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Original Research Article

Frequency of morphological defects produced on the active surface of continuous and reciprocating rotation instruments after repeated use

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Abstract

Introduction: Root canal preparation is essential for the adequate sanitization of dentinal tubule systems, allowing favorable conditions for sealing in the cervical-apical direction. **Objective:** To analyze the frequency of morphological defects produced in continuous and reciprocating rotation instruments after repeated uses by scanning electron microscopy (SEM). **Material and methods:** Forty-five replicates of prototyped lower molars were randomly assigned to three groups according to the system used: G1. Biorace®, G2. V-File®, or G3. Protaper Next®. After root canal preparation, all the instruments were washed in an ultrasonic vat and subsequently analyzed by SEM to visualize the morphological defects (dullness of the edges, grooves, microcavities, and cracks) in images obtained with a magnification of 50x to 1500x. To determine defects on each instrument's surface, the active part was divided into 14 parts, with segments on the two sides from 1 to 7. The relationship between the number of defects observed in the different instruments was assessed using chi-square tests. **Results:** Defects were observed in all tested instruments, with statistically significant differences between the systems (P<0.05). BioRace® system was associated with a significant higher number of defects, than V-File® (P<0.05) but was not significantly different from ProTaper Next® (P>0.05). No significant difference was observed between V-File® and ProTaper Next® groups (P>0.05). **Conclusion:** All the analyzed instruments showed defects in the active surface after repeated use.

Introduction

Root canal preparation is essential for the adequate sanitization of dentinal tubule systems, allowing favorable conditions for sealing in the cervical-apical direction. Recent advances in the development and incorporation of new nickel-titanium (NiTi) instruments have contributed to notably improved quality of modeling in clinical practice [12, 22]. In this sense, studies have continually investigated NiTi instruments with respect to their mechanical properties, and clinical performance [5, 7, 18, 23, 29, 30].

Technological advances have occurred regarding NiTi alloys in recent years, through unique heat-treatment processes and even electrochemical polishing on the active surfaces of instruments. These have allowed greater flexibility and expressive evolution regarding resistance to cyclic fatigue fractures [1, 15, 19, 21].

Although the results of the improvements to these instruments have been impactful, the risk of fracture during endodontic practice has still been a constant concern [3, 13]. Studies have shown the presence of morphological defects on the active surfaces of these instruments, arising from the manufacturing process during machining [17, 26].

These pre-existing morphological defects on the surface of new (unused) instruments, such as microcavities, dullness of the cutting blade, and/or splinters, can intensify and form cracks, potentially contributing to the instrument rupturing during the preparation of a root canal. Within this context, it is relevant for professionals to understand the nickel-titanium instruments' different physical and mechanical properties to identify the advantages of one system over another [19].

The main concern in using NiTi instruments, regardless of the commercial brand, is low cycle fatigue fractures, which can occur when the instrument is subjected to a rotational flexing load inside of a curved root canal [14, 28]. Another critical factor to be considered and questioned is whether there is a limit to using these instruments in clinical practice since multiple uses will cause fatigue [14]. Fatigue fractures can be unpredictable and occur without any warning, often being influenced not by the instrument's torque, but by the number of repeated cycles and the intensity of the tensile and compressive stresses applied to the flexed area of the instrument. Insufficient knowledge of the instrument's characteristics can lead to serious procedural errors.

The aim of this study was to use SEM to analyze the frequency of morphological defects produced on the active surfaces of continuous and reciprocating rotation instruments after repeated uses. The null hypotheses were that repeated use does not interfere with the morphology of instruments with a special surface treatment and that the type of movement (continuous or reciprocating) does not influence the frequency of morphological defects.

Material and methods

The present study did not require the approval of the ethics committee or even the consent for its realization, as it involved artificial teeth. Forty-five replicates of prototyped lower molars (IM do Brasil Ltda., São Paulo, SP, Brazil) were randomly distributed into three experimental groups (n=15), according to the NiTi system: Group 1. BioRace® (FKG Dentaire, Switzerland), Group 2. V-File® (VF, TDKaFile, Mexico City, Mexico); or Group 3.

Protaper Next® (PTN, Dentsply Maillefer, Ballaigues, Switzerland).

Initially, access cavities were performed with spherical diamond tips (#1013, #1014; KG Sorensen, Barueri, SP, Brazil) and an Endo Z drill (Dentsply Maillefer), both refrigerated and in high rotation. Subsequently, the root canals were explored and emptied with #10 and #15 K-file instruments (Dentsply Maillefer). The working length was determined using a #15 K-file instrument (Dentsply Maillefer) until the instrument was visualized through the apical foramen. One millimeter was taken from this length to obtain the actual working length.

