Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth

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Abstract

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Aim To compare the cleaning effectiveness and shaping ability of Mtwo, K3, and RaCe nickel–titanium rotary instruments during the preparation of curved root canals in extracted human teeth.

Methodology A total of 60 root canals of mandibular and maxillary molars with curvatures ranging between 25° and 35° were divided into three groups of 20 canals. Based on radiographs taken prior to instrumentation with the initial instrument inserted into the canal, the groups were balanced with respect to the angle and the radius of canal curvature. Canals were prepared using a low-torque control motor. Using pre- and post-instrumentation radiographs, straightening of the canal curvatures was determined with a computer image analysis program. The amount of debris and smear layer was quantified on the basis of a numerical evaluation scale. The data established for scoring the debris and the smear layer was separately recorded and analysed statistically using the Kruskal–Wallis test.

Results During preparation no instrument separated. Completely clean root canals were never observed. For debris removal Mtwo instruments achieved significantly better results ($P < 0.001$) than K3 and RaCe instruments. The results for remaining smear layer were similar and not significantly different ($P > 0.05$). Mtwo instruments maintained the original canal curvature significantly better ($P < 0.05$) than the other instruments. Instrumentation with Mtwo files was significantly faster than with K3 or RaCe instruments ($P < 0.05$).

Conclusions Under the conditions of this study, Mtwo instruments resulted in good cleaning and maintained the original curvature significantly better than K3 or RaCe files.

Keywords: canal curvature, canal straightening, debris, irrigation, smear layer.

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Introduction

Successful root canal treatment depends among other factors on the removal of microorganisms through chemo-mechanical instrumentation of the root canal system. This includes the removal of the infected dentine and organic tissue by shaping and dissolution. Thus, the cleaning ability of any root canal instrument is of importance for the outcome of the root canal treatment.

Recently, the new Mtwo rotary nickel–titanium instruments (VDW, Munich, Germany) have been introduced. In the first part of this two-part study the shaping ability of these instruments was investigated in simulated curved canals (Schäfer *et al.* in press). Although standardized root canal models are an ideal experimental model to compare the shaping ability of

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different instruments, care should be exercised in the extrapolation of the results obtained in simulated canals with the clinical situation (Ayar & Love 2004). Therefore, studies using real root canals in extracted teeth are required in order to fully assess the efficiency of root canal instruments. Up to now only one report is available, evaluating the cleaning efficiency of Mtwo files in extracted teeth (Foschi *et al.* 2004). In that study, Mtwo files produced clean and debris-free dentine surfaces in the coronal and middle thirds of the canals, whereas in the apical portion increasing amounts of debris were found. No attempts have been made in this study to evaluate the shaping ability of the Mtwo files.

The superior cleaning ability in the coronal and middle parts of the root canal has been described for different rotary nickel–titanium instruments when compared with the apical part (Wu & Wesselink 1995, Hülsmann *et al.* 1997, Gambarini & Laszkiewicz 2002, Hülsmann *et al.* 2003, Schäfer & Schlingemann 2003, Foschi *et al.* 2004, Schäfer & Vlassis 2004, Paqué *et al.* 2005). In general, there are some clues that the flute design of rotary nickel–titanium files may be a key factor for the cleaning efficiency of these instruments. According to some recent reports, instruments with sharp cutting edges seem to be superior to those having radial lands in cleaning the root canal (Jeon *et al.* 2003, Schäfer & Vlassis 2004).

The aim of this investigation was to compare the cleaning efficacy (residual debris, quality of the smear layer) after preparation of severely curved root canals with Mtwo, K3 (SybronEndo, West Collins, CA, USA) and RaCe files (FKG, La Chaux-de-Fonds, Switzerland). Moreover, another purpose of this study was to assess whether instrumentation had an effect on canal curvature.

Materials and methods

Extracted teeth

A total of 60 extracted human teeth with at least one curved root and curved root canal were selected for this investigation. Coronal access was achieved using diamond burs and the canals were controlled for apical patency with a root canal instrument of size 10. Only teeth with intact root apices, and whose root canal width near the apex was approximately compatible with size 15 were included. This was checked with silver points sizes 15 and 20 (VDW).

