SVOA Dentistry

ISSN:2753-9172

ScienceVolks Open Access

Research

Comparative Study of Cutting Capacity and Wear in 3 Commercial Brands of Ni-Ti Manual Endodontic Files

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***Received:** October 13, 2022* ***Published:** October 27, 2022*

Abstract

The purpose of this article was to compare the cutting capacity and wear of manual nickel titanium endodontic files. For this objective, ten nickel-titanium instruments from the brands Dentsply-Maileffer™, FKG™ and Densell™ were used, all numbered thirty-five. The files were attached to a wear testing device that performed continuous and linear movements on grooved plates based on phenolic resin. These plates were weighed on an analytical balance before and after instrumentation. Analyzes by optical microscopy of the endodontic files were also carried out in order to verify the wear on the surface of the instruments. Due to the characteristics of the data, in the statistical analysis, Student's "t" test and ANOVA test: one criterion, Tukey's test were used. It was concluded that the instruments presented similar cutting capacities without significant statistical differences. As for the wear of the instruments, it was verified that the cutting blades of the Densell™ brand deformed less compared to the instruments of the Dentsply-Maileffer™ and FKG™ brands. However, between the latter two, there was no statistically significant difference.

***Keywords:** Endodontics; Nickel-Titanium; Root canal therapy; Microscopy.*

Introduction

The nickel-titanium instruments have great flexibility, ensuring greater confidence to the operator during instrumentation. Made in nickel-titanium alloy (Ni-Ti), they were developed for use in teeth with curved canals. Having as justification the re-establishment force of the metal to be identical to the minimum force that needs to be flexed, in most of the times, it guarantees that the instrument bends obeying the anatomical characteristics of the root canal, generating a re-establishment force insufficient to overcome the resistance of the dentin wall[1-6].

It is worth clarifying that, among the Ni-Ti instruments of different brands, it is essential not to ignore the cutting and wear capacity of these hand files, which have been little studied in comparative terms.

Daily practice shows that it is becoming more and more difficult to obtain human teeth for research, thanks to the execution of preventive dental treatments. Currently, several studies are performed on the cutting and wear capacity of Ni-Ti instruments, using substrates such as acrylic resin and phenolic resin[7,8]. Thus, it is necessary the use of an experimental model that uses phenolic resin plates as substrate in endodontic experiments having as main purpose to evaluate these parameters with different files made of Ni-Ti metal.

The purpose of this study was to compare the cutting ability and the wear of three different brands of Ni-Ti hand files using phenolic resin plates as experimental substrate.

Material and Methods

Confection of test bodies

Initially, thirty plates were made from Multfast Brown™ (Struers LLLC, Cleveland, OH, US) phenolic resin. Red granulated phenolic resin (280g) were weighed in a digital analytical balance (Figue 1). This quantity was placed in a TempoPress 2™ (Struers LLLC, Cleveland, OH, US) filling unit (Figure 2). The resin was molded in a closed steel cylinder. After 15 minutes with 20kN pressure and 200°C (392°F), the sample was cooled with the presence of a stainless steel coil where water circulated. The final product is a phenolic resin plate 8mm high and 30mm in diameter (Figure 3).

The plate was worn down with a water sandpaper with grit number 180 in an automatic polisher, driven at a speed of 300rpm (Figure 4).

Figure 1: *Red granulated phenolic resin (280g) were weighed in a digital analytical balance.*

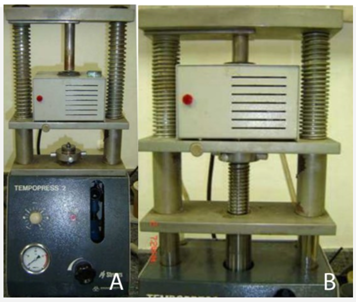

Figure 2: *Compaction process of the powder portion at the bottom of the thermo-plasticising device matrix.*

Figure 3: *Phenolic resin plate.*

Figure 4: *Automatic polisher.*

The plates were clamped in a vice and grooves were made on their surfaces using a rapid steel saw containing 24 teeth/ inch, totalling four or five grooves per surface 1mm deep by 1mm wide.

After making the channels, the plates were dried in an oven for a period of two hours at a temperature of 100°C (212°F); and then weighed on a precision balance, constituting the initial weight (P0) and mounted in the wear test device.

File handle demarcation

It was chosen 30 manual endodontic files (#35) of 25mm length being 10 files of each brand (Dentsply-Maileffer™, Tulsa, OK, US; Densell™, Buenos Aires, Argentina; and FKG™, Le Crêt-du-Locle, Switzerland) (Figure 5). A previous mark was made in the handle of the instrument with 1013 ball burs mounted in high rotation with the intention to guide the assembly of the instrument in the wear test device and later analysis in microscope.

