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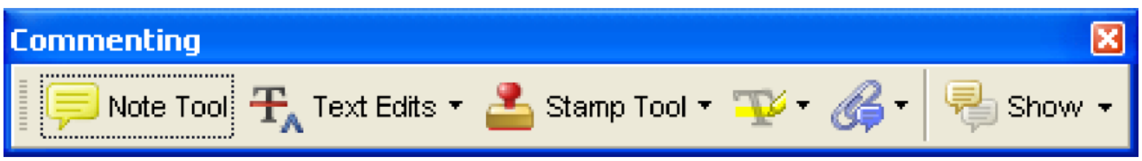

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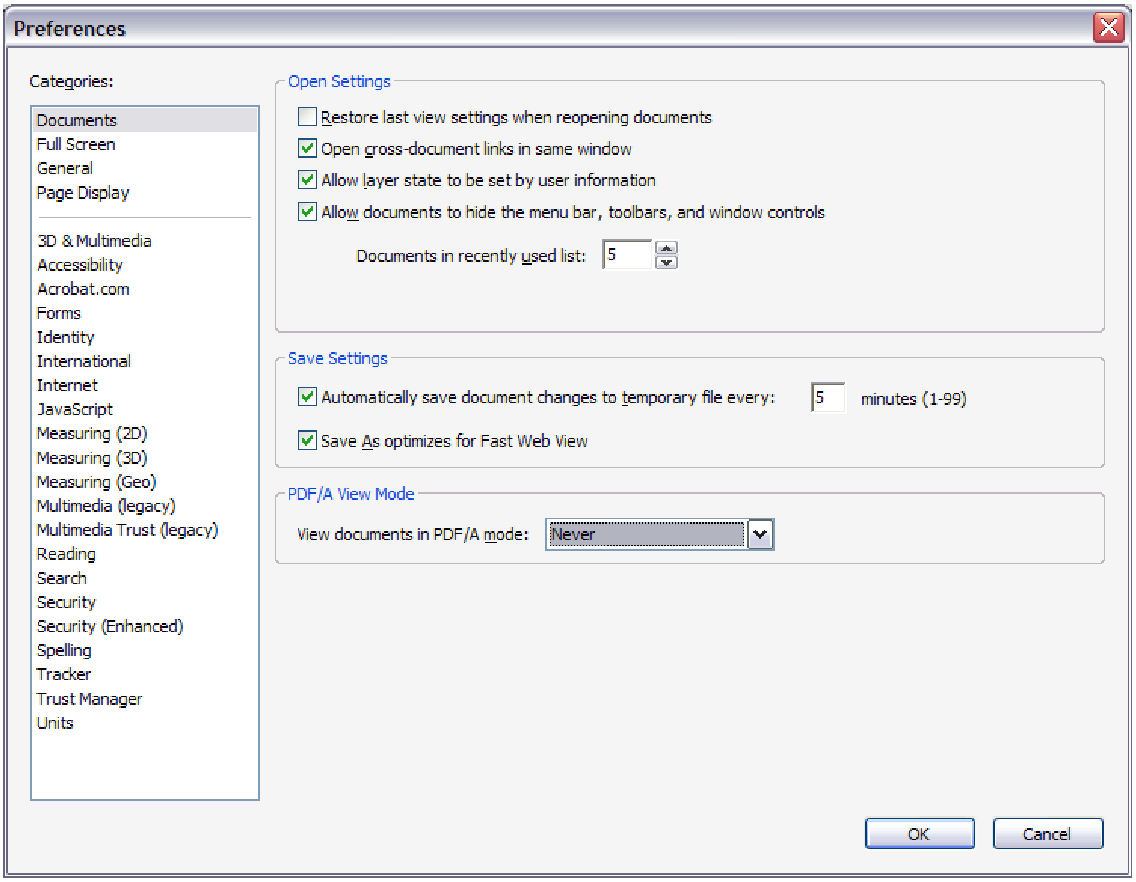

