Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 1. Shaping ability in simulated curved canals

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Abstract

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Aim To compare the shaping ability of Mtwo instruments with K3 and RaCe instruments. Part 1 of this two-part report describes the efficacy of these nickel–titanium instruments in simulated curved root canals.

Methodology Simulated canals with 28° and 35° curves in resin blocks were prepared with Mtwo instruments using a single length technique and with K3 and RaCe instruments using a crowndown preparation technique ($n = 20$ canals in each case). Pre- and post-instrumentation images were recorded and assessment of canal shape was completed with a computer image analysis program. Material removal was measured at 20 measuring points, beginning 1 mm from the endpoint of preparation. Incidence of canal aberrations, preparation time, changes of working length and instrument failures were also recorded. The data were analysed statistically using ANOVA and Student–Newman–Keuls test.

Results On an average, canals prepared with Mtwo instruments remained better centred compared with those enlarged with K3 or RaCe instruments. Six RaCe instruments, four K3 files and none of the Mtwo instruments fractured during preparation ($P > 0.05$). In both of the canal types, Mtwo was significantly faster ($P < 0.001$). It was possible with all types of instruments to control working length as well.

Conclusions Mtwo instruments prepared curved canals rapidly, respected original canal curvature well and were safe to use.

Keywords: canal transportation, curved root canals, nickel–titanium, resin blocks, root canal preparation, rotary instruments.

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Introduction

The aim of root canal instrumentation is to create a tapered shape with adequate volume to allow effective irrigation and filling (European Society of Endodontology 1994). Many instruments, devices and instrumentation techniques have been recommended but only few seem to be capable of consistently achieving these primary objectives of root canal preparation. It has become evident that rotary nickel–titanium instruments are able to maintain the canal shape even in severely curved canals and that preparation with these instruments is substantially faster than hand preparation (Thompson & Dummer 1997, Schäfer 2001, Schäfer & Lohmann 2002).

A crown down instrumentation sequence has been recommended for most of these rotary nickel–titanium instruments, in which larger files precede smaller ones, which in turn progress further apically (Peters 2004). This technique is mandatory to reduce intracanal friction and thus to minimise the risk of instrument separation.

Recently, a new instrument design has been introduced which no longer requires a crowndown

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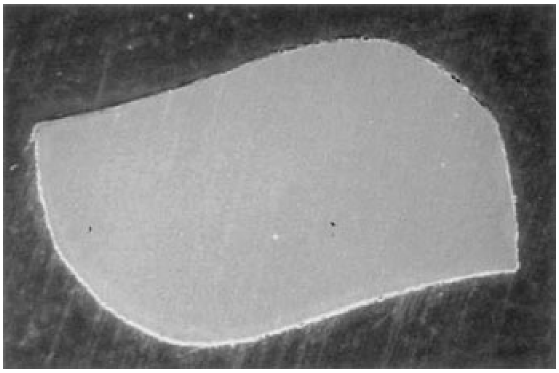

Figure 1 Scanning electron microscope image of the S-shaped cross-section of the Mtwo nickel-titanium instruments showing sharp cutting edges (size 30, 0.05 taper; original magnification 80×).

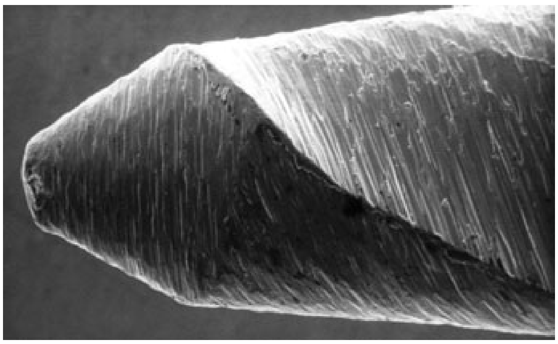

Figure 2 Scanning electron microscope image of the tip region of a Mtwo instrument showing a non-cutting flattened tip with a rounded transitional angle (size 30, 0.05 taper size; original magnification 320×).

