Comparison of preparation of curved root canals with Hyflex CM and Revo-S rotary nickel–titanium instruments

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Abstract

Aim To compare the shaping ability of three different nickel–titanium rotary instruments during the preparation of curved root canals in extracted teeth.

Methodology A total of 60 root canals with curvatures ranging between 25° and 35° were divided into three groups of 20 canals. Based on radiographs taken prior to instrumentation, the groups were balanced with respect to the angle and the radius of canal curvature. Canals were prepared to a final apical size of 35 using Mtwo, Hyflex CM, and Revo-S. Using pre- and post-instrumentation radiographs, straightening of the canal curvatures was determined with a computer image analysis program. Preparation time, changes of working length and instrument failures were also recorded. These data were analysed statistically using ANOVA and Student–Newman–Keuls test.

Results During preparation, no file fractured. Mtwo and Hyflex CM maintained the original canal curvature significantly better than Revo-S (P < 0.05). Instrumentation with Mtwo and Hyflex CM was significantly faster than with Revo-S and resulted in less loss of working length (P < 0.05), whilst no significant differences were obtained between Mtwo and Hyflex CM (P > 0.05).

Conclusions Under the conditions of this study, Mtwo and Hyflex CM respected the original canal curvature well and were safe to use. The use of Revo-S instruments required more time to prepare the curved canals and resulted in more pronounced canal straightening compared with Mtwo and Hyflex CM.

Keywords: canal curvature, canal straightening, CM-wire, controlled memory wire.

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Introduction
Attempts have been made to modify and improve the metallurgical properties of nickel–titanium (NiTi) instruments. Whilst conventional superelastic NiTi has an austenite structure, the recently developed M-wire is a mixture of nearly equal amounts of R-phase and austenite (Alapati et al. 2009, Gutmann & Gao 2012). M-wire NiTi contains substantial amounts of martensite that does not undergo phase transformation resulting in a metallurgical microstructure that exhibits alloy strengthening (Alapati et al. 2009). Besides this M-wire technology, another innovative approach is the use of a controlled memory alloy (CM-wire) to produce rotary NiTi instruments, the Hyflex CM files (Coltène/Whaledent, Allstätten, Switzerland) (Gutmann & Gao 2012).

Hyflex CM instruments are made from specific NiTi alloy that has a lower per cent in weight of nickel (52.1% wt) than conventional NiTi alloys (Zinelis et al. 2010). These instruments are characterized by a symmetrical cross-sectional design showing three cutting edges (Fig. 1) except the instruments with size...
25.04 taper, which have a square cross section with four flutes. A conventional grinding process is used to manufacture these instruments (Peters et al. 2012). A specific sequence of heat treatment is used during their manufacturing process (Gutmann & Gao 2012) leading to very flexible instruments (Testarelli et al. 2011, Peters et al. 2012, Ninan & Berzins 2013, Plotino et al. in press). Fatigue resistance of Hyflex CM was found to be markedly higher and working torque during canal instrumentation considerably lower compared with other NiTi instruments (Peters et al. 2012). The manufacturer states that permanently deformed instruments will regain their original shape when sterilized at approximately 134 °C.

It is claimed that due to their increased flexibility, Hyflex CM instruments are best suited to prepare curved root canals and possess a superior centring ability compared with conventional NiTi instruments (Gutmann & Gao 2012). However, at the moment, there is only limited information available regarding the shaping ability of this particular instrument.

Another recently introduced file, generated from 55-NiTi, is the Revo-S instrument (Micro Mégà, Besançon, France). These files are characterized by an asymmetrical cross section (Fig. 2) with three sharp cutting edges (Hashem et al. 2012). This design feature is claimed to improve the ability of the instruments to negotiate canal curvatures and to facilitate progression of the instruments towards the apical part of the canal due to a so-called ‘snake-like’ movement of the files (Aguiar et al. 2012). Moreover, it is claimed by the manufacturer that the asymmetrical cross-sectional design decreases the stress on the instrument (Basrani et al. 2011) and avoids the screwing effect. Only the Revo-SC2 instrument has a symmetrical cross section with three identical cutting edges. It is claimed that this design feature should allow a better guided penetration of the instrument to the apical portion of the root canal due to an equilibration of forces. The cross-sectional design of all Revo-S instruments progressively changes from the tip to the shaft region. At the shank, the cross section is symmetrical showing three cutting edges, resembling the cross-sectional design of OneShape instruments (Micro Mégà) (Fig. 3).

The design features of Mtwo instruments, which were used as a control in this study, have been described in detail previously (Schäfer & Vlassis 2004, Schäfer et al. 2006). In brief, these instruments are...
characterized by an S-shaped cross-sectional design with a noncutting tip. The two cutting edges have a positive rake angle and the pitch length increases from the tip to the shaft.

The null hypothesis tested was that there is no difference between the three rotary NiTi systems regarding canal straightening in severely curved root canals.

Materials and methods

Extracted teeth

A total of 60 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 terminus was approximately compatible with size 15 were included. This was checked with silver points sizes 15 and 20 (VDW, Munich, Germany).

