MicroMega, Besançon, France), Group 4 (RaCe; FKG, La Chaux-de-Fonds, Switzerland), and Group 5 (Mtwo; VDW, Munich, Germany). In Group 6 (ProTaper Universal; Denstply, Tulsa Dental Specialties, Tulsa, OK), apical preparation was completed with F3 file using the instrument order offered by the manufacturer. In Group 7 (K-Flexofile), instrumentation was made using the crown-down method with triangular flexible stainless steel K-Flexofile instruments. Apical preparation was completed with ISO No. 30/0.02 instrument. Irrigation was performed with 2 mL 2.5% NaOCl solution after each file, and 5 mL 2.5% NaOCl was used for the final flush. A 30-gauge round tip special endodontic irrigation needle (KerrHawe SA, Bioggio, Switzerland) was used without bending by proceeding to the deepest point of the canal.

A longitudinal groove was prepared exercising care not to penetrate the root canal, and the roots were split longitudinally. Teeth showing evidence that the groove had penetrated the canal or samples with an irregular cleavage pattern were discarded and replaced. As a result of these eliminations, the number of the samples in each group was fixed to 10.

Images analyzed a series of SEM photomicrographs at magnifications of 500× for debris assessment and 2500× for smear layer assessment obtained from canal walls from apical, middle, and coronal regions. The amount of debris and smear layer in each assessment unit was scored using a numerical criterion (Table 1) (Hülsmann et al., 1997).

The data obtained from debris and smear layer assessment were recorded. As the data were not normally distributed, the Kruskal–Wallis test, the nonparametric equivalent of one-way variance analysis, was used and the median of the groups were compared. Furthermore, dichotomous comparisons were made using the Mann–Whitney *U* test in order to determine

TABLE 1. Scale of values assigned to the two different parameters evaluated

	Score 1	Score 2	Score 3	Score 4	Score 5
Debris remnants	Clean canal wall, only very little debris particles	Few small conglomerations	Many conglomerations covering less than 50% of the canal walls	Debris covering more than 50% of the canal walls	Debris covering almost all or all the parts of canal walls
Smear layer	No smear layer and orifice of all dentine tubuli are patent	Small amount of smear layer, some dentinal tubuli open	Homogeneous smear layer along almost the entire canal wall, only very few dentinal tubuli open	Almost all the canal walls are covered with smear layer and the orifice of dentine tubuli are closed	A thick homogenous layer covering all the entire canal walls

TABLE 2. The scores of remaining debris and smear layer

	Remaining debris													Smear layer										
	Coronal third				Middle third				Apical third				Total scores	Coronal third				Middle third				Apical third				Total scores
Groups	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TF	2	3	4	1	—	4	2	2	—	—	4	3	2	1	6	9	9	5	1	2	4	2	1	1	1	—	—	5	2	2	1	6	13	5	4	2
GTX	4	4	1	1	—	3	3	2	—	—	2	2	4	2	7	9	5	7	2	2	5	2	2	1	4	3	3	—	—	2	4	4	4	8	7	6	5
Revo-S	3	4	2	1	—	3	5	2	—	—	4	3	1	2	6	13	7	2	2	—	2	3	4	1	—	2	4	3	—	1	—	2	2	4	4	9	9	5	3
RaCe	—	4	3	2	1	2	3	3	2	—	3	2	2	3	2	10	8	6	4	—	3	1	3	3	1	1	2	3	3	1	—	1	4	2	3	2	7	8	6	7
Mtwo	1	2	5	1	1	1	3	5	1	—	1	3	4	1	1	3	8	14	3	2	2	3	4	1	—	1	2	5	2	—	—	2	4	3	1	3	7	13	6	1
ProTaper U	2	3	4	1	—	2	5	3	—	—	3	4	1	2	4	11	11	2	2	1	2	4	3	—	—	1	3	4	1	1	—	1	3	2	4	2	6	11	6	5
K-Flexofile	3	4	3	—	—	4	4	2	—	—	1	2	4	1	2	8	10	9	1	2	1	3	3	3	—	1	4	4	—	1	—	6	—	2	2	2	13	7	5	3
P values			0.127					0.466					0.759				0.216				0.842							0.117				0.097				0.094			

the groups between which the difference was present ($P < 0.001$).

RESULTS

The remaining debris and smear layer scores of groups have been presented in Table 2. No completely cleaned canal wall was observed in any of the root canals (Figure 1). No statistically significant difference was observed between the groups in the coronal, middle, and apical third regions and the total canal area in terms of debris scores and smear layer scores ($P > 0.05$). Without considering the preparation method used, while no statistically significant difference was found between the coronal third and the middle third ($P > 0.05$), a statistically significantly higher amount of debris and smear layer were found in apical third ($P = 0.001$).

