INFLUENCE OF AXIAL MOVEMENT ON FATIGUE OF PROFILE® NI-TI ROTARY INSTRUMENTS: AN IN VITRO EVALUATION

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Abstract

The aim of this study was to evaluate the influence of the axial movement and the angle of curve (in degrees) on fatigue of nickel-titanium (Ni-Ti) ProFile® rotary endodontic instruments.
Ni-Ti ProFile® rotary instruments (Maillefer SA, Ballaigues, Switzerland), 25 mm long in the range of ISO size 15 to 40 with two tapers (0.4 and 0.6) were evaluated. They are divided in two groups: the instruments with axial movement and those without axial movement. The system used to test the fatigue is maintained in mechanical conditions as close as possible to the clinical situation. The axial movement is in the order of 2mm in corono-apical direction with a frequency of 1Hz. The concave radii incorporating a notched V-form for guiding the instruments were: 5; 7,5 and 10 mm. The rotary system is mounted on an electric handpiece and rotated at 350 rpm speed as recommended by the manufacturers. The instruments are rotated until their separation, and the time, in seconds, is recorded. Statistical evaluation is undertaken using a two-way t-test to identify significant differences between variables in the study ($p < 0{,}05$).
We found significant statistical difference ($p<0{,}05$) between Ni-Ti engine drive ProFile® instruments incorporating an axial movement and the instruments without axial movement with the same radius of curvature, size and taper.
The incorporation of the axial movement increases significantly the life-span of the ProFile® rotary instruments. This should reduce the risk of the instrument separation during the endodontic treatment.

KEY WORDS: axial movement, fatigue, instrument separation, life-span, Ni-Ti instruments, simulated canals.

Introduction

The cleaning and the shaping of root canals are two of the most important phases in endodontic therapy. Total debridement of infected or contaminated pulpal tissue and dentin achieves the first phase, and developing a continuous tapering conical form, keeping the original shape of the canal and positioning of the apical foramen achieves the second (1). Mechanical preparations of the curved root canals represent a particular problem to the endodontic practitioner. Inadvertent errors such as ledging and zip formation occur occasionally, and alter the root canal morphology. These situations disrupt the adequate sealing of the conducts and therefore considerably affect the treatment prognosis (2). In addition, fracture or separation of the instruments, files and reamers, in the canal is a serious concern in endodontics (3). Recently, Nickel-Titanium (Ni-Ti) endodontic instruments have been introduced to minimize these complications. These instruments were initially introduced by Walia et al. (4), who evaluated their bending and torsional properties compared to K-type files. The Ni-Ti files showed superior flexibility in bending, and great resistance to torsional fracture due to a very low modulus of elasticity (~30 versus ~200 GPa for stainless steel alloys). Ni-Ti is classified as a super-elastic alloy (4,5). These instruments are able to flex far more than stainless steel (SS) before exceeding their elastic limits and allow preparation of curved canals while minimizing root canal transportation (6). A number of studies have been conducted evaluating Ni-Ti files (7,8,9) as described by ISO (International Standards Organization 1992) specifications (10) and ANSI/ADA (American National Standards Institute / American Dental Association) specification No. 28 (11). Rowan et al. (9) compared the torsional fracture of Ni-Ti and SS files in clockwise and anticlockwise rotation, concluding that the necessary force to cause fracture was similar for both alloys and in both directions. The recent development of engine-driving rotary endodontic instruments of non standardized shape and variable size and taper necessitates further testing for cyclic fatigue. The rotation of endodontic instruments subjects them to both tensile and compressive forces in the area of curvature of the canal with tensile forces on the outside of the canal curvature and compressive on the inside. This is of particular concern with respect to instrument failure. Pruett et al. (12) indicated in their study that the continuous cycle of tensile and compressive forces with engine-drive instruments produces a very destructive form of loading. Recently, after analysed several devices that have been used in endodontic literature for cyclic fatigue testing, Plotino et al. (13) found that differences in the methodology affected the fatigue behavior of rotary instruments. Likewise, Parashos et al. (14) showed that factors related to clinician experience, technique, and competence have been indicated to be influential. However, these works did not show the effect of the axial movement during the preparation of the canals. The present study is aimed to evaluate the influence of the axial movement and angle of the curve (in degrees) on the separation of Profile® Ni-Ti endodontic instruments taper 0.4 and 0.6. The relationship between the size of the instrument and the angle of curvature with the axial movement at the fracture is also investigated.