instrumentation sequence. The new Mtwo instruments (VDW, Munich, Germany) have a S-shaped cross-sectional design (Fig. 1) and a noncutting safety tip (Fig. 2). Thus, these instruments are characterised by a positive rake angle with two cutting edges, which are claimed to cut dentine effectively. Moreover, Mtwo instruments have an increasing pitch length (blade camber) from the tip to the shaft. This design is alleged to have two functions: (i) to eliminate threading and binding in continuous rotation, and (ii) to reduce the transportation of debris towards the apex.

The basic series of Mtwo instruments comprises eight instruments with tapers ranging between 4% and 7% and sizes from 10 to 40. According to the manufacturer the instruments should be used in a single length technique. That means, all files of the instrumentation sequence should be used to the full length of the root canal.

K3 instruments (SybronEndo, West Collins, CA, USA) have a slightly positive rake angle in combination with so called radial land relief and an asymmetrical cross-sectional design (Schäfer & Florek 2003). The RaCe instruments (Reamer with Alternating Cutting Edges) have a triangular cross-sectional design with sharp cutting edges with the exception of the 0.02 taper size 20 files, which have a square cross-section (Schäfer & Vlassis 2004).

The purpose of the present study was to compare Mtwo instruments with K3 (SybronEndo, West Collins, CA, USA) and RaCe files (FKG, La Chaux-de-Fonds, Switzerland) during the shaping of simulated curved root canals in resin blocks using different parameters.

Materials and methods

Simulated canals

Simulated canals made of clear polyester resin (Viapal uP 004/64; Vianova Resins, Hamburg, Germany) with coloured canal walls were used to assess instrumentation. The degree of curvature was either 28° or 35°. The diameter and the taper of all simulated canals was equivalent to an ISO standard size 15 root canal instrument. The 28° canals were 13-mm long, the straight part being 5.5 mm and the curved part 7.5 mm. The curvature was defined mathematically with a radius of 7.5 mm resulting in an angle of 28° according to the Schneider method (Schneider 1971). The 35° canals were 13 mm long, the straight part being 5 mm and the curved part 8 mm. The radius of the curvature was 6.5 mm.

Preparation of simulated canals

The simulated canals were prepared with either Mtwo, K3 or RaCe rotary nickel–titanium instruments. The transparent blocks were covered with adhesive tape during the preparation phase. All instruments were used to enlarge four canals only. Prior to use, each instrument was coated with glycerine to act as a lubricant, and copious irrigation with water was performed repeatedly after the use of each instrument. All canals were enlarged by an operator experienced in preparation with the different types of instrument. Measurement of the canals was carried out by a second examiner who was unaware of the experimental groups. A randomly laid down sequence was used to avoid bias towards one of the three instrumentation techniques. Only, six resin blocks (three with 28° curves and three with 35° curves) were instrumented at a time to minimise operator fatigue and familiarity. These six resin blocks were defined as a set. The order of use of the three instrument types within a set was rotated.

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, Munich, Germany). For each file the individual torque limit and rotational speed programmed in the file library of the Endo IT motor were used. In a pilot study, the following instrumentation sequences allowed preparation of the different canals without difficulties.

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 13 mm, the full length of the canal.
2. A 0.05 taper size 15 instrument was used to 13 mm, the full length of the canal.
3. A 0.06 taper size 20 instrument was used to 13 mm, the full length of the canal.
4. A 0.06 taper size 25 instrument was used to 13 mm, the full length of the canal.
5. A 0.05 taper size 30 instrument was used to 13 mm, the full length of the canal.
6. A 0.04 taper size 35 instrument was used to 13 mm, 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

