doi:10.1111/j.1365-2591.2006.01171.x

The influence of various automated devices on the shaping ability of Mtwo rotary nickel-titanium instruments

S. Bürklein & E. Schäfer

Department of Operative Dentistry, University of Münster, Münster, Germany

Abstract

Bürklein S, Schäfer E. The influence of various automated devices on the shaping ability of Mtwo rotary nickel-titanium instruments. *International Endodontic Journal*, **39**, 945–951, 2006.

Aim To compare the shaping ability of Mtwo rotary nickel-titanium instruments in simulated curved canals and in curved canals of extracted teeth when set into permanent rotation with two different torque-limited automated devices.

Methodology Root canal instrumentation was performed with two different torque-limited automated devices (Mtwo direct handpiece and Endo IT motor) using Mtwo rotary nickel-titanium instruments up to size 35. *Simulated canals*: 28° and 35° curved canals in resin blocks ($n = 20$ canals in each group) were prepared. Pre- and post-instrumentation images were recorded and assessment of canal shape was completed with a computer image analysis program. *Extracted teeth*: a total of 40 curved root canals were divided into two groups, which were balanced with respect to the angle and the radius of canal curvature. Straightening of the canal curvatures was determined with a computer image analysis program. Incidence of canal aberrations, preparation time, changes of working length and instrument failures were recorded both in simulated and real canals and were analysed using the *t*-test and a chi-square test.

Results In simulated canals, instrumentation with Endo IT was significantly faster than with Mtwo direct ($P < 0.05$). No significant differences between the two devices were noted when all other parameters were assessed ($P > 0.05$). Only one instrument separated (Mtwo direct) during the enlargement of 28° curved simulated canals. All systems maintained working distance well.

Conclusions Both systems respected original root canal curvature well and were safe, indicating that the Mtwo direct handpiece is suitable for preparing curved root canals with the Mtwo instruments.

Keywords: canal straightening, Mtwo direct, resin blocks, rotary instruments, torque control.

Received 12 April 2006; accepted 5 June 2006

Introduction

Rotary nickel-titanium instruments facilitate the preparation of curved root canals (Hülsmann *et al.* 2005). In general, the use of these instruments results in well centred preparations in curved canals that are completed in a shorter time in comparison with manual instrumentation (Kum *et al.* 2000, Schäfer & Vlassis 2004b, Hülsmann *et al.* 2005, Schäfer *et al.* 2006a,b). Nevertheless, despite these advantages, care should be taken when using rotary nickel-titanium instruments with respect to instrument fracture (Hülsmann *et al.* 2005). Therefore, the use of special motors or handpieces with low speed and torque-control is recommended (Hülsmann *et al.* 2005).

Several automated devices have been developed including electric high- and low-torque control motors (Gambarini 2000, 2001, Hülsmann *et al.* 2005) and torque-limited rotation handpieces (Yared & Sleiman 2001, Dammaschke & Schäfer 2004, Schäfer *et al.*

Correspondence: Prof. Dr Edgar Schäfer, Department of Operative Dentistry, University of Münster, Waldeyerstr. 30, D-48149 Münster, Germany (Tel.: +251 834 70 40; fax: +251 834 70 37; e-mail: eschaef@uni-muenster.de).

Figure 1 The swivel type adjustment ring of the Mtwo direct handpiece for selection of the different torque settings. Notice that the eight different settings which are located at the left and the right side of the adjustment ring are coded according to the taper and the size of the eight different Mtwo instruments. Thus, the settings for every Mtwo instrument are marked on this handpiece.

2005). In a previous study it has been shown that both electric low-torque control motors and torque-limited air-driven handpieces are suitable for the preparation of curved canals and were at the same time safe to use (Schäfer *et al.* 2005). The Endo IT motor (VDW, Munich, Germany) is an example of low-torque control motors with individually adjusted torque limits for each instrument (Yared *et al.* 2003, Hülsmann *et al.* 2005). The air-driven torque-limited rotation handpiece Mtwo direct (Sirona, Bensheim, Germany) was introduced recently (Fig. 1). The torque settings of this handpiece are specially adjusted for Mtwo instruments (VDW) and only these files can be used with this handpiece.

