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Microleakage of five separated nickel-titanium rotary file systems in the apical portion of the root canal

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ABSTRACT

Background: The aim of this study was to evaluate the rate of apical microleakage following the fracture of five types of nickel–titanium rotary file systems (ProTaper Universal, Mtwo, RaCe, Revo-s, HeroShaper) in the apical one-third of the canal.

Materials and Methods: In this laboratory experiment, 49 mandibular premolars were collected and randomly divided into seven groups. Root canal treatment was performed by five different rotary file systems with different cross-sections. All files, except in the control groups, were scratched at the 3-mm end by a handpiece. After separation of the apical end of the file in the root canal, the apical seal was measured, using the fluid infiltration technique. Data were analyzed in SPSS, using one-way ANOVA and Tamhane's T2 tests at $P < 0.05$.

Results: The Hero Shaper and RaCe files showed the highest (3.14 μL/min) and the lowest (2.51 μL/min) rates of microleakage over time, respectively. There were significant differences between the Hero Shaper and RaCe files and between Hero Shaper and ProTaper files in terms of microleakage (Tamhane's T2 tests, $P < 0.05$)

Conclusion: The presence of a separated file and its cross-section type affects the apical microleakage.

Key Words: Nickel–titanium, root canal treatment, rotary, separation

INTRODUCTION

Optimal apical obturation and apical seal are key factors in the success of root canal therapy, as ideal obturation should prevent microorganisms from entering the periapical space and proper apical seal plays an important role in the health of periapical tissues and enhances the success of root canal therapy by up to 97%.[1,2] Microleakage, which occurs in the absence of apical seal, is a major cause of failure in root canal treatment.[3]

According to previous studies, rotary files are more prone to separations than manual stainless steel files.[4] The prevalence of separation in rotary files is estimated at 4%–5%.[5] There are various types of rotary files available with different cross-section designs. Studies have reported that the cross-sectional design of rotary systems might play a role in the incidence of separation.[6,7] The rate of sealing failure in the apical one-third of the canal is higher than in

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the middle and coronal thirds.[8] Evidence shows that a separated file compromises the root canal cleaning, preparation, and obturation[9] and is a threat to the success of root canal therapy.

Although the coronoapical location of a separated file and bypassing it does not implicate on the success rate,[10] the retrieval of the separated files is suggested. However, removing a separated rotary file is very difficult and even impossible in some cases. According to the results of a study by Parashos and Messer,[11] if the separated file is located beyond the curvature, its removal is rarely suggested. Furthermore, if the file separation is in the early stages of canal preparation or the size of the separated file is small, canal debridement is inadequate, and the apical seal is compromised.[12]

It seems that rotary systems with different cross-sectional designs may have different microleakage rates following separations. Various studies have been performed on different types of separated rotary files within the root canal. These studies have reported different results in rate of apical microleakage based on the type of separated rotary system and the following obturation method.[13-17] Considering the inevitability of file separations during root canal treatment, expanding our knowledge about factors affecting apical seal is necessary. Therefore, it is important to identify the appropriate cross-section design in rotary files with the least amount of microleakage after file separation.

This study aimed to evaluate the rate of apical microleakage, using the modified fluid transport test, following the separation of five types of nickel-titanium rotary systems (i.e., ProTaper Universal, Mtwo, RaCe, Revo-s, HeroShaper) in the apical one-third of the root canal.

MATERIALS AND METHODS

Sample selection

This laboratory experiment was performed during 2019–2020. In this study, 49 mandibular premolars, extracted due to periodontal diseases, prosthetics, or orthodontic reasons were collected. There was approval by the University Ethics Committee (IR.MUI.RESEARCH.REC.1398.112).

The inclusion criteria were roots with a mature apex, curvature <25°, and root length of 19 mm. Moreover, teeth having cracks, caries, root resorptions and/or fractures and teeth with more than one root canal or calcified canals were excluded from the study.

