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ORIGINAL ARTICLE

Comparison of some physical properties of finger spreaders made of stainless steel or nickel-titanium alloys

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Abstract The purpose of this study was to evaluate the flexibility, shape, and surface finishing of stainless steel (SS) and nickel-titanium (NiTi) finger spreaders as well as to compare the load required to insert these spreaders along a gutta-percha point adapted to the apical segment of curved or straight artificial canals. Instrument flexibility was investigated by using a universal testing machine in the cantilever-flexibility test. Scanning electron microscopy (SEM) was used to examine the shape and surface finishing of different sizes of SS and NiTi finger spreaders. Penetration load was evaluated only for spreaders size C by using the universal testing machine in a compressive test. As for flexibility, the load needed to bend the SS finger spreader sizes A, B, C, and D was approximately 167%, 146%, 102%, and 64% greater than the respective sizes of NiTi finger spreaders. SEM analysis revealed that the instrument tips were always tapered, but with different vertices. NiTi spreaders showed tips with circumferential grooves; whereas, those from SS spreaders exhibited longitudinal grooves. NiTi finger spreaders required a significantly higher penetration load than SS spreaders. This difference was probably related to the different shapes and surface finishing of the instrument tips. Different characteristics of finger spreaders may result in different clinical performance during the lateral compaction technique.

Keywords Finger spreaders · Penetration load · Flexibility · Lateral compaction technique · Root canal obturation

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Introduction

The lateral compaction technique is one of the most widely taught and used root canal filling techniques and has become the "gold" standard for comparison with new obturation methods [1]. This technique consists of placing accessory cones laterally to a master cone adapted to the apical part of the prepared root canal. The space for accessory cones is created by spreaders. While hand and finger spreaders are available for use in the lateral compaction technique, the main advantage of the latter is that it is not possible to exert the high lateral pressure during compaction that may occur when using hand spreaders. Consequently, the chances for root fracture are reduced with finger spreaders when compared to hand spreaders [2, 3]. Finger spreaders are made of stainless steel (SS) or nickel-titanium (NiTi) alloy [4]. NiTi spreaders present increased flexibility, resulting in reduced stress on the dentinal walls during lateral compaction of gutta-percha and have been shown to penetrate to a significantly greater depth than SS instruments [5–9].

Spreader penetration within 1 and 2 mm of the working length seems to exert a significant effect on the quality of the apical seal [10, 11]. Ideally, spreaders should be introduced up to that position without transmitting excessive stress to the root canal walls during the filling process. This goal can be easily achieved in straight canals. However, in curved canals, spreaders usually find more resistance in their progression through the filling mass and consequently induce a greater stress on the root canal walls [4, 7].

Induction of stress on the root canal walls during the filling process by means of the lateral compaction technique may be influenced by factors that are inherent to the tooth anatomy and the type of the spreader used. As far as the tooth anatomy is concerned, the root diameter, presence of curvatures, and the radius of curvature are important factors. As to the spreader, its shape, surface finishing, flexibility, and load required to penetrate in the canal should be considered. These properties may be related to a better performance of the spreader during the root canal filling approach, including promotion of an adequate homogeneous obturation and safety to the root. Therefore, the purpose of this study was to evaluate these properties of the SS and NiTi finger spreaders as well as to compare the load required to insert these instruments along a gutta-percha point adapted to the apical segment of curved or straight artificial canals.

Materials and methods

The NiTi and SS finger spreader sizes A, B, C and D, all 25-mm long (Dentsply/Maillefer, Ballaigues, Switzerland), were used in the flexibility test and scanning electron microscope (SEM) analysis. Only spreader size C was used in the analysis of penetration load (compressive test).

Flexibility test

Six-finger spreaders of each size and metallic alloy were subjected to the cantilever bending test. A universal testing machine (Emic, DL 10.000, São José dos Pinhais, Paraná, Brazil) was used. Load was applied by means of an intertwined nylon cord (six cords tightly twisted together, each one with a length of 50 cm and a diameter of 0.2 mm), with one of the extremities fastened to the testing machine head and the other end 3 mm away from the spreader tip. The bending test was conducted until the tip of each specimen underwent an elastic displacement of 10.5 mm.