Cleaning of files in ultrasonic cleaner

All instruments were inserted into an ultrasonic tank for cleaning and removal of impurities for five minutes[9].

Wearing test

A motorised device was used to make the horizontal linear movements of the instruments, cut the plates and wear the cutting surfaces of the files, with the least possible influence from the operator.

For the wear test, five cycles of linear movements were simulated, whose frequency of movements was pre-set by means of a cycle counter and a speed regulator housed in the side of the device. Thirty 25 mm manual files (#35) of the three different brands were individually fixed in the wear test device (Figure 6).

For three minutes, 480 linear back and forth movements were performed. Concomitantly, an implant motor was used with irrigation with 20ml of 1% sodium hypochlorite to eliminate the material cut by the instrument.

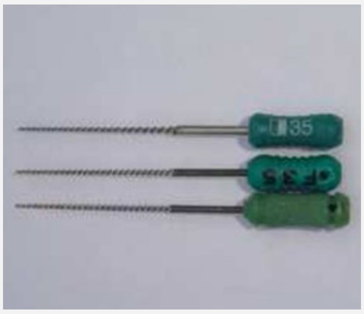

Figure 5: Endodontic files.

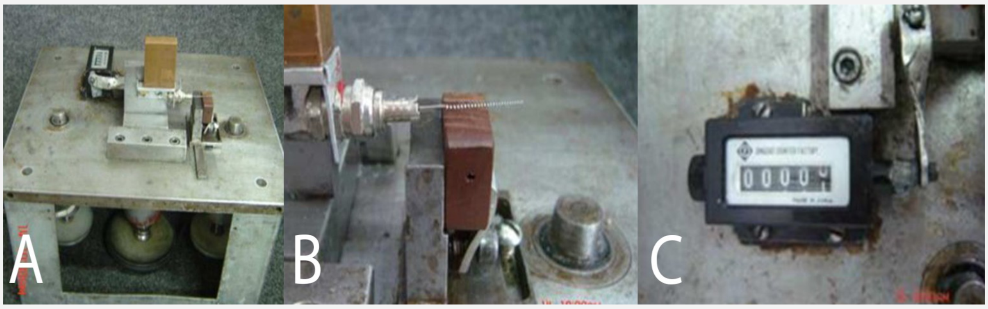

Figure 6: Wearing test device (A). Adaptation Lima/wearing test mechanism (B). Cycle counter (C).

After three minutes, the speed regulator, represented by the cycle conter, was reset to zero. Then the preparation of a new wear cycle with another plate and file was restarted.

The worn surfaces of the plates, once removed, were irrigated again. Subsequently, for dehydration and drying, an oven was used for two hours at a temperature of 100ºC (212ºF). The plates were then weighed again and the values obtained were recorded in a table, considering them as first use plates.

Other plates were weighed on the precision balance. The values obtained were noted and mounted on the wear test device in the same way as in the first procedure.

The same procedures were employed for all files and repeated five times.

All the instruments used in the wear tests were washed in running water. Subsequently, they were immersed in an ultrasonic tank with distilled water solution for removal and cleaning of the material adhered to the cutting surface of the instrument and finally sterilized after each use.

Microscopic analysis

For microscopic evaluation of the worn instrument samples, a microscope Epiphot 200™ (Nikon, Melville, NY, US) with dark-field episcopic illumination of the Materials and Image Analysis Laboratory of the Materials and Technology Department, School of Engineering, Guaratinguetá Campus of State University of São Paulo was used (Figure 7).

Microscopic analyses of all files were performed before starting the procedures. After use, five files of each commercial brand (Dentsply-Maileffer™; Densell™; and FKG™) were randomly selected.

In the microscopic evaluation of the active part of the files, positions of approximately 15mm from their tip were chosen, with magnifications of 50X and 100X (Figure 8). This position was chosen because of the greater contact of the file with the phenolic resin during preparation.

The files were attached to a clamp and positioned, one by one, above the base of analysis, so that the worn region in the tests was directed to the focus of the microscope (Figure 1).