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The Self-Adjusting File Optimizes Debridement Quality in Oval-Shaped Root Canals

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Abstract

Aim: Oval-shaped canals represent a challenge for rotary nickel-titanium (NiTi) files because buccal and/or lingual recesses are commonly left uninstrumented. The aim of the present study was to evaluate the debridement quality of the Self-Adjusting File (SAF) system in oval canals and compare it with the debridement achieved by a commonly used NiTi rotary system. **Methods:** A careful specimen selection resulted in two equal groups each consisting of 12 extracted mandibular canines with oval canals that had vital pulps before extraction. All canals had a buccolingual diameter that was at least 2.5 times larger than that of the mesiodistal one as defined from radiographs. One group was subjected to the SAF protocol, whereas the other group underwent conventional protocol; the ProTaper system up to the F2 instrument was used with syringe and open end needle irrigation. Sodium hypochlorite (5.25%) was used as an irrigant for both groups. The roots were then histologically processed and 0.6-μm-thick cross-sections were obtained every 0.5 mm from the 1- to 5-mm apical levels. Morphometric evaluation was performed on cross-sections to determine the amount of remaining pulp tissue as a percent of the root canal area. **Results:** The group-by-location interaction was not significant ($P > .05$), which means that the group comparisons were not dependent on the cross-sectional level. There was significantly greater residual pulp tissue left after ProTaper system instrumentation versus SAF instrumentation (21.4% vs 9.3%, $P < .05$). **Conclusion:** The SAF protocol was significantly more efficient for debridement of oval root canals than the rotary ProTaper protocol. *(J Endod 2011;■:1–5)*

Key Words

Debridement, instrumentation, oval canals, ProTaper, Self-Adjusting File

The introduction of nickel-titanium (NiTi) rotary file systems has resulted in significant progress being made in the mechanical preparation of the root canal space. Nevertheless, the results from high-definition micro–computed tomography (micro-CT) scanning studies have underlined the inadequate quality of mechanical preparation by the current NiTi rotary systems. Using micro-CT technology, it has been shown that the amount of mechanically prepared root canal surface is frequently below 60% (1–3). Rotary NiTi techniques leave a substantial amount of untreated dentin areas. The rotary motion of these files tends to prepare the main root canal space into a circular shape, leaving unprepared buccal and lingual extensions (4, 5). This phenomenon cannot be observed in two-dimensional clinical periapical radiographs, which represent a buccolingual projection. On the other hand, it can easily be observed in histological cross-sections.

Proper mechanical instrumentation should uniformly plane the entire perimeter of the root canal, thus completely removing the inner layers of heavily contaminated dentin. This, in turn, will also ensure the removal of as much of the remaining soft tissue and bacterial biofilm as possible, which may adhere to and cover the vast areas of the inner surface of the canal and may predispose to or cause and perpetuate disease (6). [Q1] The limitations of current technologies should lead to the pursuit for more efficient preparation techniques, which may improve the debridement of the root canal space.

Initial reports of the Self-Adjusting File (SAF) system sound promising (7, 8). This [Q2] innovative instrument consists of a hollow file composed of lattice threads that are lightly abrasive and allow for dentin removal with a back-and-forth grinding motion (9). The SAF is designed as a compressible file with the ability to adapt itself to the root canal cross-section.

Oval-shaped canals represent a critical challenge for any root canal cleaning and shaping protocol. Thus, the present study was designed to assess the tissue debridement efficacy of the SAF protocol in oval-shaped canals and to compare those results with the performance of the ProTaper NiTi system, which served as the control (10). The [Q3] amount of residual pulp tissue was used as the outcome parameter to test the null hypothesis that there is no difference in the debridement of pulp tissue between the SAF or ProTaper systems for oval-shaped canals.

