Influence of the rotational speed on the cyclic fatigue resistance of the Logic rotary system

Murilo Priori **ALCALDE**[1]
Renan Diego **FURLAN**[1]
Rodrigo Ricci **VIVAN**[1]
Marco Antonio Hungaro **DUARTE**[1]

DOI: https://doi.org/10.14436/2358-2545.10.1.049-053.oar

ABSTRACT

Objective: The aim of this study was to evaluate the influence of rotational speed on the cyclic fatigue resistance of Logic 25.06 rotary instruments (LOG 25.06; Easy Equipamentos Odontológicos, Belo Horizonte, Brazil). **Methods:** 20 Logic 25.06 instruments were used (n=20). The cyclic fatigue test was performed in an artificial canal made of stainless steel with 60° of curvature and 5 mm of radius. The instruments were activated 950 and 550 rotations per minute (RPM) until the fracture occurred. The time (in seconds) and the number of cycles to fracture (NCF) were measured. The data were statistically analyzed using One-way ANOVA and Tukey Test, the level significance used was 5 %. **Results:** the 550 RPM promoted a significantly higher time and NCF of LOG 25.06 in comparison with 950 RPM (P>0.05). The time increased in 95.9% and the NCF 27.25%. **Conclusion:** The results of this study showed that the rotational speed had a significant influence on the cyclic fatigue resistance of the Logic 25.06 rotary instruments. The 550 RPM rotational speed seems to be safer than 950 RPM, increasing the cyclic fatigue resistance of Logic 25.06.

Keywords: Endodontics. Fatigue. Dental Instruments.

How to cite: Alcalde MP, Furlan RD, Vivan RR, Duarte MAH. Influence of the rotational speed on the cyclic fatigue resistance of the Logic rotary system. Dental Press Endod. 2020 Jan-Apr;10(1):49-53.
DOI: https://doi.org/10.14436/2358-2545.10.1.049-053.oar

[1] Universidade de São Paulo, Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Odontológicos (Bauru/SP, Brazil).

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

Submitted: September 26, 2018. Revised and accepted: September 30, 2018.

Contact address: Murilo Priori Alcalde
Rua Dr. Servio Tulio Carrijo Coube, nº 3-33, apto. 22B
Jardim Infante Dom Henrique - CEP: 17.012.632 – Bauru/SP
E-mail: murilo_alcalde@hotmail.com

© 2020 Dental Press Endodontics

Introduction

The Nickel-Titanium rotary instruments have been widely used for root canal preparation of curved canals because of the high flexibility, which favors centered root canal preparation with low risk of modification of root canal anatomy and low rate of instruments separation.[1,2]

The separation of rotary instruments can occur due to many causes, one of the most common causes is the cyclic fatigue[3]. Cyclic fatigue occurs by repeated compressive and tensile stress when the instrument rotates in a curved canal.[3] The cyclic fatigue of Nickel-Titanium rotary instruments can be influenced by instrument features (taper, cross-section, tip diameter, type of NiTi)[1-3] and the rotational speed[4-6]. It was previously reported that the greater rotational speed during root canal preparation could increase the rate of instrument separation.[5] This fact can be explained due to the greater rotational speed increases the compressive and tensile stress when the instrument rotates in a curved canal, favoring faster instrument fatigue.[4,6] In addition, the less operator experience can increase the risk of instrument separation.[5,6] Therefore, the association of inexperienced operators and higher rotational speed could increase the risk of instrument separation during root canal preparation.

Currently, the manufacturers have developed instruments with different designs (tapers, cross-section, and tip size) and thermal treatments of NiTi alloys to improve the mechanical properties and reduce the risks of instrument separation.[1,2,8,9] Since the development of thermally treated Nickel-Titanium rotary instruments, the manufacturers have been indicating greater rotational speed to use their instruments in comparison with instruments manufactured with conventional Nickel-Titanium. Some manufacturers have been proposing to use with 550 rotations per minute (RPM) or more. Considering the influence of rotational speed on the cyclic fatigue resistance of the Nickel-Titanium rotary instruments, it would be suitable to evaluate if the rotational speed indicated by the manufacturers are safe.