Recently it has been shown that the Mtwo nickel-titanium instruments which no longer require a crowndown instrumentation sequence (Schäfer *et al.* 2006a) respected original canal curvature well, prepared even severely curved root canals rapidly and were safe to use when set into rotation with the Endo IT motor (Veltri *et al.* 2005, Schäfer *et al.* 2006a,b). According to these studies, Mtwo instruments can be used in the so-called single-length technique which means that all files can be used to the full length of the root canal. Because of this modification of the instrumentation technique more blades are at the same time in contact with the canal wall compared with the crowndown procedure. Hence, it can be speculated that this might result in a higher frictional resistance. Therefore, the question arises whether Mtwo instruments can be set into rotation with an air-driven torque-controlled handpiece without an increased risk of instrument separation, as already described for FlexMaster instruments (VDW) when used in a crown-down sequence (Schäfer *et al.* 2005).

The aim of this study was therefore to investigate the influence of different automated devices (Mtwo direct handpiece and Endo IT motor) on the shaping ability and the incidence of instrument fracture of Mtwo instruments in simulated curved canals in resin blocks and in extracted human teeth with curved root canals.

Materials and methods

In the first group the instruments were set into permanent rotation with the torque-limited rotation Mtwo direct handpiece at a maximum speed of 350 rpm. Torque settings were selected with a turning ring chosen for each file according to the manufacturer's instructions (Fig. 1). In the second group the instruments were set into permanent rotation with a 4 : 1 reduction handpiece (WD-66EM; W&H, Buermoos, Austria) powered by a torque-limited electric motor (Endo IT). For each instrument the individual torque limit and rotational speed programmed in the file library of the Endo IT motor were used.

All root canal preparations in simulated canals and real teeth were completed by one operator whilst the assessments prior to and after instrumentation were carried out by a second examiner who was blind in respect of both experimental groups.

Simulated canals

Simulated canals made of clear polyester resin (Viapal uP004/64; Vianova Resins, Hamburg, Germany) with coloured canal walls were used to assess instrumentation. The degree of curvature was either 28° or 35° with a radius of 7.5 or 6.5 mm (Schneider 1971). The diameter and the taper of all simulated canals (13 mm long) were equivalent to an ISO size 15 instrument. The transparent blocks were covered with adhesive tape during the preparation phase. Each instrument was used to enlarge four canals only, was coated with glycerine to act as a lubricant; copious irrigation with water was performed repeatedly after each instrument. A randomly laid down sequence was used to avoid bias towards one of the two devices. All canals were enlarged to an apical size 35 in the following sequence of instruments size 10, .04 taper, size 15, .05 taper, size 20, .06 taper, size 25, .06 taper, size 30, .05 taper, size 35, .04 taper, as described in detail in a previous study (Schäfer *et al.* 2006a). In each of the two groups, 20 canals with 28° and 20 with 35° curves were enlarged. Thus, a total of 80 canals were prepared.

The time for canal preparation including total active instrumentation, instrument changes within the sequence and irrigation was recorded and analysed statistically using the *t*-test. The loss of working length determined by subtracting the final length (measured to the nearest 0.5 mm) was analysed using a Mann–Whitney *U*-test and the differences concerning instrument failure and deformation by a chi-square test at a significance level of $P < 0.05$.

The assessment of preparation shape was carried out with the computer program Image 1.41 (National Institutes of Health public domain program). Therefore, pre- and post-instrumentation canal shapes were taken in a standardized manner and magnified 40 times by means of a CCD-camera (SSC-M370CE; Sony Corporation, Tokyo, Japan), stored in a computer, and superimposed. The amount of resin removed before and after instrumentation was measured one-dimensionally perpendicular to the surface of the canal with a precision of ±0.01 mm at 10 measuring points in 1 mm steps from the apical ending at the outer and 10 points at the inner side of the canal (Schäfer *et al.* 1995) using the Image 1.41 program. In the same manner assessments were made according to the presence of different types of canal aberrations (Thompson & Dummer 2000b).