Instrumentation was performed using the X-Smart Plus® (Dentsply (Maillefer), following the technical specifications for torque (N), speed (rpm), and the technical sequence for each group. G1. Biorace®: consisted of six instruments each (BR0 #25/0.08; BR1 #15/0.05; BR2 #25/0.04; BR3 #25/0.06; BR4 #35/0.04; and BR5 #40/0.04). G2. V-File®: consisted of three instruments each (V1 #25.0.08; V2 #40.0.06; and V3 #50.0.05). G3. Protaper Next®: consisted of four instruments (X1 #17/0.04; X2 #25/0.06; X3 #30/0.07; and X4 #40/0.06). The root canals were irrigated with distilled water using a Navitip irrigation syringe (Ultradent Products Inc., South Jordan, USA).

After root canal preparation, the instruments were washed in an ultrasonic vat (Odontobrás Equipamentos Médicos e Odontológicos Ltda., Ribeirão Preto, SP, Brazil) with enzymatic detergent (Riozime IV, Rioquímica, São José do Rio Preto, SP, Brazil) diluted in water at 5 mL per liter, for 20 min. After the cleaning process was finished, the instruments were dried and later underwent analysis of morphological defects on their active surface using SEM images from a Jeol JSM-6610 equipped with EDS (Thermo-Scientific NSS spectral imaging with secondary electron detector, 10 kV voltage, working distance [WD] 10 mm, and beam diameter 40 nm).

The instruments were fixed to a stub in a standardized position so that they could be observed. For image acquisition, each instrument was analyzed on sides A and B, with side A formed by the convex face of the fixation rod (mandrel) and B by the flat face. To determine the morphological defects on each instrument's active surfaces, the active part of 16 mm in length was divided into seven parts named segments 1 to 7 (figure 1).

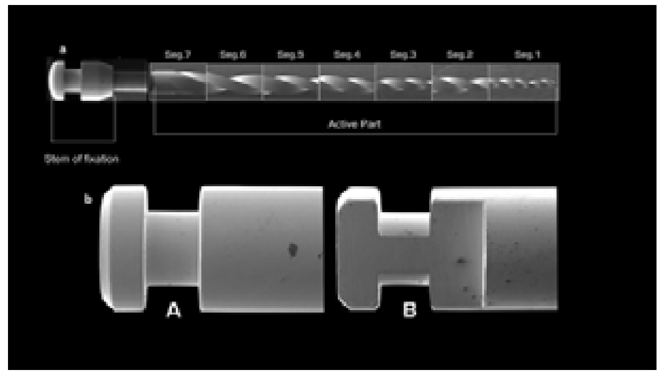

Figure 1 – a) SEM image of instrument's active surfaces, the active part of 16 mm in length was divided into seven parts named segments 1 to 7. b) Side A formed by the convex face of the fixation rod (mandrel) and side B formed by the flat face

A total of 84 images were taken from Group 1 (Biorace®), 42 images were taken of Group 2 (V-File®), and 56 images were taken of Group 3 (Protaper Next®). The images were analyzed by one blind examiner, twice at a 7-days interval. The examiner was previously calibrated at a magnification of 50X to 1500X.

The types and criteria for defining the presence of morphological defects on the active surface were dullness (loss of the cutting part or folding of a blade), the presence of cracks or grooves (open discontinuity on the surface or inside, originating from localized tensions, whose values exceed the limit of rupture of the material), and microcavities and splinters (penetrating tip forming an acute angle or sharp penetrating protrusion of the cutting part [17] (figure 2).