Standardized radiographs were taken prior to 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 silicon-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 (Dur-Dental XR 24 Nova, Dur, 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 3.7 mm and 9.1 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 and the distance between the apex and the cemento-enamel junction were allocated into three similar groups of 20 teeth. The homogeneity of the three groups with respect to the aforementioned three parameters 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) 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 major apical foramen minus 1 mm. Instruments were used to enlarge four canals only. After each instrument, the root canal was flushed with 2 mL of a 2.5 % NaOCl solution and at the end of instrumentation with 5 mL of NaCl using a plastic syringe with a NaviTip needle (NaviTip 31ga sideport, Ultradent, South Jordan, UT, USA). The needle was inserted as deep as possible into the root canal without binding. Although known to be less effective than flat needles, the NaviTip needles were selected due to their flexibility ensuring sufficient insertion of the needle into the severely curved canals used in this study.

All instruments were set into permanent rotation with a 6 : 1 contra-angle handpiece (Sirona, Bensheim, Germany) powered by a torque-limited electric motor (VDW.Silver Reciproc motor, VDW, Munich, Germany). The preparation sequences were as follows:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Curvature [°]</th>
<th>Radius [mm]</th>
<th>P-value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Mtwo</td>
<td>29.8 ± 3.63</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Hyflex CM</td>
<td>30.4 ± 3.56</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Revo-S</td>
<td>29.6 ± 3.10</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>P-value (ANOVA)</td>
<td>0.832</td>
<td>0.996</td>
<td>0.952</td>
</tr>
</tbody>
</table>

Table 1 Characteristics of curved root canals (n = 20 teeth per group)
Group A: For each Mtwo file, the individual torque limit and rotational speed programmed in the file library of the motor were used. All Mtwo instruments were used to the full length of the canals (single-length technique) 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.
2. A 0.05 taper size 15 instrument.
3. A 0.06 taper size 20 instrument.
4. A 0.06 taper size 25 instrument.
5. A 0.05 taper size 30 instrument.
6. A 0.04 taper size 35 instrument.
Once, the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

Group B: All Hyflex CM instruments were used in a gentle in-and-out motion with a rotational speed of 500 rpm, and the torque was adjusted to 2.5 Ncm according to the manufacturer’s instructions. All instruments were used to the full length of the canals (single-length technique). The instrumentation sequence was:
1. A 0.04 taper size 15 instrument.
2. A 0.04 taper size 20 instrument.
3. A 0.04 taper size 25 instrument.
4. A 0.06 taper size 20 instrument.
5. A 0.04 taper size 30 instrument.
6. A 0.04 taper size 35 instrument.
Once, the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

Group C: All Revo-S instruments were used in a gentle in-and-out motion with a rotational speed of 350 rpm according to the manufacturer’s instructions. The torque was adjusted to 2.5 Ncm, and a crown-down approach was selected. The instrumentation sequence was:
1. A SC1 instrument (0.06 taper size 25) was used to two-thirds of the working length.
2. A SC2 instrument (0.04 taper size 25) was used to full working length.
3. A SU instrument (0.06 taper size 25) was used to full working length.
4. A AS30 instrument (0.06 taper size 30) was used to full working length.
5. A AS35 instrument (0.06 taper size 35) was used to full working length.
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. Instruments were used to instrument four canals only. After preparation of one single canal, all instruments were autoclaved at 121 °C.

Evaluations
All root canal preparations were completed by one operator, whilst the assessments 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.

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 analysis of variance (ANOVA) and post hoc Student–Newman–Keuls test were used for comparisons of the different 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, cleaning of the flutes of the instruments and irrigation. The preparation time and the changes of working length were analysed statistically using the 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.

Results
During the preparation of the curved canals, no instrument fractured and no deformation of Mtwo and Revo-S instruments were noted. A total of 27 Hyflex CM instruments (\( 9 \times 0.04 \) taper size 20; \( 4 \times 0.04 \) taper size 25; \( 7 \times 0.04 \) taper size 30; \( 7 \times 0.04 \) taper size 35) showed deformations following instrumentation.

The mean time taken to prepare the canals with the different instruments is shown in Table 2. Instrumentation with Mtwo and Hyflex CM files was significantly faster than with Revo-S instruments (\( P < 0.05 \)).

All canals remained patent following instrumentation, thus, none of the canals were blocked with dentine. With all instruments, no canal had overextension of preparation and loss of working length of about 0.5 mm was noted in 1 canal prepared with Hyflex CM and in 2 canals prepared with Mtwo. Using Revo-S loss of working length was noted in 50% of all canals instrumented and ranged between...
0 mm and 3 mm. Mean loss of working length was 0.7 mm, and the difference between Revo-S and the two other instruments was statistically significant (P < 0.05).

The mean straightening of the curved canals is shown in Table 3. Mean canal straightening ranged between 1.60° (Hyflex CM) and 6.10° (Revo-S). The use of Revo-S files resulted in significantly more straightening during instrumentation compared with all other instruments (P < 0.05). No significant difference was obtained between Hyflex CM and Mtwo regarding canal straightening (P > 0.05).