Materials and Methods

In Vivo Prospective Selection Process of Vital Teeth

One hundred sixty adult subjects voluntarily participated in the present study, which was reviewed and approved by the Ethics Committee. All teeth were scheduled for extraction because of advanced periodontal disease or nonrestorability.

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Only mandibular canines with vital pulp were included in the present study. To ensure pulp vitality, teeth were first tested using Green Endo-Ice refrigerant spray (Hygenic, Akron, OH). Teeth that responded positively were then anesthetized and accessed to verify the presence of a bleeding pulp. Teeth that failed to provide the dual proof for vital pulp were excluded from the study. It took 5 months (November 2009-March 2010) to collect 106 mandibular canines with confirmed vital pulps. After extraction, each tooth was immediately placed into a vial labeled with a four-digit alphanumeric code and containing 10 mL of buffered 10% formalin. Radiographs were taken in buccolingual and mesiodistal projections to select only teeth with a single root canal and to categorize them as either oval or circular shaped. Root canal diameters were measured 5 mm from the apex using image-analysis [Q4] software (AxioVision software 4.11; Carl Zeiss, Germany); when the buccolingual diameter was 2.5 or more times larger than that of the mesiodistal diameter, the canals were classified as oval shaped. Round-shaped canals, in which the mesiodistal diameter was similar to the buccolingual diameter, were excluded from the present study.

All teeth presenting isthmus, lateral, accessory, or two canals were also excluded from the study. Furthermore, only root canals with an initial apical size equivalent to a size 10 K-file were included.

This selection process resulted in 68 vital mandibular canines that met all of the previously described criteria. From this collection, 12 pairs of teeth (total 24) were radiographically pair matched, and one tooth from each pair was randomly assigned to one of the two groups in this study. After the groups were established, a flip of a coin was used to define which teeth would be treated with each protocol. Six additional teeth were used as histological controls.

Root Canal Preparation

Tooth length was standardized to 18 mm by cutting off part of the crowns, and the root canal patency was confirmed by inserting a size 15 instrument. The working length (WL) was established at the apical foramen. The same operator performed all preparation procedures.

For the ProTaper preparation, 12 teeth were prepared with the ProTaper Universal instruments driven at 300 rpm with 2 N/cm of torque (XSmart; Dentsply-Maillefer, Balleigues, Switzerland). The sequence followed was (1) S_X file (one half of the WL), (2) S_1 file (one third of the WL), (3) S_2 file (two thirds of the WL), (4) F_1 files (the full WL), and (5) [Q5] F_2 files (the full WL). Shaping S_X, S_1, and S_2 files were used in the canal with a brushing motion according to the anatomy of each root canal. Irrigation with 1 mL 5.25% sodium hypochlorite (NaOCl) solution was used between each instrument applied with a syringe and an open-end needle. After each instrument, the needle was inserted as far as it reached and retracted 2 mm before irrigation was applied. After the last instrument was used, the needle was placed 2 mm from the WL, and irrigation was applied. The smear layer was then removed using 3 mL 17% EDTA for 3 minutes. Three milliliters of bidistilled water was then used for 3 minutes as a final rinse.

For the SAF preparation, 12 teeth were prepared using the SAF system (ReDent-Nova, Ra'anana, Israel). A glide path was verified or established using a #20 K-file. The SAF file was operated in each canal for 4 minutes with continuous irrigation. The file was used with a vibrating handpiece head (RDT3, ReDent-Nova) at an amplitude of 0.4 mm and at 5,000 vibrations per minute. An in-and-out manual motion was continuously performed by the operator. Irrigation with 5.25% sodium hypochlorite was applied through the hollow file throughout the 4 minutes of operation. The irrigant was continuously provided by a VATEA peristaltic pump (ReDent-Nova) at a rate of 4 mL/min. A smear layer was then removed with 3 mL of 17% EDTA for 3 minutes. Three milliliters of bidistilled water was then used for 3 minutes as a final rinse.

