CYCLIC FATIGUE OF PROFILE ROTARY INSTRUMENTS IN RELATION TO THEIR SIZE AND DIAMETER

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ABSTRACT

The purpose of this in vitro study was to invent a testing device similar to curved canals to investigate the cyclic fatigue of 0.04 and 0.06 Profile system by recording the time lapsed from the beginning of rotation until separation occurred. Revolution number and length of separated pieces were also determined. A metal device was designed and 120 Profile were tested after dividing them randomly into 2 equal groups from size 15-40 of the same taper either 0.04 or 0.06. The result demonstrated that the smaller size significantly resist fracture and take longer time and more revolution to separate when compared to larger sizes. The mean length of separated pieces was significantly longer (P<0.001) and near the end of the cutting section for the Profiles 0.04 when compared to those of 0.06. This may indicate that smaller diameter Profiles considered safer and stronger in clinical practice.

Key words: *Profile, Cyclic fatigue, Separation, Fracture*

INTRODUCTION

The preparation and instrumentation of curved canals present a great challenge and a considerable problem for endodontic practitioners. Inadvertent errors may occur ranging from ledge formation or perforation to zipping[1-4]. This damage not only destroys the apical constriction but also produces an hourglass-shaped canals. Accordingly, this may adversely alter the root canal morphology and thus detrimentally may affect the prognosis for subsequent root filling. In addition, separation of traditional files or reamers in the canal can seriously jeopardize the therapy[6]. As a consequence, new endodontic instruments and techniques have been introduced to minimize these undesirable complications during instrumentation of fine and curved canals.

Of particular importance has been the development ofnickel-titanium (NiTi) endodontic instruments. Files made from this alloy are biologically accepted, highly flexible, considerably stronger in fatigue resistance, as well as cut more efficiently and decrease the working time than stainless steel files[7-16]. Furthermore, despite an increased flexibility, failure is still a concern because these NiTi instruments can undergo separation within their elastic limit and without any visible sings of previous permanent deformation[16-20] However, some workers revealed, in their SEM study, that the fracture mode was observed, in which crack propagation, approximately parallel to the local flute orientation, connected pitted region on the surface[21]. Moreover, all NiTi engine-driven rotary systems require the instruments to be activated at a predeter-

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mined rpm before insertion into the canal[16]. Furthermore, the use of a pecking motion (an inand-out motion) during instrumentation by NiTi engine-driven rotary files would be expected to significantly extend the life span of the instrument[22]. Manufactures stated that the number of cases that an instruments may be used varies from 4 to 16. According to some practitioners, rotary instruments could be safely used in clinical practice up to 10 times[15,18].

This investigation was undertaken to develop a testing device that simulate curved canals to evaluate the cyclic fatigue of 0.04 and 0.06 ProFile NiTi rotary instruments by recording the time lapsed from the beginning of rotation until separation occurred. The number of revolutions and lengths of separated pieces were also determined.

MATERIALS AND METHODS

A test metal device was designed to simulate the rotation action of NiTi instrument while bent inside the curved canals. This device has a file-guiding 1.5 mm U-shaped gutter made in the middle of a stainless steel half-pipe of 36 mm internal diameter (Fig. 1). The calculated angle of curvature was 58.8 using Scheneider's method[23]. The sloped surface of the device was polished adequately and lubricated with industrial motor oil before testing the ProFiles. Oil temperature was maintained between 21° C — 23° C and oil changed every 12 files. The NiTi instruments were operated at 300 rpm, using a slow-speed high torque endodontic electric motor (TCM ENDO, NOUVAG, Mailefer, Dentsply, Switzerland) with a 16:1 gear reduction handpiece (WH 975, Dental Work, Burmoos, Austria) and torque protection of 1 Ncm. The micromotor is capable of producing constant preset torque as well as revolutions per minute. The device was also equipped with torque protection mode for a quick change of direction of rotation when files reach the preselected torque level. The digital read out indicates the speed and torque level.

