Efficacy of NiTi rotary systems cleaning process compared to manual instruments in narrow and flattened root canals

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ABSTRACT

Objective: To compare, *ex vivo*, the cleanness efficacy of three rotary systems (Mtwo, K3, and ProTaper) and a manual one (K-Flexofile) in narrow and flattened root canals, based on dye removal from dentin walls. **Methods:** Root canals of 40 human teeth were filled with black ink. Once the dye had dried, the teeth were randomly divided into four groups (n = 10), according to the instrumentation system used: G1 = Mtwo; G2 = K3; G3 = ProTaper, and G4 = K-Flexofile. After instrumentation, teeth were split longitudinally. Qualitative analysis was based on the amount of remaining dye adhered to dentin walls in the apical, middle and coronal thirds of the root canal, and also on the overall amount, according to four scores. For quantitative analysis, each root canal split was scanned and analyzed by Image Tool software. Cleanness efficacy was determined by quantifying the difference between the total area of each root canal and the noninstrumented area in mm^2. Data were subjected to Kruskal-Wallis test or one-way ANOVA and Bonferroni *post hoc* tests ($p < 0.05$). **Results:** No thoroughly cleaned root canals were found. Nonstatistically significant difference was apparent among instrumentation systems at the qualitative analysis ($p > 0.05$). In terms of quantitative analysis, Mtwo instruments presented significantly superior cleanness efficacy compared to the other systems ($p < 0.05$). **Conclusions:** In general, cleanness efficacy of the Mtwo system was slightly superior compared to that of K3, ProTaper and K-Flexofile instruments, within the parameters of the present study and regardless of limitations.

Keywords: Dentin. Endodontics. Root canal preparation.

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Introduction

An effective root canal preparation depends on efficient physical action of endodontic instruments which should promote a centered and tapered preparation. It also results in a significant reduction of microorganisms[1] and their endotoxins,[2] which is favorable for endodontic success.

Rotary nickel-titanium (NiTi) instruments have been continuously developed, optimized and modified over time in order to achieve the ideal parameter of cleaning and shaping.[3] They are characterized by unique design properties, such as conical shape, number of files, cross-sectional shape, blade type and tip.[4] Although modifications and promising results have been demonstrated in several investigations,[5] it is beyond dispute that a complete mechanical debridement of the root canal system is quite difficult,[6] particularly in oval, flattened, narrow or curved root canals. Thus, even with the innovative proposal of NiTi files, which are an evolution on standardization of root canal preparation,[7] some studies have showed that manual instrumentation can produce cleaner root canals,[8] with less residual debris and smear layer.

There are well-established rotary NiTi instruments in the literature, such as K3 (Kerr, SybronEndo, California, USA) and ProTaper (Dentsply Maillefer, Ballaigues, Switzerland). K3 instruments are known for their asymmetrical cross-sectional design and slightly positive rake angle.[9] On the contrary, ProTaper files have a convex triangular cross-sectional design, multiple tapers within the shaft[10] and negative rake angle.[11] Previous reports have investigated both systems in many aspects of endodontic treatment.[12] However, one of the most current successful NiTi rotary systems, regarding cleaning and shaping, is the Mtwo system (VDW, Munich, Germany).[5,13] These instruments have a noncutting tip and an S-shaped cross-sectional design with two cutting edges. The positive rake angle is one of the most effective in NiTi rotary instruments, which determines the great capacity of Mtwo files to cut dentin.[14]

In view of this background, there is no consensus regarding which system could be more efficient in debridement quality. Therefore, the present study aimed to compare, *ex vivo*, the cleanness efficacy of three different rotary systems (Mtwo, K3, and Protaper) and one manual system (K-Flexofile) in narrow and flattened root canals, based on dye removal from dentin walls.

Material and Methods

The study was approved by the Ethics Committee of Universidade Federal de Pelotas (UFPEL) School of Dentistry (IRB 08/05). Forty extracted mandibular central and lateral incisors were used. The teeth presented narrow and accentuated proximally flattened root canals, similar in size, straight roots and fully formed apices. Root canals similarity was confirmed by radiographs.