Histological Assessment

Specimens were immediately immersed in 10% buffered formalin for 48 hours and then demineralized in a 22.5% (vol/vol) formic acid solution and a 10% (wt/vol) sodium citrate solution for a period of 2 to 3 weeks. The endpoint was monitored radiographically. After rinsing for 24 hours in tap water, the specimens were dehydrated and processed for routine histological examination. Teeth were embedded in paraffin blocks, and serial 0.6-μm-thick cross-sections were obtained every 0.5 mm from the 1- to 5-mm apical levels. This resulted in a total of 10 slides per tooth. Sections were mounted on glass slabs and stained with hematoxylin-eosin.

Morphometric Evaluation

The specimens were visualized using an Axioplan 2 Imaging fully motorized light microscope (Carl Zeiss Vision, Hallbergmoos, Germany). Image analysis and processing were completed using the Axion Vision image 4.5 Zeiss system (Carl Zeiss). An outline of the area of the remaining pulp tissue and the cross-sectional area of each root canal was traced. Next, the percentage of remaining pulp

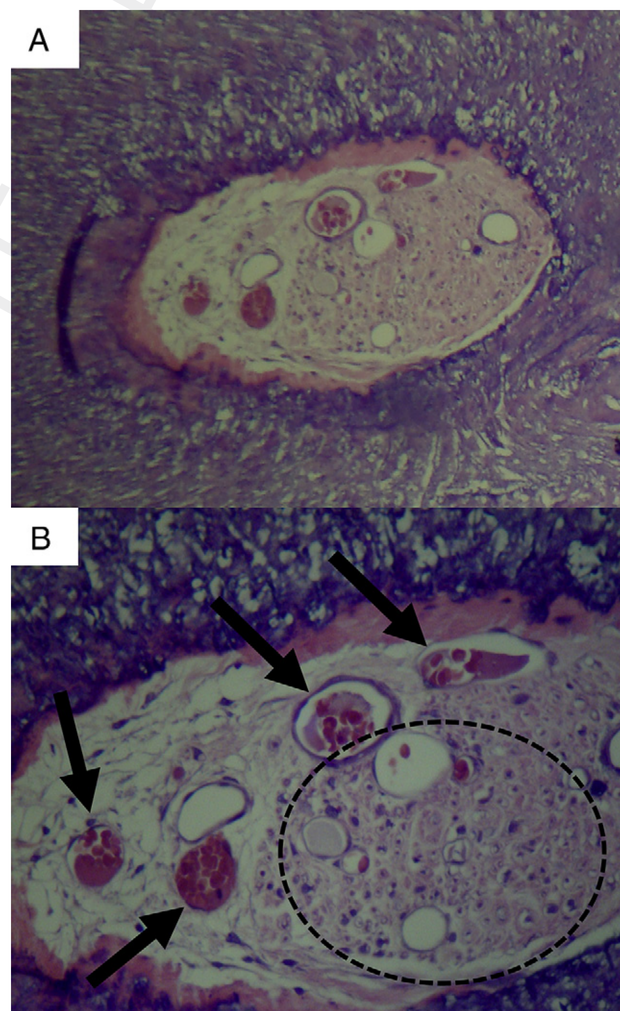

Figure 1. (*A*) A noninstrumented canal from the histologic control group. The root canal space is completely full with pulp tissue. This canal is less oval than those selected to the experimental groups and serves only as a histological control. (*B*) A higher magnification of the same control specimen. Arrows indicate the presence of preserved vessels and nerve bundle is shown in the framed area.

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TABLE 1. The Percent of Residual Pulp Tissue Left After the Use of ProTaper and SAF System

Technique	Mean (± Standard Deviation)
ProTaper	21.4% (±8.2)[a]
SAF System	9.3% (±3.7)[b]

Different letters indicate significant differences between techniques at $P < .05$.

tissue area (PRPT) was calculated for each root canal section by dividing the remaining pulp tissue area by the total area of the root canal in the same section. The operator who made the measurements was blinded as to which samples were treated with which method, and all the measurements were repeated twice to ensure reproducibility.

