Shaping ability of NT Engine and McXim rotary nickel–titanium instruments in simulated root canals. Part 1

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Summary

The aim of this study was to determine the shaping ability of NT Engine and McXim nickel–titanium rotary instruments in simulated root canals. In all, 40 canals consisting of four different shapes in terms of angle and position of curvature were prepared by a combination of NT Engine and McXim instruments using the technique recommended by the manufacturer. Part 1 of this two-part report describes the efficacy of the instruments in terms of preparation time, instrument failure, canal blockages, loss of canal length and three-dimensional canal form. Overall, the mean preparation time for all canals was 6.01 min, with canal shape having a significant effect (P<0.01) on the speed of preparation. One instrument fractured and only four instruments deformed, with most of the failures occurring in canals with curves which began 12 mm from the orifice, that is, in short acute curves. None of the canals became blocked with debris. Following preparation, 20 canals retained their original working length but 19 lost length and one gained in length; there were significant differences (P<0.05) between the canal shapes in terms of mean loss of distance and in the category of distance change. Apical stops as determined from intracanal impressions were present in 37 of the canals; 16 were judged to be of good quality and 21 of poor quality. The canals were found to be smooth in the apical half of the canal in 33 specimens and in the coronal half of 39 specimens. All canals had good taper characteristics and 35 had good flow characteristics. Under the conditions of this study, NT Engine and McXim instruments prepared canals rapidly, with few deformations, no canal blockages and with minimal change in working length. The three-dimensional form of the canals demonstrated good flow and taper characteristics.

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Introduction

The development of endodontic instruments made from nickel–titanium alloy has the potential to enhance the shaping of narrow, curved root canals (Walia *et al.* 1988), a procedure which has proved difficult to achieve using stainless steel instruments because of their inherent stiffness and propensity to create aberrations such as zips, ledges and danger zones (Weine *et al.* 1975, ElDeeb & Boraas 1985, Alodeh & Dummer 1989). Indeed, Walia *et al.* (1988) concluded that Nitinol files would be useful in preparation of curved root canals, because of their superior resistance to torsional fracture and low modulus of elasticity.

Currently, much research is being conducted into the shaping ability of various rotary nickel–titanium instruments when used with high torque, low speed electric motors which provide the precise control necessary with these systems. Initial results have been promising, with reports describing the ability of nickel–titanium instruments to maintain canal shape and to decrease the time taken for canal preparation compared to hand instruments (Esposito & Cunningham 1995, Glosson *et al.* 1995). In fact, a number of these nickel–titanium rotary systems have been investigated under laboratory conditions, with results suggesting that canal shaping with this new generation of instruments results in few instrument failures, creates few aberrations, produces minimal transportation and forms canal shapes with acceptable taper and flow characteristics (Thompson & Dummer 1997a,b,c).

One of the many innovations incorporated into the design of some NiTi rotary files is an increase in their taper. Conventional ISO instruments have a taper of 0.02, meaning that the files increase in diameter by 0.02 mm from tip to shank. Files of increased taper have been developed in the hope that they will produce the desired flare in the canal form more effectively and with less need to supplement their use with burs, such as Gates Glidden drills. At first, tapers of 0.04 were utilized, but recently a variety of rotary and reciprocating systems have been described with tapers up to 0.12. As yet, little evidence exists to support the concept behind these developments, although the 0.04 taper has been shown to be of benefit (Thompson & Dummer 1997b) with the ProFile system (Tulsa Dental Products, Tulsa, OK, USA).

The objective of this study was to determine the ability of NT Engine and McXim nickel–titanium rotary instruments (NT Company, Chattanooga, TN, USA) to shape simulated canals in resin blocks.

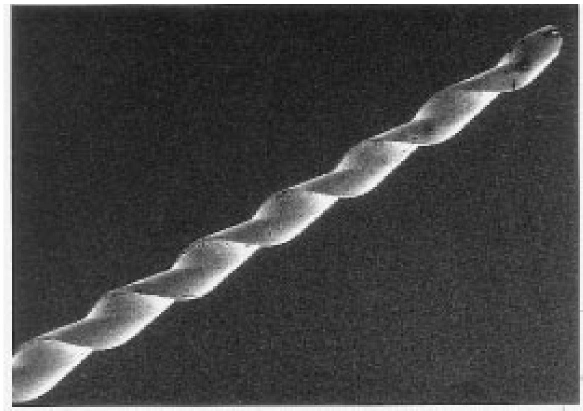

Fig. 1 Scanning electron microscopic image of an NT Engine file with 0.02 taper (original magnification ×20).