Each finger spreader was fastened by its handle to a Jacob mandrel, which, in turn, was immobilized by a bench vise. The spreader was fastened at a 30-degree downward inclination relative to the vise jaws. The force application point was made by fastening aluminum jaws 3 mm away from the tip of each specimen. The jaw weighed 2.0 gf and this value was reduced from the applied force. The distance (useful length of the test specimen) between the fastening point of the finger spreader handle on the mandrel and the force application point was 22 mm (25−3 mm).

The test speed was 15 mm/min. The load cell employed was of 20 N. For each test, the machine was calibrated (zero) to assure zero load provision by the apparatus. During the cantilever-flexibility test, it was possible to obtain a load×displacement diagram. The mean values of the maximum force to bend SS and NiTi finger spreaders were compared. Data obtained were submitted to statistical analysis using the Student's t test with the significance level set at 5% ($p<0.05$).

SEM analysis of the spreader tips

The shape and surface finishing of the tips of the SS and NiTi finger spreaders were examined under SEM (JEOL JBM 5800, Tokyo, Japan). The angle of the instrument tips was also measured.

Penetration load test

Diameters at D_3 and D_{13} of the SS and NiTi spreaders, size C, were measured by using a Nikon Profile Projector (6C-2, Tokyo, Japan). Next, the taper (T) and the diameter in D_0 were calculated using the expressions $T = D_{13} - D_3/10$ and $D_0 = D_3 - T \times 3$ [12]. Gutta-percha points, size 40 and 0.02 tapered (Dentsply, Petrópolis, RJ, Brazil), also had their diameters at D_3 and D_{13} measured.

Two 17-mm long artificial canals (one straight and the other curved) were prepared in resin blocks using NiTi K-type instruments, size 40 (Nitiflex, Dentsply/Maillefer). The curved canal had an arc measuring 6 mm, a curvature radius of 7.5 mm, and a straight segment that was 11 mm in length.

The load needed to introduce the spreaders in the artificial canals was determined by means of a compressive test. This assay consisted of using increasing loads in a universal testing machine (Emic DL 10.000, São José dos Pinhais,Parana, Brazil). The spreader handles were mounted in the universal machine fixed by a metallic device. A gutta-percha point, size 40, was adjusted in the apical segment of the acrylic block, which was then positioned parallel to the long axis of the spreader adapted to the universal testing machine. Next, the load needed to introduce the spreader up to 15 mm in the canal along the gutta-percha point was continuously recorded by a computer coupled with the universal testing machine. In all tests, the spreader was introduced between the gutta-percha point and the same wall of the artificial canal. The artificial canals (straight or curved) were the same for all tests. Ten experiments were performed for each canal and instrument. After every experiment, the gutta-percha point was replaced by a new one. The data were analyzed by the Student's t test.

Results

Flexibility test

The maximum force to bend the test spreaders is presented in Table 1. The results of the cantilever-bending test demonstrated significant differences between the SS and the NiTi finger spreaders of the same size, with the latter being significantly more flexible ($p<0.05$). For spreaders of the same metallic alloy, flexibility decreased with the increase in the instrument diameter. By comparing the values shown in Table 1, it is possible to observe that the maximum force needed to bend SS finger spreader A was approximately 167% greater than the force necessary to bend the NiTi spreader of the same size. For spreaders B, C and D, the forces were 146%, 102% and 64% greater, respectively.

SEM analysis of the spreader tips

SEM evaluation revealed that the working part of the SS finger spreaders presented longitudinal grooves formed by the manufacturing process and tips having a smooth surface and circular conical shape with rounded vertices (Fig. 1). The working part of the NiTi finger spreaders exhibited circumferential grooves formed by the milling tool and the tips had a circular conical shape with truncated and beveled vertices (Fig. 1).

Specifically for spreaders C, which were used in the penetration load experiment, the mean angle measured for the SS spreader tip was 20° (Fig. 2). The NiTi spreaders, in turn, showed tips with two angles: one at the tip extremity forming a bevel of 90° and the other of 20° located at the posterior part of the tip (Fig. 2).

