Morphometric analysis of shank-to-flute ratio in rotary nickel–titanium files

M. T. Biz[1] & J. A. P. Figueiredo[2]

[1]UNIPLAC Dental School, Lages, SC; and [2]Post-Graduate Program of Dentistry, ULBRA, Canoas, Brazil

Abstract

Biz MT, Figueiredo JAP. Morphometric analysis of shank-to-flute ratio in rotary nickel–titanium files. *International Endodontic Journal*, **37**, 353–358, 2004.

Aim To evaluate the shank-to-flute ratio in rotary nickel–titanium (Ni-Ti) instruments.

Methodology The cutting portion of 15 size 30 Ni-Ti rotary instruments, ProFile .04, ProFile .06, Pow R .02, Pow R .04 and Quantec series 2000, were examined. The handles of the instruments were fixed to a bench and supported by a removable resin base. The cutting portion was then manually abraded with abrasive strips along one aspect of their length. All instruments were fixed in a stub that permitted the adaptation and inspection of six instruments at the same time. A scanning electron microscope (SEM; Phillips model XL 20; Eindhmoven, the Netherlands) at ×60 magnification was used to collect cross-sectional measurements of the shank and the flutes at the first, third and fifth flutes from the tip. The software AUTOCAD 2000 was used to measure these areas.

Results The shank percentage value was, on average, equal to or greater than the flute percentage value at the sites analyzed. A regular and proportional pattern of increase of shank and flute measurements, as well as the ratio between them, was preserved. There was no significant difference between instruments and between flute sites on the same instrument ($P > 0.05$). However, the Quantec instruments had a flute area twice the flute area of the other instruments.

Conclusions The instruments had a shank percentage measurement value equal to or greater than the flute percentage value; the cross-sectional shank-to-flute ratio was preserved. The instruments had similar shank areas, but the flute area of the Quantec instruments was twice their shank area; i.e. the design of the Quantec files provides longitudinal reinforcement by means of a gain in flute area.

Keywords: dental files, fracture, instrumentation, root-canal treatment.

Received 27 January 2003; accepted 2 September 2003

Introduction

Because of its properties of elasticity and shape memory, and its high resistance to fracture, Walia *et al.* (1988) suggested the use of nickel–titanium (Ni-Ti) in the manufacture of endodontic instruments. However, several questions about the resistance to fracture of these instruments have been raised. Wolcott & Himel (1997) compared the torsional properties of Ni-Ti and stainless steel files, and observed that fracture caused by torsion increased with increase in size. This finding is consistent with those reported by Camps & Pertot (1994), who also showed that the opposite is observed for stainless steel files, i.e. an increase in size results in a decrease in fractures caused by torsion.

In a similar study, Haïkel *et al.* (1999) evaluated instruments of the ProFile (Dentsply Maillefer, Ballaigues, Switzerland), Quantec (Analytic Endodontics, Glendora, CA, USA) and Hero systems (MicroMega, Besançon, France), and found that the Quantec instruments had more precise taper values, as well as the greatest resistance to torsional fracture. They also observed, however, that the increase in taper, from .04 to .06 in the ProFile instruments, resulted in a decrease in resistance to fracture, although it would be expected that an increase in taper would result in greater resistance to fracture. The authors emphasized the need

Correspondence: José Antônio Poli de Figueiredo, R. Luciana de Abreu, 20/201, Porto Alegre, RS 90570-060, Brazil (Tel.: +55 51 3346 2197; e-mail: endofig@terra.com.br).

for further investigation of the indirect association between taper and instrument resistance.

The design of the cutting blade in the form of a radial land (smooth external surface, radial portion or guide) tends to reduce threading of instruments into the dentine walls during use (Camps & Pertot 1994). Such design of the cutting blade and the taper of the active section of the instrument are features that make Ni-Ti files the most revolutionary concept in the preparation of narrow and curved canals (Camps & Pertot 1994).

The taper of different systems, together with the fact that instruments of greater taper and size fracture more frequently, raises the question of whether the increase in taper is created by reducing the instrument's core along the shank, thus resulting in more fragile instruments.

The purpose of this study was to evaluate the morphometric relationship between the shank and flute in Ni-Ti rotary instruments – ProFile (Dentsply Maillefer), Pow R (Moyco Union Broach, York, USA) and Quantec (Analytic Endodontics).