Extracted teeth

A total of 40 extracted human teeth with at least one curved root and curved root canal were selected. 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 of the tooth. The long axis of the root canal was parallel and as near as possible to the surface of the Kodak Ultra-speed film (Kodak, Stuttgart, Germany). 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 5.0 and 9.0 mm and whose angles of curvature ranged between 25° and 35° were included. The teeth were allocated into two identical and homogenous groups of 20 teeth (*t*-test). 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 order to compare the initial curvatures with those after instrumentation. Only one canal was instrumented in each tooth. The preparation sequence was the same as described above for the preparation of simulated canals in resin blocks.

The working length was obtained by measuring the length of the initial instrument (size 10) at the apical foramen minus 1 mm. FileCare EDTA (VDW) was put on each file to reduce stress on the file and to allow easier preparation. 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.

All root canal preparations were completed by one operator whilst the assessment of the canal curvatures prior to and after instrumentation was carried out by a second examiner who was blind in respect of both experimental groups.

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. The *t*-test test was used for comparisons of the two groups. The level of statistical significance was set at $P < 0.05$.

The time for canal preparation including total active instrumentation, instrument changes within the sequence and irrigation was recorded. 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 and the loss of working length were statistically analysed using the *t*-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 two devices.

Results

Simulated canals

One instrument fractured (Table 1) in a 28° curved simulated canal (.04 taper size 10; used for the fourth

Table 1 Results of the instrumentation of the simulated curved canals

	28° curved canals						35° curved canals					
	Preparation time (s)		Loss of working length (mm)		Number of		Preparation time (s)		Loss of working length (mm)		Number of	
Device	Mean	SD	Mean	SD	Fractures	Deformations	Mean	SD	Mean	SD	Fractures	Deformations
Mtwo direct	195.5	15.5	0.10	0.19	1	6	186.6	6.1	0.25	0.38	0	9
Endo IT	162.1	20.1	0.20	0.33	0	4	160.2	12.5	0.15	0.22	0	6
P values	<0.001		0.415		1.0	0.733	<0.001		0.695		1.0	0.765

canal) using Mtwo direct. The number of permanently deformed instruments (28° curved canals: $P = 0.733$; 35° curved canals: $P = 0.765$) was not significantly different between the groups. The mean time taken to prepare the 28° and 35° curved canals with the Endo IT motor was significantly faster than with Mtwo direct ($P < 0.001$; Table 1). 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 several canals. No significant differences were obtained concerning the loss of working length, either in the 28° curved ($P = 0.415$) or in the 35° curved canals ($P = 0.695$). The different types of canal aberrations evaluated in simulated canals were not significantly different between the devices ($P > 0.05$; Mtwo direct: nine canals with aberrations; Endo IT: 5), even though more zips and ledges were created with Mtwo direct. In the 28° curved canals, at five of 20 measuring points, significant differences occurred between the resin removal achieved with the two devices (Fig. 2). In the 35° curved canals, significant differences were obtained at four of 20 measuring points (Fig. 3).

Extracted teeth

According the *P*-values obtained, the two groups were well balanced with respect to the angle and the radius of canal curvature of the extracted teeth (Table 2). During preparation of the 40 canals in extracted teeth no separation or permanent deformation of instruments occurred (Table 3). Concerning the mean time to prepare the canals with the two automated devices no significant differences were found ($P = 0.185$). All canals remained patent following instrumentation. Within the accuracy of the measurements, no changes of the working length were detected in either group. Concerning the straightening of the curved canals, no significant differences ($P = 0.188$) were obtained between the groups (Table 3).

Discussion

This study describes the shaping ability of rotary nickel-titanium Mtwo 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