The K3 instruments were used in a crowndown 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 7 mm.
2. A 0.04 taper size 30 instrument was used to 9 mm.
3. A 0.04 taper size 25 instrument was used to 10 mm.
4. A 0.04 taper size 20 instrument was used to 11 mm.
5. A 0.02 taper size 20 instrument was used to 13 mm, the full length of the canal.
6. A 0.02 taper size 25 instrument was used to 13 mm, the full length of the canal.
7. A 0.02 taper size 30 instrument was used to 13 mm, the full length of the canal.
8. A 0.02 taper size 35 instrument was used to 13 mm, 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 crowndown 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 5 mm.
2. A 0.08 taper size 35 instrument was used to 7 mm.
3. A 0.06 taper size 30 instrument was used to 9 mm.
4. A 0.04 taper size 25 instrument was used to 11 mm.
5. A 0.02 taper size 25 instrument was used to 13 mm, the full length of the canal.
6. A 0.02 taper size 30 instrument was used to 13 mm, the full length of the canal.
7. A 0.02 taper size 35 instrument was used to 13 mm, 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 with 28° and 20 canals with 35° curves were enlarged. Thus, a total of 120 canals were prepared.

Assessment of canal preparation and analysis of data

The time for canal preparation was recorded and included total active instrumentation, instrument changes within the sequence and irrigation. Changes of working length were determined by subtracting the final length (measured to the nearest 0.5 mm) of each canal after preparation from the original length (13 mm). The preparation time and the loss of working length were statistically analysed using analysis of variance (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. A chi-square test was used to determine whether there were significant differences between the three instruments concerning failure and deformation.

The assessment of preparation shape was carried out with the computer program Image 1.41 (National Institutes of Health public domain program, National Institutes of Health, Bethesda, MD, USA). Therefore, pre- and post-instrumentation canal shapes were taken in a standardised manner and magnified 40 times by means of a charged coupled device (CCD) camera (SSC-M370CE; Sony Corporation, Tokyo, Japan) and stored in a computer (Macintosh Quadra 660 AV; Apple Computer, Ismaning, Germany). Thereafter, a composite image was produced of the pre- and post-instrumentation images and superimposed. The amount of resin removed, e.g. the difference between the canal configuration before and after instrumentation was determined both for the inner and the outer side of the curvature in 1 mm steps using the Image 1.41 program. The amount of resin substance removed in all canals was measured one-dimensionally with a precision of ±0.01 mm. The first measuring point was 1 mm away from the apical ending of the canal, the last measuring point was 10 mm from the apical end, resulting in 10 measuring points at the outer and 10 points at the inner side of the canal, and thus, in a total of 20 measuring points (Schäfer *et al.* 1995). All measurements were made at right angles to the surface of the canal. The data were analysed by using ANOVA and *post hoc* Student–Newman–Keuls test for all pairwise comparisons at a significance level of $P < 0.05$.

Furthermore, based on the superimposition of pre- and postoperative images, assessments were made according to the presence of different types of canal aberrations, such as apical zip associated with elbow, ledge, and perforation. These different types of canal aberration were defined according to the detailed descriptions published previously (Thompson & Dummer 2000b).

Results

During preparation of the 120 canals, a total of 10 instruments were separated. Therefore, the following results are based on the remaining 110 canals. Five canals with 28° and five canals with 35° curves were excluded.

Instrument failure

Table 1 details the number of deformations and fractures of instruments that occurred during the study. Both in the 28° curved and in the 35° curved canals four K3 (two of the 0.02 taper size 35 instrument, one of the 0.02 taper size 25 instrument, and one of the 0.02 taper size 30 instrument; all used for the fourth canal) and three RaCe instruments (five of the 0.02 taper size 25 and one of the 0.02 taper size 35; all used for the third or forth canal) fractured.