DISCUSSION

One of the basic purposes of root canal instrumentation is removal of vital and/or necrotic pulp tissue, infected dentine, and dentine debris in order to eliminate the microorganisms in the root canal system (European Society of Endodontology, 2006). In this study, the abilities of TwistedFile, GT Series X, Revo-S, RaCe, Mtwo, and ProTaper Universal rotary files and the K-Flexofile hand file to achieve these goals were evaluated. The number of studies evaluating the cleaning efficiency of TwistedFile, GT Series X, and Revo-S systems is found to be limited.

For analyzing the cleaning efficiency of different files, debris and smear layer have been used as criteria. Debris is composed of dentin chips, pulp remnants, residual vital or necrotic pulp tissue and particles loosely attached to the root canal wall which in most cases is infected (Hülsmann et al. 1997). The smear layer is a thin film layer of 1–2 μm which forms when the canal is instrumented (Mader et al., 1984). Although the effect of the smear layer on the root canal treatment results is controversial (Shahravan et al., 2007), some authors recommend its removal due to the potentially harmful effects (Lim et al., 2003; Violich and Chandler, 2010). Since root canal cleaning ability of different rotary files was analyzed in this study, chelating agents that would be used for removal of the smear layer were not used on purpose. Thus, it should be remembered that the cleaning efficiency of the files assessed in this study may be enhanced with the combination of NaOCl and EDTA.

Using extracted teeth in this type of studies may be perceived as conceding from standardization due to the complex root canal anatomy and varying dentine hardness; however, more importantly, it enables investigating canal cleaning with SEM and makes the circumstances as close to the clinical condition as possible (Williamson et al., 2009). As in similar studies (Haikel and Allemann, 1988; Hülsmann et al., 1997), in this study, the cleaning efficiency was analyzed using the numerical scoring scheme of debris and smear layers via photomicrographs obtained from coronal, middle, and apical thirds of canals with SEM. These micrographs were taken with high magnifications, but cleaning efficiency studies showed that only preferable and restricted area had been monitored (Williamson et al., 2009; Zmener et al., 2005). In this study, the magnifica-