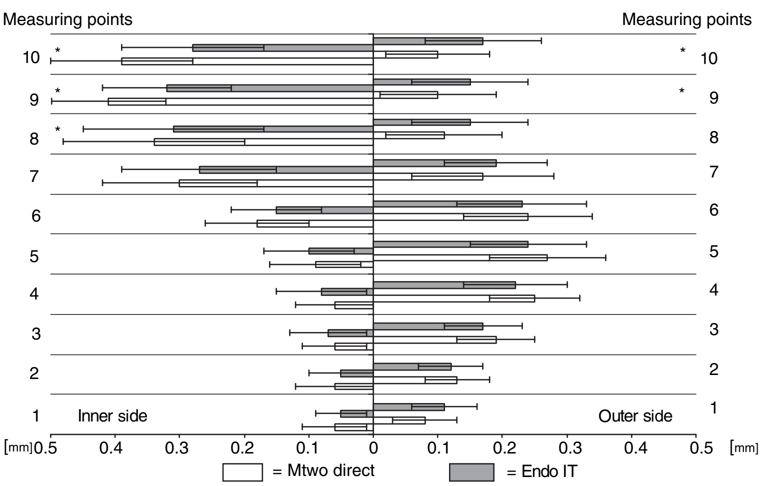

Figure 2 Mean amount of resin removal by Mtwo instruments when set into rotation with the two different devices at 10 measuring points at the inner and the outer side of the curvature of 28° curved simulated canals (*$P < 0.05$).

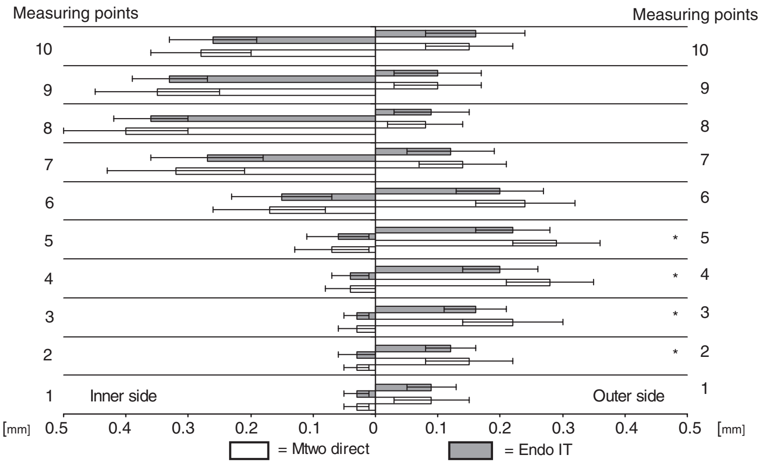

Figure 3 Mean amount of resin removal by Mtwo instruments when set into rotation with the two different devices at 10 measuring points at the inner and the outer side of the curvature of 35° curved simulated canals (*$P < 0.05$).

Table 2 Extracted teeth: characteristics of curved root canals ($n = 20$ teeth per group)

	Curvature (°)				Radius (mm)			
Device	Mean	SD	Min	Max	Mean	SD	Min	Max
Mtwo direct	30.71	3.36	25.2	35.0	6.58	1.09	5.1	9.0
Endo IT	30.66	3.27	25.1	35.0	6.51	1.12	5.3	8.8
P values	0.962				0.917			

Table 3 Results of the instrumentation of the curved canals in extracted teeth

	Preparation time (s)		Straightening (°)	
Device	Mean	SD	Mean	SD
Mtwo direct	143.4	21.2	2.24	2.35
Endo IT	133.6	24.3	1.24	2.36
P values	0.185		0.188	

(Thompson & Dummer 1997, Baumann & Roth 1999, Kum *et al.* 2000). However, resin blocks allow a direct comparison of the shaping ability of different instruments (Schäfer *et al.* 1995). Therefore, both simulated curved canals in resin blocks as well as curved canals in extracted human teeth were enlarged.

Despite variations in the morphology of natural teeth, several attempts have been made to standardize teeth in balanced experimental groups with respect to the apical diameter of the root canal, the angle and the radius of canal curvature based on the initial radiograph using a computerized digital image processing system (Schäfer *et al.* 2002). According to the *P*-values, the defined constraints were well balanced in both groups (*t*-test). The curvatures of all root canals ranged between 25° and 35° and the radii ranged between 5.1 and 9.0 mm (Table 2). Thus, the curvatures of the human root canals were comparable with those of the simulated canals in resin blocks, allowing a comparison of the results.

With regard to the instrumentation results (different types of aberrations) in the simulated canals, no significant differences between the devices ($P > 0.05$) were obtained. The original shape of simulated curved canals was maintained well (Fig. 4). Although there was a tendency for Mtwo direct to remove more material on the outer side of the canals and to produce more canal aberrations than Endo IT, these differences were not statistically significant. In the curved canals of extracted teeth, a similar observation was noticeable since the mean straightening of the canals was greater when the files were set into rotation with Mtwo direct in comparison with the Endo IT motor (2.24° vs. 1.24°). Again, this difference was not statistically significant (Table 3). Clearly, it is questionable whether a straightening of approximately 2° would have any clinical significance.