Standardized radiographs were taken prior to the instrumentation with the initial root canal instrument of size 15 inserted into the curved canal. The tooth was placed in a radiographic mount made of silicone based impression material (Silaplast Futur; Detax, Ettlingen, Germany) to maintain a constant position. The radiographic mount compromised of a radiographic paralleling device embedded in acrylic resin. This device was attached to a Kodak Ultra-speed film (Kodak, Stuttgart, Germany) and was aligned so that the long axis of the root canal was parallel and as near as possible to the surface of the film. The X-ray tube, and thus, the central X-ray beam was aligned perpendicular to the root canal. The exposure time (0.12 s; 70 kV, 7 mA) was the same for all radiographs with a constant source-to-film distance of 50 cm and an object-to-film distance of 5 mm. The films were developed, fixed, and dried in an automatic processor (Dürr-Dental XR 24 Nova; Dürr, Bietigheim-Bissingen, Germany).

The degree and the radius of canal curvature were determined using a computerized digital image processing system (Schäfer *et al.* 2002). Only teeth whose radii of curvature ranged between 4.0 mm and 9 mm and whose angles of curvature ranged between 25° and 35° were included (Table 1). On the basis of the degree and the radius of curvature the teeth were allocated into three identical groups of 20 teeth. The homogeneity of the three groups with respect to the degree and the radius of curvature was assessed using analysis of variance (ANOVA) and *post hoc* Student–Newman–Keuls test (Table 1). At the end of canal preparation, the canal curvatures were redetermined on the basis of a radiograph with the final root canal instrument inserted into the canal using the same technique (Schäfer *et al.* 2002) in

Table 1 Characteristics of curved root canals ($n = 20$ teeth per group)

Instruments	Curvature (°)			Radius (mm)		
	mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Mtwo	30.20 ± 3.26	25.1	35.0	6.64 ± 1.14	4.1	9.0
K3	30.21 ± 3.33	25.0	34.9	6.39 ± 1.03	4.4	8.7
RaCe	30.15 ± 3.54	25.3	34.8	6.74 ± 1.04	4.2	8.8
P-value (ANOVA)	0.999			0.570		

order to compare the initial curvatures with those after instrumentation. Only one canal was instrumented in each tooth.

Root canal instrumentation

The working length was obtained by measuring the length of the initial instrument (size 10) at the apical foramen minus 1 mm. Instruments were used to enlarge four canals only. After each instrument, the root canal was flushed with 5 mL of a 2.5% NaOCl solution and at the end of instrumentation with 5 mL of NaCl using a plastic syringe with a closed-end needle (Hawe Max-I-probe; Kerr-Hawe, Bioggio, Switzerland). The needle was inserted as deep as possible into the root canal without binding.

All types of instruments were set into permanent rotation with a 4:1 reduction handpiece (WD-66 EM; W & H, Buermoos, Austria) powered by a torque-limited electric motor (Endo IT motor; VDW). For each file the individual torque limit and rotational speed programmed in the file library of the Endo IT motor were used. The preparation sequences were the same as described in Part 1 of this two-part report (Schäfer *et al.* in press).

Group A: All Mtwo instruments were used to the full length of the canals according to the manufacturer's instructions using a gentle in-and-out motion. The instrumentation sequence was:

1. A 0.04 taper size 10 instrument was used to the full length of the canal.
2. A 0.05 taper size 15 instrument was used to the full length of the canal.
3. A 0.06 taper size 20 instrument was used to the full length of the canal.
4. A 0.06 taper size 25 instrument was used to the full length of the canal.
5. A 0.05 taper size 30 instrument was used to the full length of the canal.
6. A 0.04 taper size 35 instrument was used to the full length of the canal.

Once the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

Group B: K3 instruments were used in a crown down manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument:

1. A 0.06 taper size 20 instrument was used to one-third of the working length.
2. A 0.04 taper size 30 instrument was used to one-third to one half of the working length.
3. A 0.04 taper size 25 instrument was used to one-half to two thirds of the working length.
4. A 0.04 taper size 20 instrument was used to two thirds of the working length.
5. A 0.02 taper size 20 instrument was used to the full length of the canal.
6. A 0.02 taper size 25 instrument was used to the full length of the canal.
7. A 0.02 taper size 30 instrument was used to the full length of the canal.
8. A 0.02 taper size 35 instrument was used to the full length of the canal.

