Shaping ability of GT™ Rotary Files in simulated resin root canals

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Abstract

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Aim The aim of this study was to determine the shaping ability of GT™ Rotary Files in simulated root canals.

Methodology Forty canals with four different shapes in terms of angle (40° and 60°) and position of curvature (straight section before curve: 8 and 12 mm) were prepared using a crown-down/stepback technique. Pre-operative and post-operative pictures, recorded using an image analysis system, were superimposed and aberrations recorded. Measurements were carried out at 5 different points: at the canal orifice (O); half-way to the orifice in the straight section (HO); the beginning of the curve (BC); the apex of the curve (AC); the endpoint (EP).

Results Two instrument fractures occurred and 9 instruments were deformed. Overall, eight zips and one ledge were created. There were significant differences ($P < 0.001$) for the total width of the canals between the various canal shapes at AC, BC and HO. There were significant differences ($P \leq 0.001$) for the amount of resin removed from the outer aspect of the curve at AC, BC and HO; and for the amount of resin removed from the inner aspect of the curve at all five measuring points (O, AC and EP ($P < 0.05$) and HO and BC ($P \leq 0.001$)). Mean transportation was towards the inner aspect of the canal in canals with straight sections of 12 mm regardless the curve angle; towards the outer aspect in canals with straight sections of 8 mm and 40° curves at all the five measuring points, and at AC, BC and HO when the curve was 60°.

Conclusions Under the conditions of this study, GT™ Rotary Files produced acceptable canal shapes. In narrow and curved canals, the length of the straight section of the canal determines the direction of transportation more than the angle of the curve. In the 60° curves, a high incidence of instrument deformation was found when using the 0.04 tapered instruments.

Keywords: GT™ Rotary Files, nickel–titanium, root canal preparation.

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Introduction

The objectives of root canal instrumentation are to clean and shape the canal system (Schilder 1974). The ideal preparation for the root canal is a funnel shaped form with the smallest diameter at the apex and the widest diameter at the orifice (Schilder 1974). This is not an easy task in teeth with curved canals and in teeth with complex root canal anatomy.

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The funnel shaped form can be achieved either by hand or by mechanical preparation. This optimal shape can be easily provided in straight canals, however, in narrow and curved canals aberrations, such as ledging, zipping, danger zones and canal transportation appear because larger instruments tend to straighten the canal (Esposito & Cunningham 1995, Glosson *et al*. 1995).

More flexible files made of nickel–titanium have been effective in minimizing complications in narrow and curved canal preparation (Wu & Wesselink 1995, Zmener & Banegas 1996, Thompson & Dummer 1997). In this respect, it has been shown that nickel–titanium instruments have several advantages over stainless steel files such as a greater flexibility due to superelasticity, a shape memory effect and a better resistance to torsional fracture (Walia *et al.* 1988).

Rotary nickel–titanium instruments for the mechanical preparation of root canals are available in various designs. At this time, there is little information available on the shaping ability of GT™ Rotary Files (Kum *et al.* 2000). The aim of the present study was, therefore, to investigate the shaping ability of the GT™ Rotary File System (Dentsply Maillefer, Ballaigues, Switzerland) during preparation in simulated root canals and to record the aberrations that appeared. In this respect, root canals with 40° and 60° curves were produced. The shaping ability of nickel–titanium instruments in canals with a 60° curve has not yet been investigated.

Materials and methods

Construction of simulated canals

A total of 40 simulated root canals were made in clear resin blocks (Dummer *et al.* 1991). Annealed silver points size 20 were used as root canal templates. Four different canal types (Fig. 1) were made by precurving silver points using canal formers. The bent silver points were then checked under magnification (8×) for their alignment to the canal former, and inappropriate points were discarded. Clear spectrophotometer cuvettes were used as moulds to retain the self-polymerizing resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium) that was poured around the preformed silver points. The finished clear resin blocks were 3.5 cm long.

In all, 40 simulated canals were produced, with either 40° and 60° curves and with a straight section prior to the curve of either 8 or 12 mm. The four different canal types are pictured in Fig. 1. The angle and radius of the curvature were determined according to Pruett *et al.* (1997); the radius was 6 mm.