Materials and methods

Fifteen size 30 Ni-Ti instruments with different tapers were evaluated. Three instruments of each of the following were selected: ProFile .04 (Dentsply Maillefer Instruments SA, Ballaigues, Switzerland), ProFile .06 (Dentsply Maillefer Instruments, SA), Pow R .02 (Moyco Union Broach, York, USA), Pow R .04 (Moyco Union Broach) and Quantec Series 2000 (Analytic Endodontics, Glendora, USA).

All instruments were fixed in stubs developed by the Electron Microscopy Laboratory at the Universidade Luterana do Brazil (ULBRA), which permitted the adaptation of six files at the same time. Files were analysed under a scanning electron microscope (SEM; Phillips model XL 20; Eindhmoven, the Netherlands), at ×60 magnification, to check the surface integrity of the instruments. Each instrument was then gripped by the handle in a vice (Ambika, Porto Alegre, Brazil) fixed to a bench to facilitate longitudinal abrasion on only one side of the instrument's active section. The instrument was supported by a removable resin base to avoid bending and movement during the abrasion procedure; the base was removed whenever the pattern of abrasion was evaluated.

A pachymeter (Stainless 1/10 mm; Golgran, Sao Paulo, Brazil) was used for the cross-sectional measurement of the instrument in the areas corresponding to the first, third and fifth flutes, so that the abrasion could be evaluated when the thickness was reduced to half the original thickness of the instrument. The abrasion was performed manually with 6-mm steel-coated abrasive strips (GN Injecta; Diadema, Brazil), and was complete when the pachymeter measurement confirmed that half the original thickness was achieved for each flute.

The instruments were cleaned with a medium toothbrush (Oral-B 30; Gilette do Brazil, Manaus, Brazil) and running water to remove abrasion debris, and were then visualized in the SEM, as before, in order to inspect the abraded surface. The facilities of the SEM allowed cross-sectional measurements of each instrument at the sites of the first, third and fifth flutes, separating flute values from shank values (Figs 1 and 2).

Means for each instrument were calculated and these were used to calculate the percentage ratio of shank to total cross-sectional measurement, i.e. the Shank/Total

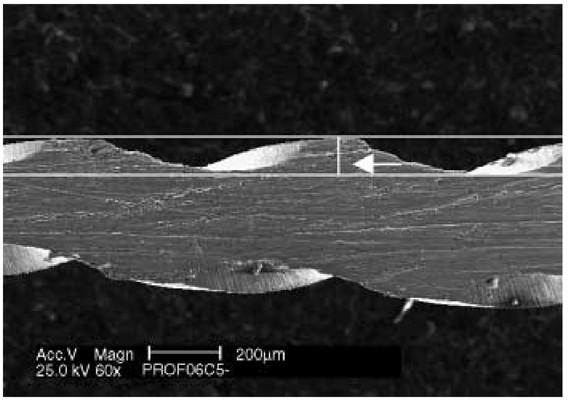

Figure 1 Cross-sectional measurement (arrow) of the fifth flute of instrument C ProFile .06.

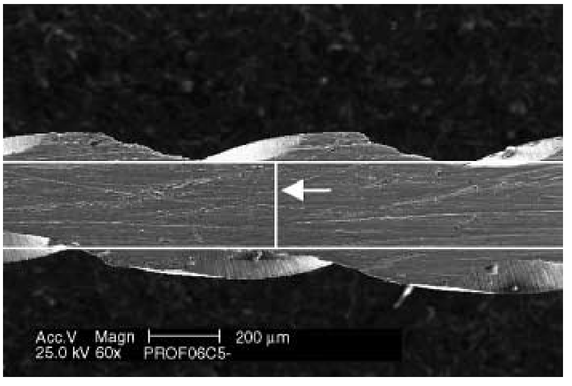

Figure 2 Cross-sectional measurement (arrow) of the shank corresponding to the fifth flute of instrument C ProFile .06.

Index (STI) of the files for each flute, which allowed analysis of the relationship between the shank and flute of the instruments.