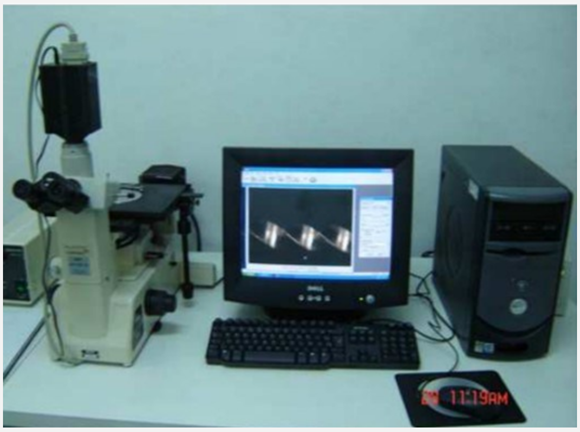

Figure 7: *Microscope model Epiphot 200.*

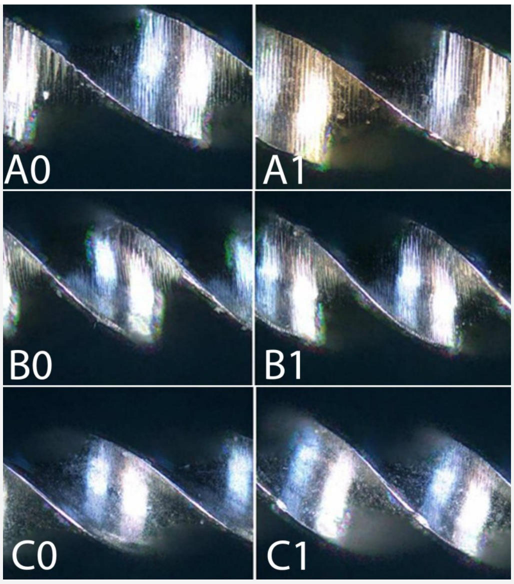

Figure 8: *Photomicrographs after wear of the endodontic file groups. Dentsply-Maileffer™ (A0 = pre-test; A1: post-test). Densell™ (B0 = pre-test; B1: post-test); FKG™ (C0 = pre-test; C1: post-test).*

Photographic reconstruction technique

The photographs were taken from the focus of greatest depth to the one of least depth and, obeyed the sequence every ten seconds. The focus cursor rotated manually, clockwise, counted one photo every ten units, totalizing twenty-one photos per file at each magnification. The technique of focus extension reconstruction[10] was used, in which the twenty-one photographs were stored in a specific folder of the computer attached to the microscope. Subsequently, they were submitted to the NIH ImageJ program[11], achieving a single sharper image from the focus of each of the twenty-one photos.

After performing the experiment with all thirty files, five files of each brand, randomly selected, were again analysed microscopically, repeating the same steps used for the analysis of files before use.

Statistical Analysis

The results obtained in the experiments were statistically analyzed at a 5% significance level using the BioEstat 3.0 program. The statistical tools used were the Kolmogorov-Smirnov test to verify the normality of the data behavior. Due to the characteristics of the data, Student's "t" parametric test was used for comparison in relation to the removal of material. For comparison of the wear of the instruments the ANOVA and Tukey tests were applied.

The evaluation of the abrasions was performed by three clinical professionals, not endodontic specialists, so that there was no influence of the commercial brand or previous knowledge about the shape of the files. They evaluated fifteen files before and after use in two different magnifications, 50X and 100X, and attributed values to the micrographs in a calibrated score from 0 to 4, where 0 = total absence of wear; 1 = minimum presence of wear; 2 = presence of medium wear; 3 = presence of high wear; and, finally, 4 = extremely worn. The qualitative results were converted to quantitative values for the analyses.

Results and Discussion

Cutting capacity

The possibility of interference in the evaluation of the cutting ability of endodontic instruments is quite common and may influence research results[12]. For this reason, the in vitro methodology with the minimum possible operator interference was selected.

Hardness is a measure of the surface resistance of a material to plastic deformation due to penetration or scratching produced by another material. For example, the inherent strength of the cutting blades or abrasive particles of a dental instrument must be large enough to remove substances from the substrate without losing cutting ability or fracturing too quickly. The durability of an abrasive is related to the hardness of the particles or the surface of the material[1].

A determinant factor in the choice of phenolic resin was the fact that teeth may have several hardnesses, consistencies and shapes, which may change and difficult the standardization of the substrate to be worn. Some studies used bovine bone plates as substrate to be worn out due to structural and chemical similarity with dentin. Despite of having as advantage the easy acquisition and standardization of the hardness, on the other hand, it has as disadvantage, the high hygroscopic power, that is, depending on the amount of water present in the substrate, it can have differences of results in the tests[6].

Another material widely used in studies about cutting and wear capacity is the acrylic resin for having, as advantages, the extensive domain of the dental surgeon about the material, easy handling, transparency and acquisition. However, its major disadvantage is its low hardness (21.1 kg/mm^2) compared to dentin, and it may suffer plastic deformation due to heat, which makes its use unfeasible[6].