Statistical Analysis

Statistics were used to compare the effect of each preparation method on the PRPT between teeth of each matched pair. Because preliminary analysis of the raw pooled data showed a Gaussian distribution (D'Agostino and Person omnibus normality test), the *t* test for paired samples was used. Moreover, one-way analysis of variance was used to assess the group-by-location interaction. The alpha-type error was set at 0.05, and Prisma 5.0 (GraphPad Software Inc, La Jolla, CA) was used as an analytic tool.

Results

All microscopic images for the histologic control group displayed a substantial amount of residual pulp tissue (Fig. 1). Thus, this control group confirmed the experimental histologic model as well as the efficiency of the prospective *in vivo* collection of the specimens. [F1]

The group-by-location interaction was not significant ($P > .05$), meaning that the group comparisons were not dependent on the cross-sectional level. As a result, data from each specimen were pooled to provide a single mean value. Each experimental group included 120 sections upon which the analysis was based.

Overall, tissue remnants were found mainly in the uninstrumented buccal and/or lingual recesses (Table 1 and Fig. 1*A*). Pair-wise [T1]

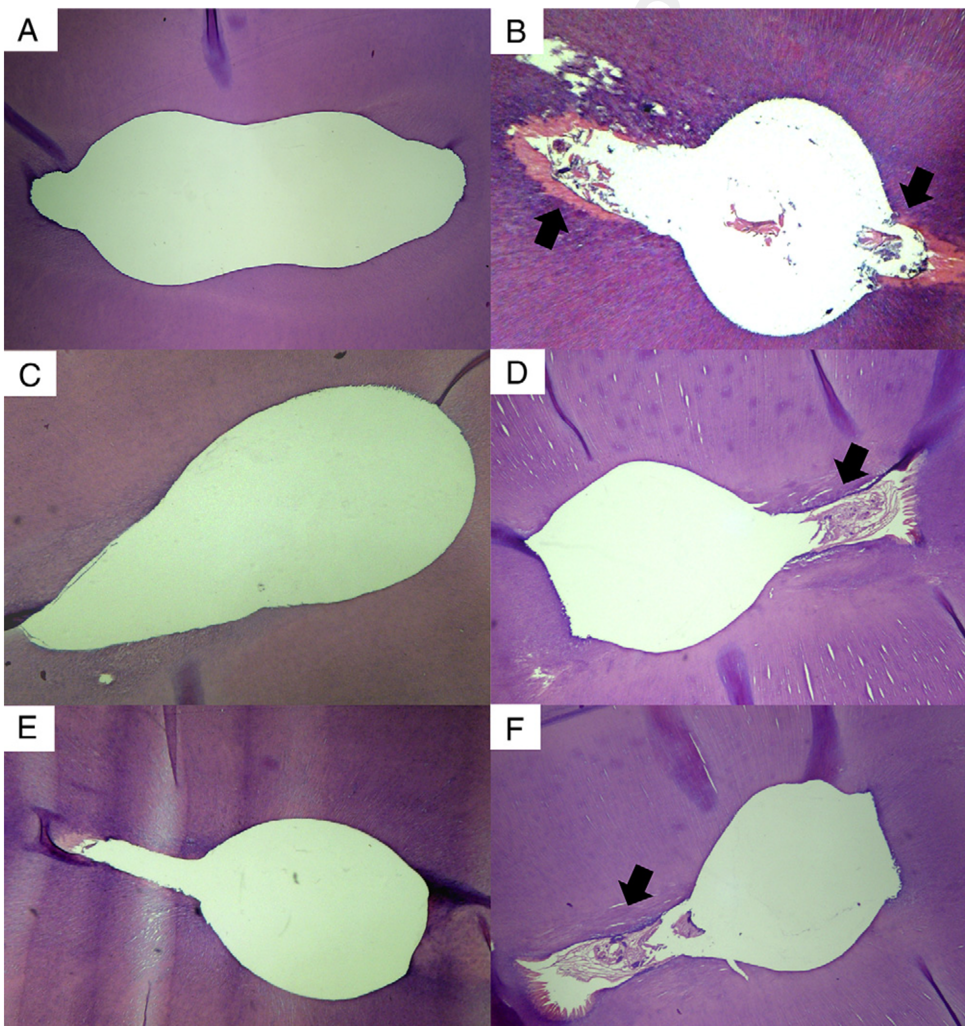

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Figure 2. (*A*) An oval-shaped canal instrumented with the SAF system. The root 'canal space is free of remaining pulp tissue. (*B*) The counterpart tooth instrumented with the full range of ProTaper Universal instruments. The arrows indicate the presence of a significant amount of remaining pulp tissue in the unprepared buccal and lingual extensions. (*C*) A clean oval-shaped canal instrumented with the SAF system. (*D*) The counterpart tooth instrumented with the SAF system. The arrow indicates the presence of a significant amount of remaining pulp tissue in the unprepared buccal extension. (*E*) An oval-shaped canal instrumented with the SAF system with lingual extension almost completely free of pulp tissue. (*F*) The counterpart tooth instrumented with the ProTaper technique. The arrow indicates the presence of a significant amount of remaining pulp tissue in the unprepared buccal extension. [Q6]