Penetration load test

The average length and diameter of the NiTi and SS finger spreaders, size C, are depicted in Table 2. Values

Table 1 Means and SD of the maximum force (N) to bend SS and NiTi endodontic finger spreaders (elastic displacement of 10.5 mm)

Spreader	N	Mean (SD)			
		A	B	C	D
NiTi	6	0.9 (0.02)	1.9 (0.05)	3.3 (0.1)	5.4 (0.1)
SS	6	2.3 (0.2)	4.7 (0.1)	6.6 (1.8)	8.9 (0.2)

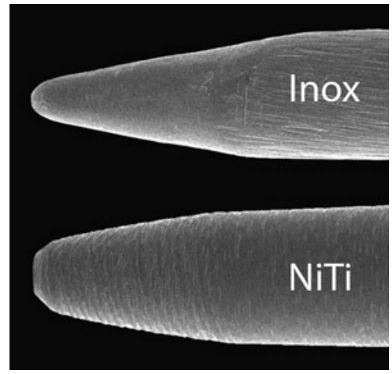

Fig. 1 Finger spreader tips. (*Top*) stainless steel spreader, *Inox*, with rounded and smooth tip (original magnification, ×150). (*Bottom*) *NiTi* spreader, truncated and beveled tip vertex (original magnification, ×150)

obtained for D_3 and D_{13} of the gutta-percha points were within the tolerance limits adopted by this study (±0.02 mm).

Table 3 displays the results of the compressive test as to the maximum force needed for a finger spreader size C to penetrate 15 mm in apical direction within straight or curved artificial canals containing a gutta-percha point adapted to the apical segment. Statistical analysis using the Student's t test revealed that the penetration load for the NiTi spreaders was significantly higher than the SS spreaders at the 1% significance level. These results were regardless of whether the canal was straight or curved.

Discussion

In order to reduce variables when instruments of different metallic alloys are compared, it seems important that they

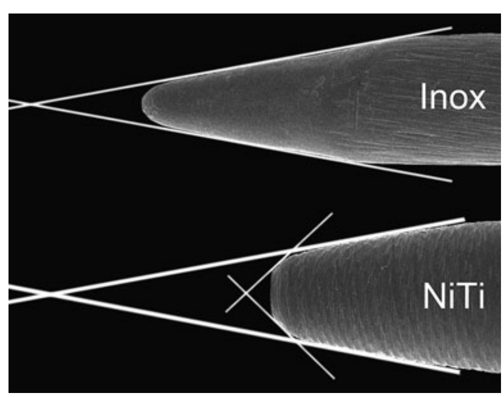

Fig. 2 Tip angle. (*Top*) stainless steel spreader, *Inox* (20°) (original magnification, ×150). (*Bottom*), *NiTi* spreader (small angle=20° and large angle=90°) (original magnification, ×150)

Table 2 Mean dimensions of SS and NiTi finger spreaders size C (in millimeters)

Spreader	Diameter (mm)				Length (mm)			
	D_3	D_{13}	D_0	taper	total	shank	neck portion	working part
NiTi	0.37	0.83	0.22	0.05	35.00	10.00	8.00	17.00
SS	0.37	0.84	0.22	0.05	34.87	10.03	4.84	20.00

present a similar design [13, 14]. Therefore, the SS and NiTi endodontic finger spreaders used in this study were from the same sizes and from the same manufacturer.

For the flexibility analysis, the present study used the cantilever-bending test proposed by Serene et al. [15]. The bending load during the testing of the specimens was slowly applied in a speed of 15 mm/min. The proposed displacement was 10.5 mm so that the deformation determined by the load applied to the spreader could remain within the elastic limit of the metallic alloy. A minimum of six specimens per group to be used in the bending test has been recommended [15]. The apparently small sample size can be justified by the standard deviations observed for each group. The results demonstrated a statistically significant difference concerning the maximum force needed to bend the NiTi and SS finger. As expected, the NiTi finger spreaders were significantly more flexible than their counterparts made of SS. The greater flexibility of the NiTi finger spreaders was due to the smaller modulus of elasticity of this alloy in relation to SS [15]. In this regard, the contribution of this study is to quantify how great that flexibility is.

