Failure of ProFile instruments used with air, high torque control, and low torque control motors

Ghassan Yared, DDS, MSc,[a] and Philippe Sleiman, DDS,[b] Toronto, Ontario, Canada, and Beirut, Lebanon

UNIVERSITY OF TORONTO AND LEBANESE UNIVERSITY

Objective. The purpose of this study was to evaluate the influence of 350-rpm rotational speed on the failure incidence of *P*roFile nickel-titanium *r*otary *i*nstruments (PRI) when used by an experienced operator in conjunction with different motors.
Study design. Extracted human mandibular and maxillary first and second molars demonstrating curvatures greater than 25° were used. PRI sizes 40 to 15 and with 0.06 taper were used in crown-down fashion at 350 rpm. In groups 1 through 4, air, high torque control, low torque control, and very low torque control motors were used, respectively. Each group included 30 canals. One set of PRI was used for each canal. Before each use the PRI set was sterilized by steam autoclave. The canals were enlarged until a size 25 PRI reached the working length. A 2.5 × magnification was used to check for instrument deformation after each passage. The number of deformed and separated instruments was recorded for the various experimental groups.
Results. Instrument deformation and separation did not occur in any of the 4 groups.
Conclusions. The results suggested that the use of PRI in conjunction with the different motors by an experienced operator in a crown-down manner at 350 rpm is safe.
(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;93:92-6)

Instrument separation and deformation are serious concerns in root canal treatment. During shaping, instruments might lock or thread (screw) into the canal. Locked instruments are subjected to high levels of stress, frequently leading to separation. Several studies have evaluated the influence of various factors on the fatigue life and resulting separation of endodontic nickel-titanium (Ni-Ti) alloy instruments. In 1 study, Pruett et al[1] investigated the effect of the angle and radius of curvature on cyclic fatigue of Lightspeed rotary Ni-Ti instruments (Lightspeed Technologies, Inc, San Antonio, Tex). Ramirez-Salomon et al[2] evaluated the incidence of the Lightspeed separation. Thompson and Dummer[3,4] and Bryant et al[5] demonstrated that the incidence of Ni-Ti rotary instrument deformation and separation was related to instrument design and instrumentation technique.

The influence of operator experience was assessed in 3 studies that showed proper tuition or experience was necessary to minimize the incidence of instrument separation.[6-8]

[a]Assistant Professor, Director, Undergraduate Program of Endodontics, Department of Endodontics, Faculty of Dentistry, University of Toronto, Ontario, Canada.

[b]Instructor, Department of Endodontics, Faculty of Dentistry, Lebanese University, Beirut, Lebanon.

Received for publication Mar 22, 2001; returned for revision May 24, 2001; accepted for publication Jun 13, 2001.

1079-2104/2002/$35.00 + 0 **7/15/118095**

doi:10.1067/moe.2002.118095

Pruett et al[1] found that the rotational speed did not affect cyclic fatigue of Lightspeed instruments. Yared et al[8] and Gabel et al[9] demonstrated that Ni-Ti rotary instrument failures are less likely to occur at a lower rotational speed.