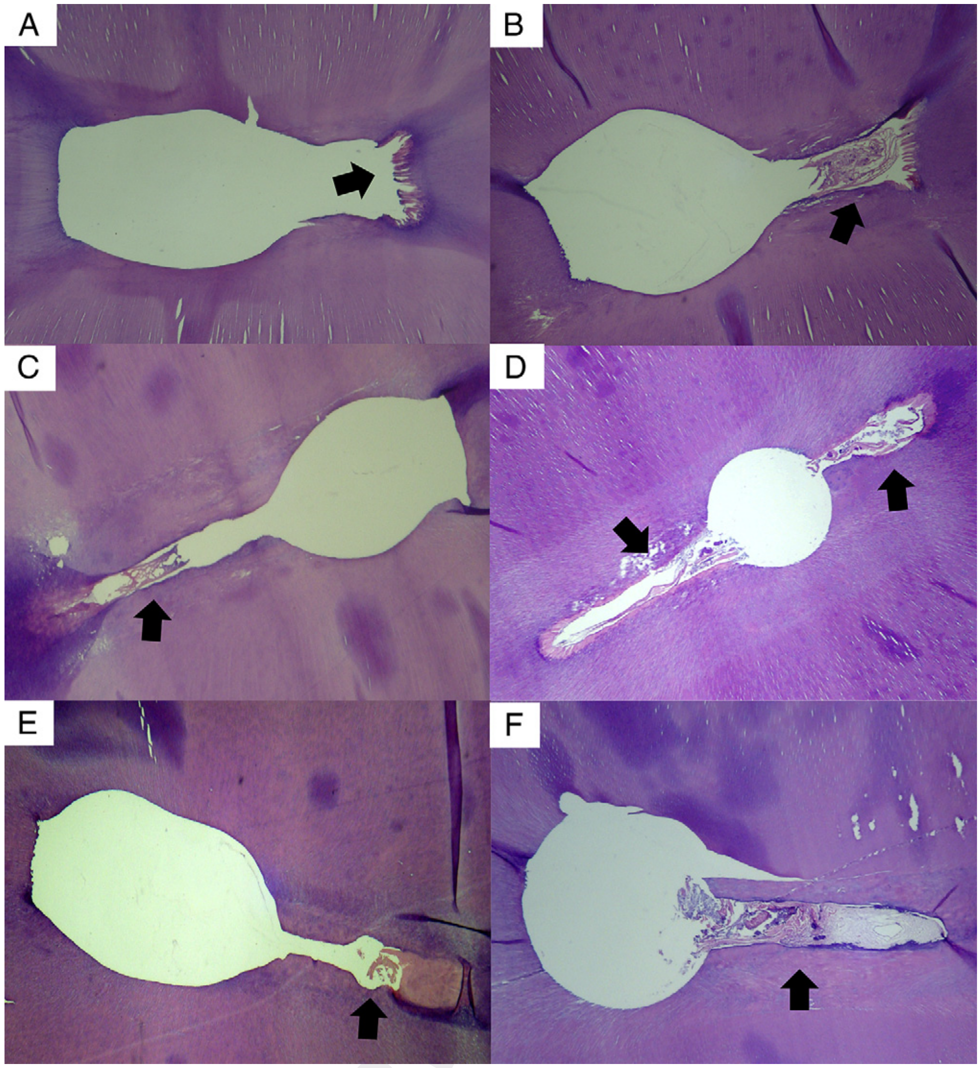

Figure 3. (*A*) An oval-shaped canal instrumented with the SAF system. The root canals space is free of remaining pulp tissue. The arrow indicates the presence of pulp tissue at the end of the lingual extension. (*B*) The counterpart tooth instrumented with the full range of ProTaper Universal instruments. The arrows indicate the presence of a significant amount of remaining pulp tissue in the unprepared lingual extension. (*C*) An oval-shaped canal instrumented with the SAF system. The arrow indicates the presence of pulp tissue in the buccal extension. (*D*) The counterpart tooth instrumented with the full range of ProTaper Universal instruments. The arrow indicates the presence of a significant amount of remaining pulp tissue in the unprepared buccal and lingual extensions. (*E*) An oval-shaped canal instrumented with the SAF system with lingual extension almost completely free of pulp tissue. The arrow indicates some unprepared area at the end of the lingual extension. (*F*) The counterpart tooth instrumented with the full range of ProTaper Universal instruments. The arrow indicates the presence of a significant amount of remaining pulp tissue in the unprepared lingual extension.

comparison showed that the instrumentation technique significantly influenced PRPT ($P < .05$); there was significantly greater residual pulp tissue left after ProTaper system instrumentation versus SAF instrumentation (21.4% vs 9.3%, $P < .05$, Table 1). The SAF-treated canals had a more evident preparation of the buccal and/or lingual recesses (Fig. 1*B*).

Discussion

The SAF system substantially reduced the amount of remaining pulp tissue by 57% as compared with the conventional full sequence of ProTaper Universal NiTi files. In other words, the SAF system improved the debridement standard produced by the conventional NiTi rotary preparation approach. In the ProTaper system group, substantial amounts of pulp tissue remained in the canals; 21% of the root canal cross-section