The Prodesign Logic rotary instruments (Logic (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) presenting a modified S-shaped cross-section design and are manufactured with specific thermal treatment based on the CM-Wire.[10] This system is composed by shaping files (25.06, 30.05, 35.05 and 40.05) and glide path files (25.01, 30.01, 35.01 and 40.01). The manufacturer proposes the use of one glide path file and shaping file with same tip diameter for root canal preparation.[10]According the manufacturer's instructions, the shaping files can be used at 950 RPM.[9]

In view of the influence of rotational speed on the cyclic fatigue resistance of rotary instruments, the aim of this study was to evaluate the cyclic fatigue resistance (time and number of cycles to fracture) of Logic 25.06 when activated at 950 and 550 RPM. The null hypothesis of this study: there would be no differences on the cyclic fatigue resistance of LOG 25.06 when used at different rotational speeds.

Material and Methods

Cyclic fatigue

A total of 20 Logic 25.06 rotary instruments were used to perform the cyclic fatigue test (n=20). Previously to the mechanical test, all instruments were inspected under a stereomicroscope (Carls Zeiss, LLC, USA) at 16x magnification to detect possible defects or deformities; none were discarded. All instruments used were 25-mm long, with 10 instruments of each group being used.

The static cyclic fatigue test was performed in a custom-made device that simulated an artificial canal made of stainless-steel, with a 60^0 angle of curvature and a 5-mm radius of curvature (Fig 1A), as previously described.[11] Both the arch and guide cylinder had a 1-mm-deep groove located 5 mm from the top, to match the height of the counter-angle. The groove served as a guide path for the instrument, which remained curved and free to rotate (Fig 1B).

The rotary instruments were activated by using a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) powered by a torque-controlled motor (Silver Reciproc, VDW). Ten instruments were used at 950 and 550 RPM for each group. To reduce the friction of the instrument as it came into contact with the artificial canal walls, a special high-flow synthetic oil prepared for the lubrification of mechanical parts (Super Oil, Singer Co Ltd, Eliza-

© 2020 Dental Press Endodontics

Figure 1. A) Representative image of the cyclic fatigue device used in this study. **B**) Representative image of the Logic 25.06 coupled on the cyclic fatigue device with 60° and 5 mm of radius of curvature.

bethport, NJ) was applied. The time to failure was recorded using a digital chronometer and video recording was made simultaneously to ensure the exact time of instrument fracture. The number of cycles to failure (NCF) was calculated using the following formula: time to failure (in seconds) X RPM/ 60.

Statistical analysis

The data normality was performed with the Shapiro-Wilk test, showing that the data were normally distributed. The One-way analysis of variance (ANOVA) and Turkey tests were used for multiple and individual comparisons. The level of significance was set at 5%.

Results

Table 1 shows results of the cyclic fatigue test in time and NCF of Logic 25.06 when activated at 950 and 550 RPM. The results of this study showed that the activation of Logic 25.06 at 550 RPM favored a significantly increase of time and NCF in comparison of 950 RPM ($P<0.05$). The results (in percentage) showed that there was an increase in 95.9% of time and 27.25 of NCF (Fig 2).

© 2020 Dental Press Endodontics

Table 1. Means and standard deviations of cyclic fatigue resistance (time and number of cycles) at different rotation speeds.

	Cyclic fatigue resistance			
	950 RPM		550 RPM	
LOG 25.06	Time (seconds)	Cycles	Time (seconds)	Cycles
	168,0 ± 45,99[a]	2,370±689,9[a]	329,2±115,5[b]	3,016±1,0[b]

Different superscript letters in the same column indicate statistical differences among groups (P < .05).

