Influence of taper and immobilization point on the flexibility of RaCe nickel-titanium rotary instruments

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ABSTRACT

Objective: This study compared the flexibility of RaCe nickel-titanium rotary instruments with different tapers at different diameters of the shaft (D3 and D6). Materials and **Methods:** Thirty RaCe files (FKG, La Chaux-de Fonds, Switzerland) size #40 with tapers 0.02, 0.04 and 0.06 mm/mm, and length of 25 mm were divided in three groups of ten instruments each, according to their tapers. In the cantilever bending test (45 degrees), two tests with loads applied at D3 and D6 were performed for each group. **Results:** Comparison of the loads applied at D3 and D6 of RaCe files with different tapers showed significantly different maximum load values to bend the files: D3 < D6, with flexibility at D3 greater than at D6. Comparison of the loads applied at D3 in the three groups revealed significant differences between the groups ($p<0.0001$), while the Student-Newman-Keuls (SNK) test showed differences in flexibility between the three groups: .06 < .04 <.02 tapers. The same result was observed for the loads applied at D6. **Conclusions:** The flexibility of the file increases with the reduction of the taper ($p <0.05$), and decreases the larger the diameter of the helical shaft ($p<0.05$).

Keywords: Nickel-titanium rotary instruments. Flexibility. Taper. RaCe rotary files.

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Introduction

The goals of chemomechanical preparation are to clean, widen, and shape the root canal. Although distinct, these goals are attained simultaneously.[1]

Root canal cleansing aims to eliminate irritants, such as microorganisms and its products, as well as vital or necrotic pulp tissues, creating an environment conducive to periradicular tissue repair.[1] Widening and shaping are achieved by means of instrumentation, aiming to achieve a conical shape with greater diameter at the coronal level and smaller diameter at the apex. This cone-shaped canal, also known as surgical canal (in contrast with the anatomical canal, which is necessarily within the surgical canal's limits) is generally achieved in straight canals.[2] In curved canals, maintenance of the original canal shape and location of the apex after instrumentation are difficult tasks to attain, with success being greatly influenced by the flexibility of the endodontic instrument.[2,3,4,5,6]

Bending flexibility is the elastic deformation of the endodontic instrument when subjected to a load applied to its tip, perpendicularly to its long axis.[7,8]

With the goal of minimizing these problems, endodontic instruments have been manufactured using alternative alloys, such as nickel-titanium (NiTi). This alloy has a small modulus of elasticity in comparison with stainless steel, which allows for manufacturing of endodontic instruments with great flexibility and resistance to plastic deformation and to cyclic fatigue failure.[3,5,6,7,9,10,11]

The bending flexibility of an endodontic instrument is an important mechanical property because during clinical use, it may influence the final shape of a curved root canal. Moreover, it may affect the instrument's resistance to cyclic fatigue failure. Several studies have shown that instruments that are more flexible maintain a more centered instrumentation in curved canals and present greater resistance to cyclic fatigue failure[4,7,10,12,13,14]. However, it is worth pointing out that the curved segments are not always located on the apical segment of the root canal. Moreover, the flexibility of an endodontic instrument varies along its shaft, due to its tapered shape.

The goals of the present study were to perform the cantilever bending test at 45° to evaluate: (1) the flexibility of size 40 RaCe files with 0.02, 0.04, and 0.06 mm/mm tapers, and (2) the loads variations at D3 and D6 of the three tapers of RaCe instruments.

Methods

Endodontic Instruments

Thirty RaCe files (FKG, La Chaux-de Fonds, Switzerland) with diameter at D0 = 0.40 mm and working length of 25 mm were divided into three groups of ten instruments, according to their tapers: Group 1- 0.02 mm/mm; Group 2- 0.04 mm/mm, and Group 3- 0.06 mm/mm.

Morphometric Characterization of the Instruments

Five instruments in each group had their cross-section diameter evaluated at 3 and 6 mm from the tip, using an Opticam optical microscope (São Paulo, Brazil), attached to a PixeLINK camera, model PLa662 (PixeLINK, Ottawa, Canada), and TSView 7.1 software. With the aid of computer software, the taper of each instrument was calculated by measuring the difference between two defined diameters (D3 and D6) and dividing that number by the distance between the two points (Taper = (D6 - D3) / 3) (Fig 1).