Sample preparation

The teeth were disinfected by immersion in 5.25% hypochlorite solution (Milton; Laboratoire Rivadis, Louzy, France) for 1 h. After that, they were stored in a 10% formalin solution (Baxter Scientific Products, IL) at room temperature until further use. In order to obtain standardization and to avoid anatomical variations, the anatomical crown in all teeth was cut by a diamond bur (Dentsply, Maillefer) and high-speed handpiece. To determine the working length, a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the canal. Immediately after viewing the tip of the file in the apical foramen, 0.5 mm of the length was subtracted, and then, the canal length was determined. Afterward, all root canals of the teeth were instrumented, using the F1 ProTaper Universal Nickel–Titanium rotary file system (Dentsply Maillefer, Ballaigues, Switzerland) followed by F2 and F3 files, respectively, according to the manufacturer's instructions. Subsequently, the teeth were numbered from 1 to 49 and divided into seven groups (n = 7) by simple random sampling:

Group 1: Preparation of teeth using the F3 (30/0.09) ProTaper Universal Nickel Titanium Rotary file system (Dentsply Maillefer, Ballaigues, Switzerland) with a convex triangular cross-section.

Group 2: Preparation of teeth using the Mtwo (30/0.06) Nickel–Titanium Rotary file system (VDW, Munich, Germany) with a S-shaped cross-section.

Group 3: Preparation of teeth using the RaCe (30/0.06) Nickel–Titanium Rotary file system (FKG Dentaire, La-Chaux-de-Fonds, Switzerland) with a triangular cross-section.

Group 4: Preparation of teeth using a Revo-S (30/0.06) Nickel–Titanium Rotary file system (Micro-Mega, Besancon, France) with an asymmetrical cross-section.

Group 5: Preparation of teeth using a HeroShaper (30/0.06) Nickel–Titanium Rotary file system (Micro-Mega, Besancon, France) with a triangular cross-section.

Group 6: Preparation of teeth using the F3 (30/0.09) ProTaper Universal Nickel–Titanium Rotary file system (Dentsply Maillefer, Ballaigues, Switzerland). This group was considered as the positive control without any broken files.

Group 7: Preparation of teeth using the F3 (30/0.09) ProTaper Universal Nickel–Titanium Rotary file system (Dentsply Maillefer, Ballaigues, Switzerland). The canal space and the apical end of the teeth were blocked with wax as the negative control.

All groups were prepared and shaped, using a rotary electric motor (ENDO-MATE DT, NSK, Japan) at the speed and torque, according to the manufacturer's instructions for each rotary system. Irrigation was performed with 5.25% hypochlorite solution (Milton; Laboratoire Rivadis, Louzy, France) between each successive filing. The final file of all groups, except groups 6 and 7, was scratched by a diamond bur and a high-speed handpiece 3 mm from the tip of the file, in order to facilitate the separation. In all groups, except the control groups, the scratched file was inserted into the canal at the working length, tug-back feeling was checked by the operator to ensure the engagement between the scratched file and the root canal dentine and to eliminate samples with loose file within the canal. After that, the scratched file was rotated through the canal until it was separated. Radiographs were acquired of the teeth to make sure that the separated part is located at the apical region. As most file fractures inside the canal occur at 2–4 mm of file length,[18] the length of separated parts in the apical region was considered to be 3 mm in the current study. Final irrigation was performed using 5 mL of 5.25% NaOCl (Milton; Laboratoire Rivadis, Louzy, France) and 5 mL of 17% EDTA (Vista Dental, Racine, WI) for 1 min, followed by irrigation with 5 mL of saline to eliminate the effect of the preceding irrigants and then root canals were dried with sterile paper points.

To reduce the risk of transportation, a root curvature <25° (straight root to moderate curvature) was selected, according to the Schneider's method.[19] To evaluate the microleakage of the canal, each root specimen was attached to the fluid infiltration device, and 50 kPa pressure was applied on the syringe attached to the device. The average value of microleakage for each sample was calculated after measuring the displacement of air bubbles for two times during 24 h in a glass tube.

Statistical analysis

Data were analyzed in SPSS version 22 (IBM, Chicago, USA), using one-way ANOVA and Tamhane's T2 tests. $P < 0.05$ was considered as statistically significant.

