Influence of the curved root canal segments length on the fatigue fracture of rotatory NiTi instruments

Hélio Pereira **LOPES**[1]
Márcia Valéria Boussada **VIEIRA**[2]
Carlos Nelson **ELIAS**[3]
Victor Talarico Leal **VIEIRA**[4]
Letícia Chaves de **SOUZA**[4]
Carlos **ESTRELA**[5]

ABSTRACT

Introduction: The aim of this study was to evaluate the influence of the curved root canal segments length on the number of cycles needed to induce fatigue fracture of a rotatory nickel-titanium (NiTi) instrument. **Methods:** The instruments used in this study were Mtwo with 0.35 mm D_0 diameter, 0.02 mm/mm taper and 25 mm length. The instruments were used in two artificial metallic root canals with curved segments under 300 rpm speed. The curvatures were located in the root canals extremities and had different curved segments lengths. The device used in the rotating bending test of the selected endodontic instruments was described previously by Lopes et al.[1] **Results:** The number of cycles needed to cause fatigue fracture was influenced by the artificial root canal curved segments length. **Conclusion:** The number of cycles needed to induce fatigue fracture on the instruments used at rotating bending in artificial root canals of same radius sizes decreased with the curved segments length increasing.

Keywords: Curved segments length. Fatigue. Fracture.

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[1]Department of Endodontics, School of Dentistry, Estácio de Sá University, Rio de Janeiro, RJ, Brazil.

[2]PhD and MSc in Materials Science, Military Institute of Engineering, Rio de Janeiro.

[3]Full Professor, USP. PhD in Endodontics, USP. MSc in Endodontics, Pelotas Federal University – UFPEL.

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Contact address: Márcia V. B. Vieira
Rua Coelho Neto, 36 – 402 Bloco B – Laranjeiras – Rio de Janeiro/RJ
CEP: 22231-110 – E-mail: mvieirabrasil@gmail.com

Introduction

A substantial concern when rotatory nickel-titanium (NiTi) instruments are used in curved root canals is the fatigue fracture. When used in curved root canals, these instruments undergo a rotating bending loading, which induce an alternating compressive and tensile stresses. The repetition of these stresses promotes microstructural cumulative changes that induce fatigue fracture of the endodontic instrument.[2-4]

The rotating bending test allows to identify the number of cycles that an endodontic instrument is able to resist until the fatigue fracture at a established loading condition.[2,5-7]

The number of cycles until fatigue fracture of an endodontic instrument is related to the curved root canals geometry (radius length, curved segments length and curved segments position along the root canal).

The aim of this study was to evaluate the influence of the curved root canals segments lengths of same radius on the number of cycles needed to induce fatigue fracture of a rotatory nickel-titanium (NiTi) instrument.

Material and methods

Twenty rotatory NiTi instruments Mtwo (VDW, Munich, Germany) of 0.35 mm D_0 diameter, 0.04 mm/mm taper and 25 mm length were selected.

Artificial grooves simulating two artificial canals measuring 1.5 mm in width, 20 mm in length, 3.5 in depth with U-shaped bottom and curved segments on the tips with a curvature radius of 6.0 mm were machined into AISI-316L stainless steel blocks by computer-assisted milling. The curved segments of the first canal (A) measured 9.42 mm (90-degree angle), whereas the second canal (B) measured 12.56 mm (120-degree angle). A 1 mm-thick metal plate was manufactured and screwed in front of each simulated canal. The curvature radius of the artificial canal was measured taking into consideration the concave surface of the interior of the canal (Figs 1 and 2).

The apparatus used in the fatigue test (rotating-bending) was described previously.[1] Ten instruments were subjected to clockwise rotation at 300 rpm inside each artificial canal until fracture. The time of fracture was recorded by the same operator using digital stopwatch (Technos, Manaus, Brazil) and was established when there was visual observation of the instrument fracture. The number of cycles to fracture (NCF) was obtained by multiplying the rotational speed by the time (in seconds) until fracture occurred. During the test, the artificial canal was filled with glycerin to reduce the friction of the instrument against the canal wall and to minimize the release of heat. Data relative to the number of cycles until the instruments fractured because of curved canal segments length with the same radius were obtained and statistically analyzed by the Student's *t* test at the 5% significance level.