Torque is another parameter that might influence the incidence of instrument deformation and separation. Different types of motors are used in conjunction with Ni-Ti instrumentation. When a high torque control motor is used, the instrument is very active and the incidence of instrument locking and, consequently, deformation and separation would tend to increase. With these motors, torque at failure of the instrument is often exceeded. Air motors do not allow torque control, and variation in air pressure could affect the rotational speed and, consequently, torque. For instance, a drop in air pressure would lead to a decrease of torque. The instrument would become less active, and the operator would tend to force the instrument into the canal, leading to deformation and separation. Recently, a generation of low and very low torque control motors has been introduced; torque values as low as 1 and 0 Ncm can be set on the low and very low torque control motors, respectively. These motors take into consideration the low torque at failure values of Ni-Ti rotary instruments. Wolcott and Himel[10] showed that torque values at fracture for 0.04 taper *P*roFile nickel-titanium *r*otary *i*nstrument (PRI; Tulsa Dentsply, Oklahoma) sizes 15, 25, and 35 were 0.21, 0.48, and 1.24 Ncm, respectively. According to Kobayashi et al,[11] torque should be set between 0.40 to 0.80 Ncm for PRI to avoid instrument failure. Svec and Powers[12] compared the torque at failure values of used and unused PRI and showed that torque at failure was 0.78, 1.06, and 1.47 Ncm for unused 0.04 taper PRI sizes 25, 30, and 35, respectively. Recently, Bortnick et al[13] demonstrated no significant difference in instrument deformation and breakage between air and high torque control motors. They used the Ni-Ti rotary instruments at 150 and 170 rpm. Yared et al[14] evaluated in vitro the failure incidence of 0.06 taper PRI when used at 170 rpm in conjunction with different motors and a specific instrumentation technique. Their results indicated no difference among the air, high torque control, and low torque control motors. In their study an experienced operator performed the canal preparation. Yet, it should be noted that the use of a slow speed could have masked any differences among the motors.[8,9] The use of very low torque control motors may minimize the high incidence of PRI separation when used at 350 rpm.

The purpose of this study was to evaluate the influence of 350-rpm rotational speed on the failure incidence of PRIs when used by an experienced operator in conjunction with air, high torque control, low torque control, and very low torque control motors.

MATERIAL AND METHODS

The methodology of this study was similar to that of Yared et al.[8,14,15] Extracted human mandibular and maxillary first and second molars with mature apices and demonstrating curvatures greater than 25° were used[16]; the teeth were kept in 10% formalin at 37°C. Access openings were made, the canal orifices were located, and the cavity was irrigated with 2.5% NaOCl. Patency of the canals was determined with a size 6 K-type file (Dentsply/Maillefer, Ballaigues, Switzerland). Only canals having a snug fit with an 8 or 10 K-type file were included. The snugness indicated that the canal was narrow and suitable for inclusion in the study. The working length of each canal was determined by passing a size 6 K-type file to the apical foramen and then subtracting 0.5 mm. Working length and reference points were recorded for each canal. Initial radiographs were taken from the buccal and proximal directions, and exposure time and processing were standardized. The radiographs were used to detect canals that joined each other. In these cases only 1 canal was included in the study. The angle of curvature and the radius of curvature were determined on the initial buccal radiograph by using the method of Pruett et al.[1] Canals were ordered according to radius of curvature (least to greatest) and then randomly and blindly assigned to 4 groups, such that all ranges of radii of curvature were equally represented in each group, and such that each group included 30 canals. One canal was assigned to each of the 4 groups, starting with one group (ie, group order: 1, 2, 3, and 4); then this procedure was repeated starting with a different group (ie, group order: 2, 3, 4, and 1); and so on (same procedure repeated 30 times) until the 120 canals were assigned to the 4 groups.

In the 4 groups, 25-mm-long PRI with 0.06 taper sizes 40 to 15 were used in a crown-down technique sequentially in descending order of size. Within each group the rotational speed was set at 350 rpm. In group 1 the PRIs were placed in a Micro-Mega 324 air motor (Besancon, France) with contra-angle (6:1) reduction, set at approximately 350 rpm (333.33 rpm). Placing the contra-angle of the air motor on the "Turtle" setting and placing the indicator on 2000 determined the speed. Air pressure at full rheostat depression was 40 psi. In group 2 the PRIs were used in a handpiece in conjunction with a high torque motor (Nouvag TC 3000; Nouvag, Goldach, Switzerland). The torque on this motor was set at 10 Ncm. This motor allows setting torque at very high levels varying from 10 to 55 Ncm. In group 3 the PRIs were used with a low torque motor (Nouvag Micromotor TCM Endo 2) that allowed low torque values (settings 1, 1.5, 2, and 3). According to the manufacturer, these settings correspond to torque values of 1, 1.5, 2, and 3 Ncm, with a range between 1 and approximately 12 Ncm (corresponding to setting ∞). This motor had an auto torque reverse function. In group 4 the PRIs were used with a new generation, very low torque control motor (Tecnika, ATR, Pistoia, Italy). This motor allowed setting very low torque values (less than 1 Ncm). It also has an auto torque reverse function. This motor was used with the torque values set by the manufacturer.