The electromicrographs obtained were uploaded onto the AUTOCAD 2000 software (Mechanical Desktop Power Pack; Microsoft Corporation, Redmond, USA), which is a program used for engineering and architecture projects, to calculate areas, volumes and figure measures (Figs 3 and 4).

A longitudinal measurement of 800 μm was used to standardize a limit for all sites in an instrument and between files. Therefore, the areas were limited and their numeric values were determined. Similar to the cross-sectional measurements, the percentage values of shank and flute were calculated, and the comparisons between files were made.

ANOVA was performed for statistical analysis.

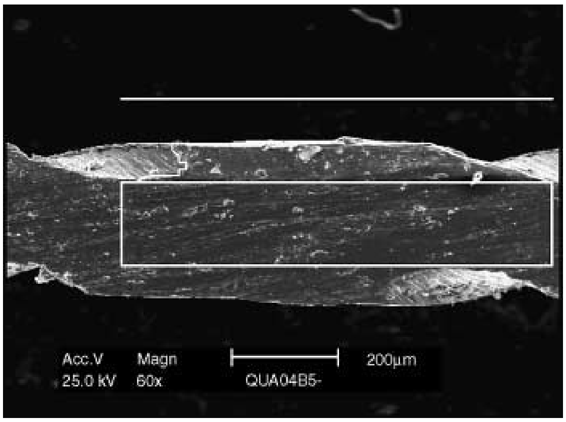

Figure 3 Shank-to-flute measurement of the delineated area corresponding to the fifth flute of instrument B Quantec.

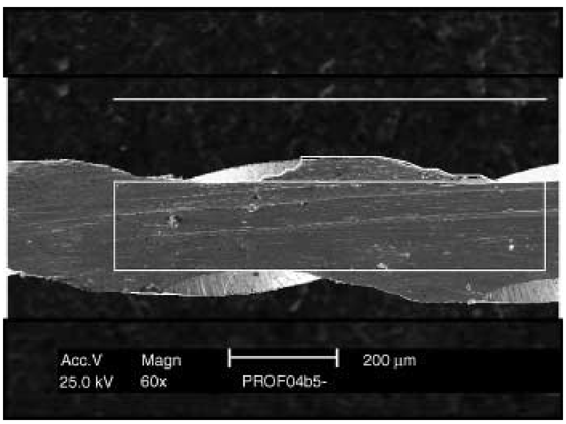

Figure 4 Shank-to-flute measurement of the delineated area corresponding to the fifth flute of instrument B ProFile .06.

Results

Cross-sectional measurement

Means for the flute and shank measurements at the first, third and fifth flutes for each group of instruments are shown in Table 1.

Table 2 shows the STI, i.e. the percentage ratio of shank to the total cross-sectional measurement at the sites of the first, third and fifth flutes, and the confidence interval for each STI. Except for the site of the first flute of the Quantec Series 2000 instrument, all the instruments had a shank percentage value equal to or greater than the flute percentage value.

Table 1 Means obtained for the cross-sectional measurements in the groups (μm)

		Means		
Group	Area	1[a]	3[a]	5[a]
ProFile .04	Flute	49.7	64.6	72.8
	Shank	169.0	220.3	254.0
ProFile .06	Flute	59.6	80.4	97.6
	Shank	159.0	218.6	297.3
Pow R .02	Flute	61.4	70.5	71.0
	Shank	179.3	186.0	203.3
Pow R .04	Flute	69.9	73.3	102.1
	Shank	157.0	211.0	253.0
Quantec	Flute	62.1	75.4	74.5
	Shank	121.6	150.0	193.6

Table 2 STI (%)

Group	Flute	STI
ProFile .04	1	63
	3	62
	5	63
ProFile .06	1	57
	3	57
	5	60
Pow R .02	1	59
	3	56
	5	58
Pow R .04	1	53
	3	49
	5	55
Quantec	1	49
	3	49
	5	56

All the instruments had a regular pattern of increase in the measurements of shank, flute and total cross-sectional length, which revealed the preservation of the shank-to-flute ratio, with no statistically significant differences between the instruments or between the sites of the flutes analysed for each instrument ($P > 0.05$).

Area measurement

Means for shank and flute area measurements are shown in Table 3. Table 4 gives the percentage values for these measurements.