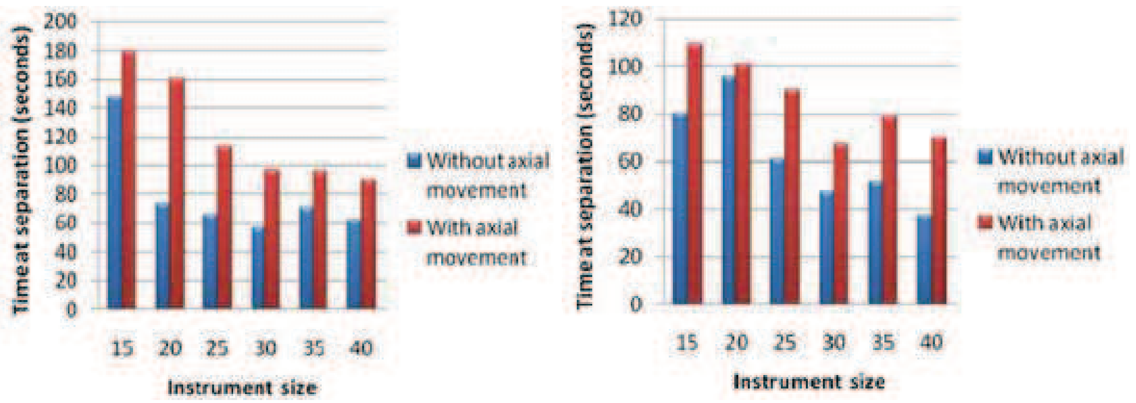
Materials and Methods

Endodontic instruments

Ni-Ti ProFile® rotary instruments (Maillefer SA, Ballaigues, Switzerland), 25 mm long, ISO size 15 to 40, two tapers .04 and .06 were evaluated. Twenty new instruments, randomly selected of each size and taper were tested with three radii sizes. To evaluate the influence of the axial movement on separation, a total of 720 Ni-Ti endodontic instruments were used in this study. They are divided in two groups: (a) the instruments with axial movement and (b) those without axial movement.

Experimental method

Based on a previous work of Haïkel et al. (15,16) the same fatigue test system was used, by maintaining conditions as close as possible to the clinical situation. This test system comprises two main parts: a dental handpiece (WH 975 AE 500 Reduction 20/1, Dental Work, Burmoos, Austria) mounted in a support block. The support block is independent of the rest of the device and is mounted on an electronically controlled table (SELEDATA SM 512C Selection, Lyss, Switzerland) to allow an easy position of the instrument. The shaping block is fixed and consists of a concave-tempered steel radius and a convex-tempered steel cylinder which standardizes the angle of the curve. The concave radius incorporates a notched V-form for guiding the instruments and came in three radius sizes: 5, 7,5 and 10 mm. The instruments are mounted in the handpiece and rotated at 350 rpm speed as recommended by the manufacturer. The files are cooled under a cold air spray during the experiment to prevent overheating and subsequent alteration of the Ni-Ti alloy structure. The files are then guided into the V-notch of the radius and rotated until fracture. The axial movement



a) b)

FIGURE 1. Results obtained with instruments with taper .04 (Figure 1a) and taper .06 (Figure 1b): At 5mm radius of curvature, the time of separation of instruments with taper .04 is longer than that of instruments with .06

is of the order of 2mm in corono-apical direction with a frequency of 1Hz. The separation time was recorded at the instrument fracture time (1/100 s chronometer). The position of the fracture along the length of the instruments is measured using calipers with 0,02 mm increments. A statistical evaluation was then undertaken with two-way t-test to identify significant differences between variables in the study ($p<0,05$).

