*Braz Dent J (2008) 19(2): 109-113* ISSN 0103-6440

# Surface Finishing of Unused Rotary Endodontic Instruments: A SEM Study

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During endodontic therapy, cleaning of root canals is performed using endodontic files and auxiliary chemical substances, and it is important that the endodontist be familiar with the instruments used in daily practice. This study evaluated, under scanning electron microscopy (SEM), the quality of the surface finishing of unused rotary endodontic instruments. Fifty sizes 20, 25 and 30 rotary files from different commercial brands (ProFile, Protaper, Race, Hero and K3 Endo) were removed directly from their packages and had their final 3 mm examined with a scanning electron microscope at ×190 magnification with no previous preparation. The images were evaluated by 3 skillful, calibrated, blinded observers according to the following criteria: cutting edge, debris, grooves, microcavities, tip shape, tip position, scraping and transition angle. Data were recorded in worksheets designed for the study. Irregular edges were observed in 50-100% of the files. Except for ProFile, all commercial brands presented surface debris in 100% of samples. Only Race files showed no grooves or microcavities. K3 Endo files presented the best tip centralization. Excetp for ProTaper files, all commercial brands presented blunt-cutting edges in 100% of samples. All types of files presented surface scraping. K3 Endo files and Protaper had a high percentage of transition angle. Based on the evaluation criteria used in the present study, most samples presented a minimum of 2 alterations and a maximum of 7 alterations *per* instrument. Under the tested conditions, the quality of the surface finishing of the examined instruments was not as expected, given that no instrument was free of imperfections and most of them presented at least 2 and up to 7 types of surface defects. These results suggest that the manufacturing process and the packaging conditions of rotary endodontic instruments are far from ideal.

Key Words: endodontic instruments, surface finishing, scanning electron microscopy, manufacturing defects.

## INTRODUCTION

Cleaning, disinfecting and shaping of the root canals are performed using endodontic instruments and adjuvant chemical irrigants. With the advent of engine-driven instruments, mainly rotary files, the sequence of root canal preparation has been inverted, that is, the cervical third in now the first to be prepared, followed by the middle and apical thirds. This approach reduces the contact of the file with the canal walls, which minimizes the risk of breakage during clinical use and permits a progressive emptying of root canal content. One of the advantages of rotary instrumentation is hence to improve cervical preflaring in order to facilitate apical file size determination and enhance canal shaping at the apical third (1,2). A previous study (3) investigated the shaping ability of rotary nickel-titanium (NiTi) instruments (taper 0.04 ProFile) in simulated root canals and observed that none of the canals became blocked with debris and presented minimal change in the working distance. Pécora and Capelli (4), however, have called the attention to the fact that while rotary file taper is a positive factor for cervical preflaring, it may result in underpreparation of the apical portion of the canal.

Bonetti Filho et al. (5) examined K-files, NiTi instruments and Flexofiles before use and after being

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used one, three or five times in maxillary premolars, and detected manufacturing defects even after the first use. Parashos et al. (6) examined used and discarded rotary NiTi instruments in order to identify factors that may influence defects produced during clinical use. The authors concluded that the operator was the most important factor influencing failure rates, which may be related to clinical skills or to a conscious decision to use instruments a specified number of times or until defects were evident. Cheung et al. (7) compared the type of defects and mode of material failure of engine-driven and hand-operated ProTaper instruments after clinical use and concluded that the failure mode of engine-driven and hand-operated instruments differed from each other. About 62% of hand instruments failed because of torsional fracture and approximately 66% of engine-driven instruments failed because of fatigue.

In view of the high incidence of breakage of engine-driven files during clinical use, Cheung et al. (8) investigated the mode of failure of a brand of nickel-titanium instruments separated during clinical use, by detailed examination of the fracture surface. The authors concluded that, due to the microstructure of the metallic alloys used for manufacturing of the files, fractures have a transgranular pattern and are caused by the coalescence of microcavities. Manufacturing defects were observed in the cutting edge of the K-files of all commercial brands.

Zinelis et al. (9) examined the current status of standardization of stainless steel H- and K-files as well as rotary NiTi files in order to determine the incidence and degree of deviation from the ISO 3630-1 standard:1992 specifications. The authors observed differences in the diameters of instruments of the same size from the same or different manufacturers, but all files were within the ISO tolerance limits. Kuhn et al. (10) investigated the process history on fracture life of NiTi files by SEM and observed a large number of imperfections on the alloys, concluding that the surface conditions of the files is a key factor in failure and fracture initiation.