Once, the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

Group C: RaCe instruments were also used in a crown down manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument:

1. A 0.10 taper size 40 instrument was used to one-third of the working length.
2. A 0.08 taper size 35 instrument was used to one-third to one half of the working length.
3. A 0.06 taper size 30 instrument was used to one-half to two thirds of the working length.
4. A 0.04 taper size 25 instrument was used to two thirds of the working length.
5. A 0.02 taper size 25 instrument was used to the full length of the canal.
6. A 0.02 taper size 30 instrument was used to the full length of the canal.
7. A 0.02 taper size 35 instrument was used to the full length of the canal.

Once, the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

In each of these three test groups, 20 canals were enlarged. Thus, a total of 60 canals were prepared.

Evaluations

All root canal preparations were completed by one operator whilst the scanning electron microscope (SEM) evaluations and the assessment of the canal curvatures prior to and after instrumentation were carried out by a second examiner who was blind in respect of all experimental groups and who underwent a training process with reference to the scoring system of the SEM evaluations.

Shaping ability

Based on the canal curvatures assessed prior to and after instrumentation, canal straightening was determined as the difference between canal curvature prior to and after instrumentation. An ANOVA and *post hoc* Student–Newman–Keuls test were used for comparisons of the three groups. The level of statistical significance was set at $P < 0.05$.

The time for canal preparation was recorded and included total active instrumentation, instrument changes within the sequence and irrigation. The change of working length was determined by subtracting the final length (measured to the nearest 0.5 mm) of each canal after preparation from the original length. The preparation time was statistically analysed using the ANOVA and *post hoc* Student–Newman–Keuls test at a significance level of $P < 0.05$. The number of fractured and permanently deformed instruments during enlargement was also recorded.

Canal cleanliness

After preparation, all root canals were flushed with sodium chloride solution and dried with absorbent paper points. Roots were split longitudinally, prepared for SEM investigation and examined under the SEM (Philips PSEM 500X, Eindhoven, The Netherlands) at 20–2500× magnification.

Separate evaluations were recorded for debris and smear layer. The cleanliness of each root canal was evaluated in three areas (apical, middle, and coronal third of the root) by means of a numerical evaluation scale (Hülsmann *et al.* 1997). The following scheme was used:

Debris (dentine chips, pulp remnants, and particles loosely attached to the canal wall):

- Score 1: clean canal wall, only very few debris particles.
- Score 2: few small conglomerations.
- Score 3: many conglomerations; less debris than 50% of the canal wall covered.
- Score 4: more than 50% of the canal wall covered.
- Score 5: complete or nearly complete covering of the canal wall by debris.

Smear layer (dentine particles, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigant):

- Score 1: no smear layer, orifice of dentinal tubules patent.
- Score 2: small amount of smear layer, some open dentinal tubules.
- Score 3: homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules.
- Score 4: the entire root canal wall covered with a homogenous smear layer, no open dentinal tubules.
- Score 5: a thick, homogenous smear layer covering the entire root canal wall.

The data established for scoring the debris and the smear layer were separately recorded and analysed statistically. Owing to the ordinal nature of the scores, the data were subjected to the nonparametric Kruskal–Wallis test. P-values were computed and compared with the $P = 0.05$ level.

Results

During preparation of the 60 canals no instrument separated and no instrument was permanently deformed.

Instrumentation results

The mean time taken to prepare the canals with the different instruments is shown in Table 2. Instrumentation with Mtwo files was significantly faster than with K3 or RaCe instruments ($P < 0.05$). There was no statistically significant difference between K3 and RaCe ($P > 0.05$).

All canals remained patent following instrumentation, thus, none of the canals were blocked with dentine. With all instruments, no canal had overextension of preparation or a loss of working distance.

The mean straightening of the curved canals is shown in Table 3. The use of Mtwo files resulted in significantly less straightening (1.22°) during instrumentation ($P < 0.05$) compared with K3 and RaCe (Fig. 1). No significant difference ($P > 0.05$) was obtained between K3 (2.84°) and RaCe (2.59°).

Canal cleanliness

The scores for debris and smear layer are detailed in Tables 4 and 5. Completely cleaned root canals were

Table 2 Mean preparation time (min) and SD with the different instruments

	Preparation time (min)	
Instruments	Mean*	SD
Mtwo	3.84^a	0.98
K3	5.47^b	0.71
RaCe	5.48^b	0.69

*Values with the same superscript letters were not statistically different at $P = 0.05$.