Materials and methods

Construction of simulated canals

Using annealed size 20 silver points as templates, a total of 40 simulated root canals were produced (Dummer *et al.* 1991). Prior to use, the silver points were precurved with the aid of a canal former to form four different canal shapes. Ten silver points were produced of each canal shape; the beginning of the curve was positioned either 8 or 12 mm from the canal orifice and the degree of curvature was either 20° or 40°. The radius of the arc that comprised the curved portion of the canals was 16 mm.

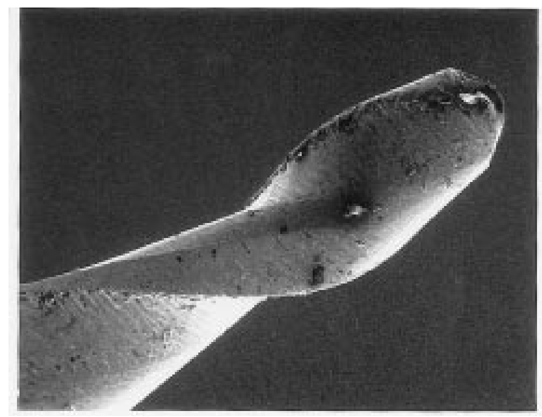

Fig. 2 Scanning electron microscopic image of an NT Engine file with 0.02 taper (original magnification ×120).

Instruments

NT Engine files have a standard 0.02 taper and two different rotary instrument designs. Sizes 15–35 are H-type files with radial lands and are essentially Hedstrom files which have been manufactured by grinding a single L-shaped groove which spirals around the tapered round wire (Figs 1 and 2). A space has been left between each groove to create a 'land' or 'flat', a phenomenon which the manufacturer claims makes the file a planing instrument, preventing it from screwing into the canal. The files have equal land and groove widths which are said by the manufacturer to prevent canal transportation during preparation. NT Engine files sizes 37.5–60 have a dissimilar helical design which is claimed to prevent locking of the file within the canal. The working surfaces of these instruments contain two or more blades which spiral around the shaft at different angles and rates, a property which the manufacturer claims keeps the instrument loose within the canal and allows preparation of ramifications within the canal system.

The McXim files are made by the same company and supplement the NT Engine files. They incorporate six tapers ranging from a conventional 0.02 design through 0.03, 0.04, 0.45, 0.05 to a 0.055 taper; all have an ISO size 25 tip. The McXim 0.03T, 0.045T and 0.055T files have a U-file design with three equally spaced grooves ground into the file shaft (Figs 3 and 4). The 0.04T and 0.05T files incorporate the H-type design with radial lands (Figs 5 and 6) which are wider towards the instrument tip, in an attempt to prevent canal transportation at the apex, and narrower coronally, to allow flaring.

Preparation of simulated canals

All canals were prepared with NT Engine and McXim instruments using a 16:1 reduction handpiece powered by an electric motor with an NT-Matic control box (NT

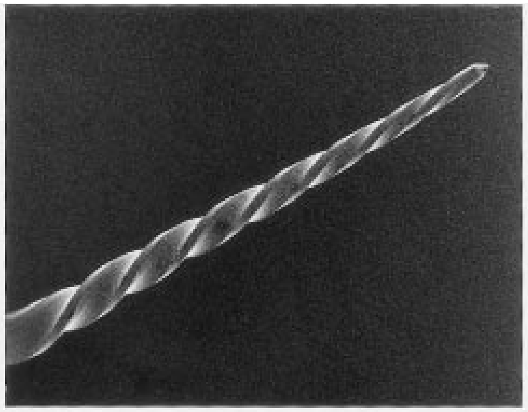

Fig. 3 Scanning electron microscopic image of a McXim file with 0.055 taper and U-file design (original magnification ×20).

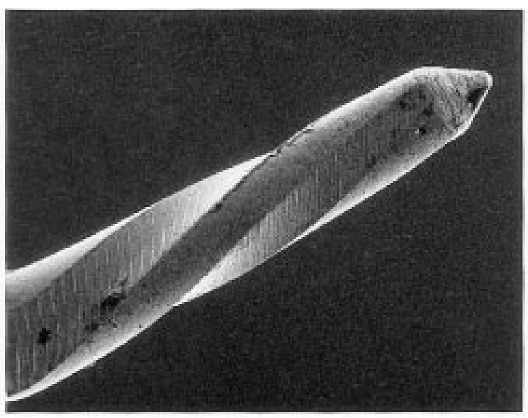

Fig. 4 Scanning electron microscopic image of a McXim file with 0.055 taper and U-file design (original magnification ×120).