Instruments

The instruments in the GT™ Rotary File system (Dentsply Maillefer) feature flat outer edges with a U-file design which prevent self-threading. The files have variable tapers, common tip sizes, radial-landed flutes, maximum flute diameters and non-cutting tips. According to the manufacturer, they also posses the properties of nickel–titanium alloy which allows creation of a tapered funnel around curvatures, whilst keeping the preparation in the canals original position. The system comprises three types of instruments. The first four instruments are the GT™ Rotary Files with a taper of 6, 8, 10 and 12%. The instruments all have the same tip diameter of 0.20 mm. The second four instruments are the GT™ Rotary Files 0.04 having a 4% taper with a tip diameter ranging from size 20 to size 35. These files are used for the preparation of the apical third and are identical to the ProFile series. The final files are the GT™ Accessory Files with a 12% taper and a tip diameter of size 35, size 50 and size 70.

Preparation of simulated canals

All canals were prepared with GT™ Rotary instruments using a 128 : 1 reduction hand piece (Anthogyr,

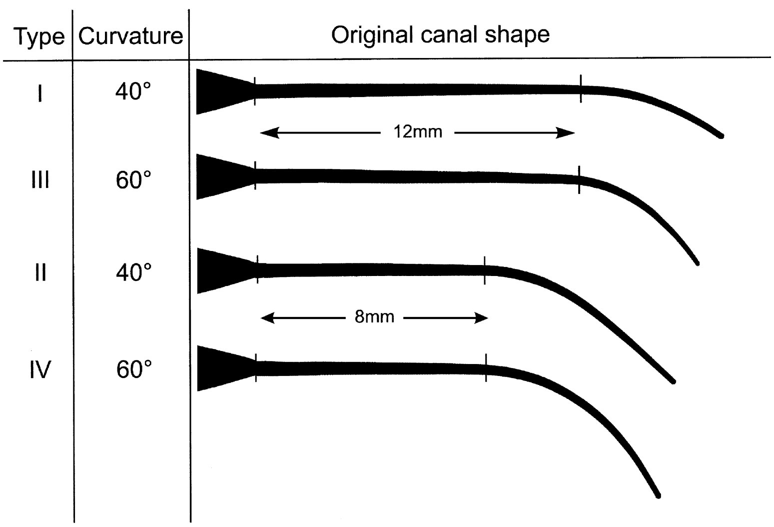

Figure 1 The four different canal types.

Endodontic Ni-Ti Contra Angles, Sallanches, France) powered by an electric motor (40 000 rpm). Ten canals of each shape were prepared by the operator to a working length of 16 mm using a constant speed of 312 rpm. The preparation followed the instructions of the manufacturer. The basic method was a 'crown-down/stepback' method. A new set of instruments was used per canal. The files were wiped off on a gauze to remove resin particles. Irrigation with tap water using disposable syringes was performed after each file. A size 15 Flexofile (Dentsply Maillefer) was used as a patency file. The method for preparation was as follows:

1 a file with taper 0.12 and tip diameter 20 was used to prepare the first 4 mm of the straight section with a slight in and out movement;
2 a file with taper 0.10 and tip diameter 20 was used to a depth of 8 mm;
3 a file with taper 0.08 and tip diameter 20 was used to a depth of 12 mm;
4 a file with taper 0.06 and tip diameter 20 was used to a depth of 14 mm;
5 a file with taper 0.04 and tip diameter 20 was used to the full working length of 16 mm;
6 a file with taper 0.04 and tip diameter 25 was then used to full working length;
7 a file with taper 0.04 and tip diameter 30 was used to full working length minus 0.5 mm;
8 a file with taper 0.04 and tip diameter 35 was then used to full working length minus 1 mm.

During preparation, each resin block was placed in a copper holder, masking the entire canal, to aid handling (Fig. 2). Masking the resin blocks ensured that the process was carried out with purely tactile sensation.

Assessment of canal preparation

The results of the canal preparations were assessed using a video camera (CCTV Camera, Panasonic WV-BL604, Matsushita Industrial Co, Osaka, Japan) connected to a light microscope (Reichert-Jung Polyvar, Reichert optische werke AG, Wien, Austria) and attached to a Pentium III computer with image analysis software (Interactive Bild-analyse System (IBAS), Kontron Electronic Gmbh, Germany). Measurements were made on superimposed pre- and post-operative digitized images. In order to achieve a standardized position of the resin blocks under the microscope, a holder was made in which the resin blocks could be placed and repositioned in exactly the same position. Reference points were recorded by means of the microscope's nonius scale. At the experimental magnification, it was impossible to visualize the entire canal. One image on screen corresponded to 2.3 mm of the real canal length. Depending on the canal type, 8–10 images were needed to assemble the entire canal. Both *X* and *Y* coordinates on the microscope's nonius scale were recorded for each image, allowing repositioning and reproduction of the pictures at any given moment (i.e. pre- and postoperative).