Table 3 Mean degree of straightening of curved canals (°) and SD after canal preparation with the different instruments ($n = 20$ canals in each group)

Instruments	Straightening (°) Mean*	SD	Minimum	Maximum
Mtwo	1.22[a]	1.32	0	3.1
K3	2.84[b]	2.40	0	7.0
RaCe	2.59[b]	2.32	0	6.5

*Values with the same superscript letters were not statistically different at $P = 0.05$.

never found (Fig. 2). In general, the use Mtwo instruments resulted in significantly less debris ($P < 0.05$) compared with canal preparation with K3 and RaCe instruments (Table 4). K3 files resulted in significantly less debris compared with RaCe instruments ($P < 0.05$). The average score for debris was 1.80 for the Mtwo, 2.25 for the K3, and 2.43 for the Race instruments respectively.

In terms of smear layer (Fig. 3), the RaCe files resulted in 35%, the K3 instruments in 23.3%, and the Mtwo system in 21.7% of specimens having scores 1 and 2 (Table 5); no statistically significant differences were apparent ($P = 0.241$).

Discussion

The aim of this two-part report was to assess both the shaping ability and the cleaning efficiency of the new rotary nickel–titanium Mtwo instruments.

Cleaning effectiveness

One of the most important objectives during root canal instrumentation is the removal of vital and/or necrotic pulp tissue, infected dentine, and dentine debris in order to eliminate most of the microorganisms from the root canal system (European Society of Endodontology 1994, American Association of Endodontists 1998). The ability to achieve some of these objectives was examined *in vitro* in this investigation on severely curved root canals, involving Mtwo, K3, and RaCe rotary nickel–titanium instruments. The latter two systems were used as comparison for the results obtained with Mtwo, because their cleaning efficiency has been investigated in recent studies (Schäfer & Schlingemann 2003, Prati *et al.* 2004, Schäfer & Vlassis 2004, Paqué *et al.* 2005). On the contrary, up to now little information exists about the performance of Mtwo files in terms of shaping ability in real teeth and their cleaning efficiency.

In this study, the cleaning efficiency of the different instruments was assessed using two criteria: debris and smear layer. Debris was defined as dentine chips, and residual vital or necrotic pulp tissue attached to the root canal wall, which in most cases is infected (Hülsmann *et al.* 1997). Thus, debris might prevent the efficient removal of microorganisms from the root canal system. The smear layer is a surface film of a thickness of approximately 1–2 μm (American Association of Endodontists 1998). Smear layer, which is mainly inorganic, is produced when a canal is

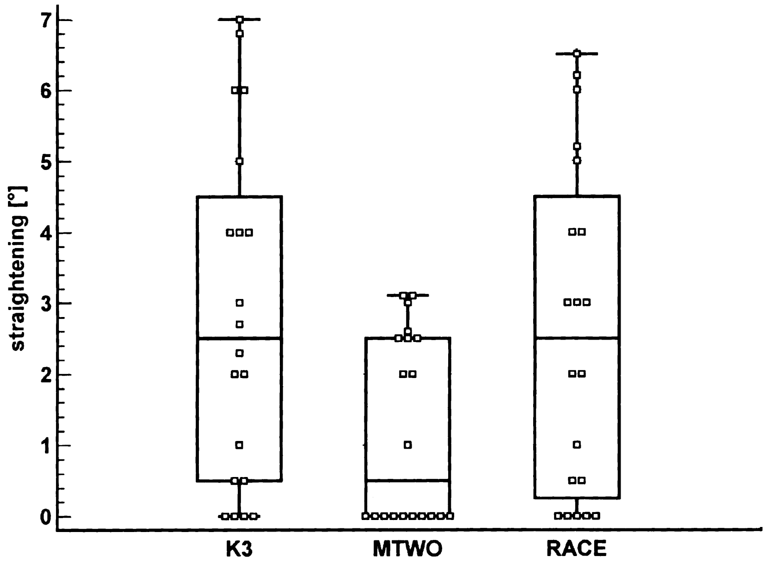

Figure 1 Straightening of the curved canals after preparation with the different instruments ($n = 20$ canals in each group): Combined box-and-whisker and dot plot, each dot represents a reading of the difference between canal curvature prior to and after instrumentation.