RESULTS

The positive and negative control groups showed the highest and least mean of microleakage, respectively (8.55 ± 1.50 µl/min and 0.86 ± 0.12 µl/min).

Among the experimental groups, the HeroShaper files showed the highest microleakage over time (3.14 ± 0.19 µl/min), while the RaCe files (2.51 ± 0.31 µl/min) had the lowest microleakage [Table 1 and Figure 1].

The mean of microleakage was significantly different between the experimental groups (One-way ANOVA test, $P < 0.01$). Although the rate of microleakage between the HeroShaper and the RaCe files and between HeroShaper and ProTaper files was significantly different (One-way ANOVA, *post hoc*: Tamhane's T2 tests, $P < 0.05$), it was not significant between the other groups.

DISCUSSION

File separation in endodontic treatment is an unexpected and important event during the treatment

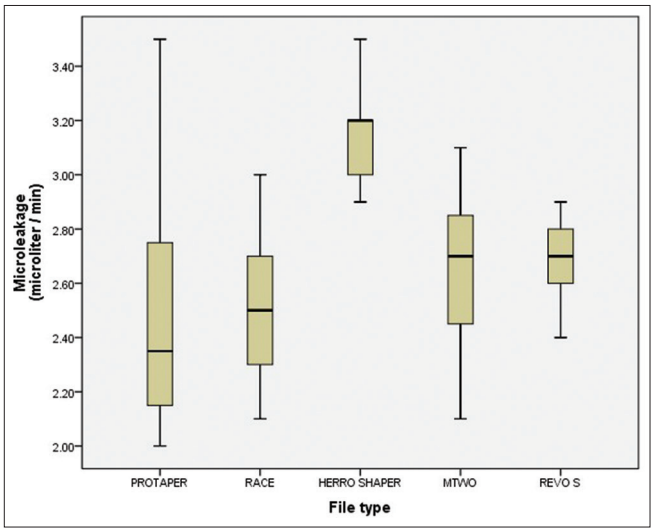

Figure 1: The rate of microleakage in the experimental groups (microliter/min)

Table 1: Mean±standard deviation of microleakage in the experimental groups

File type	n	Mean microleakage (microliter/min)	95% CI	
			Lower bound	Upper bound
ProTaper	7	2.52±0.54	3.02	2.01
RaCe	7	2.51±0.31	2.80	2.22
HeroShaper	7	3.14±0.19	2.95	2.32
M-two	7	2.64±0.33	2.95	2.33
Revo-s	7	2.68±0.17	2.84	2.52

CI: Confidence interval

process. In case of a file separation, the best solution is to remove or bypass the separated part. Otherwise, the root canal treatment is completed until reaching the site of the separated file, and the patient is followed-up to undergo surgical intervention if the treatment fails.[20]

Some studies have shown that the separated file itself does not have any effects on microleakage, bacterial penetration, or sealing ability of the obturation material,[21-23] and the success of root canal treatment depends on coronal seal and the absence of any residual stimuli within the canal and space around the separated file.[23] Leaving the separated file inside the canal, acceptable obturation for proper sealing and using the remaining file as part of obturation can be a good practice in such cases.[13,24] Other studies have reported significant differences in rate of microleakage in presence of a separated file.[13-17]

Evren *et al*. and Hegde *et al*. reported significantly higher rates of apical microleakage in teeth obturated in the presence of a separated file as compared to the teeth with no separated file within the canal, regardless of the obturation material or type of the rotary system.[15,16] However, in a study by Taneja *et al*.,[17] the presence of a separated file, irrespective of the type of file, resulted in reduced microleakage in the obturated canals. In addition, the type of obturation technique influenced the final apical seal rate. This variation in results may be due to the differences in obturation materials and techniques, types of rotary system used in the study, and different methods of microleakage assessment. In addition, the screwing force applied to the file during the file separation step can compress the file into the canal wall and can prevent the accumulation of debris and thus reduce the apical microleakage.[13]