For each resin block, the captured images, representing parts of the canal, were precisely aligned to form a picture of the entire canal. The centre of the original canal path was calculated by the software.

After preparation with the GT™ Rotary Files the simulated canals were viewed again in the microscope. For each resin block, setting the previously recorded *X* and *Y* coordinates of the original canal, corresponding images of the post-operative canal were captured and

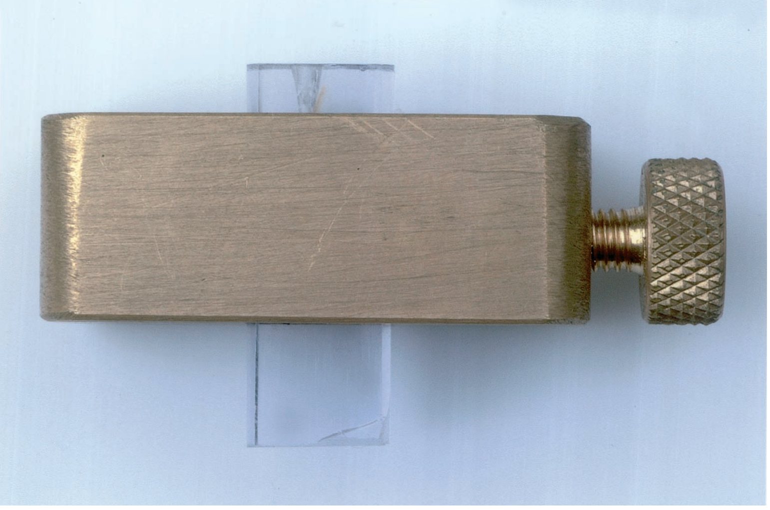

Figure 2 Each resin block was placed in a copper holder, masking the entire root canal, to aid handling during root canal preparation.

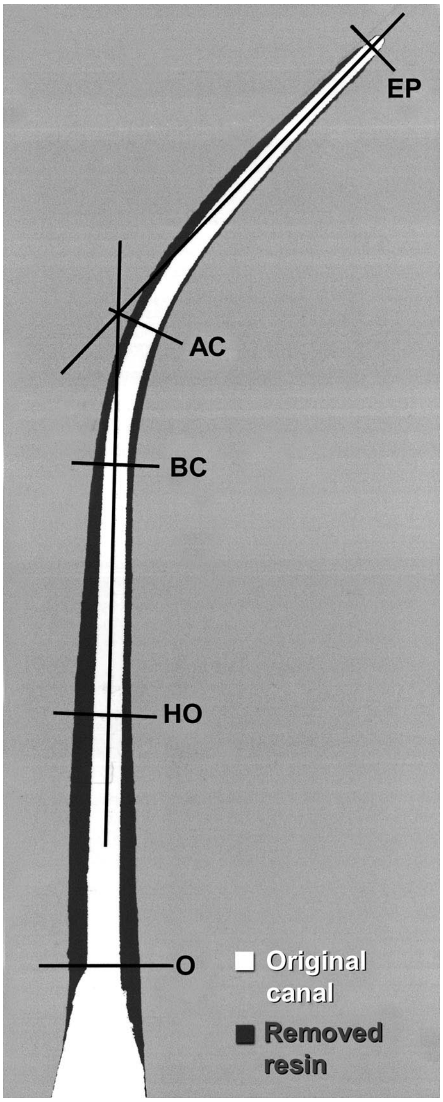

Figure 3 Composite print of a type II canal outlining the 5 positions of measurement. The white region defines the image of the canal before preparation, the grey region defines the canal after preparation.