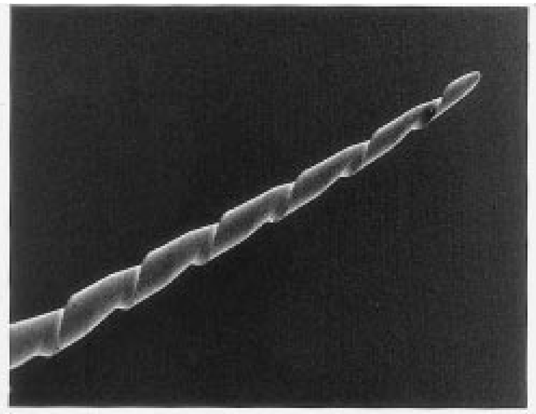

Fig. 5 Scanning electron microscopic image of a McXim file with 0.05 taper and H-file design (original magnification ×20).

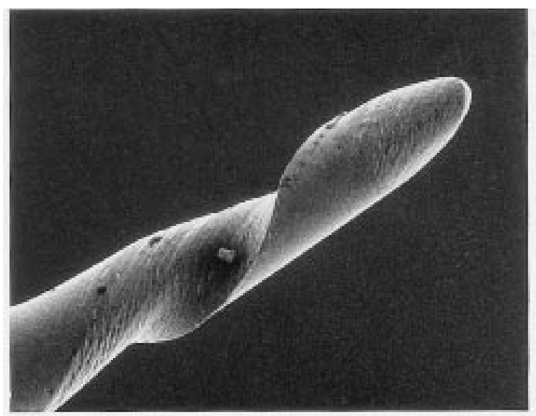

Fig. 6 Scanning electron microscopic image of a McXim file with 0.05 taper and H-file design (original magnification ×120).

Company, Chattanooga, TN, USA). The box features a digital display indicating RPM which allows maintenance of a constant speed, while compensating for load. Ten canals of each shape were prepared by one operator, using a constant speed of 280 r.p.m. All canals were prepared to a working distance of 16 mm and to a size 35 master apical file. Each instrument was used four times before being replaced. If instruments failed before this time, the information was recorded and a new instrument substituted.

Copious irrigation with water was performed before preparation and after use of each instrument using disposable syringes (Monoject, Ballymoney, N. Ireland) and 27 gauge irrigating tips (Endo-Tips; Ultradent Products Inc., Utah, USA). Approximately 20 mL of water was used per block. Prior to use, each file was coated in Hibiscrub (Zeneca, Cheshire, UK) to act as a lubricant. Files were wiped regularly on a sponge to remove resin debris.

Canal preparation varied with canal shape and in particular with the position of the beginning of the curve. The basic crowndown methodology of instrumentation followed that recommended by the manufacturer; the preparation sequence is shown in Table 1.

Canals with curves beginning at 8 mm

Ten canals with 20° and 10 canals with 40° curves were prepared as follows.

1 A size 0.045T McXim instrument was used to prepare 8 mm (the straight portion) of each canal in a gentle in and out (pecking) motion. Once the file had negotiated to this length and had rotated freely for 10 s, it was removed and inspected.

Table 1 Instrumentation sequence used with NT Engine and McXim instruments

20°/40°, 8 mm canals		20°/40°, 12 mm canals	
Size	Length	Size	Length
0.045T	8	0.045T	12
15	16	15	16
20	16	20	16
25	16	25	16
0.03T	16	0.03T	16
0.04T	14	0.04T	14
0.045T	16	0.045T	16
0.05T	14	0.05	14
0.055T	16	0.055T	16
30	16	30	16
35	16	35	16

2 A size 15 NT Engine file was used to 16 mm (the full working distance).
3 A size 20 NT Engine file was used to 16 mm.
4 A size 25 NT Engine file was used to 16 mm.
5 A size 0.03T McXim file was used to 16 mm.
6 A size 0.04T McXim file was used to 14 mm.
7 A size 0.045T McXim file was used to 16 mm.
8 A size 0.05T McXim file was used to 14 mm.
9 A size 0.055T McXim file was used to 16 mm.
10 A size 30 NT Engine file was used to 16 mm.
11 A size 35 NT Engine file was used to 16 mm.