Rotary instruments are well incorporated to the clinical endodontic arsenal. However, in most cases, the files are not checked for quality before use. Instead, they are often removed from the packages, sterilized and used without being examined for the presence of imperfections or debris.

The purpose of this study was to evaluate, under SEM, the quality of the surface finishing of unused rotary endodontic instruments from different commercial brands removed directly from their packages without any previous preparation.

## MATERIAL AND METHODS

Rotary NiTi files of different commercial brands were used in this study: Profile .04 (size 20 to 30; Maillefer Instruments, Ballaigues, Switzerland); Profile .06 (size 20 to 30; Maillefer Instruments); ProTaper (size 20 to 30; Maillefer Instruments); Hero 642 .02 (size 20 to 30; Micro-Méga, Besançon, France); Hero 642 .04 (size 20 to 30; Micro-Méga); Race .02 (size 20 to 30; FKG Dentaire, La Chaux-de-Fonds, Switzerland); Race .04 (size 20 to 30; (FKG Dentaire); K3 Endo .02 (size 20 to 30; Sybron Dental Specialties/Kerr Corporation, Orange, CA, USA); K3 Endo .04 (size 20 to 30; Sybron Dental Specialities/Kerr). Ten instruments of each commercial brand were used (total=50).

The instruments were carefully removed from their original packages and mounted on metallic stubs for analysis with a scanning electron microscope (LEO 430, Zeiss-Leica, Oberkochen, Germany; Department of Pathology, Dental School, University of São Paulo, Brazil) with no type of treatment or preparation. The instruments had their final 3 mm examined at ×190 magnification and were arranged in the stubs in the following sequence: taper .02 size 20 file; taper .04 size 20 file; taper .02 size 25 file; taper .04 size 25 file; taper .02 size 30 file; taper .04 size 30 file.

The SEM micrographs were presented as digital images to 3 skillful, calibrated, blinded observers. A standard error of the mean of 0.066 was considered for intraexaminer and interexaminer calibration. Data were recorded in a worksheet that had on one side the names of instruments and on the other side the following evaluation criteria: cutting edge, debris, grooves, microcavities, tip shape, tip position, scraping and transition angle.

## RESULTS

Figures 1 to 4 illustrate representative images of manufacturing defects observed in the endodontic instruments examined in this study. The percent distribution of the evaluation criteria for each endodontic instrument is presented in Table 1.

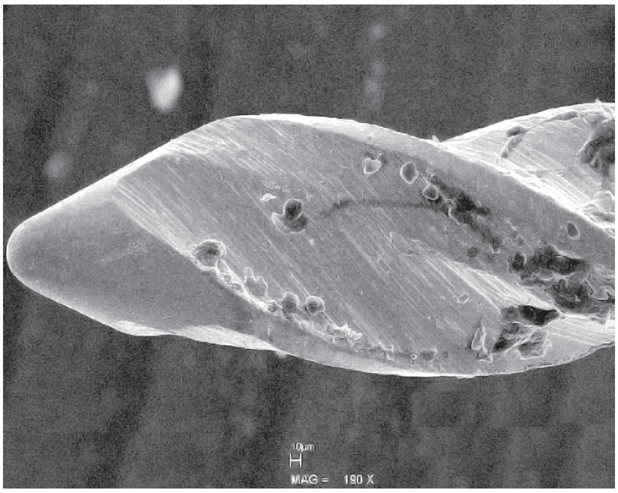


Figure 1. SEM micrograph of the final 3 mm of an instrument showing the presence of scraping on instrument surface.