Table 1 Number of fractured and permanently deformed instruments

	28° curved canals		35° curved canals	
Instrument	Fractured	Deformed	Fractured	Deformed
Mtwo	0	3	0	5
K3	2	1	2	1
RaCe	3	0	3	1

The number of fractured instruments ($P = 0.269$) was not significantly different between the instruments. In the 28° curved canals, there was no statistically significant difference concerning the number of permanently deformed instruments ($P = 0.095$), whilst in the 35° curved canals, Mtwo files deformed significantly more often than the other two instruments ($P = 0.034$).

Preparation time

The mean time taken to prepare the canals with the different instruments is shown in Table 2. Both in 28° and 35° curved canals, instrumentation with the Mtwo files was significantly faster than with K3 or RaCe ($P < 0.001$). Independent of the curvature of the canals, preparation with RaCe was significantly faster than with K3 ($P < 0.01$).

Change of working length

All canals remained patent following instrumentation, thus, none of the canals became blocked with resin debris. None of the canals had overextension of preparation, whereas a loss of working distance was found in three canals enlarged with Mtwo, in nine canals enlarged with K3, and in 13 canals enlarged with RaCe instruments.

The mean loss of working length that occurred with the different instruments is listed in Table 3. The

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

	28° curved canals		35° curved canals	
Instrument	Mean	SD	Mean	SD
Mtwo	3.92	0.24	3.51	0.25
K3	7.53	1.18	7.71	0.81
RaCe	6.26	0.85	6.04	0.62

Table 3 Mean loss of working length (mm) and SD with the different instruments

	28° curved canals		35° curved canals	
Instrument	Mean	SD	Mean	SD
Mtwo	0.02	0.11	0.02	0.11
K3	0.48	0.92	0.50	0.61
RaCe	0.47	0.67	0.57	0.89

differences between the three instruments were not statistically significant, neither in the 28° curved ($P = 0.055$) nor in the 35° curved canals ($P = 0.056$). The general trend was, that in both canal types mean loss of working length was smaller using Mtwo instruments compared with both K3 and RaCe instruments (Table 3).

Canal shapes

The results of the assessment of canal aberrations are summarised in Table 4. With respect to the different types of aberrations evaluated, both in canals with 28° and with 35° curves, there were no significant differences between the three different instruments (χ^2-test, $P > 0.05$), even though more zips and more ledges were created with K3 than with Mtwo or RaCe. Also with regard to the total number of aberrations there were no significant differences between the instruments (χ^2-test, $P > 0.05$).

On average, in the canals with 28° curves, the Mtwo instruments removed material evenly on the outer, as well as on the inner side of curvature. K3 and RaCe created minimal transportation towards the outer aspect of the curve, as indicated by the significantly greater mean material removal ($P < 0.05$) at the measuring points 1–3 compared with the material removed by the Mtwo instruments (Table 5). At eight of 20 measuring points, significant differences ($P < 0.05$) occurred between resin removal achieved with the three different instruments (Table 5). In general, the canals prepared with the different instruments remained centred.

In the canals with 35° curves, significantly less ($P < 0.05$) resin was removed by K3 and RaCe instruments at nine of 10 measuring points at the inner canal wall compared with the material removed by the Mtwo files. At the outer canal wall only minor differences occurred between resin removal achieved with the three instruments (Table 6).

Table 4 Incidence of canal aberrations

	28° curved canals			35° curved canals		
Aberration type	Mtwo	K3	RaCe	Mtwo	K3	RaCe
Zip/elbow	1	3	1	2	3	2
Ledge	2	2	3	2	4	2
Perforation	0	0	0	0	0	0

χ^2 test, no significant differences ($P > 0.05$).

Discussion

The purpose of this study was to assess the shaping ability of rotary Mtwo nickel–titanium instruments. Two other rotary nickel–titanium instruments (K3 and RaCe) were used as comparison. This was performed for two reasons. First, both systems have been reported to respect original root canal curvature well and both have been described as safe to use (Schäfer & Florek 2003, Ayar & Love 2004, Schäfer & Vlassis 2004, Paqué *et al.* 2005, Rangel *et al.* 2005, Yoshimine *et al.* 2005). The second aspect was, that K3 and RaCe instruments have been investigated under the same experimental conditions as used in the present study. Thus, these two instruments served as controls in order to ensure transferability of the results obtained for Mtwo with those of previous studies investigating other rotary nickel–titanium instruments under identical experimental conditions.