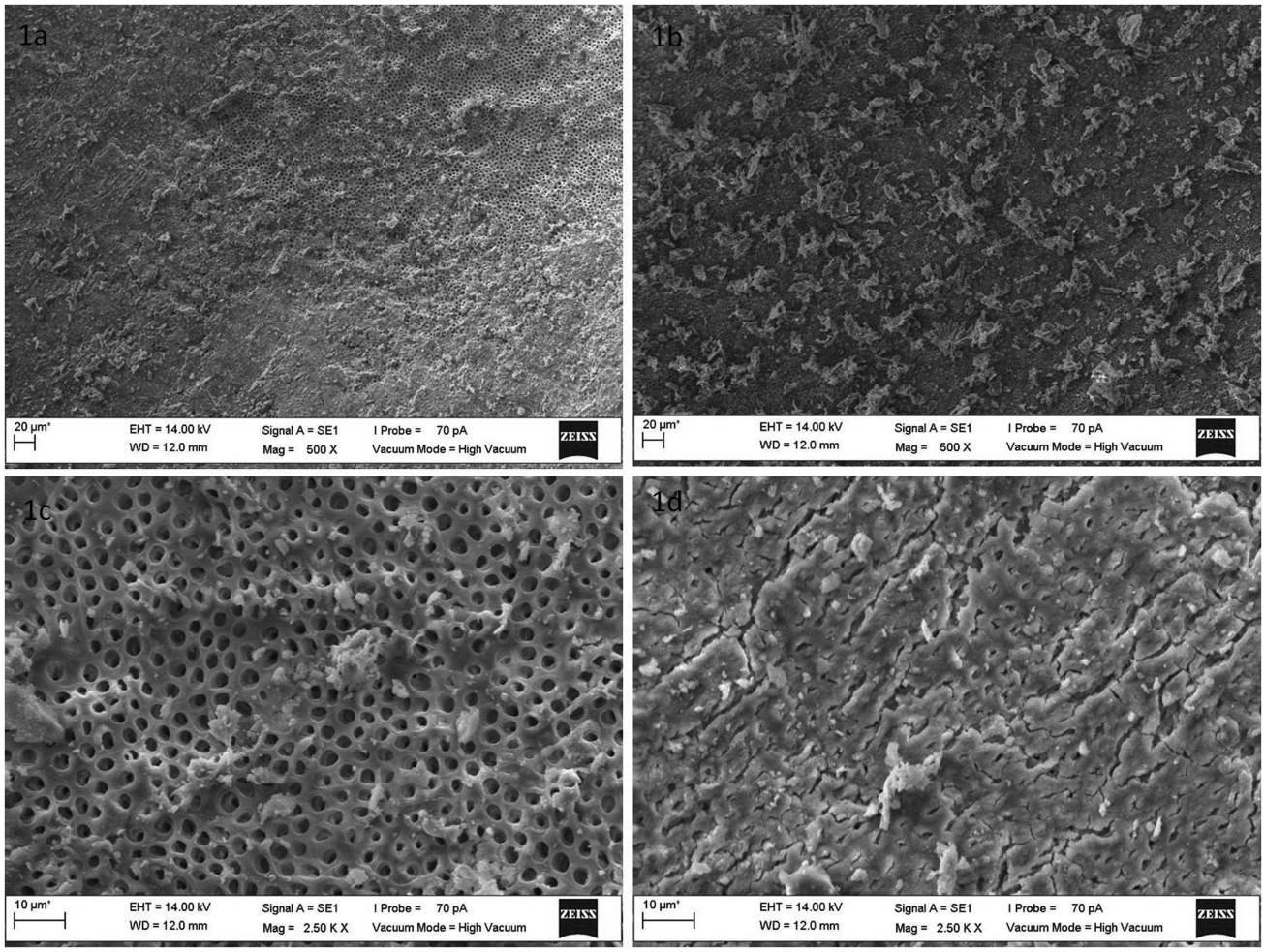


Fig. 1. Canal walls after preparation. (**a**) Few small conglomeration of debris particles in the coronal portion of the canal prepared with GT Series X (score 2, original magnification ×500). (**b**) More than 50% of the canal wall covered in the middle portion of the canal prepared with TwistedFile (score 4, original magnification ×500). (**c**) Small amount of smear layer, some open dentinal tubules in the middle portion of the canal prepared with Mtwo (score 2, original magnification ×2500). (**d**) The entire root canal wall covered with a homogenous smear layer, no open dentinal tubules in the apical portion of the canal prepared with RaCe (score 4, original magnification ×2500).

tion 500× was used because it offered a wider view, and thus, remaining debris was seen obviously; meanwhile, the smear layer was evaluated with the micrographs at 2500× magnification that covered too small a surface but gave detailed information. The drawback of the evaluation of the micrograph was that the measurements of debris and smear layer were arbitrary and at best ordinal in nature (Ahlquist et al., 2001). Unfortunately, there is currently no consensus in the precondition that was given how to select the region of the root canal wall which was taken for scoring (Bürklein et al., 2011).

In this study, it was found that there were some areas in which rotary files could not partially touch all canal sections of all experimental groups. This finding is consistent with similar laboratory studies (Bürklein et al., 2011; Fornari et al., 2010; Hülsmann et al., 1997, 2003; Paque et al., 2009) and studies in which the canal shapes were evaluated with CT (Gekelman et al., 2009; Peters et al., 2001b, 2003; Prati et al., 2004). The finding of the cleaning efficiency of rotary files having decreased from the coronal to the apical in this study is also consistent with the results of previous studies (Bürklein et al., 2011; Fornari et al., 2010; Gambarini and Laszkiewicz, 2002; Hülsmann et al., 2003; Paque et al., 2005; Schafer and Schlingemann, 2003; Schafer and Vlassis, 2004; Wu and Wesselink, 1995).

Although the GT Series X has radial lands as in its previous version, there are significant differences between specifications of the instruments. These novel instruments have been reported to have larger knife angles, lands with varying width, and up to a maximum of 1 mm handle diameter. The unique property of this newly designed instrument is that the land width on the tip and at the end of handle is half of the land size between the flutes. The manufacturer company claims that this varying width of lands minimizes the taper lock in the canal and leaves more escape area to dentine chips between the cutting flutes. Wide chip spaces are filled with debris in the long term and thus enable a longer cutting time in the canal. The results of this study showed that this system also left the debris

and the smear layer in the canal walls, as with other experimental groups.

It was claimed by Mounce (2008) that TwistedFile provided quite a high cutting efficiency and did not allow screwing in the canal and shaped the canal dentine more effectively and canalized debris toward the openings of the canal. This debris removal was concluded to be related with the groove width and the depth being designed in an increasing form from the tip to the handle. However, Twisted File system was shown to provide cleaning effectiveness only, as with other experimental groups.

The manufacturer company claims that another novel system, the Revo-S system, the cleaning efficiency of which has not been evaluated previously, enabled removal of the dentine debris toward the opening of the canal, hindered obstruction in the grooves, and thus prevented its push toward the apical (Hashem et al., 2012). The manufacturer company concluded that it was related with the asymmetrical section in instrument design. However, this system was shown to have a cleaning efficiency, as with other experimental groups.

Wu et al. (2000) reported that at least 25% of root canals, even 50% in some teeth groups (Svec, 2008) showed flat or oval shape in the buccolingual direction. The MB canal of the upper first molar used also in this study is known to have this flat and oval shape. Therefore, rotary NiTi files tend to form a round preparation shape staying at the center of the canal leaving untouched areas, and thus uncleaned surfaces should not be surprising. In recent years, it was recommended to use the NiTi rotary files combined with manual instruments and ultrasonic instruments (Burleson et al., 2007; Carver et al., 2007) or to shape the canals with oval-flat sections from two different points close to the buccal and lingual walls as if there were two different canals, in order to relieve this inadequacy of the NiTi rotary files (Paque et al., 2010).

CONCLUSIONS

According to this study, the new generation of NiTi rotary instruments including the TwistedFile and GT Series X presented similar cleaning effectiveness compared with traditionally ground NiTi rotary files.

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