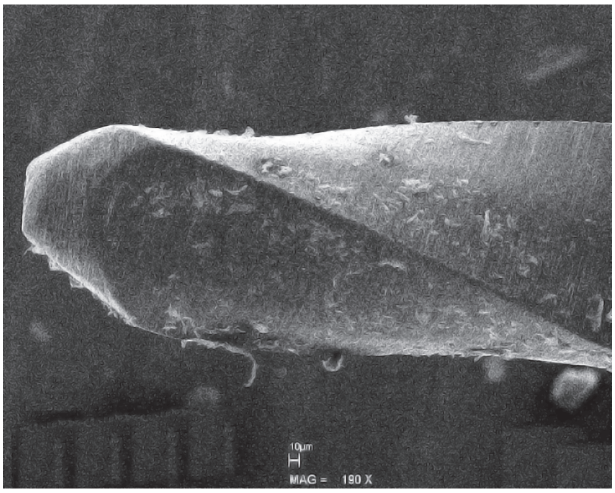


Figure 2. SEM micrograph of the final 3 mm of an instrument showing the presence of debris on instrument surface.

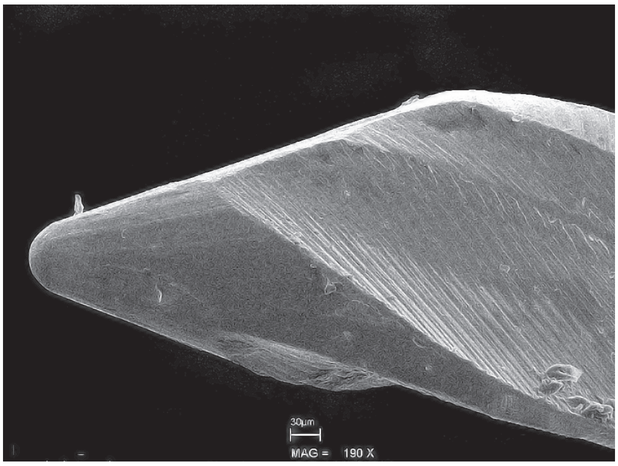


Figure 3. SEM micrograph of the final 3 mm of an instrument showing the presence of grooves on instrument surface.

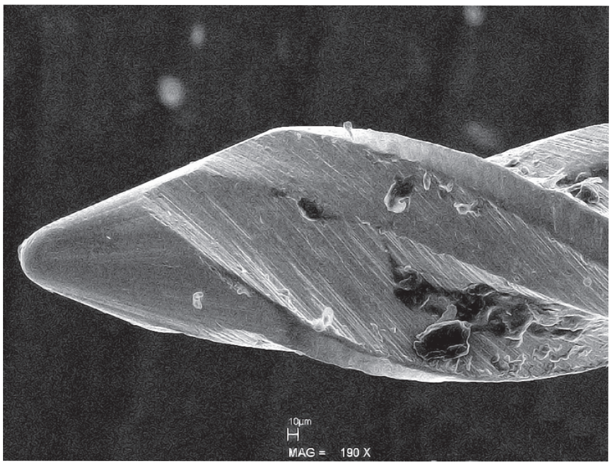


Figure 4. SEM micrograph of the final 3 mm of an instrument showing the transition angle on instrument surface.

Table 1. Distribution (%) of the studied criteria for each endodontic instrument.

| | Irregular edge | Debris | Grooves | Microcavities | Centric tip | Cutting edge | Scraping | Transition angle |
|---|---|---|---|---|---|---|---|---|
| Hero | 44.5 | 100 | 100 | 74.07 | 44.5 | 0.0 | 55.5 | 11.1 |
| K3 | 25.0 | 100 | 100 | 75.0 | 62.5 | 0.0 | 54.17 | 87.5 |
| ProFile | 11.1 | 96.3 | 45.5 | 33.5 | 11.1 | 0.0 | 33.5 | 0.0 |
| ProTaper | 0.0 | 100 | 100 | 37.5 | 0.0 | 20.83 | 100 | 50.0 |
| Race | 50.0 | 100 | 100 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 |

## DISCUSSION

The technological advances experienced in the last years led to the fabrication of endodontic instruments with metallic alloys of better quality, such as NiTi alloy, and determined other modifications, including helicoidal cross-section design, instrument tip design, helix angle and dimensions of the instrument centre. Changes in the taper and diameter of the tip of endodontic instruments have also been proposed.

In the present study, unused rotary endodontic instruments were evaluated in the form that they are available in the market and are taken to the dental office for use. The instruments were examined by SEM immediately after being removed from their packages in order to determine the quality of their surface finishing and adequacy of packaging conditions. No surface treatment was performed, differently from other study (11) in which ultrasonication in acetone was used to obtain clean and dry instruments.