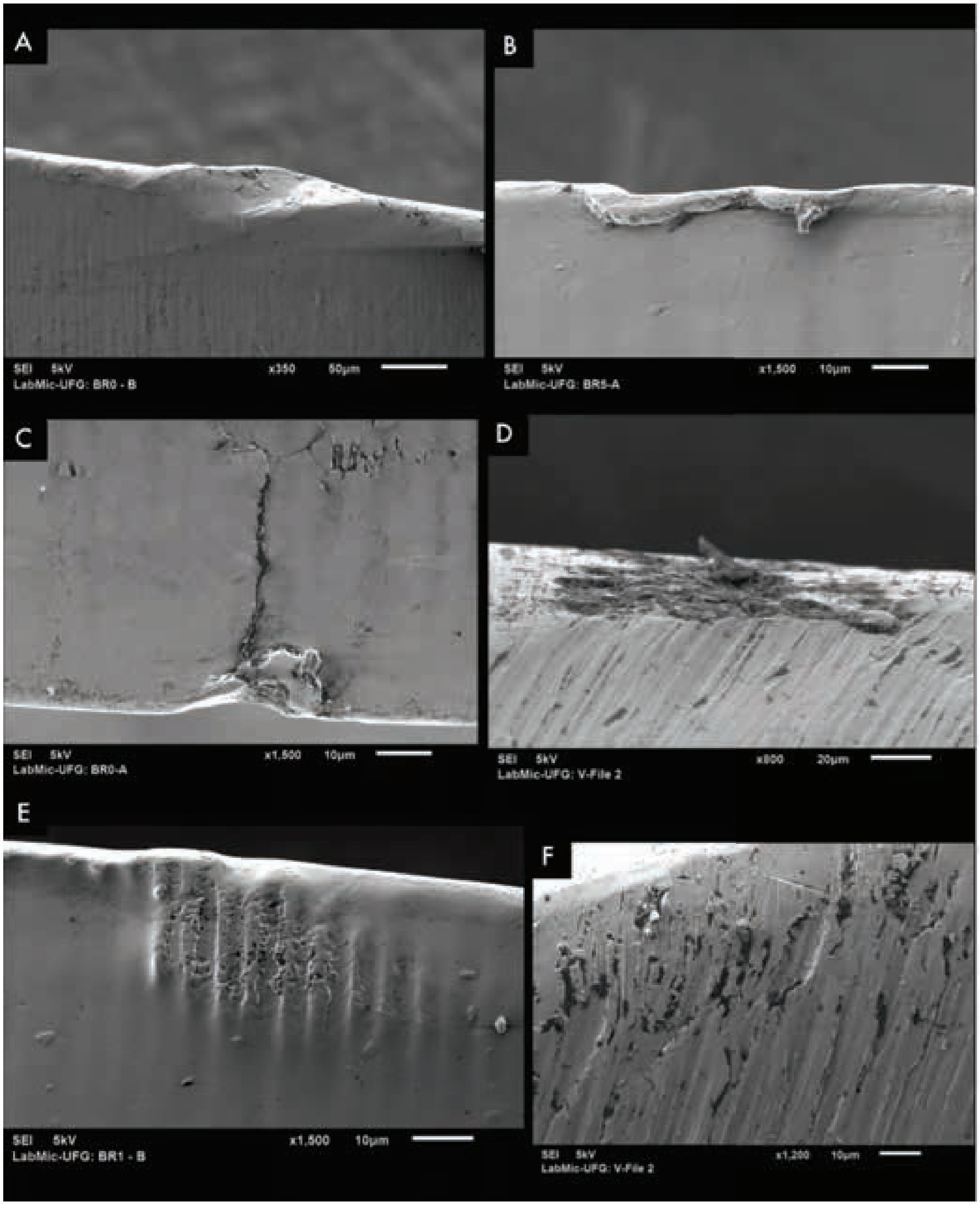

Figure 2 – Examples of the morphological defects observed in the SEM images: dullness (a and b), crack (c), splinters and fissures (d), and microcavities (e and f)

Statistical analysis

The relationship between the number of defects observed in the different instruments was assessed using chi-square tests. Values of $P<0.05$ were considered significant. Statistical analysis of the data was performed using the Jamovi software, version 1.1.9 (The Jamovi Project, 2019). The intraexaminer agreement was assessed by kappa statistics in 10% of the sample.

Results

Intraexaminer agreement was excellent (kappa = 0.85). Morphological defects were observed in all tested instruments, with statistically significant differences between the systems (P<0.05) (figure 3). BioRace® system was associated with a significant higher number of defects, than V-File® (P<0.05) but was not significantly different from ProTaper Next® (P>0.05). No significant difference was observed between V-File® and ProTaper Next® groups (P>0.05) (figure 3).

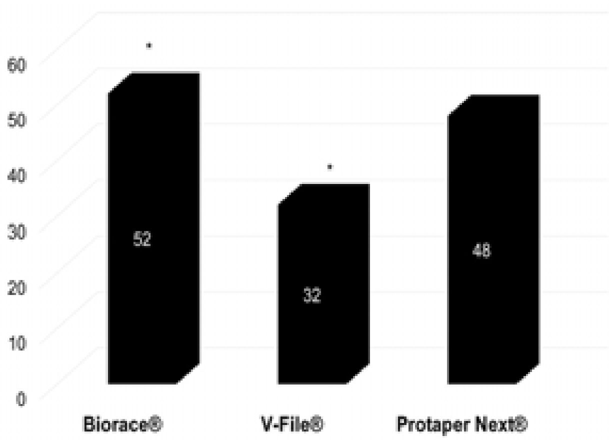

Figure 3 – Prevalence of morphological defects in tested instruments

* Indicates statistically significant differences

The morphological defects on each instrument's active surfaces (segments) is presented in table I. No statistically significant differences were observed between the tested instruments (P>0.05).

Table I – Frequency of morphological defects on each instrument's active surfaces (segments).

