
Influence of the NiTi rotary system on the debridement quality of the root canal space

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Objective. The present study was designed to test the null hypothesis that there is no significant difference in debridement quality promoted by 3 nickel-titanium (NiTi) rotary systems.

Study design. Sixty-seven vital mandibular molars that were prospectively collected in vivo were used. The teeth were extracted and then pulp tissue fixed by 10% formalin. The use of different NiTi rotary systems resulted in 3 experimental groups with 20 specimens each: G1: Hero 642; G2: K3; and G3: ProTaper Universal. Afterward, the specimens were histologically prepared and serial 0.5 μm cross-sections were obtained every 0.2 mm from the 1-3 mm apical levels. The remaining pulp tissue was assessed using a morphometric approach. The cross-sectional area of each root canal and remaining pulp tissue were measured (μm^2). Thus, the percentages of remaining pulp tissue area were calculated for each root canal.

Results. Overall, the pooled data obtained from all levels revealed a variable amount of remaining pulp tissue for all experimental groups. Remaining pulp tissue existed in every specimen. However, the Kruskal-Wallis H test was unable to show significant differences among the experimental groups ($P > .05$) for the pooled data from all levels.

Conclusions. The present study did not find a significant difference in the quality of canal debridement between different NiTi rotary systems, because an adequate tapered shape is obtained. (**Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:e71-e76**)

Cleaning and shaping the root canal system adequately is well known as a difficult task, particularly in curved and narrow canals.^{1,2} Currently, experimental results have shown that NiTi rotary systems cause less canal transportation and produce a more centered and tapered preparation.^{1,3-7} However, even with all the progress made in endodontic treatment, the quality of the root canal preparation is still less than ideal. Using the reliable microtomography method, Peters et al.⁸ reported that NiTi instruments left around 35% of the dentin surface area untouched, and this situation can offer an opportunity for microorganisms that remain in the root canal space after the deficient chemomechanical preparation to recolonize the filled canal system, leading to an endodontic failure.

The use of an efficient irrigating protocol has an important role in achieving an effective chemomechanical preparation.⁹ It enhances bacterial disinfection and promotes the debridement of necrotic tissue and debris from the root canal space. In view of this back-

ground, the final taper of the root canal is a critical requirement to optimize the efficiency of the irrigating solutions.^{10,11} Moreover, the mechanical preparation of the canal must be able to achieve a minimum standard in terms of predentin and debris removal.¹² Most of the debridement studies have concluded that hand instrumentation does not properly clean the root canal space, especially the apical region of curved canals.^{1,13}

Nickel-titanium (NiTi) instruments and systems vary widely in their specific features, such as taper, tip, kind of blade, and number of files. However, to the best of the authors' knowledge, no study has histologically assessed the influence of the NiTi rotary system on debridement quality. In the present study, the amount of the residual pulp tissue was used as an outcome measure to test the null hypothesis that there is no significant difference in the debridement quality promoted by the 3 NiTi rotary systems tested. The debridement quality was histologically assessed using the apical third of vital mandibular molars that were prospectively collected in vivo.

MATERIALS AND METHODS

In vivo prospective selection process of the vital mandibular molars

One hundred twenty-two adult subjects voluntarily participated in the present study. All subjects were in good health, as determined by a written health history and oral survey. This study was revised and approved

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by the Ethics Committee, Nucleus of Collective Health Studies, Rio de Janeiro State University, Rio de Janeiro, Brazil and a signed informed consent form was obtained from each subject. All teeth collected were planned for extraction before the recruitment of the patients into the study. The teeth were scheduled for extraction owing to advanced periodontal disease or nonrestorability. Exclusion criteria were <18 or >58 years of age. The mean age was 42.8 years.

With the sole purpose of collecting vital teeth, analysis of tooth pulpal vitality was initially performed using Green Endo-Ice refrigerant spray (Hygenic, Akron, OH). If the tooth response was positive the patient was submitted to an adequate pulpal anesthesia. Teeth were then isolated with a rubber dam, and a standard coronal access opening was prepared using tungsten carbide round burs in a high-speed handpiece with constant water spray. After confirmation of a pulpal hemorrhage, the tooth was included for the study. If no sign of pulpal hemorrhage was encountered, the tooth was excluded from the study. After control of pulpal hemorrhaging, a sterile cotton pellet was placed in the pulp chamber, and the coronal access was then sealed with Cavit (3M Espe, Sumaré, Brazil). The tooth extractions were performed using a conventional root surgical technique. After each extraction, the tooth was immediately placed into a 15 mL plastic vial containing 10 mL buffered 10% formalin. At this point, each tooth was labeled with a random 8-digit alphanumeric code corresponding to 1 of the 3 experimental groups as a way of controlling operator bias.