The half-pipe was firmly fixed on a 30x40x1 cm base facing upward. One cut edge of the half-pipe was made perfectly parallel the base. Two half-circle glass sheets were glued each to one end of the half-pipe into the gutter for 20 mm. The handpiece was firmly fixed on a sloped piece of wood attached to the base by a hinge so the working end of the handpiece was parallel to the base when the hinge is closed. The long axis of the handpiece was in one line with the gutter in the half-pipe. When the file was attached to the handpiece and the hinge was closed, the file went perpendicular to the base into the gutter. This arm was then locked when the test was performed (Fig. 2).

A total of 120 ProFile NiTi rotary instruments (Dentsply, Mailefer, Baillaiguses, Switzerland) were tested in this study. The file length was 25 mm and the length of cutting section was 16 mm. Files were divided randomly into two equal groups, 60 files each. Each group consisted often files from each size starting from size 15 to size 40 of same taper, either 0.04 or 0.06. Each file has a noncutting tip and a U-shaped cross-section with redial bands. A chronometer (Omega, Bienn, Switzerland) was used to record the time starting from beginning of rotation until separation of the file has been occurred. The numbers of revolution were determined using TCM Endo. The separation pieces were collected and their lengths were measured using a calliper. Throughout the experiment, the torque exerted on each file was kept constant Data were recorded and statistically analysed using Two-way Analysis of Variance (ANOVA) test.

RESULTS

Table **1** showing the range of files revolutions until they were separated, as well as, the time lapsed, and the length of these separated parts in relation to taper and size. Furthermore, the relation between the taper and size of the ProFiles with the mean ± SD of number of revolutions of cyclic fatigue until fractures have been occurred, as well as the rotation time in seconds (life span), and the length of the separated pieces (mm) are displaced in Tables I and II.

Fatigue failure was affected by file size and taper. Therefore, ProFile size 15, of both groups, was significantly resistant ($P<0.001$) to fatigue failure when compared to other sizes. ProFiles size 35 and 40 were significantly less fatigue resistant than the smaller files (P<0.00 **1).** Accordingly, the time of separation was increased with small files compared to large one and increased with the ProFiles 0.04 when compared with ProFile 0.06. Results also demonstrated that in almost

Fig. 1. Photograph of the U-shaped gutter design.