RESULTS

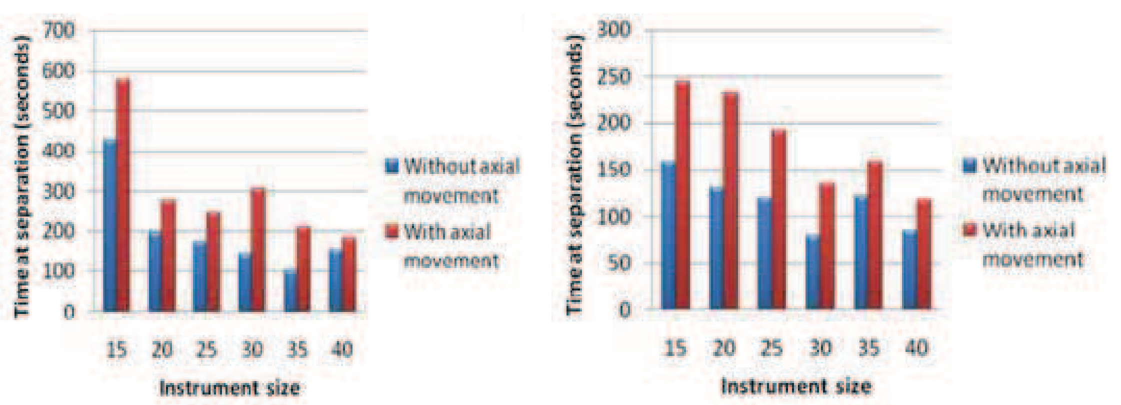
Individual results for cyclic fatigue of instruments with and without axial movement at different radius of curvature and instruments with .04 and .06 taper are displayed in Figures 1 to 3.

Comparison between groups:

Fatigue of instruments with taper .04 with or without axial movement in canals with 5mm radius presents significant statistical differences ($p<0,05$). A similar result is observed for instruments with taper .06 except in the case of size 20 instrument. The average life span increased to 54% while for taper .06 it is increased to 38% when axial movement was applied. For canals with 7,5 mm radius the separation time for all the files tested was significantly greater when axial movement was applied. The life span increased to 50% for the instruments with taper 0.04 and to 55% for instruments with taper .06. Finally, for instruments used in canals with 10mm radius, statistical differences ($p<0,05$) were observed between instruments with taper .04, size 20, 30 and 40 and with taper .06, size 15, 20 and 40, with and without axial movement. A life span increase to 14% for instruments .04 and to 36% for instruments .06 was found.

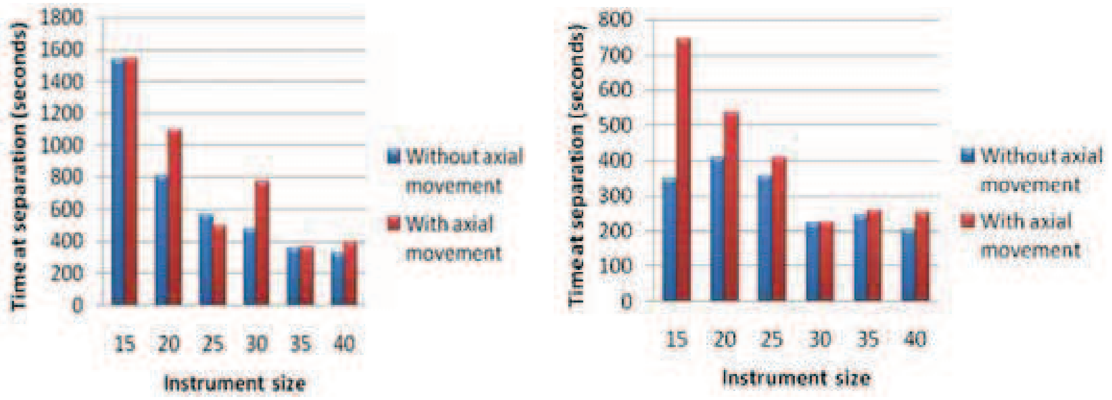
Instrument size and taper:

For each group we observed a statistical difference ($p<0,05$) in the fatigue between the instruments with and without axial movement. In general the resistance to fracture decreases when the instrument size increases due to the decrease of (in)



a) b)

FIGURE 2. Results obtained with instruments with taper .04 (Figure 2a) and taper .06 (Figure 2b) at 7,5 mm radius of curvature. The time of separation increases with respect to the same instruments than at 5 mm of radius of curvature.



a) b)

FIGURE 3. Results obtained for instruments with taper .04 (Figure 3a) and taper .06 (Figure 3b) at 10mm radius of curvature. The time of separation of the instruments increases with respect to the same instruments than at 5mm and 7,5 mm of radius of curvature.

the flexibility. We observed also a decrease in the resistance to fracture when the taper increases for tapers .04 to .06 with and without axial movement.