For 13 months (December 2006 to January 2008), following the above described selection process, 133 left and right mandibular first molar teeth were collected. To select only moderately curved mesial roots, radiographs of each tooth were taken, digitized, and stored electronically. Root canal curvature was determined based on angle of curvature initiated at the coronal aspect of the apical third of the root using Schneider's method.¹⁴ Angles of curvature were measured using an image analysis program (Axiovision 4.5; Carl Zeiss Vision, Hallbergmoos, Germany). Only those roots with angles of curvature ranging between 10° and 20° (moderated curvatures) were selected. In addition, only mesial root canals with an initial apical size equivalent to a size 10 K-file were selected for the study. As a result, just 67 molar mesial roots were included. The teeth were stored in 10% neutral formalin.

Root canal preparation

A silicone impression material (President Jet Coltène, Cuyahoga Falls, OH) was mixed to provide a matrix that simulated the bony socket site. Teeth were placed into the

unset silicone and glued with tray adhesive (3M Espe Impregum).

Tooth length was standardized to 18 mm to prevent the introduction of confounding variables that might contribute to variations in the preparation procedures.¹⁵ Root canal patency was confirmed by inserting a size 10 file through the apical foramen before and after completion of root canal preparation. The working length was established by deducting 1 mm from the canal length.

The use of different NiTi rotary systems resulted in 3 experimental groups (G1, G2, and G3) with 20 specimens each. The 7 remaining teeth were used as histologic control samples. The experimental and control groups were randomly distributed with the aid of a computer algorithm (<http://www.random.org>).

For both groups, 5.25% NaOCl solution was prepared by diluting a 10% NaOCl solution (Merck, São Paulo, Brazil). Its pH was adjusted to 10.8 with 1 N HCl. The concentration of the NaOCl solution was verified iodometrically.¹⁶ Irrigation was performed using a 5 mL disposable plastic syringe (Ultradent Products, South Jordan, UT) with a 30-gauge Endo-Eze Tip (Ultradent) placed passively into the canal, up to 2 mm from the apical foramen without binding. The aspiration was performed with a Surgitip tip (Ultradent) attached to a high-speed suction pump. Between each file, root canals were irrigated with 1 mL 5.25% NaOCl for 1 minute. The flow of irrigation (1 mL/min) was determined with the aid of an automatic syringe pump (SP100i; World Precision Instruments, Sarasota, FL). To standardize the final volume of irrigation, the final NaOCl volume irrigation varied as a function of the number of files used in each experimental group. A total volume of 12 mL NaOCl per root canal was used. The smear layer was removed with 3 mL 17% EDTA (pH 7.7) for 3 minutes (3 mL/min). Three mL bidistilled water was used for 3 minutes as a final flush. All canals were dried with paper points (Dentsply-Maillefer, Ballaigues, Switzerland), and all preparations were performed by 1 experienced operator.

All the NiTi systems were driven at 300 rpm and 2 N·cm torque using a contra-angle handpiece connected to an endodontic micromotor (XSmart; Dentsply-Maillefer) using rotatory movement. The sequences of usage and speed were in agreement with the manufacturer's instructions for each NiTi system and are summarized in [Table I](#).

In G1, Hero 642 rotary system (Microméga, Besançon, France), the use of 6 files was required to complete the root canal preparation and, as a result, 6 mL 5.25% NaOCl were consumed. Therefore, an additional 6 mL 5.25% NaOCl was used in the final irrigation, which gave a total of 12 mL for each root canal.