The percentage values of the shank and flute area measurements revealed that all the instruments had similar shank areas. The Quantec instruments had the largest flute area, followed by the ProFile and Pow R instruments; the areas of these two types of files were not significantly different ($P > 0.05$). The percentage ratio of shank to flute revealed that the flute area of the Quantec instruments was twice the flute area of the other instruments.

Table 3 Means obtained for the area measurements in the groups (μm^2)

		Means		
Group	Area	1[a]	3[a]	5[a]
ProFile .04	Flute	25.7	33.8	32.4
	Shank	192.5	222.7	290.1
ProFile .06	Flute	31.1	37.5	49.6
	Shank	159.0	218.6	297.3
Pow R .02	Flute	29.0	26.5	28.9
	Shank	220.2	208.0	218.1
Pow R .04	Flute	29.1	39.3	36.3
	Shank	186.3	228.9	275.3
Quantec	Flute	57.7	61.7	65.6
	Shank	156.5	191.0	251.5

Table 4 Percentage of flute area in the groups (%)

Group	Flute	%
ProFile .04	1	13
	3	15
	5	11
ProFile .06	1	16
	3	14
	5	14
Pow R .02	1	13
	3	12
	5	13
Pow R .04	1	15
	3	17
	5	13
Quantec	1	36
	3	32
	5	26

Discussion

Engine-driven Ni-Ti instruments have different sizes and tapers. In this study, size 30 instruments with different tapers were examined because these instruments are indicated for and frequently used in the apical preparation of root canals, and also because they were analysed in previous studies (Kazemi *et al.* 1996, Bonetti Filho *et al.* 1998, Bryant *et al.* 1999, Yared *et al.* 1999, 2000). The sites of the first, third and fifth flutes were analysed because the purpose was to include the first 3 mm of the active section of each instrument; this is the region where most fractures occur (Gabel *et al.* 1999).

The abrasion technique used is a new methodology developed to study the internal morphology of instruments. This technique makes it possible to observe and measure the diameter of the instruments at selected sites and to separate its shank, which corresponds to the body of the instrument, from its flute or cutting blade, in order to establish the relationship between the measurements obtained. The aim was to achieve half the thickness of the instrument at the selected sites, which was possible by the use of manual abrasion with steel-coated abrasion strips followed by measurements with a pachymeter to avoid excessive abrasion.

Davidowicz *et al.* (1994), who used an optical comparison microscope, and Haïkel *et al.* (1999), who used a micrometer, measured the diameters of endodontic instruments. However, the follow-up of file abrasion by those means was not feasible in this study because the files had to be kept in the same position to avoid variations in measurements. Such a procedure was possible with the use of a pachymeter because the file was not removed from the vice, and the pachymeter always gripped the file at the same site.

Therefore, the abrasion methodology proved to be an efficient method to study the internal morphology of endodontic instruments and will make new investigations possible, providing enhanced knowledge of endodontic instruments. However, other variables will contribute to instrument fracture such as root-canal anatomy, knowledge and skill of the operator, as well as positioning while rotating the instrument. Pruett *et al.* (1997) reported that fracture may occur because of the increase of the alloy mass that promotes a rapid build-up of cyclic fatigue under stress.

Analysis under SEM at a ×60 magnification, together with the computerized measurement resources of the SEM, provided cross-sectional measurements of the files, separating the measurements of the shank and the flute at each site that had been selected. The use of the AUTOCAD 2000 software provided measurements of the shank and flute areas. Previous studies in dental sciences have used the resource that calculates precise linear area or even volumetric measurements (Lagranha 2001, Masiero 2002).

The cross-sectional measurements showed a pattern in the preservation of taper, as well as in the preservation of the shank-to-flute ratio. This finding rules out the hypothesis that the shank-to-flute ratio is, because of its disproportion, a contributing factor to the occurrence of fractures during the preparation of curved canals.

The results of the ANOVA test revealed that, although there were some differences in the cross-sectional measurements of the files evaluated, these differences were not statistically significant. This demonstrates the accuracy with which Ni-Ti files are manufactured; in other words, the increase in taper is accompanied, on average, by a proportional gain in shank and flute measurements.