contained pulp tissue remnants. This represents the inability of most rotary files to access buccal and/or lingual recesses of oval canals (3). Furthermore, it represents the limited ability of the sodium hypochlorite irrigant applied with a syringe and needle to compensate for the inadequacy of the file itself. It seems that the common belief that "the file shapes; the irrigant cleans" is based more on wishful thinking rather than on experimental facts at least in the oval-shaped canals used in the present study.

The present result may have a two-fold basis: (1) the SAF ability to adapt itself to the cross-section of the canal and (2) the continuous irrigation. Because these two characteristics were present in combination during the root canal preparation in the SAF group, it is not possible to determine the contribution's of each on the final result but probable to conclude that the interplay of both characteristics aided in the performance by the SAF system. The irrigation provided by the SAF system is substantially different from the conventional syringe-needle irrigation that was applied in the ProTaper group. The latter depends on fluid

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dynamics that have been shown to be of limited efficacy (11–13). This is the reason why Siqueira et al (14) called SAF a cleaning-shaping-irrigation system because it is, in fact, a joint biomechanical preparation system. Moreover, the SAF system irrigation operates on an entirely different principle than the conventional syringe and needle. First, the SAF file vibrates at 5,000 vibrations per minute, which causes sonic activation of the irrigant throughout the procedure. Second, the metal mesh is closely adapted to the canal walls and is moved in and out by the operator, which provides a scrubbing action on the canal walls. Last but not least, the continuous replenishing of fresh irrigant throughout the procedure may also have contributed to the results as well as those reported by Metzger et al (8).