Table 1. Number of instruments used, sequence of preparation, and working length (WL) for each system

<i>Hero 642</i>	<i>K3</i>	<i>ProTaper</i>
6% taper, size 20 (WL 8 mm)	Orifice Opener 10 (WL 6 mm)	S1 file (shaping file no. 1) (WL 8 mm)
4% taper, size 20 (WL 14 mm)	Orifice Opener 8 (WL 7 mm)	SX (auxiliary shaping file) (WL 10 mm)
2% taper, size 20 (WL 16 mm)	4% taper, size 40 (WL 8 mm)	S2 file (shaping file no. 2) (WL 14 mm)
4% taper, size 25 (WL 14 mm)	4% taper, size 35 (WL 10 mm)	F1 file (finishing file no. 1) (WL 16 mm)
2% taper, size 25 (WL 18 mm)	4% taper, size 30 (WL 12 mm)	F2 file (finishing file no. 2) (WL 18 mm)
2% taper, size 30 (WL 18 mm)	4% taper, size 25 (WL 14 mm)	F3 file (finishing file no. 3) (WL 18 mm)
	4% taper, size 20 (WL 16 mm)	
	4% taper, size 25 (WL 18 mm)	
	4% taper, size 30 (WL 18 mm)	

The K3 rotary system (Sybron-Endo, West Collins, CA) was used in G2, and the technique required the use of 9 files to complete the root canal preparation and consumed 9 mL 5.25% NaOCl. Therefore, an additional 3 mL 5.25% NaOCl was used in the final irrigation, giving a total of 12 mL for each root canal. Finally, 6 files of the ProTaper Universal files were used in G3, consuming 6 mL 5.25% NaOCl. An additional 6 mL 5.25% NaOCl was used in the final irrigation, giving a total of 12 mL for each root canal.

Histologic assessment

At the end of the instrumentation, the specimens were immediately immersed in 10% buffered formalin for at least 48 hours. The teeth were then demineralized in a solution of 22.5% (vol/vol) formic acid and 10% (wt/vol) sodium citrate for a period of 2-3 weeks under constant agitation. The end point was monitored radiographically. After rinsing for 24 hours in tap water, the specimens were dehydrated and processed for routine histologic examination. Teeth were embedded in paraffin wax (Isofar Chemical Products, Rio de Janeiro, Brazil) and oriented parallel to the long axis of the root canal. Serial cross-sections of 0.6 μm thickness were obtained every 0.2 mm from the 1-3 mm apical levels. As a result, a total of 10 slides were prepared per tooth. Sections were mounted on glass slabs and stained with hematoxylin-eosin.

Morphometric evaluation

The specimens were visualized in an Axioplan 2 Imaging full motorized light microscope (Carl Zeiss Vision). Epiplan ×5 and ×10 HD objectives (Carl Zeiss Vision) were used, coupled with a 1,300 × 1,030 pixels Axiocam HR digital camera (Carl Zeiss Vision), leading to a total magnification ranging from approximately ×50 to ×100 and with a resolution of 0.1 μm/pixel.

Image analysis and processing were completed using the Axion Vision Image 4.5 Zeiss system for Windows (Carl Zeiss Vision). The image of the root canal cross-

section was displayed in a 19-inch high-contrast LCD monitor, and a precision optical computer mouse was used to trace the outline of the area of interest. In this way, the cross-sectional area of each root canal and remaining pulp tissue were measured (μm²). The percentages of remaining pulp tissue area were calculated for each root canal. The data for the computer-assisted evaluation were obtained twice to ensure reproducibility.

Data presentation and statistical analysis

Data are presented as percentage of remaining pulp tissue. The preliminary analysis of the raw pooled data from the experimental groups did not show bell-shaped distribution (Kolmogorov-Smirnov test). Further statistical analysis was performed, and the raw data were assessed using nonparametric methods: Kruskal-Wallis H test. The alpha-type error was set at .05. SPSS 11.0 (SPSS, Chicago, IL) and Origin 6.0 (Microcal Software, Northampton, MA) were used as analytical tools.

RESULTS

All of the microscopic images for the positive control group displayed a substantial amount of residual pulp tissue. Thus, the results from the positive control group confirmed the experimental histologic model as well as the efficiency of the prospective in vivo collection of the specimens.

Overall, the pooled data obtained from all levels revealed a variable amount of remaining pulp tissue for all experimental groups, ranging from 2.1 to 28.9 μm². That point can be clearly observed in the box plots in Fig. 1, which illustrates the median, minimal, and maximal remaining pulp tissue traces, as well as the variance in each experimental group. The data distribution of the remaining pulp tissue per level is given in Fig. 2.