Root canal instrumentation

The pulp chamber was conventionally accessed, and apical patency was determined by inserting a #10 K-file (Kerr, Sybron Endo, California, USA) into the root canal, until the tip was observed at the apical foramen. The working length (WL) was established by subtracting 1 mm from the root canal length, when the file was first seen. Teeth with apical foramen greater than the K-file #10 were excluded. Root canals were irrigated with 2.5% sodium hypochlorite (NaOCl) and dried with paper points (Dentsply Indústria e Comércio Ltda, Petrópolis, RJ, Brazil). Prior to instrumentation, the root canals were filled with black ink (Nanquim Acrilex, São Paulo, SP, Brazil) inserted with an insulin syringe (Embramac Material Cirúrgico Ltda, Itapira, SP, Brazil) up to extrusion through the apical foramen.

The teeth remained at room temperature during 48 hours for complete drying of the dye. After that, the teeth were randomly divided into four groups (n = 10), according to the following instrumentation systems used:

» G1 – Mtwo system (VDW): all Mtwo instruments were used up to the full working length by gentle round-tripping movement. The instrumentation sequence was: 10/0.04, 15/0.05, 20/0.06, 25/0.06, 30/0.05, and 35/0.04. Once the instrument achieved the end of the canal, and then rotated freely, it was removed.

» G2 – K3 system (Kerr): K3 instruments were used in crown-apex direction (crown-down) by gentle round-tripping movement. Instruments were withdrawn when resistance was evinced, and replaced by the next instrument (1 = 25/0.01 to one-third of the working length; 2 = 25/0.08 and 35/0.06 from one-half to two-thirds of the working length; 3 = 30/0.04 to two-thirds of the working length; 4 = 25/0.06, 30/0.04, and 35/0.06 to the full working length). Once the instrument achieved the end of the canal, and then rotated freely, it was removed.

» G3 – ProTaper system (Dentsply Maillefer): ProTaper instruments were used in crown-apex direc-

tion (crown-down) by gentle round-tripping movement. Instruments were withdrawn when lack of resistance was evinced, and replaced by the next instrument: 1 = S1 file (shaping file #1; size 17; taper 0.02-0.11) to one-third of the working length; 2 = SX file (auxiliary shaping file; size 19; taper 0.035-0.19) to one-half of the working length; 3 = S1 file from one-half to two-thirds of the working length; 4 = S2 file (shaping file #2; size 20; taper 0.04-0.115) to two-thirds of the working length; 5 = F1 file (finishing file #1; size 20; taper 0.07-0.055), F2 file (finishing file #2; size 25; taper 0.08-0.055), and F3 file (finishing file #3; size 30; taper 0.09-0.05) at the working length. Once the instrument achieved the end of the canal, and then rotated freely, it was removed. ProTaper instrumentation was limited to size #30 due to the large taper reached by that instrument.

All types of rotary instruments were set into permanent rotation (300 rpm), powered by a torque-limited electric motor (Endo Pro - VK Driller Equipamentos Elétricos Ltda, São Paulo, Brazil) with torque limitation of 5 N.cm.

» G4 – Stainless steel manual K-Flexofile (Dentsply Maillefer): instruments were used in crown-down progressive manual technique without apical pressure. After reaching the WL, all canals were sequentially prepared from size #10 up to size #35.

Apical patency was checked with a #10 K-file used between each instrument, and the canals were copiously irrigated with saline solution throughout the entire preparation. Each instrument was used five times and then discarded.

After instrumentation, the teeth were split longitudinally in buccolingual direction. A carborundum disk (Dentprium International, New York, USA) was used until the dye was visible by transparency and without exposing the canal. Subsequently, the teeth were sectioned with a LeCron spatula (S.S. White Artigos Dentários Ltda., Rio de Janeiro, RJ, Brazil).

Qualitative and quantitative analysis

The amount of remaining dye adhered to the root canal walls of each root segment was qualitative and quantitatively analyzed by two blind examiners previously calibrated.

The qualitative analysis of each root canal segment was visual and based on the presence of remaining dye adhered to the dentin walls in four areas: apical, middle, and coronal thirds of the root canal, and also overall, according to four scores previously established: score 0 = clean root canal wall (no dye); score 1 = small area of dye on one wall of the canal (up to 25% of the root canal wall); score 2 = dye occupying an entire wall of the canal (about 50%); score 3 = dye occupying the entire canal (75% to 100% of the root canal wall).