There are various methods to evaluate the effectiveness of obturation techniques and materials and the microleakage of filled canals including dye penetration, fluid filtration, dye extraction methods, electrochemical leakage test, bacterial leakage, and salivary leakage methods.[25-29] In the present study, modified fluid transport test was used. In this method, the samples were not destroyed, and it was possible to measure microleakage over long periods. Accordingly, the tendency of the groups with different cross-sections showing microleakage could easily be observed and be recorded over time. Moreover, measurements of the modified fluid transport test indicate the rate of microleakage in the total number of samples quantitatively.[30,31]

According to the results of this study, files with different cross-sections showed different levels of microleakage. In the study by Altundasar *et al*., comparison between the ProTaper and ProFile systems showed less microleakage in the ProTaper system.[13] In the study by Hegde *et al*. this comparison was made between K3 and RaCe systems and showed a lower rate of microleakage in the RaCe system.[16]

In the present study, unlike previous studies, the canals were not obturated to solely assess the sealing properties of separated files with various cross-sections and to eliminate the confounding effects of sealer and gutta-percha. Therefore, parameters such as length of a separated file, root canal shape, and irrigation protocol were the same to acquire standardization. According to the results of this study, apical microleakage was the highest in the group prepared with HeroShaper file and the lowest in the groups prepared with RaCe and ProTaper files, respectively.

Differences observed in rate of microleakage and apical sealing caused by the presence of separated files from different systems is in fact stemmed from the differences in the design of cutting edges (lands and flutes) and cross-sections; different systems' designs affect the rate of canal irrigation, debris accumulation, residual material around the separated file and positioning of the sealing and obturation materials (either by the solid or thermal method) between the separated file flutes.

The RaCe rotary system has a triangular cross-section with variable cutting edges,[32] while the Revo-S rotary system has an asymmetric cross-section with three cutting edges,[1,2] which improve debris removal, compared to HeroShaper rotary system with triangular cross-sections and noncutting edges.[33] The ProTaper Universal rotary system has a triangular cross-section with noncutting edges[32] and the M-two rotary system is S-shaped in cross-section and has two cutting edges with a positive rake angle.[33]

Previous studies have reported that nickel-titanium rotary files with active cutting edges provide more canal irrigation than files with noncutting edges.[34,35] It is known that common methods of cleaning and shaping the canal create a layer of inorganic and organic matter, called the smear layer. This layer can play an important role in the development of

microleakage and interferes with the formation of a suitable and satisfactory seal. Examination of scanning electron microscopy images of residual debris in the root canal walls showed that files with noncutting edges tend to burnish dentine particles created during the instrumentation process into the canal walls. Consequently, these particles remain in the canal walls, creating a barrier between the obturation material and the canal walls, while files with active cutting edges can reliably detach particles from the canal wall resulting in their removal from the root canal system during the irrigation process.[17]

Despite many advances that have been made to date to retrieve separated instruments within the canal, removing the separated rotary file from the apical one-third remains as a complicated procedure. Recent studies have evaluated the effects of maintaining the separated file within the canal to be considered as a part of canal obturation system. However, the extension of the results of these studies to the clinical field should be done with great caution, because in cases of file separation, the quality of apical seal is only one of the issues that can overshadow the results of the treatment.

This study helped to identify the rate of apical microleakage following the separation of five types of nickel–titanium rotary files in the apical one-third of the root canal without obturating the coronal part of the canal to eliminate the confounding effects of sealer and gutta-percha. More recent rotary systems with different convergences are suggested to be considered in the following studies. Limitations of the present study were a small number of teeth in experimental groups and that some teeth cracked during the preparation process and had to be removed from the study.

CONCLUSION

According to the present study, the presence of a separated file and its cross-section design affects the apical sealing ability of the root canal. Based on the results, the Hero Shaper rotary files showed the highest microleakage over time among the five groups of rotary systems (3.14 ± 0.19 µl/min), while RaCe (2.51 ± 0.31 µl/min) and ProTaper (2.52 ± 0.54 µl/min) files had the lowest microleakage, respectively. The rate of microleakage between the HeroShaper and the RaCe files and between HeroShaper and ProTaper files was significantly different.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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