Table 4 Summary of scores for debris

	Coronal third scores					Middle third scores					Apical third scores					Total scores				
Instruments	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Mtwo	10	8	1	1	0	7	10	2	1	0	6	11	2	1	0	23	29	5	3	0
K3	7	11	1	1	0	6	10	3	1	0	0	6	9	4	1	13	27	13	6	1
RaCe	2	12	5	1	0	1	7	7	2	3	0	7	6	5	2	3	26	18	8	5
P-values	<0.05					<0.001					<0.001					<0.001				

Table 5 Summary of scores for smear layer

	Coronal third scores					Middle third scores					Apical third scores					Total scores				
Instruments	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Mtwo	1	6	9	4	0	1	2	10	7	0	0	3	8	6	3	2	11	27	17	3
K3	1	8	7	4	0	1	3	10	6	0	0	1	6	9	4	2	12	23	19	4
RaCe	1	7	9	2	1	1	7	10	2	0	0	5	6	3	6	2	19	25	7	7
P-values	0.898					0.078					0.471					0.241				

instrumented (Grandini *et al.* 2002), no smear layer is found on areas that are not instrumented (West *et al.* 1994). Although the influence of smear layer on outcome of the endodontic treatment is still controversial, it is considered to be desirable to remove the smear layer because of its potential deleterious effects (Lim *et al.* 2003).

Although the use of antibacterial irrigants is recommended in combination with chelating agents in order to remove debris as well as the inorganic/organic smear layer (West *et al.* 1994, Hülsmann *et al.* 1997, Gambarini 1999, Grandini *et al.* 2002, Lim *et al.* 2003), in the present study NaOCl alone was used as an irrigant. This solution would appear the best available canal irrigant owing to its antibacterial and organic tissue dissolving properties (Spångberg *et al.* 1973, Turkun & Çengiz 1997), but it is not possible to remove the smear layer with NaOCl (Yamada *et al.* 1983, Grandini *et al.* 2002, Guerisoli *et al.* 2002, Lim *et al.* 2003). Nevertheless, considering the major objective of the present investigation (to compare the cleaning effectiveness of the instrumentation techniques under identical conditions) a simple irrigation technique was used, avoiding any influences of different irrigation solutions. Thus, it should be noted that the cleaning efficiency of the three instruments evaluated in the present study might be further improved using a combination of NaOCl and EDTA containing chelating agent.

In the present study, the cleaning efficacy of two instrumentation sequences was examined on the basis of a separate numerical evaluation scheme for debris and smear layer, by means of an SEM-evaluation of the coronal, the middle, and the apical portions of the canals (Haikel & Allemann 1988, Hülsmann *et al.* 1997). With all instrumentation techniques, partially uninstrumented areas with remaining debris were found in all canal sections. This finding has also been described by others (Bolanos & Jensen 1980, Hülsmann *et al.* 1997, 2003) and is consistent with two other investigations using microcomputer tomography assessment of canal shapes (Peters *et al.* 2001, 2003). Moreover, the present results indicate that on average the apical third of the canals was less clean than the middle and coronal thirds regardless of the instrument used. This observation is also in agreement with other studies (Wu & Wesselink 1995, Gambarini & Laszkiewicz 2002, Hülsmann *et al.* 2003, Schäfer & Schlingemann 2003, Schäfer & Vlassis 2004, Paqué *et al.* 2005). Generally, these investigations underline the limited efficiency of all instruments tested in cleaning the apical part of the root canal and the importance of irrigation as crucial for sufficient disinfection of the root canal system (Hülsmann *et al.* 2003, Paqué *et al.* 2005).

A comparison of the results for K3 and RaCe with those of recent studies investigating these rotary nickel–titanium instruments under identical conditions but with different operators (Schäfer & Schlingemann 2003, Schäfer & Vlassis 2004) elucidates that the results of the present study were in the same range as in the previous ones. Taking into consideration that certainly the different operators did not have the same experience with the different systems it can