Discussion

This study investigated the effect of axial movement on the cyclic fatigue life in two groups of ProFile® Ni-Ti endodontics instruments. As described by ANSI/ADA, specification No. 28, the instruments should be statistically loaded until failure (9,11). This is an inadequate method for engine-drive Ni-Ti files, due to their operation at certain speed of rotational movement before their insertion into the root canal. Cyclic fatigue plays an important role in instruments failure, and there is a clear need for the development of reliable test protocols in order to assess and define standards of fracture resistance acceptable for engine-drive Ni-Ti files (16). Canals were simulated with a device that guaranteed fixed radii of curvature. The radius of curvature is the radius of a circle that coincides with the path taken by the canal in the area of the most abrupt curvature. The instruments used in this study were operated at a constant speed of 350 rpm with an axial movement of 2mm in range and different radius of curvature (5; 7,5 and 10mm). Ni-Ti ProFile® endodontics instruments with .04 and .06 taper were investigated. In the present study, the effect of a 2mm axial movement in corono-apical direction on fatigue resistance was investigated. The incorporation of this axial movement significantly lengthens the life span of the instrument in canals with severe (5 mm) and moderate (7,5 mm) curvatures. With the axial movement of the engine driven file, the area of maximum stress is no longer concentrated in one area but is spread over the length of the instrument. Therefore, in this situation, it takes a longer time for any part of the instrument to pass its elastic module limit as the separation of the instrument occurs. Dederich and Zakariasen (17) observed a maximum increase in the life span of around 50% when the axial movement is incorporated into the engine drive file movement. We found similar results for the tested instruments. It has been determined previously that the curvature of the root canal is one of the most important factors influencing the instruments fatigue (17,18) and that the life-span increases when the root curvature decreases. In the present study three canal curvatures were applied for each group of instruments tested: severe 5mm in radius, moderate 7.5mm in radius and mild 10mm in radius. It was observed that the fracture of instruments of the same size occurs more quickly in canals with severe curvatures than in canals with moderate curvature. In addition, the life span of instruments used in canals with 10mm in radius, increases approximately three to five times (depending on the instrument, see results) compared with 7,5 mm and 5mm radius respectively. This increase is more significant for instruments used in canals with severe curvatures than in canals with less pronounced curvatures. In less curved canals, a greater length of the instrument is in contact with the walls, thus stress is better dissipated along the length of the file. The stress dissipation with the axial movement has a minimal influence. These findings suggest that the clinician should frequently dispose of these files, especially after the use in a severe curved canal. The instruments resistance to the fracture increases as the instrument taper decreases. Instruments with .06% taper have a severely diminished life time compared with .04 taper instruments. Also, we observed that the improvement of the life span due to the axial movement of small diameter files and .04 taper diminishes when the instrument size increases. The site of the fracture in most cases occurs in the tip of the instrument. In curved canals, the point of maximum curvature is closer to the apex and therefore, closer to the instrument tip. It is at this point that the most destructive stress of the cyclic fatigue acts in the file. For all of the instruments tested the separation occurs close to the domain of maximum curvature of the canal, which agrees with the results of Pruett et al. (12) showing that the separation should occur at the point of maximum curvature. Likewise, Grande et al. (19) and Inan et al. (18), found that the instruments volume at the point of maximum stress during a cycle test could affect their fatigue life because the larger the metal volume is, the lower the fatigue resistance. Thus, especially larger-size instruments should be used with great care in curved canals. The instruments used in this study were rotated at a constant speed of 350 rpm as recommended by the manufacturer. Dietz et al. (20) showed that at slower rotation speed, the separation of .04% taper Profile® endodontic instruments is less frequently occurring. However further research would be necessary to clear this fact. Moreover, as indicated by Plotino et al. (13), an international standard for cyclic fatigue testing of Ni-Ti rotary instruments is required to ensure uniformity of methodology and comparable results. In the meantime, clinical recommendations about endodontic therapy principles and those of the manufacturers have to be carefully followed to prevent endodontic instruments' fracture (14).

Conclusion

The results of the present study demonstrated that the incorporation of the axial movement into the Ni-Ti engine drive ProFile® files significantly increases the life span of the instruments when compared with the group without axial movement. This should reduce the risk of instrument separation during the treatment. However, further work on these Ni-Ti instruments is needed as well as new development testing standards.

List of Abbreviations

ISO - International Standards Organization

Ni-Ti - nickel-titan

Acknowledgment

The author's would like to thank Maillefer S.A. and Dentsply for their technical assistance.

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