Canals with curves beginning at 12 mm

Ten canals with 20° and 10 canals with 40° curves were prepared as follows:
1 A size 0.045T McXim instrument was used to prepare 12 mm (the straight portion) as described above.
2 A size 15 NT Engine file was used to 16 mm (the full working distance).
3 A size 20 NT Engine file was used to 16 mm.
4 A size 25 NT Engine file was used to 16 mm.
5 A size 0.03T McXim file was used to 16 mm.
6 A size 0.04T McXim file was used to 14 mm.
7 A size 0.045T McXim file was used to 16 mm.
8 A size 0.05T McXim file was used to 14 mm.
9 A size 0.055T McXim file was used to 16 mm.
10 A size 30 NT Engine file was used to 16 mm.
11 A size 35 NT Engine file was used to 16 mm.

Assessment of canal preparation

Preparation time

The time for canal preparation was recorded in minutes and seconds and included file changes within the instrumentation sequence as well as irrigation.

Instrument failure

NT Engine and McXim files were examined after every use and a record of permanently deformed or fractured instruments was kept, including the number of times the instruments had been used.

Canal blockage

Canals which became blocked with resin debris during preparation were noted.

Loss of working distance

The final length of each canal was determined following preparation. A size 35 NT Engine file was inserted into the prepared canal and its length within the canal measured to the nearest 0.5 mm. Change in working distance was determined by subtracting the final length from the original length.

Canal form

The internal three-dimensional shape of all canals was determined from intracanal impressions. A small amount of Microfilm (Kerr Corporation, Romulus, MI, USA) was introduced into the canal lumen to act as a lubricant. Light bodied vinyl polysiloxane impression material (President; Coltene AG, Altstätten, Switzerland) was carefully injected into each canal, followed by the introduction of a fine barbed broach, to act as support for the coronal part of the impression and to facilitate removal. The impressions of the prepared canals were removed and assessed under magnification using the following criteria (Abou-Rass & Jastrab 1982):
Apical stop. Categorized as absent, present (but poorly defined) or present (well defined).
Smoothness of the apical half of the canal. Categorized as poor or good.
Smoothness of the coronal half of the canal. Categorized as poor or good.
Horizontal or longitudinal grooves. Categorized as absent or present.
Flow. Good flow characteristics were defined as a continuous blending of the canal from orifice to apical stop. Abrupt changes in direction and the presence of ledges gave rise to poor flow characteristics.
Taper. This was categorized as good when the canal had a conical shape throughout its length. Canals with poor taper had hourglass or cylindrical shapes.

Recording, storage and analysis of data

Data were recorded directly on coding sheets and then stored in a PC. Following error and range checks, the data were analysed using MINITAB (Minitab Inc., State College, PA, USA), an interactive statistics package.

Results

Preparation time

The mean time to prepare the canals is detailed in Table 2. Overall, the shortest mean instrumentation time was recorded in canals with 40° curves which began 12 mm from the orifice (5.517 min) and the longest in 40°, 8 mm canals (6.675 min). One-way analysis of variance revealed that preparation time was influenced significantly by canal shape ($P<0.01$).

Instrument failure

In total, four instruments deformed during the study and one fractured, all in the McXim series of files. Two size 0.045T McXim files deformed in canals with 40°, 12 mm shapes. One 0.04T McXim and one 0.05T McXim file deformed in canals with a 20°, 12 mm shape. The fractured 0.03T McXim was associated with preparation in a 40°, 8 mm canal.

Canal blockage

All canals remained patent following preparation.

Change in working distance

The mean change in working distance that occurred as a result of preparation is shown in Table 3. In general, the greatest mean loss of distance occurred in 40°, 12 mm canals. One-way analysis of variance indicated that there were significant differences between the canal shapes ($P<0.05$).

In all, 20 canals (out of 40) maintained the exact working length (Table 4). Nineteen canals were associated with a loss of working distance of 0.5 mm. Only one canal (40°, 8 mm) was longer than 16 mm, the working distance. There was a significant difference between canal shapes in terms of the extent (category) of change in canal length ($P<0.05$).