Cantilever Bending Test

The ten instruments in each group were subjected to a cantilever bending test at 45 degrees in a universal testing machine (EMIC DL 200 MF, Londrina, PR, Brazil). A tractive force was applied perpendicularly to the long axis of the specimen (the endodontic instrument), with the instrument tip fastened (cantilever). Following that, the force values versus the elastic deformation were calculated.[15,16]

The instrument shafts were fastened in a Jacobs chuck attached to a vise. The instruments were held at a 45 degrees incline in relation to the horizontal plane. The point of application of force was obtained by holding each specimen at 3 and 6 mm from the tip with a small aluminum clamp. A 20N load cell was used to measure the force applied by means of a 30 cm-long nylon string that had one end tied to the testing machine head and the other end secured at 3 and 6 mm from the tip of the specimen (Fig 2). At 3 mm from the instrument tip, the load was applied at a speed of 15 mm/minute until

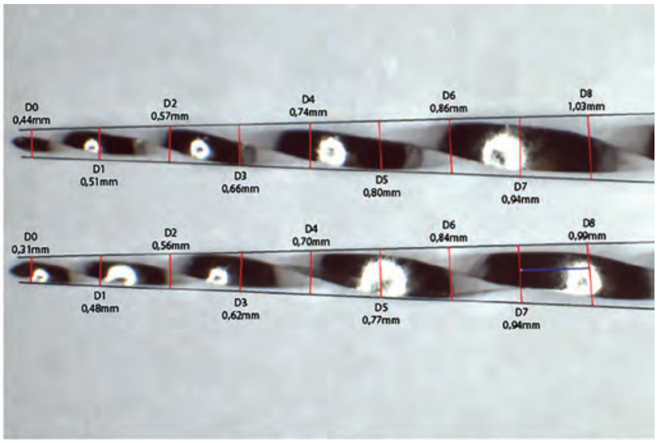

Figure 1. Taper measurement at D0, D3, and D6 using the TSView software.

Figure 2. Cantilever bending test using a universal testing machine.

a 13 mm displacement was achieved. At 6 mm, the speed was 12 mm/minute and the load was applied until a 10 mm displacement was observed.

Throughout the mechanical test, the relationship between the force applied (gf) X displacement (mm) was obtained. The force was continuously monitored by a computer connected to the universal testing machine. The TESC (Test Script) 3.04 software was used for the calculations. The weight of the aluminum clamp was subtracted when determining the force applied by the apparatus.

Statistical Analysis

Statistical analysis was conducted by using the Primer of Biostatistics 6.0 software; ANOVA and Student's t-test were used and the significance level was 5%. The Student-Newman-Keuls (SNK) multiple comparisons test was used to identify the groups that had statistically significant differences in each test. The t-student test was performed to compare forces at the diameters D3 and D6 of the different tapers (compare the table lines). The ANOVA test followed by the SNK test was done to compare the strength of the different tapers in the diameters studied (compare the table columns).

Results

Morphometric characterization of the instruments

Data referring to diameters at D0, D3, and D6, as well as the tapers of the instruments tested are shown in Table 1.

Cantilever bending test

The data obtained in the cantilever bending test were evaluated by ANOVA with the significance level at 5%, revealing statistically significant difference ($p<0.0001$). The mean values for the maximum forces to displace the instruments and the standard deviations are shown in Table 2. It was observed among the groups that the closer to D6 is the force application point, greater is the load required to bend the instruments.

In order to determine the flexibility at D3 and D6 for the three tapers separately, the Student's t-test with 5% significance was applied, showing significant difference between the groups ($p<0.0001$). According to the SNK test, when a force is applied at D3 or at D6, RaCe files with 0.02 mm/mm taper presented greater flexibility than those with 0.04 and 0.06 mm/mm taper, and files with 0.04 mm/mm taper show greater flexibility than those with 0.06 mm/mm and are less flexible than their counterparts with 0.02 mm/mm taper.

Table 1. Nominal and obtained values for diameters at D0, D3, and D6, and taper

RaCe	D0		D3		D6		Taper obtained
	nominal	*obtained*	*nominal*	*obtained*	*nominal*	*obtained*	
#40/0.02	0.4	0.37	0.46	0.45	0.58	0.51	0.02
#40/0.04	0.4	0.4	0.52	0.53	0.64	0.64	0.04
#40/0.06	0.4	0.37	0.58	0.63	0.76	0.85	0.07

Table 2. Means (± standard deviation) for the maximum load (gf) at D3 and D6

RaCe	Maximum load (gf)	
	D3	D6
#40/0.02	127 (9.3)^{A}	304 (28.4)^{B}
#40/0.04	347 (12.5)^{C}	641 (50)^{D}
#40/0.06	648 (21)^{E}	1422 (300)^{F}

Different superscript letters indicate statistically significant difference among the groups.