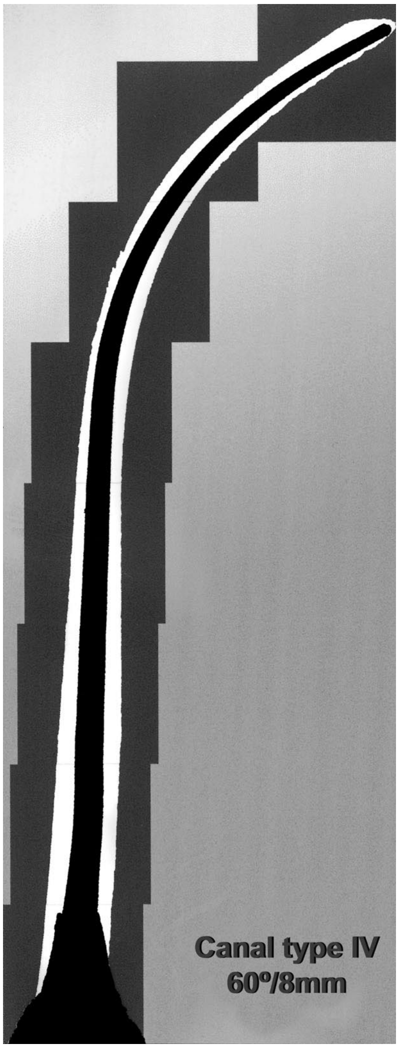

Figure 4 Composite image of the simulated resin canals (type IV) with apical zip and elbow in the GT™ Rotary File technique. The white region defines the image of the canal after the preparation, and the black region defines the canal before preparation.

aligned to form a picture of the entire canal after instrumentation. Both pre- and postoperative images were then superimposed.

At this stage, five points were determined on each central canal path, for measuring the canal width, using a modification of the method described by Alodeh & Dummer (1989) (Fig. 3):

- position 1: the canal orifice (O);
- position 2: a point half-way from the beginning of the curve to the orifice (HO);
- position 3: the beginning of the curve (BC);
- position 4: the apex of the curve of the original canal (AC), determined by the intersection of two lines (one along the coronal aspect of the central line, and the second along the apical portion of the central line);
- position 5: end point of preparation (EP).

All measurements were carried out perpendicular to the axis of the original central canal path to the nearest 0.001 mm, using the image analysis software.

The canal aberrations to be scored were zips and elbows, ledges, perforations, and danger zones (Alodeh

& Dummer 1989) as well as the 'outer widening' (Bryant *et al.* 1999). In this respect, a representative composite print of superimposed pre- and postoperative canals with apical zip and elbow is shown in Fig. 4.

Recording, storage, and analysis of data

All data were stored on PC from the image processing software directly to a database file. Following error and range checks, the data were analyzed using SPSS, a statistical analysis program. Differences at the five measuring points between the mean total widths, the mean inner widths and the mean outer widths were statistically analyzed using ANOVA. Statistical analysis of the number of canals transported towards the inner and outer aspect of the curve was done by the Kruskal–Wallis Test.

Results

Because of the presence of two separated instruments (i.e. two 0.04/30 instruments, the one in a type II canal and the other in a type IV canal), the results are based on the analysis of 38 canals.

Width measurements and transportation

Table 1 shows the mean total widths of the canals by shape. Tables 2 and 3 show, respectively, the mean right (outer) width and the mean left (inner) width of the canals by shape.

There were statistically significant differences ($P < 0.001$) in the total width (Table 1) of the canals between the various canal shapes at the apex of the curve, the beginning of the curve and half-way to the orifice in the straight section. There were statistically significant differences ($P \leq 0.001$) for the amount of resin removed from the outer aspect of the curve (Table 2) at the apex of the curve, the beginning of the curve and half-way to the orifice in the straight section; and for the amount of resin removed from the inner aspect of the curve (Table 3) at all five measuring points (orifice, apex of the curve and endpoint ($P < 0.05$); half-way the orifice ($P < 0.001$); beginning of the curve ($P = 0.001$)).

Table 4 shows the direction of transportation at the specific positions along the canal length. Transportation was towards the inner aspect of the canal in canals with straight sections of 12 mm regardless the curve angle (types I and III); towards the outer aspect in canals with straight sections of 8 mm and 40° curves (type II) at all five measuring points, and at the apex of the curve, the beginning of the curve and half-way to the orifice in the straight section when the curve was 60° (type IV). The occurrence of 'outer widening', i.e. an almost exclusive removal of resin on the outer aspect of the canal and associated with a narrower region situated more coronally was seen in three of the 10 type III canals and in three of the nine type IV canals.

Canal aberrations

Table 5 shows the incidence of canal aberrations in relation to the canal type. A zip was encountered in eight canals (canal type I: 5; type III: 1; type IV: 2). There were no zips in type II canals. There was only one ledge in a type I canal. There were no perforations nor danger zones (i.e. excessive removal of resin on the inner curve).