Table 2 Mean preparation time (min) by canal shape

	Canal shape			
n	20°, 8 mm	40°, 8 mm	20°, 12 mm	40°, 12 mm
10	5.802	6.675	6.048	5.517

Table 3 Mean change in working distance (mm) by canal shape

	Canal shape			
n	20°, 8 mm	40°, 8 mm	20°, 12 mm	40°, 12 mm
10	–0.10	–0.15	–0.20	–0.45

Canal form

Apical stop

The quality of apical stops is detailed in Table 5. Apical stops were present in 37 canals (out of 40) but 21 (52%) were designated of poor quality. There were no apical stops in three canals. There was no significant difference in the quality of apical stops between the canal shapes, although there was a trend for canals with curves beginning 12 mm from the orifice to have a higher incidence of good apical stops; poorer apical stops were associated more often with curves beginning 8 mm from the orifice.

Apical smoothness

The majority of canals (33 out of 40) had smooth apical canal walls (Table 5). All of the poor ratings were associated with canals with 40° curves and statistical analysis confirmed that the differences between the canal shapes was significant ($P<0.05$).

Coronal smoothness

The quality of coronal smoothness is outlined in Table 5. All of the canals apart from one had smooth coronal

Table 4 Change in canal length by category and canal shape

	Canal shape				
Change in canal length (mm)	20°, 8 mm	40°, 8 mm	20°, 12 mm	40°, 12 mm	Total
–0.5	2	4	4	9	19
0	8	5	6	1	20
+0.5	0	1	0	0	1
Total	10	10	10	10	40

Table 5 Assessment of apical stops and canal smoothness

	Canal shape				
	20°, 8 mm	40°, 8 mm	20°, 12 mm	40°, 12 mm	Total
Apical stop					
good	2	2	6	6	16
poor	6	7	4	4	21
absent	2	1	0	0	3
Apical smoothness					
good	10	6	10	7	33
poor	0	4	0	3	7
Coronal smoothness					
good	10	9	10	10	39
poor	0	1	0	0	1

walls and there were no significant differences between the canal shapes.

Horizontal and longitudinal grooves

None of the canals had horizontal grooves. Longitudinal grooves were present in eight specimens (20% of the canals). There was no significant differences in the presence of either horizontal or longitudinal grooves between the canal shapes.

Flow

The general flow characteristics of the prepared canals are shown in Table 6. Good flow was exhibited in 35 canals (out of 40) and poor flow in only five. Preparation of canals with 20° curves produced good flow ratings in all canals; 40° canals had more poor ratings (five out of 20). There was no significant difference between the canal shapes in terms of flow characteristics.

Taper

All of the canals exhibited good taper.

Discussion

The aim of this study was to assess under controlled laboratory conditions the use of nickel–titanium NT Engine and McXim rotary instruments using four simulated canal shapes. The advantages of using simulated canals in clear resin blocks as an experimental model have been identified in previous studies (ElDeeb & Borass 1985, Al-Omari *et al.* 1992a,b). The ability to assess preparation procedures and instrument performance by producing simulated canals with defined shapes in a standardized way (Dummer *et al.* 1991) means that variables encountered in root canals in real teeth are eliminated, allowing clear comparisons between canal shapes.

NT Engine and McXim files are marketed with an instructional video and technique booklet explaining the rationale for their use and design. During the preparation of simulated canals, there is a danger of rotary instruments binding in the resin and use of a lubricating agent to prevent this occurrence is advised. Rotational speeds of approximately 300 r.p.m. are recommended, along with the use of copious irrigation. The importance of using a constant speed is stressed with the instrument rotating at the chosen speed on entry to the canal. A slight pumping motion is advised with the instrument advanced apically by approximately 0.5 mm S^{-1}. Although all these factors were taken into account during this study, caution should clearly be exercised when extrapolating the results to the clinical situation because of the use of simulated canals.

As the beginning of the curve was either 8 mm or 12 mm from the orifice, the preparation techniques varied a little between the canal shapes (Table 1). However, both canal types were prepared in a similar manner; coronal widening was achieved initially to the beginning of the curve with 0.045T McXim files and then a stepdown procedure was utilized with the NT

Table 6 Flow characteristics by canal shape from intracanal impressions

	Canal shape				
Flow	20°, 8 mm	40°, 8 mm	20°, 12 mm	40°, 12 mm	Total
Good	10	7	10	8	35
Poor	0	3	0	2	5

Engine files (0.02 taper) to the full working distance until the apical region was enlarged to a size 25. Further use of McXim files with progressively greater taper widened the orifice region further prior to the continued use of NT Engine files until a size 35 apical stop was obtained. As all the McXim files have a size 25 tip, their use created coronal widening only and did not contribute to apical preparation. It should be noted that 0.04T and 0.05T McXim files were always kept 2 mm short of the apex, as they had a tendency to draw into the canal. This preparation technique is recommended by the manufacturer and it should be emphasized that details of the instrument sequence were confirmed prior to the study by visiting the manufacturer and through discussion with the instrument designer (J. McSpadden, personal communication). Furthermore, considerable experience was gained in piloting the regimen prior to the study.