Discussion

Reamer with Alternating Cutting Edges (RaCe) rotary instruments are made of conventional NiTi wire and have a noncutting tip, a triangular cross-section design and a negative cutting angle. The alternating cutting edges avoid the screwing effect and have the advantage of operating with extremely low torque.[13] RaCe system endodontic files with different tapers were selected in order to confirm those variations in taper and shifting the point of application force towards D6 influences the flexibility values of these instruments. The method used to evaluate the bending flexibility was the same described in previous studies.[14,15,16,17] The force to bend the instruments was applied at 3mm and 6 mm from the tip of each file.

The morphometric characterization was performed prior to the flexibility test, in order to evaluate the dimensions and the presence of variations between instruments in the same group.[14] The geometric shape and the dimensions of endodontic instruments are directly related to their mechanical behavior. Although obvious, this scientific evidence is important and needs to be proven, because it is of clinical relevance. Among the factors that affect their performance are: the area and design of the instruments' cross-section, the chemical composition and treatment of the alloy, and the diameters along the instrument shaft.[18,19,20,21] All the files in the RaCe system present triangular cross-section; therefore, this characteristic does not explain the differences in flexibility among the groups. According to the morphometric characterization, an increase in diameter from D0 to D6 was observed in all groups. This is in agreement with the desirable action of endodontic instruments during instrumentation: to promote a cone shape to the root canal, with greater diameters at the middle and cervical segments.[2,22] Characterizing the diameters at D3 and D6 of the instruments tested is important because these are the points of application of force during the cantilever bending test.[23,24]

This bending test consists of applying a tractive load perpendicularly to the long axis of the instrument, with the goal of evaluating its elastic deformation.[8] According to some studies,[8,25] an instrument is considered rigid when it shows resistance to bending deformation. Results from bending test can be applied to the clinical practice in order to predict the performance and the mechanical behavior of endodontic instruments during instrumentation of curved canals. During chemomechanical preparation, the instrument is subjected to tractive and compressive forces, which may lead to plastic or elastic deformation.[12,18]

Instruments that are more flexible (less stiff) result in more centered curved canals after instrumentation, compared to stiff instruments.[3,5,26] In addition, flexible instruments present greater resistance to cyclic fatigue failure.[14,19]

From an anatomical and clinical perspective, it is important to note that the curved segment may be located at the cervical portion of the canal.[27] In this scenario, maintenance of the original shape of the root canal after instrumentation is unlikely. This explains the formation of ledges in the cervical segment of a root canal when stiff endodontic instruments are used. According to Necchi et al.[28], the change of position of an arc with the same length influenced the presented stress levels, increasing from the apical to the mid root position.

The results from the cantilever bending test demonstrate that, both at D3 and at D6, instruments of greater taper are less flexible (more rigid), which corroborates other studies where the flexibility was shown to be inversely proportional to the dimensions of the instrument.[5,19,29,30] When the forces applied to instruments of the same taper were compared, it was observed that the closer to D6, the more rigid the instrument. TSAO et al.[31] compared the flexibility and stress distribution along the shafts of RaCe and Mani NRT instruments, and reported that RaCe was more flexible (less stiff).

The results obtained in our study showed that, for all three tapers tested, the stiffness of the instruments increased as the point of application of force shifted cervically along the instrument shaft. For RaCe 40/0.02 files, the stiffness at D6 is 139% greater than at D3. For RaCe 40/0.04 and 40/0.06, the stiffness was 84% and 129% greater, respectively.

AL-SUDANI & AL-SHAHRANI[13] investigated the ability of instruments to maintain the root canal centered and observed that the RaCe system resulted in less instances of canal transportation in comparison with other instruments evaluated. Contrastingly, other studies did not report significant differences in canal transportation between RaCe and other instruments.[32,33] SCHÄFER & VLASSIS[34] compared RaCe and ProTaper systems with regard to their abilities to maintain the root canal centered and observed that the RaCe system was better than ProTaper in its ability to maintain the original curvature of the canal.

An important clinical consideration in curved canals is that the more cervical the position of the curvature, the smallest taper should be selected. A smaller conicity implies that in larger diameters (such as D6 and in the cervical region), the files will have greater flexibility. The use of stiff files in canal curvatures positioned in the middle and cervical thirds can induce high levels of stress, which can cause instruments fractures and canal deviations.

Conclusion

Based on the results obtained in the present study, we have concluded that:

a) The stiffness of a file increases as the taper of its helical shaft increases. The levels of flexibility were as follows: 0.02 mm/mm > 0.04 mm/mm > 0.06 mm/mm.

b) When a load was applied in D3 and D6, the flexibility was greater at the smaller diameters for all the evaluated tapers.

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