This study described the shaping abilities of the instruments under strictly controlled laboratory conditions, using clear resin blocks. Use of simulated canals in resin blocks does not reflect the action of the instruments in root canals of real teeth because of differences in the surface texture, hardness and cross-section (Peters 2004). However, resin blocks allow a direct comparison of the shaping ability of different instruments and studies on extracted teeth fully confirmed observations made on resin blocks (Peters 2004).

The results obtained for K3 and RaCe are in agreement with those reported previously when testing these instruments under identical experimental conditions (Schäfer & Florek 2003, Schäfer & Vlassis 2004). Mtwo instruments provided a centred apical preparation of the simulated canals and maintained the original shape of the curved canals. This finding cannot be compared with existing data because so far no reports on the shaping ability of Mtwo instruments are available. In order to completely assess the shaping potential of Mtwo instruments, further studies are required to focus on other criteria for canal preparation such as three-dimensional analysis of the prepared canal in order to assess smoothness, flow characteristics and taper of the enlarged canals.

Table 5 Mean material removed (mm) and SD at the different measuring points after instrumentation of simulated 28° curved canals

	Inner canal wall (mm from the apex)										Outer canal wall (mm from the apex)									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Mtwo																				
Mean	0.04	0.04	0.05	0.06	0.10	0.19	0.31	0.38	0.37	0.33	0.12	0.16	0.22	0.25	0.25	0.19	0.13	0.09	0.07	0.08
SD	0.03	0.04	0.04	0.05	0.09	0.11	0.10	0.08	0.10	0.10	0.05	0.07	0.06	0.06	0.08	0.10	0.08	0.06	0.05	0.06
K3																				
Mean	0.02	0.02	0.04	0.05	0.06	0.08	0.11	0.14	0.15	0.13	0.10	0.21	0.26	0.30	0.30	0.27	0.20	0.11	0.10	0.09
SD	0.01	0.01	0.03	0.04	0.04	0.05	0.06	0.08	0.10	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.08	0.04	0.04	0.04
RaCe																				
Mean	0.02	0.02	0.03	0.05	0.07	0.12	0.19	0.24	0.24	0.21	0.19	0.27	0.30	0.31	0.28	0.22	0.16	0.12	0.10	0.10
SD	0.02	0.02	0.02	0.04	0.06	0.09	0.11	0.11	0.11	0.11	0.07	0.07	0.09	0.11	0.10	0.10	0.09	0.10	0.09	0.08
P-value	0.059	0.087	0.390	0.771	0.144	**	**	**	**	*	**	**	*	0.072	0.120	0.058	0.071	0.247	0.168	0.535

$*P < 0.05$; $**P < 0.01$.

Table 6 Mean material removed (mm) and SD at the different measuring points after instrumentation of simulated 35° curved canals

	Inner canal wall (mm from the apex)										Outer canal wall (mm from the apex)									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Mtwo																				
Mean	0.04	0.05	0.06	0.08	0.13	0.24	0.37	0.44	0.43	0.38	0.11	0.14	0.19	0.25	0.27	0.19	0.10	0.07	0.07	0.10
SD	0.02	0.04	0.04	0.05	0.08	0.11	0.10	0.10	0.09	0.10	0.05	0.05	0.05	0.07	0.09	0.10	0.09	0.06	0.06	0.08
K3																				
Mean	0.03	0.03	0.03	0.04	0.06	0.08	0.14	0.16	0.16	0.13	0.10	0.20	0.26	0.29	0.28	0.21	0.13	0.09	0.09	0.09
SD	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.07	0.05	0.05	0.06	0.08	0.06	0.06	0.05	0.07	0.07	0.06	0.06	0.06
RaCe																				
Mean	0.02	0.03	0.03	0.05	0.06	0.11	0.18	0.23	0.23	0.22	0.10	0.21	0.25	0.29	0.29	0.24	0.17	0.11	0.11	0.11
SD	0.02	0.02	0.03	0.04	0.04	0.07	0.09	0.11	0.10	0.10	0.05	0.04	0.06	0.06	0.08	0.07	0.07	0.07	0.06	0.06
P-value	0.055	*	*	**	**	**	**	**	**	**	0.819	**	**	0.186	0.485	0.200	0.055	0.102	0.270	0.570