NT Engine and McXim files prepared canals quickly and on average in approximately 6 min. Although canal shape did significantly influence preparation time, the actual differences between the canal shapes was of no clinical relevance. Thompson & Dummer (1997a,b,c) have reported the speed with which other rotary nickel–titanium instruments prepared simulated canals under conditions identical to the present study. Since all the systems tested prepared canals in under 10 min, it can be concluded that this new generation of nickel–titanium instruments is extremely effective. Preparation with such instruments has also been reported to be quicker than using hand instruments (Esposito & Cunningham 1995, Glosson *et al.* 1995). Clearly, operator and patient fatigue would be considerably reduced using rotary nickel–titanium rotary instruments.

Although one McXim instrument fractured during the study, this was of no significance as the broken fragment was retrieved easily; none of the NT Engine files fractured. Four McXim instruments bound in the resin blocks and deformed, but this occurred only in 12 mm canals, that is, those with acute, sharp curves. Deformations occurred equally amongst the different file sizes in the McXim series, so file design did not appear to be of significance. However, it was quite obvious that the instruments of greater taper tended to bind rather more. Thompson & Dummer (1997b) reported a high number of deformations associated with use of ProFile 0.04 Taper Series 29 nickel–titanium instruments (Tulsa Dental Products) which also have an increased taper. Thus, caution should be exercised when using instruments of this design in order to prevent fractures and deformations.

The importance of controlling the working length during root canal treatment to avoid extrusion of debris through the apex, to maintain the apical constriction, and to allow effective obturation of the canal system is well known. Half of the canals in this study maintained the correct working length, with only one specimen being over-prepared. Thus, the perception that engine instrumentation is generally associated with over-preparation and increases in working distance as a result of lack of tactile sense does not apply with these systems. Loss of working distance occurred in 19 specimens and more often in canals where the curve began 12 mm from the orifice. Thompson & Dummer (1997b) found that ProFile 0.04 Taper instruments were also frequently associated with under-preparation, whilst Lightspeed instruments (Lightspeed Technology Inc., San Antonio, TX, USA) were more frequently associated with over-preparation (Thompson & Dummer 1997a). Although further work on these systems is required, there does seem to be a tendency for those files with increased taper to underprepare canals, presumably as a result of the area of increased taper binding more in the coronal region. It must be emphasized that this does not occur because of canal blockages; indeed, all the NiTi rotary systems tested so far have maintained a patent canal lumen (Thompson & Dummer 1997a,b,c).

The three-dimensional postoperative canal form was assessed using canal impressions. The majority of the canals had apical stops (Table 5), and most canals were smooth throughout their length. Smooth canals and adequate apical stops have been described with ProFile 0.04 Taper Series 29 instruments (Thompson & Dummer 1997b), Lightspeed instruments (Thompson & Dummer 1997a) as well as Mity Roto 360° (JS Dental Manufacturing, Inc. Ridgefield, CT, USA) and Naviflex (Brasseler USA, Savannah, GA, USA) files (Thompson & Dummer 1997c).

In this study, the taper and flow characteristics of the preparations were excellent and similar to those produced by the ProFile system (Thompson & Dummer 1997b). However, poorer taper and flow characteristics have been noted with conventional 0.02 taper instruments (Mity Roto 360° and Naviflex) and the Lightspeed system (Thompson & Dummer 1997a,c). These less than ideal shapes are inevitable with 0.02 taper instruments, as they inherently cannot produce the preferred conical form. However, it is possible that a more effective stepback phase would improve the flow and taper when using Lightspeed instruments. Clearly, the results of this study confirm the efficacy of using files with increased taper.

Conclusions

Under the conditions of this study, NT Engine and McXim rotary nickel–titanium instruments prepared simulated canals rapidly, with no blockages, with little change in working length and with few instrument failures. The majority of canals were smooth and showed excellent flow and taper characteristics.

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