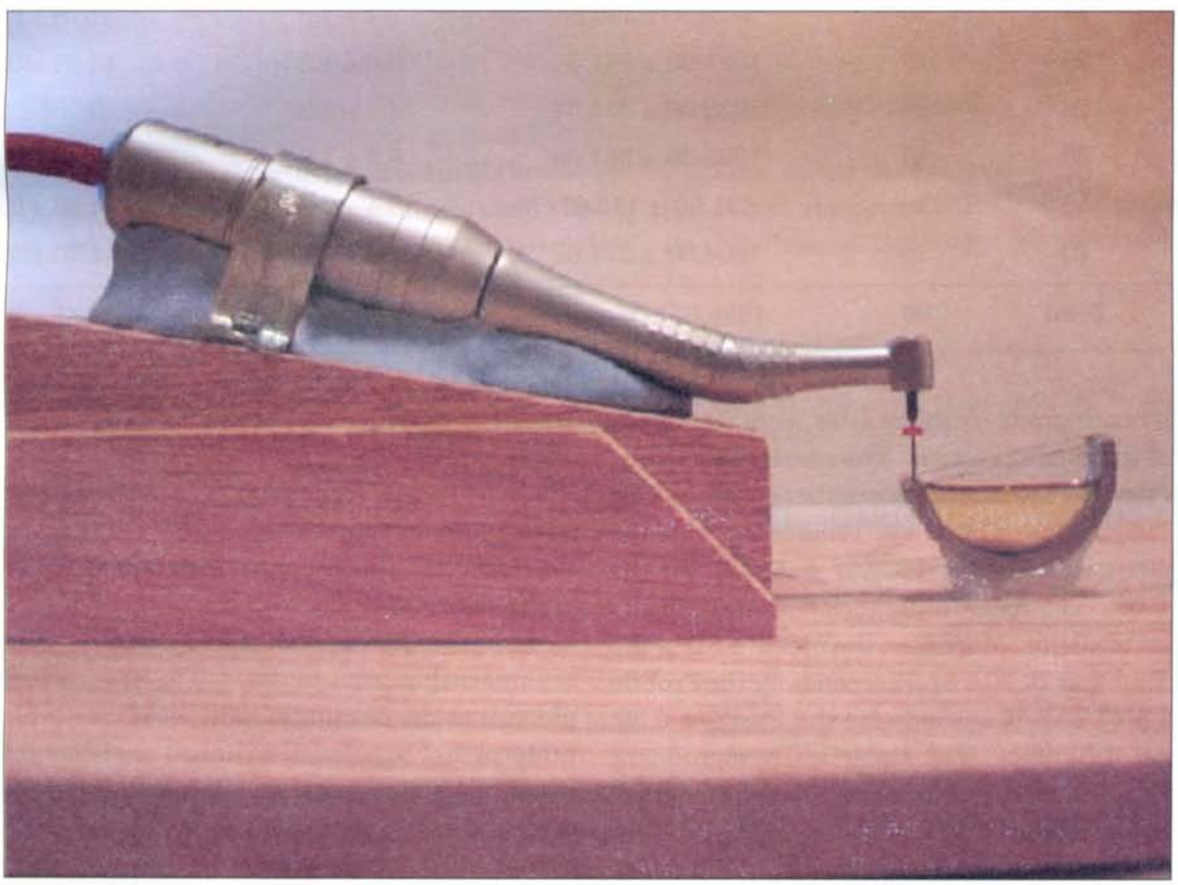

Fig. 2. Photograph of the testing device.

TABLE I: RELATION BETWEEN THE TAPER (0.04) AND SIZE OF THE PROFILE WITH MEAN ± SD OF NUMBER OF REVOLUTIONS OF CYCLIC FATIGUE, FRACTURE TIME (SECONDS) UNTIL SEPARATION, AND LENGTH (MM) OF SEPARATED PIECES

Taper	Size	No.	Revolutions (Mean ± SD)	Fracture Time(s) (Mean ± SD)	Length (Mean ± SD)
0.04	15	10	26162.00 ± 7836.65	87.2 + 26.1	1353 ± 4.25
	20	10	2396.00 ± 587.65	8.82 ± 4.7	16.00 ± 0.0
	25	10	2310.00 ± 908.36	3.8 ± 2.5	16.00 ± 0.0
	30	10	2643.00 ± 1409.20	7.9 ± 1.9	15.61 ± 0.85
	35	10	2651.50 ± 746.64	7.7 ± 3.0	15.17 ± 0.69
	40	10	1469.00 ± 450.19	4.9 ± 1.5	15.47 ± 0.36
	Total		6271.92 ± 9517.83	20.90 ± 31.7	15.30 ± 1.92

TABLE II: RELATION BETWEEN THE TAPER (0.06) AND SIZE OF THE PROFILE WITH MEAN ± SD OF NUMBER OF REVOLUTIONS OF CYCLIC FATIGUE, FRACTURE TIME (SECONDS) UNTIL SEPARATION, AND LENGTH (MM) OF SEPARATED PIECES

Taper	Size	No.	Revolutions (Mean ± SD)	Fracture Time(s) (Mean ± SD)	Length (Mean ± SD)
0.06	15	10	2213.00 ± 398.85	7.4 + 1.3	15.07± 1.49
	20	10	1881.00 ± 542.54	6.6 ± 1.3	14.31 ± 0.84
	25	10	1922.00 ± 353.54	6.4 ± 1.2	13.12 ± 1.0
	30	10	1996.50 ± 381.88	6.3 ± 1.8	14.69 ± 0.84
	35	10	821.50 ± 175.67	3.4 ± 0.9	14.56 ± 0.45
	40	10	1004.00 ± 277.62	2.7 ± 0.6	14.70 ± 0.53
	Total	60	1639.67 ± 639.97	5.5 ± 2.1	14.42 ± 0.94