$*P < 0.05$; $**P < 0.01$.

In the present study none of the canals became blocked with resin debris and none of the canals showed overextension of preparation. Thus, the only changes of working length was a loss of working distance. In general, it was possible with all types of instruments to control the working distance well (Table 3). This finding is in agreement with several observations of other studies in that only small mean changes in working distance occurred with rotary nickel–titanium instruments (Kum *et al.* 2000, Thompson & Dummer 2000a, Schäfer & Florek 2003, Schäfer & Vlassis 2004, Paqué *et al.* 2005, Rangel *et al.* 2005, Yoshimine *et al.* 2005). On the whole, it is questionable, whether the small changes in working length observed in the present study would have any clinical significance. These changes may be probably because of minor canal straightening during canal enlargement or lack of length control by the operator (Thompson & Dummer 2000a).

The mean time for canal preparation was recorded and included instrument changes within the instrumentation sequences. Both in the 28° and 35° curved canals, Mtwo instruments were significantly faster than both K3 and RaCe instruments (Table 2). Compared with other rotary nickel–titanium files, instrumentation times with Mtwo instruments were substantially faster than with all other rotary nickel–titanium instruments tested under identical experimental conditions (Schäfer & Vlassis 2004). This may be due to the S-shaped cross-sectional design of the Mtwo files, resulting in very aggressive cutting edges (Fig. 1) and a positive rake angle, which is known to require less energy to cut dentine than blades with a neutral or negative rake angle (Wildey *et al.* 1992). In order to examine this hypothesis, further studies comparing the cutting efficiency of different rotary instruments in reliance on their cross-sectional design seem to be indicated.

During the present study, six RaCe files, four K3 instruments, and no Mtwo instruments fractured. It is worth emphasising, that all fractured files were used for the third (RaCe) or fourth (K3, RaCe) canal. No fractures occurred when instruments were used to enlarge two canals only. Thus, when using K3 or RaCe files according to the instrumentation sequence described in the present study, the fracture rates of both instruments were low as long as they were used to prepare only two or three canals. This observation is in accordance with previous reports (Thompson & Dummer 2000a, Schäfer & Florek 2003, Ankrum *et al.* 2004, Schäfer & Vlassis 2004, Paqué *et al.* 2005, Rangel *et al.* 2005, Yoshimine *et al.* 2005). The fact that none of the Mtwo files fractured even after enlargement of four canals may be due to the increasing pitch length from the tip to the shaft of these instruments. As already reported, a varying pitch length along the working part of the instrument reduces the tendency of the file to screw-in (Diemer & Calas 2004) minimising the risk of instrument fracture. Nevertheless, some care should be taken when using the Mtwo files because of the relatively high incidence of permanent deformations of the instruments. In the 35° curved canals the Mtwo instruments deformed significantly more often than the other two instruments ($P < 0.05$) and during this study a total of 8 Mtwo instruments permanently deformed (Table 1). Thus, the working part of these instruments should be carefully examined after every use and those permanently deformed should be discarded.

Conclusions

Within the limitations of this study, Mtwo instruments respected original canal curvature well and prepared curved canals rapidly without substantial change in working length. The results indicate that Mtwo instruments were safe to use.

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