### Discussion

The aim of this study was to assess and compare the shaping ability of two novel rotary NiTi systems, Hyflex CM and Revo-S with the Mtwo system in severely curved root canals of extracted human molar teeth. Mtwo was included in this study as a control to ensure reliability of the results. The results obtained for Mtwo in the present investigation were comparable in terms of canal straightening and preparation time with those of previous studies conducted under nearly identical experimental conditions (Bürklein & Schäfer 2006, Schäfer et al. 2006, Bürklein et al. 2011, 2012).

Despite the variations in the morphology of natural teeth, attempts were made in the present study to ensure comparability of the experimental groups.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Mean*</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mtwo</td>
<td>211.6°</td>
<td>38.5</td>
</tr>
<tr>
<td>Hyflex CM</td>
<td>242.4°</td>
<td>39.8</td>
</tr>
<tr>
<td>Revo-S</td>
<td>279.8°</td>
<td>53.9</td>
</tr>
</tbody>
</table>

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

The final apical preparation was set to size 35 in each group to ensure comparability between the groups. Prior to instrumentation of the curved canals, no glide path was created as all root canals had a canal diameter which was compatible with size 15. This was one inclusion criterion when selecting the teeth and was check with silver points sizes 15 and 20.

Preparation time is dependent on the technique and the numbers of instruments used, the operator experience and on further details of the study design (Hülsmann et al. 2005). In this study, the preparation time included active instrumentation as well as the time required for changing instruments, cleaning the flutes of the instruments and irrigation to allow comparison of the results with those of previous studies conducted with an identical experimental setup (Bürklein & Schäfer 2006, Schäfer et al. 2006, Bürklein et al. 2012). Mtwo and Hyflex CM were found to require significantly less time to prepare the canals compared with Revo-S (Table 2). The Mtwo and the Hyflex CM system, as used in this investigation, consisted of six instruments to prepare the root canal to a size of 35, whilst only five instruments were used for Revo-S. Thus, it can be concluded that Mtwo and Hyflex CM were clearly more efficient than Revo-S.

The results regarding canal straightening of Hyflex CM instruments were comparable to the results obtained with Mtwo. The present findings corroborate those of a recent micro-computed tomography evaluation of mesiobuccal canals in extracted maxillary first molars enlarged using Hyflex CM instruments (Zhao et al. 2013). In the latter study, Hyflex CM instruments prepared curved canals without significant shaping errors and no instrument fractured during this study (Zhao et al. 2013). It can be assumed that the good shaping ability of Hyflex CM can be
attributed to the increased flexibility of these instruments (Testarelli et al. 2011, Peters et al. 2012).

Regarding canal straightening, the results for Revo-S were different compared with recently published findings (Hashem et al. 2012, Çelik et al. 2013). These studies reported similar results for Revo-S compared with other rotary NiTi systems when enlarging severely curved root canals whilst in the present investigation, the use of Revo-S resulted in significantly more pronounced canal straightening compared with Mtwo and Hyflex CM. This difference might be due to the fact that in this study, the curved canals were enlarged to an apical size of 35, whilst in the two other investigations, final apical preparation was set to size 30 (Hashem et al. 2012, Çelik et al. 2013). In fact, it was noticed in this study that enlarging the canals from Revo-S size AS30 to AS35 was difficult and that canal straightening and loss of working length often resulted when using the final instrument (AS35). This observation warrants further investigations.

During this study, no instrument fractured. All instruments were used to enlarge four curved canals (Bürklein & Schäfer 2006, Bürklein et al. 2011). However, 90% of Hyflex CM instruments were plastically deformed following canal preparation. This is in agreement with a recent report (Peters et al. 2012), in as far as about 82% of Hyflex CM instruments were permanently deformed following preparation of simulated curved canals in plastic blocks. Therefore, all instruments were autoclaved after preparation of one single canal to ensure that plastically deformed Hyflex CM instruments recovered their original shape. A recent study failed to show any undesirable autoclaving effects on fracture resistance of CM-wire instruments when autoclaved for up to 7 sterilization cycles (Casper et al. 2011). Most of the instruments regained their original shape following sterilization, however, three instruments (all size 20, 0.04 taper) still showed permanent deformation and were therefore discarded. This observation is corroborated by Peters et al. (2012) who found that autoclaving removed visible deformation of Hyflex CM instruments in 63% of cases and that in particular smaller sizes still showed deformation after the sterilization procedure. The present results are also in agreement with those of Shen et al. (2013) who reported that size 20, 0.04 taper instruments unwound the most often when used in a graduate endodontic programme. Therefore, the authors recommended considering smaller Hyflex CM instruments as single-use.

**Conclusions**

According to the results of the present investigation, the null hypothesis was rejected as significant differences between the three NiTi instruments regarding canal straightening were obtained. Within the parameters of this study, Mtwo and Hyflex CM instruments, when used according to the single-length approach, maintained root canal curvature well and were safe. The use of Revo-S files resulted in more pronounced canal straightening and loss of working length than using Mtwo and Hyflex CM.

**References**