The series of PRIs were used according to the following guidelines: The apical pressure exerted on the PRI was light and each instrument was used for only a few seconds in the canal; the PRIs were used with small in-and-out movements. Only 1 buccal canal was prepared in each molar. After the first sequence of PRI, the apical width of the canal was checked with a size 15 file. At this stage, canals were excluded from the study if the size 15 file reached the working length and was loose in the canal. The canals were then enlarged until a size 25 PRI reached the working length. Three to 5 recapitulations (waves) with PRI sizes 40 to 15 were required to complete the cleaning and shaping of each canal. Preparation was complete when a 1-1 Machtou plugger (International Standards Organization size 50; Dentsply Maillefer, Ballaigues, Switzerland) penetrated to 5 to 7 mm short of the working length, and a nonstandardized fine-medium gutta-percha cone fitted 0.5 mm short of the working length. During shaping, each canal was irrigated with 5 mL of 2.5% NaOCl by using a 5/8-inch 27-gauge

Table I. Mean and SD of the angle and radius of curvature of the 4 experimental groups

	Group 1	*Group 2*	*Group 3*	*Group 4*
Angle of curvature (degrees)	36.9 ± 1.70	37.82 ± 1.28	35.51 ± 1.41	38.09 ± 1.63
Radius of curvature (millimeters)	7.28 ± 0.37	6.81 ± 0.29	6.79 ± 0.20	6.98 ± 0.27

needle placed as far into the canal as possible without binding. The patency of the apical foramen was frequently checked by passing the tip of a size 8 K-type file through the foramen. Before each use, the PRI set (kit) was sterilized by steam autoclave for 5 minutes at 135°C; the whole cycle of sterilization lasted 35 minutes. One set of PRI sizes 40 to 15 was used for each canal. Thirty sets of 6 PRI taper 0.06 were included in each of the 4 groups. A 2.5× magnification was used to check for instrument deformation after each passage. An operator (G.Y.) blinded to the study performed the instrument inspection. When in doubt, the operator used brand-new and deformed (unwound) instruments of the same size and taper as controls. Instrument deformation and separation within each group were recorded. In a case of instrument deformation before the completion of the cleaning and shaping, the instrument was replaced. In a case of instrument separation, the cleaning and shaping were stopped. Before instrumentation of the canals, each set of PRIs was used according to the sequence determined by an endodontist experienced with the instrumentation technique who prepared 5 curved canals in endodontic resin blocks. Each set was then blindly assigned to 1 of the 3 groups if all the instruments did not show any deformation or separation. The same operator performed the cleaning and shaping procedures in all canals of the 4 groups. The canals in group 4 were prepared first, followed by the canals in groups 3, 2, and 1.

RESULTS

The mean and SD of the curvature angle and radius of the 4 groups are listed in Table I. Instrument deformation and separation did not occur in any of the 4 groups.

DISCUSSION

Torque is one among many parameters that might influence the incidence of instrument locking, deformation, and separation. Theoretically, an instrument used with a high torque (motor) is very active, and the incidence of instrument locking and, consequently, deformation and separation would tend to increase. Whereas a low torque would reduce the cutting efficiency of the instrument and instrument progression in the canal would be difficult, the operator would then tend to force the instrument and may encourage instrument locking, deformation, and separation. Torque control motors allow the setting of torque generated by the motor. In low torque control motors, torque values set on the motor are supposed to be less than the value of torque at deformation and at separation of the rotary instruments. In high torque control motors, the torque values are relatively high compared with the torque at deformation and at separation of the rotary instruments. During root canal preparation all the instruments are subjected to different levels of torque. If the level of torque is equal to or greater than the torque at deformation or at separation, the instrument will either deform or separate. Theoretically, with the low torque control motors, the motor will stop from rotating and can even reverse the direction of rotation when the instrument is subjected to torque levels equal to the torque value set on the motor. Thus, instrument failure would be avoided. With high torque control motors, the instrument torque at deformation and at separation would be reached before the relatively high torque value set on the motor. Consequently, the instrument would deform and separate. However, the results of a recent study did not indicate a difference between high and low torque motors with respect to instrument failure.[14] In that study an experienced operator used the PRI at 150 rpm.