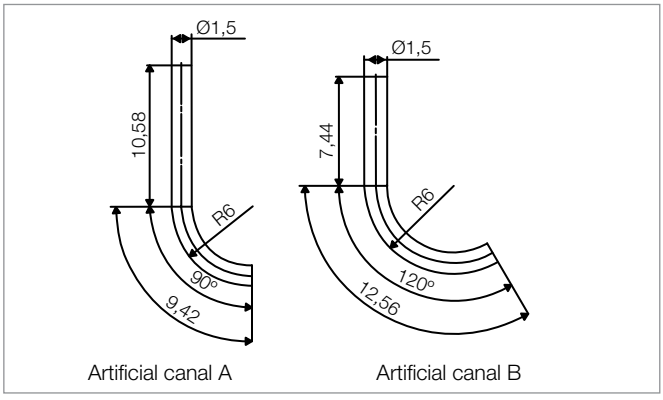

Figure 1. Schematic representation of artificial canals A and B used in the cyclic fatigue tests.

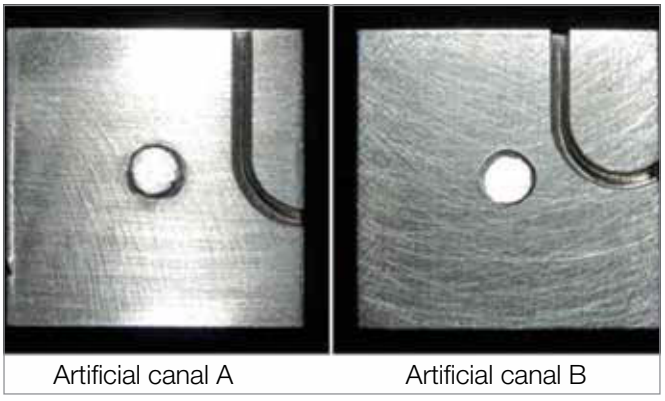

Figure 2. Artificial canals A and B used in the cyclic fatigue tests.

Results

The average and the standard deviation of the time and the number of cycles until the instrument fracture occurred are shown in Table 1.

The statistical analysis using t test showed that there was a significant difference in the number of cycles of the tested instruments in relation to the canal curved segments lengths with the same curvature radius ($p < 0.0001$).

The results showed that the Mtwo instruments tested in the canal with a 12.56 mm long curved segments (120 degrees-angle) fractured at a lower average number of cycles than those used in canals with a 9.42 mm curved segments (90 degrees-angle).

Discussion

The geometry of artificial root canals must be standardized for radius and curved segments lengths parameters to evaluate the fatigue resistance of rotatory NiTi endodontic instruments submitted to the rotating bending test. Thus, it is clear that to test the influence of the curved segments on the resistance to fatigue fracture of an endodontic instrument the other parameters must be necessarily equal.

Most studies in the literature evaluated the influence of curvature angle, not the curved segment length, on the resistance to fatigue fracture of an endodontic instrument submitted to rotating bending test.[2,6,8-12] The curvature angle is quantified in degrees, while the curved segment length is measured in millimeters. As the curvature angle is not synonymous of the curved segment length, the use of the curvature angle is doubtful, once equal curvature angle may present different radius and curvature segments with different lengths.

Table 1. Average (± SD) of the time and the number of cycles for fatigue fracture to occur in instruments based on the curved segments lengths of the artificial canals.

Curved segments (mm)	Time (seconds)	NCF
9.42	95 (13.21)	475 (66.04)
12.56	57.2 (10.17)	286 (50.87)

The curvature angle has been established by the Schneider method.[13] This method is flawed, once it does not determine the radius length, nor the curved segment length, which are decisive parameters to the resistance to fatigue fracture of endodontic instruments submitted to rotating bending test.

However, this method and the curvature fracture frequently have been applied in the evaluation of the mechanic behavior and resistance to fatigue fracture of endodontic instruments.[2,6,8-16] It is important to emphasize that the curvature angle is not quantified by the angle, but by the radius and curved segment length. The curved segment length (L) can be calculated by the curvature angle and the radius length (R), using the equation:

$$L = \frac{2\pi R \times \text{curvature angle}}{360}$$

The obtained results allows to assert the higher the curved segment length, the lower the number of cycles needed to occurrence of rotating bending fracture of a rotatory Niti endodontic instrument. The longest curved segments resulted in lower NCF values, since the location of the critical stress concentration point varies in relation to the curved segments length. Therefore, in canals with longer curved segments, the maximum stress concentration point is located where the instrument's helical shaft presents larger diameter in comparison with canals presenting shorter curved segments lengths. These results corroborate earlier studies[4,15,17] which demonstrate that the greater the diameter of the shaft at the critical stress concentration point, the lower the NCF of a given instrument.

There was significant statistical difference in the instruments NCF when compared the curved segments lengths of the artificial canals applied in this study. The results achieved agree with the described by other authors.[7,18]

Conclusion

The number of cycles necessary to induce fatigue fracture in Mtwo instruments used in rotating-bending in artificial canals with the same curvature radius decreases as the curved segments lengths increase.

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