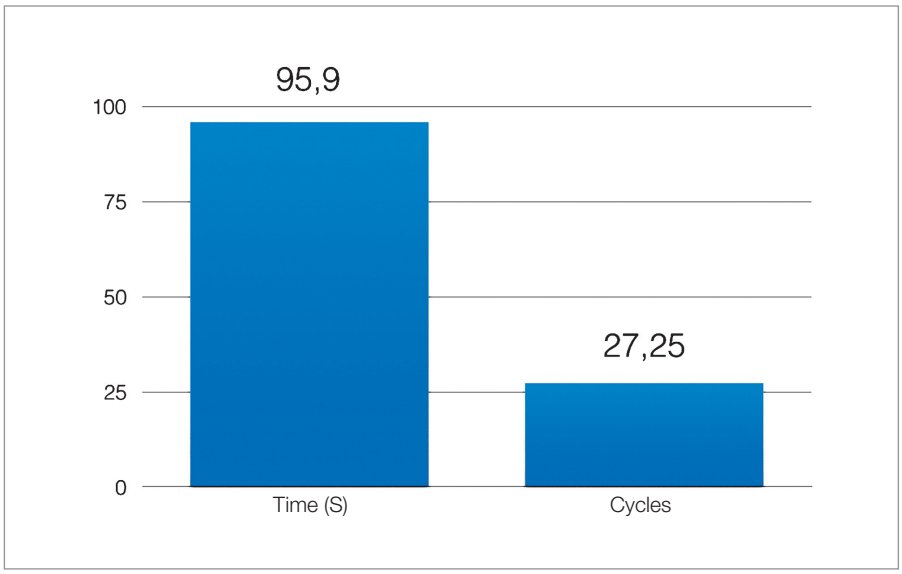

Figure 2. Representative graphic of the percentage of time and number of cycles to instrument separation using 550 RPM.

Discussion

Despite the manufacturers have been performed several modifications on the instrument's designs and on the NiTi properties with the aim to improve safety during root canal preparation, the instruments separation continues to be a concernment for the clinicians.[1,2,8,11]

Several factors can affect the cyclic fatigue resistance of the NiTi Rotary instruments, such as cross-sectional design, taper, tip diameter, rotational speed and thermal treatment of the NiTi.[1-5] Therefore, it is important to evaluate the mechanical properties of NiTi Rotary instrument, ensuring safety and efficient root canal preparation.

In this study, the static cyclic fatigue model was used, as previously reported.[11] Despite the dynamics model simulate the axial motion performed by the clinicians during root canal preparation, the static model reduces possible bias, such as the amplitude of axial movements and speed, which are completely subjective and in a clinical situation, their reproduction is unreliable because the axial motion is manually controlled.[12] In addition, the stainless steel artificial canal was previously used by several authors.[7-11]

The aim of this study was to evaluate the cyclic fatigue resistance (time in seconds and cycles) of the use Logic 25.06 at 950 and 550 RPM. The results of this study showed that the 550 RPM favored a significant increase of time and NCF in comparison to 950 RPM (P<0.05). Therefore, the null hypothesis were rejected. It is important to emphasize that the instruments used in this study present the same tip diameter, cross-sectional design, taper and type of thermal treatment. Therefore, the rotational speed was the only variable.

© 2020 Dental Press Endodontics

Some previous studies reported that the greater rotational speed on the cyclic fatigue test[4,6,7] and during root canal preparation[5] tend to reduce the cyclic fatigue resistance of the NiTi rotary instruments. The results of this study corroborate with these previous studies, showing that the rotation speed increases the mechanical stress, reducing the time and NCF.[4-6,13,14] In addition, the other factor that should be considered when a greater rotational speed is used is the instruments heating during the cyclic fatigue test. Despite the artificial canal ~~is~~ being lubricated with oil, the instruments heating always occur and this probably contributes to the instrument fatigue.[15] Therefore, the 550 RPM favored fewer instruments heating and mechanical stress, which could explain our results.