For quantitative analysis, each root canal segment was scanned (Genius Colorpage HR6X series v1.0) (Genius, KYE Systems Corp., Sanchong District, New Taipei City, Taiwan). Resolution, brightness and contrast were standardized. Thereafter, images were opened with the Image Tool software in which the total area (mm^2) of each root canal segment as well as the particular area of remaining dye, in regions that were not affected by instrumentation, were measured. Data tabulation into a spreadsheet Excel 2000 software allowed quantifying the cleanness efficacy of different instrumentation techniques by the difference between the total area of each root canal and the noninstrumented area, in mm^2.

Statistical analysis

Data established by scoring the remaining dye adhered to the walls were recorded and statistically analyzed. Due to the ordinal nature of the scores, data were subjected to the nonparametric Kruskal-Wallis test. One-way ANOVA and Bonferroni *post hoc* tests were used to analyze data obtained with the quantitative analysis. *P*-values were computed and compared. The significance level was set at 5%. All analyses were performed in Stata 12.0 software (StataCorp., College Station, TX, USA).

Results

During preparation of the 40 canals, no instrument was separated or permanently deformed.

Qualitative analysis

Tables 1 and 2 present detailed and mean scores, respectively, related to remaining dye adhered to root canal segments on coronal, middle and apical thirds, as well as overall, for each instrumentation system.

It was not possible to find root canals completely cleaned. In terms of qualitative analysis, no statistically significant difference was apparent among

instrumentation systems when evaluating coronal, middle, and apical thirds separately (p = 0.739; p = 0.362, and p = 0.527, respectively), and overall (p = 0.634). In general, Mtwo and K-Flexofile instruments were able to clean more root canal segments scored at 0, when compared to K3 and ProTaper instruments (Table 1). However, the lowest mean score for the apical third and overall was promoted by Mtwo instruments (Table 2).

Quantitative analysis

Figure 1 shows the cleanness efficacy percentage promoted by different instrumentation systems. Mtwo instruments presented significantly better cleanness efficacy compared to other instrumentation systems ($p < 0.05$), whereas no significant difference was found among K3, ProTaper and K-Flexofile instruments.

Discussion

It is well known that antibacterial solutions and chelating agents are recommended and customary used during endodontic treatment, with the purpose of removing biofilm,[15] endotoxins,[16] debris and organic/inorganic smear layer.[17,18] Nonetheless, if dentin walls remain untouched, the chances for microorganisms and endotoxins to maintain an infection would be high.[2] Thus, despite variations of natural teeth and root canals, several attempts and great efforts have been made in order to find root canals similar in diameter and flattening, allowing accurate comparability among different instruments.

Many techniques and methods have been performed in order to evaluate cleaning and shaping abilities of manual and rotary instruments.[4,12,13,19,20] To the best of our knowledge, there is no information or studies comparing Mtwo, K3, ProTaper and K-Flexofile instruments, in terms of cleanness efficacy, in natural teeth with narrow and flattened root canals.

According to the results obtained in the present research, no instrumentation system was able to entirely clean the root canal walls. This finding is in agreement with the results showed in several previous investigations.[8,9,13,19,21,22] Probably, the considerable

Table 1. Summary of scores for remaining dye adhered to root canal walls for coronal, middle and apical thirds, as well as overall.

Instrument	Coronal third scores				Middle third scores				Apical third scores				Overall scores			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Mtwo	8	5	6	1	2	5	9	4	5	14	1	0	15	24	16	5
K3	1	6	12	1	2	12	5	1	0	13	5	2	3	31	22	4
ProTaper	0	6	11	3	3	7	8	2	2	9	7	2	5	22	26	7
K-Flexofile	2	12	6	0	6	7	5	2	5	7	5	3	13	26	16	5
p	**0.739**				**0.362**				**0.527**				**0.634**			

Table 2. Median score and range values for remaining dye adhered to root canal walls for coronal, middle and apical thirds, as well as overall.