For the penetration load test, dimensions of spreaders and gutta-percha points were measured in an attempt to eliminate possible variables that could interfere with the results. The measurements obtained were similar for both the NiTi and the SS spreaders, with minimal variations, except for the length of the working part. While the working part of the NiTi spreaders was 17 mm long, that from the SS spreaders was 20 mm. Actually, finger spreaders, size C are regarded as non-standardized because they do not present dimensions regulated by the International Organization for Standardization 3630-3 [16].

Table 3 Means and SD of the maximum force (N) needed for SS and NiTi finger spreaders size C to penetrate 15 mm in apical direction within artificial straight or curved canals containing a gutta-percha point

Artificial canal	Number of assays	Spreader type	N	SD
Straight	10	NiTi	7.9	0.7
Straight	10	SS	6.8	0.8
Curved	10	NiTi	19.1	1.8
Curved	10	SS	15.7	2.2

Compressive test

Curved and straight artificial canals were used in the penetration load test with the purpose of standardizing the influence of the canal shape on the load values. Artificial canals have been suggested as substitutes for natural teeth [6, 8, 17] because some variables as canal dimensions and shape are easier to control or eliminate. The same straight or curved canal was used in all experiments. Moreover, only one spreader, either the NiTi or the SS, was used to avoid variables introduced by the instrument dimensions and the surface finishing. This was made possible because the compressive test is nondestructive for both artificial canals and spreaders [7, 8, 18–20].

Given its higher flexibility [5–9], which was confirmed in this study, it was expected that the NiTi spreader would require a lower penetration load; however, the opposite was observed. The higher load required to introduce the NiTi spreaders in the artificial canals as compared to the SS spreaders may be related to the differences in the shape and surface finishing of the instrument tips. These differences were clearly evident in the SEM analysis.

The SEM analysis revealed that the working part of the SS and the NiTi spreaders exhibited tips with the shape of a circular cone. The tips of the SS spreaders, sizes A, B, C and D, showed rounded vertices. The NiTi spreaders, in turn, showed tip vertices as beveled and truncated cones. The shape of the tip of the endodontic spreaders may exert an important role in the mechanical resistance to the instrument advanced in the canal during lateral compaction of the obturation points. Tips with truncated vertices may make it difficult for the spreader to advance through the filling material within the canal, creating the need for a higher penetration load. As for the finishing surfaces of the instruments, the circumferential grooves present in the working part of NiTi spreaders may offer a higher mechanical resistance to the apical displacement of the instrument during filling by the lateral compaction technique.

The characteristics of the tips of the NiTi spreaders, exhibiting truncated vertices, a bevel of 90° and circumferential grooves, may have resulted in a larger mechanical resistance to the instrument penetration in the canal, regardless if it was straight or curved, with a higher load being required for apical displacement of the instrument. In contrast, the smooth tip of the SS spreaders, with rounded vertices and no grooves, may have offered a reduced mechanical resistance to penetration of the spreader in the canal with consequently, a lower load required for introduction. The larger mechanical resistance to the apical advance of the finger spreader may give rise to inadequate compaction and apical control of the filling, and it may cause conditions conducive to longitudinal root fracture.

In conclusion, data from the present study demonstrated that: (1) NiTi endodontic finger spreaders were significantly more flexible than those made of SS and the load needed to bend the SS finger spreaders, sizes A, B, C and D, was approximately 167%, 146%, 102%, and 64% greater than the respective sizes of the NiTi finger spreaders; (2) the SS and NiTi finger spreaders presented different tips with regard to the shape and surface finishing; and (3) NiTi finger spreaders required a higher load to be introduced along a gutta-percha cone in curved or straight artificial canals as compared to SS finger spreaders. It is possible that such differences may result in different clinical performances of these spreaders during root canal obturation by the lateral compaction technique.

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The authors declare that they have no conflict of interest.

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