all sizes of both group, fracture sites were close from the end of the cutting section. The result collectively, revealed that the mean ± SD of number of revolutions of cyclic fatigue was 6271.92 ± 9517.83 to separate the ProFiles 0.04 while it was 1639.67 ± 639.97 for the ProFile 0.06. The mean difference was statistically significant ($P<0.05$). Moreover, the mean ± SD of the fracture time was 20.90 ± 31.72 seconds for the ProFile 0.04 and 5.47 ± 2.10 seconds for the ProFiles 0.06. The mean difference was statistically significant ($P<0.001$). Additionally, the mean ± SD of the length of separated pieces was 15.30 ± 1.92 mm for the ProFiles 0.04 while it was 14.76 ± 0.94 mm for the ProFiles 0.06. The mean difference was statistically significant ($P<0.001$).

DISCUSSION

Instrument separation is a serious concern in endodontic therapy. The current study investigated the relationship between the different tapers and sizes of the rotary ProFiles with the number of revolutions of cyclic fatigue as well as the rotation time until separation has been occurred. The length of separated pieces was also calculated. This needs to develop a test protocol that simulate the clinical conditions of curved canal instrumentation and subsequently required to design a test apparatus which has been described earlier. The slope surface of the new device was polished adequately and lubricated with oil to reduce the thermal effect of frictional stress as well as to minimize the heat build up. This also may reduce the thermal effect of frictional stress. However, some investigators used sodium hypochlorite with natural teeth[7,17,18] while others used cold air spray to reduce the temperature[10,15]. The new device of the current study seemed to be practically efficient and support the results obtained by other investigators who evaluated the cyclic fatigue of different NiTi files at different rotational speed using highly polished sloped metal blocks that simulated curved canals[10,12,13,15,16,19] However, some workers used human teeth[7,17,18] while others used the resin blocks[11,14] indicating the lack of agreement in methodology.

Tables I and II revealed that the number of revolutions needed to separate 0.04 ProFiles was significantly greater than that of 0.06 ProFiles. This finding may be due to that the smaller diameter files are more flexible and resist fracture more than the larger diameter files. This result was similar to that reported by some investigators who stated that the nickel-titanium instruments with large diameter failed after significantly fewer cycles than did smaller diameter instruments under identical test conditions[10,16]. This finding of our investigation confirmed that instrument life span is inversely proportional to instrument size and that metal fatigue is deeply implicated in file breakage. Furthermore, larger diameter instruments had a lower fatigue life and decreased fracture time than the smaller diameter ones. Therefore, larger diameter instruments should not be considered safer or stronger in clinical practice and confirming those previous data demonstrated by other studies[10,20] Haikel et al.[10] added that the radius of curvature was also found to be a significant factor in determining the fatigue resistance of the file. As radius of curvature decreased, fracture time decreased.

It is logically that separation time was significantly increased (P<0.05) with ProFile 0.04 when compared to that of ProFile 0.06. This finding was similar to that shown by many workers[13,17]. They added that the time of failure significantly decreased as the rotational speed increased where they made their ProFiles to rotate freely in shaped metal blocks at different speeds up to 400 rpm.

In the present study, all the ProFiles (0.04 or 0.06) were separated approximately near the end of the cutting section. This area may represent a weak point of such file design. Different findings were demonstrated by other investigators[17]. They showed that most separation or distortions occurred in the apical 5 mm of the ProFiles, particularly the apical 1 to 3 mm. This discrepancy may be due to they used human teeth and different rotational speed. Others[16] revealed that all the instruments did separate at the flexure of the shaft, corresponding to the midpoint of curvature within the guide tube. These dissimilar findings may be attributed to that they used different file design which was LightSpeed instruments and used different rotational speed with different curved stainless-steel guide tube.

CONCLUSION

The use of the ProFile 0.04 and 0.06 taper must be accompanied with extreme caution, sudden unexpected separation of files should be expected especially in curved canals, larger file sizes tend to separate faster than smaller ones. Clinician should adhere to manufacturer's instructions to minimizes these incidences

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