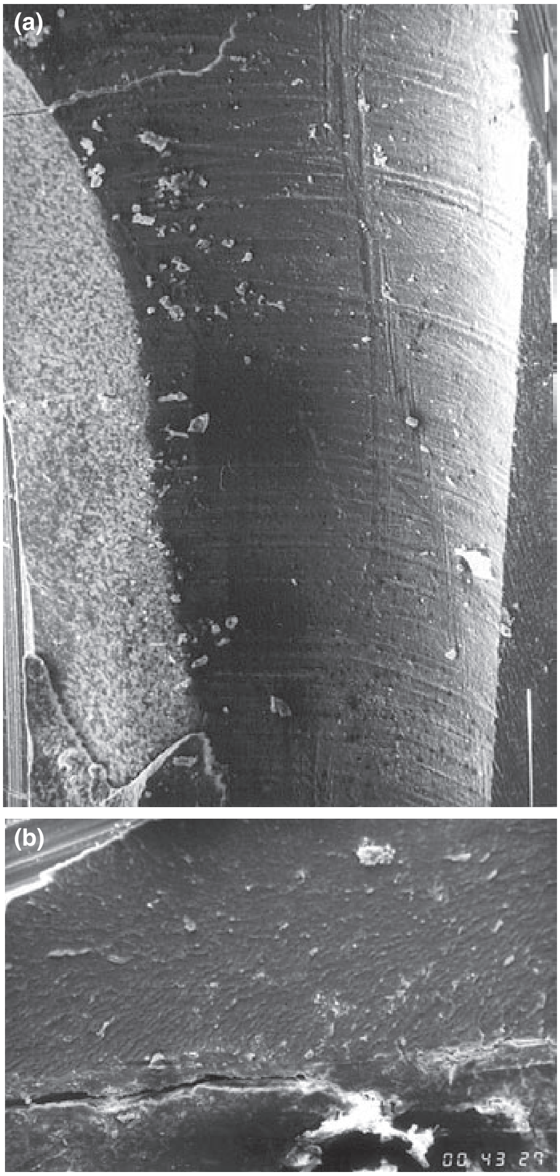

Figure 2 Canal wall after preparation with the rotary nickel–titanium instruments. (a) Nearly clean canal wall with small agglomerations of debris particles in the middle portion of the canal prepared with Mtwo files (score 1, original magnification 80×). (b) Apical portion of the canal after enlargement with RaCe instruments (score 2, original magnification 160×).

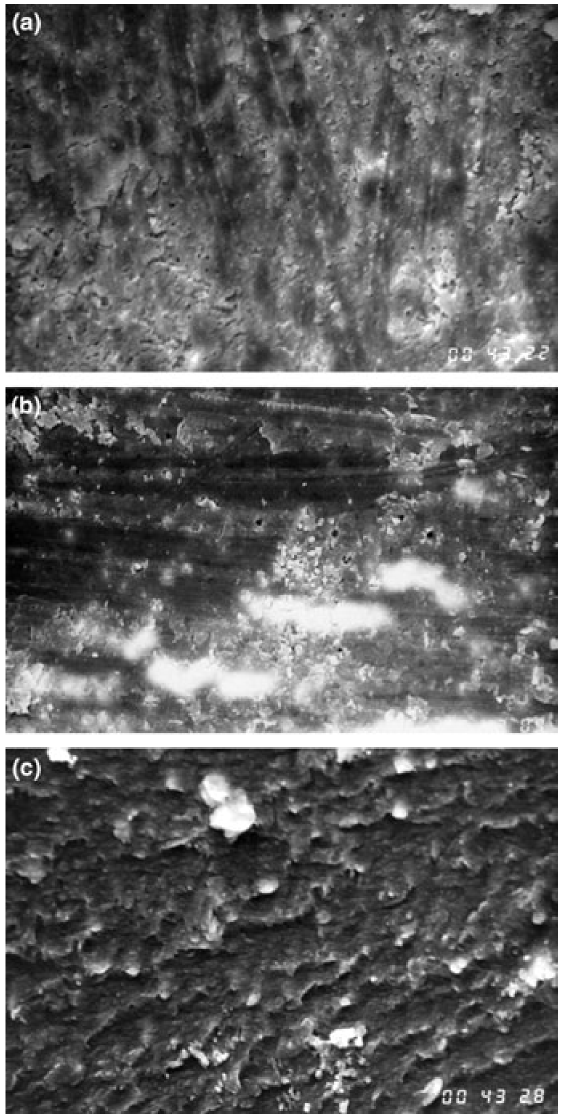

Figure 3 Canal wall after preparation with the rotary nickel–titanium instruments (original magnification 640×): (a) Mtwo: score 2. (b) K3: score 3. (c) RaCe: score 4.

nevertheless be concluded that the present findings can be compared with recently published data on the cleaning efficiency of other rotary nickel–titanium instruments. Moreover, the results concerning the cleaning ability of RaCe files are in good agreement with those published by Paqué *et al.* (2005). For debris they found 51% scores 1 and 2, the results from the present study were 48% scores 1 and 2 for RaCe.