This is the first comprehensive study that evaluated the incidence of Ni-Ti rotary instrument failures when used at 350 rpm in conjunction with different types of motors.

We had the impression that it would be more interesting to compare the motors by using used ProFile. Differences in the incidence of instrument locking, deformation, and separation among the different motors could have been masked if new instruments were used in each canal. For this reason, each set was used in resin blocks according to the described technique and by the same operator.

In the present study, apical enlargement was kept as small as practical according to the principles of Schilder[17] and because, in our opinion, any greater apical enlargement should have been completed with hand instruments.

As in recent studies,[8,14,15,18] it was impossible to standardize the number of recapitulations (waves). Canal width and anatomy influenced the frequency of recapitulations needed before a size 25 PRI reached the working length. However, 3 to 5 recapitulations were sufficient for all the canals.

The instruments were inspected for deformation with 2.5× magnification after each passage in the canal. In a previous study[18] we noted that deformations went undetected if magnification was not used. The use of a dental operating microscope, where available, might decrease the incidence of false-negatives (undetected deformations).

The manufacturer recommends using the ProFile instruments at speeds between 150 and 350 rpm. The rotational speed was set at 350 rpm. Previous studies have shown significantly less Ni-Ti rotary instrument failures at slower speeds.[8,9] Yet, it should be noted that the use of a slow speed could have masked any differences among the motors. In these studies, low and very low torque control motors were not used.

The torque value (10 Ncm) set on the motor of the second group was the lowest allowed by this motor. In the third group the torque value was set at 2 Ncm. This motor allowed different low torque settings (1, 1.5, 2, and 3 Ncm). In a pilot study we noticed that at settings equal to or lower than 1.5 Ncm, the rotation of the files was frequently reversed. With the air motor, torque control was not possible.

Wolcott and Himel[10] showed that torque at fracture for 0.04 taper ProFile sizes 15, 25, and 35 were 0.21, 0.48, and 1.24 Ncm, respectively. In laboratory experiments, Kobayashi et al[11] indicated that the torque threshold for the auto torque reverse mechanism in the Tri Auto ZX (Morita, Kyoto, Japan) for PRI taper 4% should be set between 0.39 and 0.78 Ncm. Svec and Powers[12] showed that torque at failure was 0.78, 1.06, and 1.47 Ncm for unused 0.04 taper PRI sizes 25, 30, and 35, respectively. Consequently, it was not expected that deformation and separation would not occur in the present study, especially with the air, high torque control, and low torque control motors. With the air motor, torque control was not available and instruments could have been subjected during instrumentation to torque levels exceeding their torque at failure values. In addition, with the air motor, the rotational speed might not be constant; a sudden increase in the speed (because of air pressure variation) would result in a rapid increase of the torque to which the instrument was subjected,[11] leading to instrument failure. In groups 2 and 3 the torque setting on the motors was relatively high (10 and 2 Ncm, respectively).[10-12] The fact that instrument deformation and separation did not occur in any of the groups could only be related to the applied instrumentation technique. Sattapan et al[19] showed that torque at failure was significantly higher than torque during instrumentation. In the present study the instruments were used with a slight apical pumping as in the study of Sattapan et al[19]; thus, it seems that torque during instrumentation by an experienced operator could have been lower in the 4 groups than the torque at failure of the specific instruments.