Instrument evaluation

Instrument failure is characterized either by fracture or by deformation. A total of nine instruments deformed during preparation (five in a type IV canal and four in a type III canal) and two fractured. The fracture of these two instruments, both 0.04/30, occurred at the tip of the instrument and beyond the apex of the curve (the one in a type II canal and the other in a type IV canal and in both canal types the beginning of the curve starts

Table 1 Mean total widths (mm) of canals by canal shape

Canal shape	40°, 12 mm Type I $n = 10$	40°, 8 mm Type II $n = 9$	60°, 12 mm Type III $n = 10$	60°, 8 mm Type IV $n = 9$	*P*-values
Orifice	1.079	1.068	1.066	1.108	NS
Half-way to orifice	0.807	0.908	0.872	0.929	<0.001
Beginning of curve	0.539	0.656	0.608	0.700	<0.001
Apex of curve	0.472	0.581	0.501	0.555	<0.001
0.5 mm from endpoint	0.352	0.331	0.345	0.337	NS

Table 2 Mean outer width measurements (mm) of canals by canal shape

Canal shape	40°, 12 mm Type I $n = 10$	40°, 8 mm Type II $n = 9$	60°, 12 mm Type III $n = 10$	60°, 8 mm Type IV $n = 9$	*P*-values
Orifice	0.236	0.282	0.254	0.258	NS
Half-way to orifice	0.212	0.226	0.176	0.261	=0.001
Beginning of curve	0.159	0.140	0.104	0.233	<0.001
Apex of curve	0.109	0.139	0.052	0.136	=0.001
0.5 mm from endpoint	0.040	0.065	0.057	0.067	NS

Table 3 Mean inner width measurements (mm) of canals by canal shape

Canal shape	40°, 12 mm Type I $n = 10$	40°, 8 mm Type II $n = 9$	60°, 12 mm Type III $n = 10$	60°, 8 mm Type IV $n = 9$	*P*-values
Orifice	0.288	0.257	0.272	0.327	<0.05
Half-way to orifice	0.172	0.279	0.231	0.227	<0.001
Beginning of curve	0.078	0.150	0.160	0.108	=0.001
Apex of curve	0.108	0.124	0.164	0.116	<0.05
0.5 mm from endpoint	0.104	0.053	0.080	0.087	<0.05

Table 4 Number of canals transported towards the inner and outer aspect of the curve by canal shape

Canal shape	40°, 12 mm Type I $n = 10$			40°, 8 mm Type II $n = 9$			60°, 12 mm Type III $n = 10$			60°, 8 mm Type IV $n = 9$			
	Outer	None	Inner	Outer	None	Inner	Outer	None	Inner	Outer	None	Inner	*P*-values
Orifice	2	2	6	5	2	2	2	2	6	2	2	5	<0.01
Half-way to orifice	2	2	6	6	2	1	3	1	6	4	2	3	<0.05
Beginning of curve	2	3	5	5	1	3	3	2	5	4	3	2	<0.05
Apex of curve	4	2	4	6	0	3	3	1	6	5	2	2	<0.05
0.5 mm from endpoint	4	0	6	5	1	3	3	1	6	3	2	4	<0.05

Table 5 Incidence of canal aberrations and instrument failures by canal shape

Canal shape	40°, 12 mm Type I $n = 10$	40°, 8 mm Type II $n = 9$	60°, 12 mm Type III $n = 10$	60°, 8 mm Type IV $n = 9$
Zip and elbow	5 (outer)	0	1 (outer)	2 (outer)
Ledge	1 (outer)	0	0	0
Instrument fracture	0	1	0	1
Instrument deformation	0	0	4	5

at 8 mm from the orifice). The deformations were seen at the tip (5×) and at the mid-portion (4×) of the instruments with 0.04 tapers.

Discussion

The maintenance of canal curvature and the creation of a funnel shaped canal form with the smallest diameter at the apex and the widest diameter at the orifice are the objectives during instrumentation of root canals (Schilder & Yee 1984). The problem of straightening occurs mostly in severely curved canals and at the apex of the canal (Weine *et al.* 1975). In recent years, a great number of reports described the advantages of nickel–titanium rotary instruments. These instruments have the potential to prepare root canals rapidly and safely to produce relatively few aberrations during the root canal preparation. Care, however, should be taken when canals with short curves beginning near the end-point are to be prepared (Bryant *et al.* 1999).