Remaining pulp tissue existed in 96% of the specimens (Fig. 3). However, the Kruskal-Wallis H test results showed that there were no significant differences among the experimental groups (*P* > .05) for the pooled data from all levels. When the apical level was

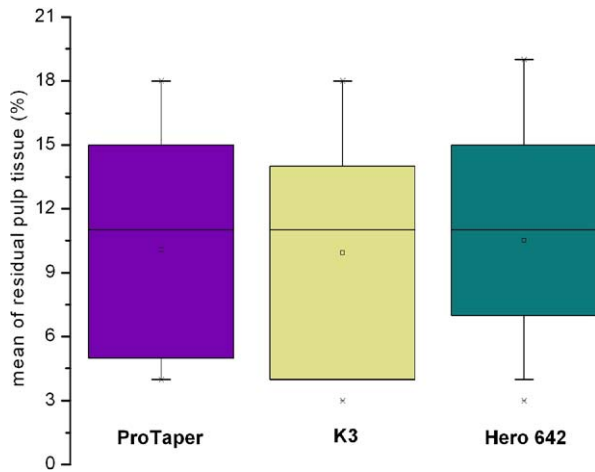


Fig. 1. Box plots illustrating the median traces, minimal and maximal remaining pulp tissue traces, and variance in each experimental group.

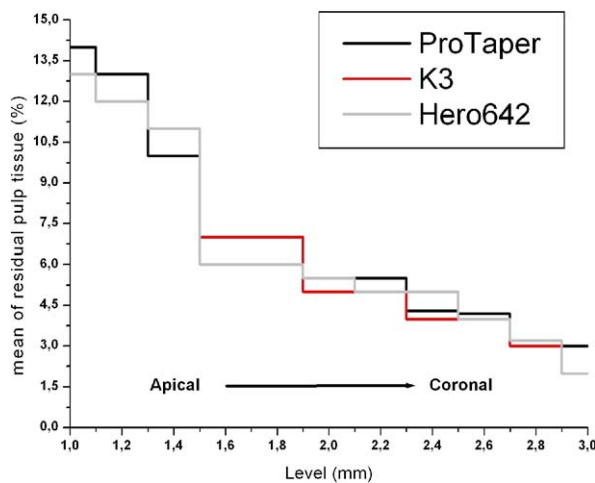


Fig. 2. Data distribution of the remaining pulp tissue per level.

used as factor, it was not possible to detect significant differences among the experimental groups at the individual scale ($P > .05$); However, there was a significant negative correlation between apical level and the amount of remaining pulp tissue ($P < .05$).

DISCUSSION

The results showed no differences in root canals prepared by the ProTaper, Hero 642, or K3 NiTi systems. Therefore, the null hypothesis was accepted, because a similar pattern of cleanliness was achieved independent from the NiTi system used. As an in vitro study, these results must be interpreted with caution;

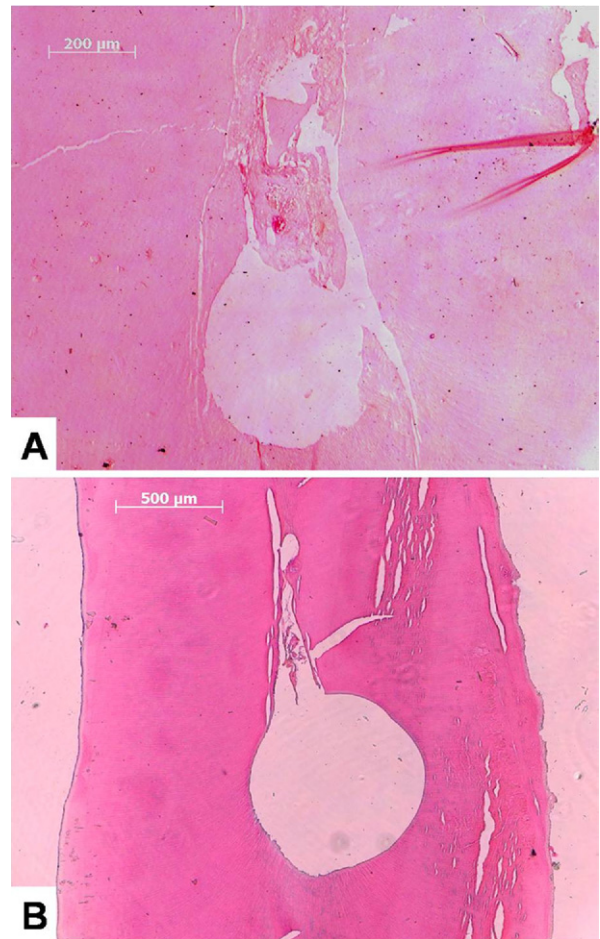


Fig. 3. **A**, Photomicrography showing a site at which a great amount of remaining pulp tissue was recorded: 1.2 mm level from the K3 group. **B**, Photomicrography showing a site at which a small amount of remaining pulp tissue was recorded: 2.6 mm level from the ProTaper group.

but it is worth noting that Peters et al.¹⁷ similarly found that the treatment outcome is unaffected by the specific choice of NiTi instrumentation system.