Instrument	Coronal third	Middle third	Apical third	Overall
Mtwo	1.5 (0-2)	1.5 (0-3)	2 (0-2)	2 (0-3)
K3	1.5 (0-2)	1 (0-2)	1 (1-2)	1 (0-2)
ProTaper	1.5 (1-3)	1.5 (0-2)	1 (0-2)	1 (0-3)
K-Flexofile	1 (0-1)	1 (0-2)	1 (0-3)	1 (0-3)
p	**0.392**	**0.313**	**0.441**	**0.219**

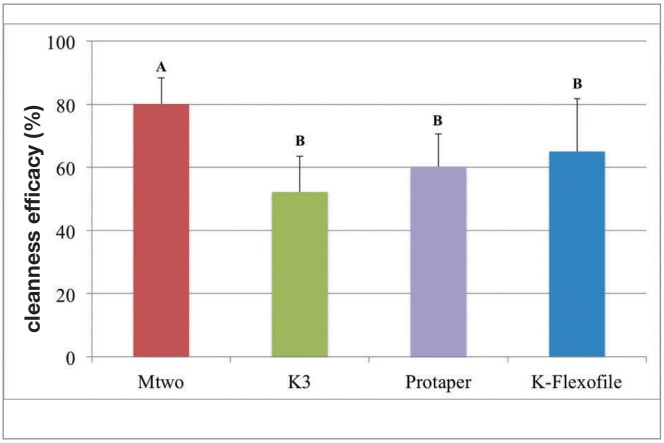

Figure 1. Percentage of cleanness efficacy promoted by the instrumentation systems, and standard deviation.
* Different capital letters stand for statistical difference.

flattening of root canals allowed particular areas to remain untouched, once instrument accessibility to the whole root canal might have been limited.[23] In addition, it is possible that root canal irregularities, such as grooves, depressions and large pits, have hampered instrument contact.[24]

Qualitatively, no significant difference in cleanness efficacy was found among different instrumentation systems when evaluating coronal, middle, and apical thirds separately or overall. The literature has shown conflicting results in this regard. Statistical difference is indicated in some studies;[24] however, it is not pointed out in others.[13]

In spite of being insignificant, Mtwo instruments showed a slightly better performance in the qualitative analysis, once it was possible to notice a lower mean score for overall remaining dye adhered to the walls, in comparison to K3, ProTaper and K-Flexofile instruments.

In agreement with the previous observation, the Mtwo system promoted the cleanest dentin walls (80.05%) when root canal segments were quantitatively analyzed by a computer program, and it was significantly superior to other systems. Previous studies demonstrated that Mtwo files displayed excellent cleaning and shaping abilities.[5,13,25] A possible explanation is that Mtwo files are characterized by two sharp cutting edges,[5,14] which allows better cutting efficiency in the entire length of the root canal.[25]

Furthermore, some differences in instrumentation techniques may be considered. While K3, ProTaper and K-Flexofile systems prepare the root canals with the crown-down technique, Mtwo prepares the canals with the step-back technique. Mtwo instruments are applied up to the total working length[5] to shape the entire length of the root canal. The manufacturer declares that the crown-down instrumentation sequence is no longer required because each instrument creates an access way for the next sequential instrument. Thus, greater friction in the dentin walls is expected, mainly by the action of the initial files,[17] which might lead to better cleanness of the root canal.

In the present study, Mtwo and K-Flexofile instruments were able to clean a higher number of root canal segments with a score 0 in the apical third, in agreement with a recent research.[21] The outcomes might be considered essential for endodontic therapy of straight, narrow and flattened root canals, since the apical third is the most difficult area to be cleaned, where it is possible to find uninstrumented dentin surfaces.[5,21]

In general, although not significant, manual instrumentation presented superior cleanness efficacy than K3 and ProTaper, in both qualitative and quantitative analyses. The literature has reported distinct results regarding manual instrumentation, in which stainless steel or NiTi manual instruments promoted superior,[8] comparable[19] or inferior[12,23] cleaning efficacy when compared to rotary instruments.

The results of the present study must be compared to others with care and limitation. Variations can be found between different rotary or manual instruments in terms of physical characteristics, between methodologies used in each investigation, as well as the operator's expertise.

Conclusions

In general, within the parameters of the present study and regardless of limitations, the use of the Mtwo system resulted in slightly superior cleanness efficacy compared to K3, ProTaper and K-Flexofile instruments. Nevertheless, even with all the progress in endodontic technologies, the quality of root canal preparation is still less than ideal, and prudence is necessary for extrapolating results to the clinical practice.

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