In general, the use of Mtwo instruments resulted in significantly less remaining debris (Table 4) compared with canal shaping with K3 or RaCe instruments ($P < 0.001$), whereas for smear layer no significant differences between these instruments occurred (Table 5, $P = 0.241$). A reason for this difference in the debris removal capacity of the three instruments may be that the Mtwo files are characterized by two sharp cutting edges and a relatively small core diameter.

The smaller the core diameter the greater the space between the cutting edges and the canal wall. This file design together with the increasing pitch length from the tip to the shaft of these files may enhance the debris removal capacity of the Mtwo file. Certainly, these assumptions warrant further investigations.

A comparison of the results obtained in previous studies under identical experimental conditions reveals that the Mtwo instruments showed a relatively good cleaning ability. The mean score for debris was 1.80 whereas in previous studies the mean scores ranged between 2.33 and 3.64 (Schäfer & Vlassis 2004).

Shaping ability

Despite the variations in the morphology of natural teeth, several attempts have been made to ensure standardization of the experimental groups. Therefore, the teeth in all experimental groups were balanced with respect to the apical diameter of the root canal and based on the initial radiograph the teeth were also balanced with respect to the angle and the radius of canal curvature. To achieve this a computerized digital image processing system was used to determine both the angle and the radius of curvature (Schäfer *et al.* 2002). The homogeneity of the three groups with respect to the defined constraints was examined using ANOVA and *post hoc* Student–Newman–Keuls test. According to the P-values obtained (Table 1), the groups were well balanced. The curvatures of all root canals ranged between 25° and 35° and the radii ranged between 4.1 mm and 9.0 mm (Table 1). Thus, the curvatures of the human root canals were comparable with those of the simulated canals in resin blocks used in the first part of this two-part report (curvatures: 28° and 35°; radii: 6.5 mm and 7.5 mm), allowing a comparison of the results obtained in simulated and in human root canals (Schäfer *et al.* 2006).

Concerning the ability of the three different instruments to maintain canal curvatures, better compliance with original canal shape was obtained using the Mtwo files compared with the two other instruments ($P < 0.05$; Fig. 1). In general, the results of the present study using extracted human teeth confirm the findings obtained in the first part of this two-part report after preparation of simulated canals (Schäfer *et al.* 2006), in that the use of Mtwo instruments resulted in better-centred canals. Both in simulated and in real canals Mtwo instruments were significantly faster than K3 and RaCe. Certainly, the instrumentation sequence of Mtwo comprised only six instruments whereas both for K3 and RaCe eight files were used to prepare the root canal. Nevertheless, because of the large differences in the mean preparation time between Mtwo on the one hand and K3 and RaCe on the other hand, it can be assumed that the main reason for this difference is the greater cutting efficiency of Mtwo, as already speculated in the first part of this investigation (Schäfer *et al.* 2006).

Interestingly, although the results for all three instruments were comparable with those of recent investigations under identical experimental conditions (Schäfer & Vlassis 2004), the mean value for straightening of Mtwo files was even smaller than those for other rotary instruments. The mean straightening was 1.22° when using Mtwo whereas the mean straightening for other rotary nickel–titanium instruments was in the range of 1.36° and 3.22° (Schäfer & Vlassis 2004). This comparison shows that out of all rotary nickel–titanium systems investigated under an identical experimental set-up, Mtwo files respected the original canal curvature well.

Instrument failure

During the present study no instrument separated and no instrument was permanently deformed. Summarizing these data and the findings obtained in the first part of this two-part report after preparation of simulated canals (Schäfer *et al.* in press) and in comparison with previously published studies conducted under the same experimental conditions as used in the present investigation (Schäfer & Vlassis 2004), the three different types of instruments were safe to use. This observation is in agreement with previous reports (Schäfer & Schlingemann 2003, Ankrum *et al.* 2004, Schäfer & Vlassis 2004, Paqué *et al.* 2005, Rangel *et al.* 2005, Yoshimine *et al.* 2005). Thus, these files can be used to enlarge at least four canals in real teeth using the instrumentation sequence described in the present study without an increased risk of instrument fracture.

Conclusions

Within the parameters of this study, the use of Mtwo files resulted in significantly less debris compared with canal preparation with K3 or RaCe instruments, whereas in terms of smear layer no statistically significant differences were apparent. Mtwo files maintained the original curvature significantly better than the two other systems.

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