In a recent study a high incidence of instrument deformation and separation occurred during the preparation of canals with PRI by using air, high torque control, and low torque control motors.[15] The operator probably exerted excess apical pressure on the PRI[11] or used them for too long in the canal, or both. Consequently, these PRIs locked into the canal and were subjected to a high level of torque; failure occurred instantly. The instruments were subjected to torque greater than their torque at fracture.[10,12] The same operator performed the instrumentation procedures in the present study and in the study of Yared et al.[15] The difference in the experience of the operators[8] and the learning curve[7] would also account for the difference in the results between the present study and that of Yared et al.[15]

Bortnick et al[13] showed a trend toward deformation with the smaller instruments. The results of the present study did not confirm their results.

CONCLUSIONS

The results of the present study suggested that the air, high torque control, and low torque control motors were as safe as the very low torque control motor when PRI taper 6% was used in crown-down fashion at 350 rpm and according to specific guidelines.

REFERENCES

1. Pruett JP, Clement DJ, Carnes DL. Cyclic fatigue of nickel-titanium endodontic instruments. J Endod 1997;23:77-85.
2. Ramirez-Salomon D, Soler-Bientz R, de la Garza-Gonzàlez R, Palacios-Garza CM. Incidence of Lightspeed separation and the potential for bypassing. J Endod 1997;23:586-7.
3. Thompson SA, Dummer PMH. Shaping ability of ProFile 0.04 taper Series 29 rotary nickel-titanium instruments in simulated root canals. Part 2. Int Endod J 1997;30:5-15.
4. Thompson SA, Dummer PMH. Shaping ability of Quantec Series 2000 rotary nickel-titanium instruments in simulated root canals. Part 1. Int Endod J 1998;31:259-67.
5. Bryant ST, Thompson SA, Al-Omari MAO, Dummer PMH. Shaping ability of ProFile rotary nickel-titanium instruments with ISO sized tips in simulated root canals. Part 1. Int Endod J 1998;31:275-81.
6. Barbakow F, Lutz F. The Lightspeed preparation technique evaluated by Swiss clinicians after attending continuing education courses. Int Endod J 1997;30:46-50.
7. Mandel E, Adib-Yazdi M, Benhamou L-M, Lachkar T, Mesgouez T, Sobel M. Rotary Ni-Ti ProFile systems for preparing curved canals in resin blocks: influence of operator on instrument breakage. Int Endod J 1999;32:436-43.
8. Yared G, Bou Dagher F, Machtou P. Influence of rotational speed, torque, and operator's proficiency on ProFile failures. Int Endod J 2001;34:47-53.
9. Gabel WP, Hoen M, Steiman HR, Pink FE, Dietz R. Effect of rotational speed on nickel-titanium file distortion. J Endod 1999;25:752-4.
10. Wolcott J, Himel VT. Torsional properties of nickel-titanium versus stainless steel endodontic files. J Endod 1997;23:217-20.
11. Kobayashi C, Yoshioka T, Suda H. A new engine-driven canal preparation system with electronic canal measuring capability. J Endod 1997;23:751-4.

12. Svec TA, Powers JM. Effects of simulated clinical conditions on nickel-titanium rotary files. J Endod 1999;25:759-60.
13. Bortnick KL, Steiman HR, Ruskin A. Comparison of nickel-titanium file distortion using electric and air-driven handpieces. J Endod 2001;27:57-9.
14. Yared G, Bou Dagher F, Machtou P. Failure of ProFile instruments used with high and low torque motors. Int Endod J 2001;34:471-5.
15. Yared G, Bou Dagher F, Machtou P. Cyclic fatigue of ProFile rotary instruments after simulated clinical use. Int Endod J 1999;32:115-9.
16. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg 1972;32:271-5.
17. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269-96.
18. Yared G, Bou Dagher F, Machtou P. Cyclic fatigue of ProFile rotary instruments after clinical use. Int Endod J 2000;33:204-7.
19. Sattapan B, Palamara JEA, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod 2000;26:156-60.

Reprint requests:

Ghassan Yared, DDS, MSc
Department of Endodontics (Room 348)
Faculty of Dentistry
University of Toronto
Toronto, ON M5G 1G6
Canada