The results of this study were converted in percentage (Fig 2). The use of 550 RPM increases the time and number of cycles to fatigue in 95.9% and 27.25%, respectively. Clinically, the results of this study would ensure safer root canal preparation than 950 RPM, reducing the chance of instrument separation and increasing the lifespan of the LOG 25.06 rotary instruments. However, probably will occur less efficiency on the dentin cutting ability. Therefore, the clinician should evaluate the benefits and the risks to use the LOG 25.06 rotary instruments in a greater rotational speed during root canal preparation of curved canals.

Conclusion

The results of this showed that the rotational speed has significant influence on the cyclic fatigue of Logic 25.06 rotary instrument. The 550 RPM seems to be safe, increasing the time and number of cycles to instrument separation.

References

1. Gao Y, Gutmann JL, Wilkinson K, Maxwell R, Ammon D. Evaluation of the impact of raw materials on the fatigue and mechanical properties of ProFile Vortex rotary instruments. J Endod. 2012;38(3):398-401.
2. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod. 2013;39(2):163-72.
3. Sattapan B, Nervo GJ, Palamara JEA, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod. 2000;26(3):161-5.
4. Lopes HP, Ferreira AA, Elias CN, Moreira EJ, de Oliveira JC, Siqueira JF Jr. Influence of rotational speed on the cyclic fatigue of rotary nickel-titanium endodontic instruments. J Endod. 2009;35(7):1013-6.
5. Martín B, Zelada G, Valera P, Bahillo JG, Magán F, Ahn S, Rodrígues C. Factors influencing the fracture of nickel-titanium rotary instruments. Int Endod J. 2003;36(4):262-6.
6. Zelada G, Varela P, Martín B, Bahillo JG, Magán F, Ahn S. The effect of rotational speed and the curvature of root canals on the breakage of rotary endodontic instruments. J Endod. 2002;28(7):540-2.
7. Khurana P, Khurana KK. Effect of curvature angle and rotational speed on fracture of various NiTi rotary files used in extracted molars. J Conserv Dent. 2013:1(2):49-54.
8. Pedullà E, Lo Savio F, Boninelli S, Plotino G, Grande NM, La Rosa G, et al. Torsional and cyclic fatigue resistance of a new nickel-titanium instrument manufactured by electrical discharge machining. J Endod. 2016;42(1):156-9.
9. Peters OA, Gluskin AK, Weiss RA, Han JT. An in vitro assessment of the physical properties of novel Hyflex nickel-titanium rotary instruments. Int Endod J. 2012;45(11):1027-34.
10. Menezes SEAC, Batista SM, Lira JOP, Monteiro CQM. Cyclic fatigue resistance of WaveOne Gold, Prodesign R and Prodesign Logic Files in curved canals In vitro. Iran Endod J. 2017;12(4):468-73.
11. Duarte P, Silva PB, Alcalde MP, Vivan RR, Rosa RA, Duarte MAH, et al. Canal transportation, centering ability, and cyclic fatigue promoted by Twisted File Adaptive and Navigator EVO instruments at different motions. J Endod. 2018 Sept;44(9):1425-9.
12. Pereira ESJ, Peixoto IFC, Viana ACD, Oliveira II, Gonzalez BM, Buono VT, et al. Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments. Int Endod J. 2012;45(5):469-74.
13. Gabel WP, Hoen M, Steiman HR, Pink FE, Dietz R. Effect of rotational speed on nickel-titanium file distortion. J Endod. 1999;25(11):752-4.
14. Dietz DB, Di Fiore PM, Bahcall JK, Lautenschlager EP. Effect of rotational speed on the breakage of nickel-titanium rotary files. J Endod 2000;26(2):68-71.
15. Eggeler G, Hornhogen E, Yawny A, Heckmann A, Wgner M. Structural and functional fatigue of NiTi shape memory alloys. Mater Sci Eng A. 2004:378(1-2);24-33.

© 2020 Dental Press Endodontics