In general, it was possible with both systems to control the working distance well. The finding of small mean changes in working distance is in agreement

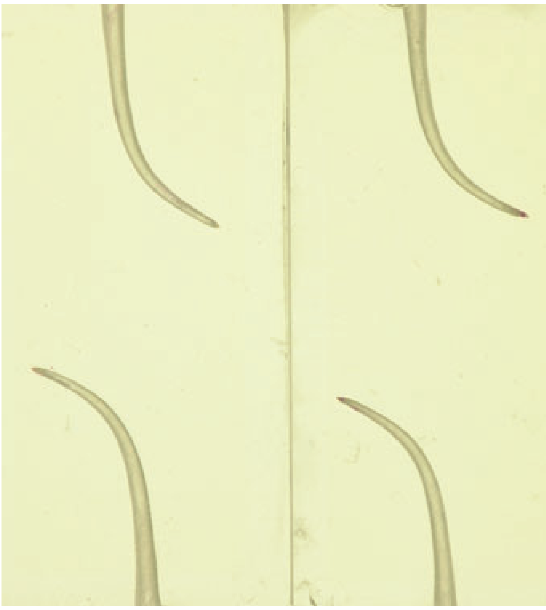

Figure 4 Representative examples of canal shapes of 28° curved canals as the result of instrumentation with Mtwo instruments set into rotation by Endo IT motor (left two canals) and Mtwo direct handpiece (right two canals). Notice that only rarely are sections of red coloured canal walls visible, indicating that resin has been removed along the whole length of the canals.

with other studies with rotary nickel-titanium instruments (Kum *et al.* 2000, Thompson & Dummer 2000a, Schäfer & Vlassis 2004b) and it is doubtful whether the small changes of working length have any clinical significance. These changes may be due to minor canal straightening during canal enlargement or lack of length control by the operator (Thompson & Dummer 2000a).

Although the preparation time is certainly not the most important aspect when evaluating the shaping ability of root canal instruments, it allows a comparison of the efficiency of different instruments and it might be of interest for the clinical use. The mean time for canal preparation was therefore recorded in this study and included instrument changes within the sequences. Both in 28° and 35° curved simulated canals, instrumentation with the Endo IT motor was significantly faster than with Mtwo direct ($P < 0.05$) whereas this difference was not significant in real teeth ($P > 0.05$). Thus, there was a tendency that root canal preparation with an electric torque control motor was faster than with torque-limited rotation handpieces, which is in accordance with a previous report (Schäfer *et al.* 2005).

During the study, only one file fractured when used with the Mtwo direct handpiece. This instrument fractured during the enlargement of 28° curved simulated canals when used for the instrumentation of a fourth canal. Related to the total number of Mtwo instruments set into rotation with the Mtwo direct handpiece, a fracture rate of approximately 1.1% (one of 90 Mtwo instruments used when all instruments were used to enlarge four canals) resulted. This fracture rate is in agreement with previously reported fracture rates of rotary nickel-titanium instruments (Baumann & Roth 1999, Kum *et al.* 2000, Thompson & Dummer 2000a,b, Schäfer & Vlassis 2004a,b). Nevertheless, care should be taken when using the Mtwo instruments independent of the automated device because of the relatively high incidence of permanent deformations of these instruments (Table 1). This observation corroborates the findings of a previous study (Schäfer *et al.* 2006a). Surprisingly, no deformation and no fracture was observed in root canals of real teeth. This finding seems to support the results of several previous studies in that the use of rotary instruments in resin blocks generates heat, which may soften the resin material (Kum *et al.* 2000) and lead to the binding of cutting blades, and separation or deformation of the instrument (Thompson & Dummer 1997, Baumann & Roth 1999). Nevertheless, as a precaution it can be recommended that the working part of Mtwo files should be carefully examined after every use. Permanently deformed instruments should be discarded.