In the present study, none of the NiTi systems tested was able to totally clean the root canal space. This finding is in accordance with earlier reports that also histologically assessed the root canal debridement quality promoted by several manual and rotatory techniques.¹⁸⁻²⁰ The present evaluation assumes that the characterization of the remaining pulp tissue would enable the effect of the cleaning and shaping procedures.²⁰ The pooled values referent to the residual pulp tissue achieved in the present study ranged from 3.1% to 19.5% of the total area of the root canal and these are in agreement with those reported in earlier studies that used a similar experimental setup.^{21,22} In some measure, the amount of the remaining pulp tissue found in

the present study can be correlated with earlier microscopic computerized tomography data reported by Peters et al.⁸ and Paqué et al.,² who reported that around 30% of the root canal area was untreated after instrumentation. It is worth remembering that if the pulp debris is not removed completely, it can directly interfere with the quality of the root filling.^{11,12} Therefore, an efficient debridement of the pulp tissue must be faced as one of the critical goals of the root canal treatment.

Assessing a further aspect of root canal debridement, Littman²³ highlighted the crucial role of the operator. That author concluded that the operator is more important than the technique for debridement quality. This variable cannot be related to the present study, because all root canal preparations were performed by the same operator. It must be reiterated that even with the root canal preparation being performed by an experienced endodontist in the present study, a considerable amount of remaining pulp canal tissue was found in almost every specimen. In agreement with the present results, Barbizan et al.²⁴ reported the limited debridement action of the Profile .04 NiTi rotary files. Earlier reports showed that the apical third of the root canal system is the most difficult area to clean.^{20,22-27} Therefore, the present study was designed to assess only the critical apical area.

It is also important to consider the prospective in vivo selection of vital teeth. This is an essential methodologic step in assuring the credibility of the histologic assessment.^{20,26} Only by using a rigorous and well controlled tooth selection can the root canal contents be standardized with a minimal standard of control.²⁰ Even so, there are recent studies that still make the critical mistake of using teeth with no previous diagnosis of vital pulp. As a direct consequence of improper tooth selection, results can be compromised.

Although the NiTi rotary systems have considerable differences in their shape, cutting blade, number of files, and taper, the present results reaffirm the concept that none of the systems were totally effective in the debridement of the root canal space. Indeed, the evidence established in this report shows that when an adequate taper preparation is achieved, the debridement quality is still more dependent upon the irrigation protocol than the NiTi rotary system used. The present results highlight the fundamental role of irrigation in the endodontic treatment. Even in circular shapes, the debridement efficiency does not depend only on instrumentation.²¹ Therefore, it is absolutely essential to use an efficient irrigation protocol. Because the irrigation parameters (concentration, volume, flow of the irrigant, and depth penetration of the needle) were well controlled in the present study, in an indirect manner, the

significant amount of remaining pulp tissue found stresses the limitations of the current irrigation protocols, even under monitored laboratory conditions. This leaves room to speculate that the debridement quality must be poorer in the clinical setting.²⁰ Therefore, the current scientific effort toward improving the efficiency of irrigation solutions, as well as irrigation delivery methods, can be justified to some extent by the present results.

In summary, the present study demonstrated the lower influence of the different NiTi rotary systems on the debridement quality of the root canal space. Because an adequate tapered shape is obtained, the debridement quality is more dependent on the chemical preparation. Although instrumentation is a crucial step in the final prognosis of endodontic treatment, it must always be connected to an effective irrigation protocol. Under the present in vitro conditions, none of the different NiTi systems tested were able to optimize the cleaning of the root canal space. The present results also emphasize the debridement limitations of the current chemical-mechanical preparation methods and lay emphasis on the necessity of the pursuit of more efficient irrigation solutions and protocols.

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