It is worth noting the compressibility of the SAF file because this mechanical feature allows the SAF file to adapt itself to the cross-section of oval canals (7). It may be calculated that if the lattice cylinder of the file, which has a 1.5-mm diameter, is compressed mesiodistally up to 0.2 mm, it may spread buccolingually up to 2.4 mm. This may explain how it spreads to form closer contact with the canal walls, even in the buccal and lingual recesses that were commonly unaffected by the rotary files.

Histologic methods have been used for many years to evaluate root canal instrumentation and are considered archaic when compared with current micro-CT methods. Nevertheless, they provide valuable information that cannot otherwise be obtained; thus, they should be considered an essential complimentary tool to be used with micro-CT.

When selecting teeth with vital pulps, it may be assumed that pulp tissue is present and attached around the entire perimeter of the root canal (15); this was confirmed by the current histologic controls (Fig. 1). Remaining tissue after cleaning and shaping represents an area of the canal in which the instrument failed to reach mechanically. Furthermore, the remaining tissue indicates that even the sodium hypochlorite irrigation, which is expected to clean such recesses, did not complete the task.

Micro-CT provides valuable information about changes that occurred or failed to occur in the calcified tissues surrounding the root canal. However, it provides no information about the soft tissue or biofilm that remained attached to or was cleaned off the canal walls. We assume that if a layer of dentin was removed in a given area, all attached tissue or biofilm was removed from that area as well. Nevertheless, the question always remains regarding whether the area unaffected by the procedure was or was not properly cleaned by the irrigant. Histologic sections were used in the present study as well as in previous studies to shed light on this “gray zone” (5, 15).

Because oval canals represent the major challenge to any file and/or irrigation system, this type of canal was selected for the present study. Nevertheless, high variability exists in shape, size, and dimensions of the pulp space in these teeth. Special care was taken to ensure an equal challenge in both study groups by pair matching and random allocation of the teeth to the groups. Although this process limited the size of the groups studied, it may be considered the only way to expose both instrumentation protocols to the same level of challenge. The flip of a coin to select which group would be treated with each method further helped to avoid any bias in the case selection.

The ProTaper NiTi system was selected to represent the rotary NiTi file system family of instruments because it has been used in a large variety of studies, including one by De-Deus et al (15) who used a similar methodology. It was compared with the new technology of the SAF system, which is currently, to the best of our knowledge, the sole representative of a new family of instruments: the self-adjusting files (16).

The current results indicate that, in addition to its previously reported better efficiency for circumferentially removing dentin from all canal walls, as has been shown by micro-CT studies (8, 17–19), the SAF system also has an improved debridement and cleaning efficacy in the oval-shaped canals used in the present study. This may, in turn, also aid in explaining the recently reported improved disinfection that the SAF system has in oval canals (14). Further studies should be performed to verify if similar results as those for remaining pulp tissue can be attained also with naturally occurring mixed bacterial biofilms. It would also be interesting to compare the SAF system with a combination of rotary files with one or more of the recently introduced irrigation systems, such as negative pressure and passive ultrasonic irrigation methods.

Acknowledgment

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Q4	Please provide city in Germany for Carl Zeiss.
Q5	Is sentence beginning "In the ProTaper…" as meant?
Q6	please cite figure 2 and figure 3 in text.

Thank you for your assistance.