The aim of this study was to assess the shaping ability of GT™ Rotary Files in simulated root canals with a severe curve. The preparation technique that was used was a crown-down/stepback technique, as advocated by the manufacturer. To assess instrumentation of curved canals, clear resin blocks were used in this study. These were chosen because shape, size, taper, and curvature of the experimental canals are standardized. The credibility of resin blocks as an ideal experimental model for the analysis of endodontic preparation and preparation techniques has been validated by Weine *et al.* (1975) and Dummer *et al.* (1991). Because of slight differences in hardness between dentine and the experimental resin, care should be taken, however, in extrapolating the results to the clinical situation. Nevertheless, the use of simulated canals in resin blocks results in the opportunity to standardize the research method and to exclude parameters that could influence the preparation outcome.

The determination of the degree of curvature of root canals was based on data according to Schneider (1971), i.e. the degree of canal curvature is determined by only one parameter, the angle formed by the intersection of two lines. The first line is drawn parallel to the long axis of the canal, and the second line runs from the apical foramen to the point wherein the canal begins to leave the long axis of the canal. This method was refined by Alodeh & Dummer (1989) who added the radius of the curve as a second parameter in defining the degree of root curvature.

Nickel–titanium files have already shown their efficiency in shaping the root canal. Their flexibility assumes that they could be useful during preparation of curved canals by keeping the preparation path centred, and by creating a tapered preparation thanks to the specifically tapered design of consequent instruments. Aberrations of the root canal, still occur, albeit to a lesser degree than in non-mechanical instrumentation (Kum *et al.* 2000). Additional problems, such as instrument deformation and breakage still occur, especially in curved canals. The question remains as to what critical degree of curvature a nickel–titanium file can be used safely. Some manufacturers advise not to use rotary instruments in root canals with curves exceeding 60°. The present data show that the presence of a 60° curve does not necessarily result in more aberrations than in canals with a 40° curve. In a study comparing the use of ProFile rotary nickel–titanium instruments Bryant *et al.* (1998) showed that aberrations occurred more often in canals where the curve began 12 mm from the orifice. In the present study, a similar finding was observed. When the number of separated or deformed instruments was compared, deformation of 0.04 tapered instruments occurred more frequently in a 60° curved canal. Instrument fracture was seen in 0.04/30 instruments in canals with a straight section of 8 mm regardless of the angle of curve. Bryant *et al.* (1999) stated in this respect when using 0.04 and 0.06 ProFiles that the use of 0.06 taper instruments in the crown-down technique appeared to be useful and was recommended. The crown-down approach with the GT™ Rotary Files with a taper of 6, 8, 10 and 12% is also highly recommended. Great care, however, should be taken in canals with 60° curves as instrument deformation is high and may result in consequent instrument fracture. Torque control as a safety measure has, therefore, been advocated by the manufacturer, although Yared *et al.* (2001) demonstrated that there was no difference with respect to the incidence of instrument failure between no-torque and high and low torque motors.

Canal types I and III showed a transportation towards the inner aspect of the canal, whereas transportation in canal types II and IV was to the outer aspect. Thanks to the direct visualization through the resin blocks during preparation it was seen that the canal aberrations especially became clear when enlarging the endpoint of preparation to a size 30 or 35. These sizes are more rigid than the smaller ones, and tend to straighten the canal. This suggests that in canals with short acute curvatures, instrumentation of the apical part with GT™ Rotary Files should better not exceed the size 25 in narrow canals in order to obtain a tapered shape. These findings agree with those of Bryant *et al.* (1998) in their research on ProFile 0.04 and 0.06 tapered instruments. In this respect, it must also be said that there is no difference in design between the GT™ Rotary Files 0.04 and ProFiles 0.04.

The phenomenon of 'outer widening' (Bryant *et al.* 1999) was only seen in a limited number of resin canals with a 60° curve. The use of the more tapered instruments initially to open the orifice allowed the 0.04 series to pass more easily to the end-point and to remain centered in the canal. Therefore, a strict crown-down approach to avoid stress on instruments by early opening of the coronal part of the root canal when using nickel–titanium rotary instruments is essential.

Conclusion

Under the conditions of the present study the GT™ Rotary Files performed well in all canal shapes, but great care should be taken in canals with severe curvature. The result of the present study suggest that in canals with short acute curvatures, instrumentation of the apical part with GT™ Rotary Files should not exceed size 25.

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