Concerning the present results, it has to be kept in mind that the torque settings of the Mtwo direct handpiece are specially adjusted for the Mtwo instruments and only this system can be used with this handpiece. Therefore, the findings of this study are specific to the Mtwo instruments in combination with the single-length preparation and the results cannot be extrapolated to other rotary nickel-titanium instruments or other preparation techniques.

In general, the present findings are in agreement with previously published results in as far as these files are safe to use, respect original canal curvature very well, and allow a rapid preparation of even severely curved canals (Veltri *et al.* 2005, Schäfer *et al.* 2006a,b).

Conclusions

Within the limitations of this study, the results indicate that the torque-limited rotation handpiece Mtwo direct is safe and suitable for preparing curved root canals with the Mtwo instruments used in the single-length technique. Thus, this device can be seen as an alternative to an electric low-torque control motor.

References

Baumann MA, Roth A (1999) Effect of experience on quality of canal preparation with rotary nickel-titanium files. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **88**, 714–8.

Dammaschke T, Schäfer E (2004) Mechanical root canal preparation with the ENDOflash system – a review. *Acta Stomatologica Naissi* **20**, 261–74.

Gambarini G (2000) Rationale for the use of low-torque endodontic motors in root canal instrumentation. *Endodontics & Dental Traumatology* **16**, 95–100.

Gambarini G (2001) Advantages and disadvantages of new torque-controlled endodontic motors and low-torque NiTi rotary instrumentation. *Australian Dental Journal* **27**, 99–104.

Hülsmann M, Peters OA, Dummer PMH (2005) Mechanical preparation of root canals: shaping goals, techniques and means. *Endodontic Topics* **10**, 30–76.

Kum K-Y, Spangberg L, Cha BY, Il-Young J, Seung-Jong L, Chan-Young L (2000) Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. *Journal of Endodontics* **26**, 719–23.

Schäfer E, Vlassis M (2004a) Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 1. Shaping ability in simulated curved canals. *International Endodontic Journal* **37**, 229–38.

Schäfer E, Vlassis M (2004b) Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. *International Endodontic Journal* **37**, 239–48.

Schäfer E, Tepel J, Hoppe W (1995) Properties of endodontic hand instruments used in rotary motion. Part 2. Instrumentation of curved canals. *Journal of Endodontics* **21**, 493–7.

Schäfer E, Diez C, Hoppe W, Tepel J (2002) Roentgenographic investigation of frequency and degree of canal curvatures in human permanent teeth. *Journal of Endodontics* **28**, 211–6.

Schäfer E, Erler M, Dammaschke T (2005) Influence of different types of automated devices on the shaping ability of rotary nickel-titanium FlexMaster instruments. *International Endodontic Journal* **38**, 627–36.

Schäfer E, Erler M, Dammaschke T (2006a) Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 1. Shaping ability in simulated curved canals. *International Endodontic Journal* **39**, 196–202.

Schäfer E, Erler M, Dammaschke T (2006b) 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. *International Endodontic Journal* **39**, 203–12.

Schneider SW (1971) A comparison of canal preparations in straight and curved canals. *Oral Surgery, Oral Medicine, and Oral Pathology* **32**, 271–5.

Thompson SA, Dummer PMH (1997) Shaping ability of ProFile.04 taper series 29 rotary nickel-titanium instruments in simulated canals. Part 1. *International Endodontic Journal* **30**, 1–7.

Thompson SA, Dummer PMH (2000a) Shaping ability of Hero 642 rotary nickel-titanium instruments in simulated root canals: Part 1. *International Endodontic Journal* **33**, 248–54.

Thompson SA, Dummer PMH (2000b) Shaping ability of Hero 642 rotary nickel-titanium instruments in simulated root canals: Part 2. *International Endodontic Journal* **33**, 255–61.

Veltri M, Mollo A, Mantovani L, Pini P, Balleri P, Grandini S (2005) A comparative study of Endoflare-Hero Shaper and Mtwo NiTi instruments in the preparation of curved root canals. *International Endodontic Journal* **38**, 610–6.

Yared G, Sleiman P (2001) Failure with air, high torque control and low torque control motors. *International Endodontic Journal* **34**, 471–5.

Yared G, Bou Dagher F, Kulkarni K (2003) Influence of torque control motors and the operator's proficiency on ProTaper failures. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **96**, 229–33.