During manufacturing of NiTi and stainless steel endodontic files, the companies express concern about the principles of standardization for production of instruments with good quality and adequate finishing. A previous study (9) showed that none of the tested files complied with the ISO nominal size, though all of them were within the ISO tolerance limits. Considering these results and the findings of other authors (1,10), the present SEM analysis was conducted at magnifications that allowed examining the final 3 mm of each rotary file. Samples of commercial brands that are easily found in the dental market (Hero 642 Micromega, K3 Endo Sybron Endo, Protaper Maillefer Instruments, Profile Maillefer Instruments, Race FKG) were obtained.

According to the manufacturers, the tips of rotary instruments should be conic, smooth and should not present a transition angle. Bryant et al. (3) observed that K3 Endo files had a high percentage of samples with transition angle. Accordingly, in the present study, 87.5% of K3 Endo files presented transition angle versus 50% of ProTaper files. No transition angle was observed in the other commercial brands. Regarding the shape of the tip of the instruments, the analysis of Hero, Profile, K3 and Race files was 100% in accordance with the findings of Bryant et al. (3), as these instruments presented blunt-cutting edges. Only for ProTaper files 20.8% of the samples presented cutting edge.

Race instruments did not present any scratch or groove, whereas 100% of K3, Hero and ProTaper presented grooves and 45% of Profile instruments presented scratches and grooves. These findings confirm those of Tripi et al. (12), who reported that unused files exhibited such manufacturing defects and used files presented deformations.

Another type of imperfection noted in the present study was the presence of scraping in all commercial brands. It was observed in 100% of Protaper files, 50% of K3 Endo, Hero and Race files and 33.5% of ProFile instruments. This type of imperfection has also been reported by Bonetti Filho et al. (5), who analyzed endodontic instruments as they come from the manufacturers and after being used for root canal instrumentation.

It is important to highlight the relationship between rotary instrumentation and the presence of manufacturing imperfections and possible instrument breakage. Several authors (7,8,10) have chosen the same research line, with emphasis on investigating why the files fractured or why they presented defects. In the present study, only Race files did not exhibit microcavities on their surface at ×190 magnification; in the other files, the percentage of microcavities ranged from 33.5% to 75%. These microcavited areas may present a concentration of corrosion and possibly become sites susceptible to instrument breakage.

All rotary instruments examined in this study presented debris on their surface. ProTaper files had debris in 96.3% of the samples, while the other commercial brands had debris in 100% of the samples.

Under the tested conditions, it was observed that the quality of the surface finishing of the examined instruments was not as expected, given that no instrument was free of imperfections and most of them presented at least 2 and up to 7 types of surface defects. These results indicate that the manufacturing process and the packaging conditions of rotary endodontic files are far from ideal. Likewise, most reviewed articles (6,9-11) reported a high incidence of defects in the manufacturing process of endodontic instruments. These results call the attention to two important facts: one regarding the importance of cleaning of endodontic instruments before sterilization and the other referring to the need of further research that may add information to the surface treatment and polishing of instruments in an attempt to minimize the occurrence of the imperfections identified in this study.

## RESUMO

Durante a terapia endodôntica, a ação de limpeza é realizada com os instrumentos endodônticos auxiliada por substâncias químicas. Sendo assim, é importante que o endodontista conheça como são os instrumentos. Este trabalho visou avaliar a qualidade do acabamento de superfície de instrumentos endodônticos rotatórios por meio de microscopia eletrônica de varredura. Foram selecionados, 50 instrumentos endodônticos rotatórios nos números de 20, 25 e 30, das marcas Profile, Protaper, Race, Hero e K3 Endo, da forma como são encontradas no mercado e sem nenhum preparo prévio. Os instrumentos tiveram seus 3 milímetros finais fotomicrografados em microscópio eletrônico de varredura com ampliação de ×190. As imagens foram avaliadas por três profissionais especialistas, e os resultados anotados em planilhas. A metodologia aplicada permitiu concluir que todos os instrumentos das marcas comerciais avaliadas apresentaram inadequações no acabamento da superfície. Cabe aclarar que, observando os critérios selecionados utilizados para avaliação a maioria das amostras apresentaram o mínimo de duas alterações e o máximo de sete por instrumento avaliado.

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*Accepted September 25, 2007*