As with the cross-sectional measurements, the files had similar shank areas and no significant differences were observed. This confirms the accuracy of the values obtained for the cross-sectional measurements of the shank, because the longitudinal length for the calculation of area was standardized for all sites and files.

However, while the proportion was preserved for the cross-sectional measurements of shank and flute, and similar measurements of shank area were found, the analysis of the area measurements of the flute revealed some difference. The Quantec files had a larger flute area – twice the area measured for the other files. This important finding may be explained by the presence of the longer radial land, i.e. the instrument's flute is reinforced.

Studies focusing on fracture have unanimously reported that the use of files with greater taper or size in curved canals increases the risk of fracture. This fact has not been fully explained, which generates further questions about the influence of stress, morphology and the design of these files when under such situations (Camps & Pertot 1995, Wolcott & Himel 1997, Haïkel *et al.* 1999).

Conclusions

The findings of this study lead to the following conclusions:

1 The shank percentage value was, in average, equal to or greater than the flute percentage value in the sites analysed.

2 A regular and proportional pattern of increase of shank and flute measurements, as well as the ratio between them, was preserved, and there was no significant difference between files and between flute sites on the same file ($P > 0.05$).

3 The files had similar area measurements of shank and no significant difference was observed ($P > 0.05$).

4 The Quantec files had the largest flute area, which was about twice the flute area of the other files.

References

Bonetti Filho I, Esberard M, Leonardo R, Del Rio C (1998) Microscopic evaluation of three endodontic files pre- and post-instrumentation. *Journal of Endodontics* **24**, 461–4.

Bryant S, Dummer P, Pitoni C, Bourba M, Moghal S (1999) Shaping ability of .04 and .06 taper ProFile rotary nickel–titanium files in simulated root canals. *International Endodontic Journal* **32**, 155–64.

Camps JJ, Pertot WJ (1994) Torsion and stiffness properties of Canal Master U stainlees steel and Ni-Ti files. *Journal of Endodontics* **20**, 395–8.

Camps JJ, Pertot WJ (1995) Torsion and stiffness properties of nickel–titanium K-files. *International Endodontic Journal* **28**, 239–43.

Davidowicz H, Moura A, Strefezza F (1994) Avaliação do diâmetro 'D_0' de cones de guta-percha estandardizados e calibrados comparados com limas tipo 'K' através do microscópio comparador. *Revista Da Associação Brasileira de Odontologia* **2**, 181–5.

Gabel W, Hoen M, Steiman R, Pink F, Dietz R (1999) Effect of rotational speed on nickel–titanium file distortion. *Journal of Endodontics* **25**, 752–4.

Haïkel Y, Serfaty R, Bateman G, Senger B, Allemann C (1999) Dynamic and cyclic fatigue of engine-driven rotary nickel–titanium endodontic files. *Journal of Endodontics* **25**, 434–40.

Kazemi R, Stenman E, Spanberg L (1996) Machining efficiency and wear resistance of nickel–titanium endodontic files. *Oral Surgery, Oral Medicine and Oral Pathology* **81**, 596–602.

Lagranha S (2001) Análise comparativa *in vitro* de diferentes técnicas de desobturação de canais radiculares. Thesis. Rio Grande do Sul, Brazil: Universidade Luterana do Brasil.

Masiero A (2002) Análise comparativa *in vitro* da eficiência de diferentes técnicas para a remoção do material obturador do interior de canais radiculares. Thesis. Rio Grande do Sul, Brazil: Universidade Federal de Pelotas.

Pruett J, Clement D, Carnes D (1997) Cyclic fatigue testing of Ni-Ti endodontic files. *Journal of Endodontics* **23**, 77–85.

Walia H, Brantley W, Gerstein H (1988) An initial investigation of the bending and properties of nitinol root canal files. *Journal of Endodontics* **14**, 346–51.

Wolcott J, Himel V (1997) Torsional properties of nickel–titanium versus stainless steel endodontic files. *Journal of Endodontics* **23**, 217–20.

Yared G, Bou Dagher F, Machtou P (1999) Cyclic fatigue rotary files after simulated clinical use. *International Endodontic Journal* **32**, 115–9.

Yared G, Bou Dagher F, Machtou P (2000) Cyclic fatigue of ProFile rotary files after clinical use. *International Endodontic Journal* **33**, 204–7.