Instrument's active surfaces	Biorace	V-File	ProTaper Next	P value
Segment 1	8	6	7	> 0.05
Segment 2	6	4	7	> 0.05
Segment 3	8	5	6	> 0.05
Segment 4	5	3	7	> 0.05
Segment 5	11	5	7	> 0.05
Segment 6	5	4	6	> 0.05
Segment 7	9	5	8	> 0.05

Discussion

Improvements to the active surface of NiTi instruments to minimize or eliminate finishing defects inherent to the manufacturing process have gained a prominent role, and a variety of strategies have been developed to increase hardness, flexibility, and resistance to cyclic fatigue [8, 16]. However, despite some studies pointing out that unique surface-finishing processes, such as electropolishing and heat treatments, increase the resistance to fatigue instruments [1, 4, 17, 20, 27], the relationship between these improvements and the reduction of morphological defects obtained with repeated use still seems contradictory.

In this study, we used replicates of prototyped lower molars made of phenolic resin, with a hardness comparable to that of human dentin [24]. The deformations suffered, and the morphological defects found in the present investigation can be very similar to those observed when performing human root canals preparation. Shafer and Vlassis [24] evaluated two NiTi rotating systems and performed wear tests for human root canals and resin root canals, which resulted in similar deformation findings. A systematic review study conducted by Decurcio *et al.* [10] compared educational results from using artificial teeth versus extracted teeth for preclinical endodontic training. The authors concluded that artificial teeth, when used for preclinical endodontic practice, had similar academic outcomes compared to those of extracted teeth.

Studies with scanning electron microscopy (SEM) have been fundamental for evaluating instruments after repeated uses, by being able to characterize possible manufacturing defects, wear, areas prone to fracture, and decreased cutting capacity, in order to establish a moment closer to the ideal at which to dispose of these instruments and consequently avoid complications [25, 28].

The results of this study show a considerable increase in morphological defects after repeated use. Observations of the SEM images of the active surfaces' characteristics after instrumentation revealed that all the analyzed groups showed defects (figure 2). BioRace® system was associated with a significant higher number of defects, than V-File® (P<0.05) but was not significantly different from ProTaper Next® (P>0.05). Thus, the first null hypothesis was rejected. Busquim *et al.* [6], using computerized microtomography, demonstrated that Biorace instruments touch a higher percentage of root canal walls than a reciprocating instrument. Since Biorace® touches more areas of the root canal, it would be more susceptible to morphological defects on its active surface after repeated uses. Also, as the Protaper Next instrument's kinematics promotes less tension because of the active part of the instrument with an eccentric rectangular straight section, touching only two cutting edges when advancing the instruments in an apical direction, could justify the non-difference when compared to the V- File®.

Some studies have been suggested that reciprocating movement improves instruments' resistance to cyclic fatigue [8, 9, 11]. Although in the present study, lower number of defects was observed in the V-File® group (reciprocating movement), not statistically difference was observed between this system and Protaper Next® instruments (continuous movement). Thus, it could be concluded that the movement kinematics did not influence the frequency of morphological defects ($P>0.05$). Therefore, the second null hypothesis was confirmed.

All the instruments used in the study (Biorace®, V-File®, and Protaper Next®) received, according to the manufacturers' specifications, a special treatment capable of reducing the irregularities produced in the cutting blades and improving the finish resulting from machining. However, even with these improvements, the observed data indicate that the number of uses is still critical to the frequency of produced morphological defects.

Recently, a new V-File® reciprocating system (VF, TDKaFile, Mexico City, Mexico) with heat treatment of the alloy was presented. This system has three instruments with points #25, #40, and #50, with tapper of 0.08, 0.06, and 0.05, respectively, as well as a triangular cross-section in the form of S and reciprocating kinematics of 150° clockwise and 30° counterclockwise. The lack of investigation into this system's mechanical properties justified these instruments' inclusion in the present study.

Arantes *et al.* [2] compared four commercial brands (Twisted File®, Biorace®, Mtwo®, and EndoWave®) using SEM to check the wear on the instruments after their use, considering improvements in the production of nickel-titanium instruments. Regarding the presence of wear after five uses between the evaluated groups, all the instruments showed changes in their cutting blades, with wear defects at the tip and 5 mm from it. The authors also stated that although improper use of the instruments produces harmful effects, such as deformations after use, the instruments must be able to withstand more and be more resistant when subjected to multiple cycles.

Conclusion

Based on the applied methodology and the conditions of this study, it is prudent to conclude that morphological defects were observed after repeated uses in all the tested instruments (BioRace®, V-File®, and Protaper Next®). Additionally, the type of movement did not influence the frequency of defects. However, new studies are essential to better understand the influence of multiple repetitions on propagating morphological defects in continuous and reciprocating rotation instruments.

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