For the necessity to obtain the standardization of the material to be worn, it was chosen the use of the phenolic resin since there is similarity of hardness of this material with the bone of bovine femur without the present disadvantages[6] which, in turn, has hardness similar to the human dentin. Thus, for the standardization of the material to be worn, it was chosen the use of phenolic resin thanks to the Vickers hardness that reaches indexes of 39.92 Kg/mm^2, more similar to human dentin (57 Kg/mm^2)[1,6].

The cutting ability is the measurement of the amount of removal of hard tissues by a mechanical procedure. However, several variables have been studied, such as shape; irrigation during cutting; the diameter and length of the instrument; time and amplitude of movement[6]; number of uses of the instrument[13,14]; manufacturing process and mechanical and physical properties of the alloy[7,15]; hardness and the type of specimen such as those used in human teeth[8,9,16-22]; in bovine bone plates[6]; acrylic resin blocks[4,23]; and phenolic resin blocks[6,13].

The resistance to wear is a factor that is directly linked to the type of material and to the alloy of which the instrument is made. Other studies were carried out to evaluate and compare the wear and cutting capacity of stainless steel hand files with nickel titanium files[9,14,16,17,20,21]. However, comparative studies of nickel-titanium manual files of these commercial brands (Dentsply-Maileffer™; Densell™; and FKG™) have not been carried out so far. The above mentioned brands of endodontic files were chosen by the predominance in the market. Additionally, they are files indicated in the therapy of root canals with accentuated curvatures and of lower cost than rotatory nickel-titanium files. The selected instrument was the file #35, since this diameter promotes enough wear of the substrate to evaluate the cutting ability. Besides, the selected length was 25mm, which is enough for the adaptation of the file to the wear test mechanism.

It was used a device of simulation of linear movements of manual filing for understanding that such procedure is capable to eliminate the interference of the operator coming from the fatigue, applied pressure, amplitude and frequency of the movements leading to more reliable results. Additionally, the position of the plates, applied load and faithful adaptation of the file/plate/wear test device system were also standardized[6,13].

The time was fixed thanks to the amplitude of the movement determined by the wear test device. The device performs 160 movements per minute in the lowest speed of the device with a necessary amplitude to obtain the wear in the largest possible area of the active part of the endodontic file, extending the contact area of the cutting surface of the instrument with the plate, as well as the amount of phenolic resin worn.

During instrumentation, it was necessary to use irrigation to remove residues, remains of phenolic resin and cooling of the wear system. This condition allowed, according to the experimental findings, loss of weight of the worn phenolic resin plates. In fact, there was substantial resin removal by the three instruments according to the number of use and it can be seen in Table 1.

Table 1: Averages of the amount (grams) of phenolic resin removed by the three instruments according to the number of use.

Commercial brands	1st use	2nd use	3rd	4rd use	5rd use
Densell™	0.01278	0.0115	0.01083	0.00881	0.00602
Dentsply-Maileffer™	0.01022	0.00891	0.00784	0.00593	0.00426
FKG™	0.01372	0.02236	0.01032	0.00681	0.00553

Table 2 compares the sum of the removal of the different commercial brands of files on the phenolic resin plates. It is important to emphasize that the values obtained by the total wear in the three groups of instruments express, in a convincing way, the effect of the quantitative removal of the linear instrumentation, that is, there were variations in the wear in response to the filing of the plates made of phenolic resin.

It is worth mentioning that there is no significant difference between the commercial brands, since the P value in the three comparisons were greater than 0.05 (Table 3). However, the highest removal occurred with Densell™ instruments (0.4994), followed by FKG™ (0.4874) and Dentsply-Maileffer™ (0.4645).

Table 2: Sum of the removal of material from the phenolic resin plates in grams by the three different commercial brands of endodontic files.

Commercial brands	n	Sum Averages	Deviation	K-S Pvalue
Densell™	10	0.04994	0.01827	> 0,05
Dentsply-Maileffer™	8	0.04645	0.01824	> 0,05
FKG™	10	0.04874	0.02074	> 0,05

Table 3: Student's t-test between the sum of the removal of material from the phenolic resin plates in grams by the three different file commercial brands.

Commercial brands	P value
Densell™ X FKG™	> 0,05
Densell™ X Dentsply-Maileffer™	> 0,05
FKG™ X Dentsply-Maileffer™	> 0,05

For the significance level of 5%, when comparing the different uses of the three different commercial brands, it was found that the proportion of samples of each type of instrument does not differ between them (Table 4). That is, that the amounts of phenolic resin removed by the three different instruments are similar among the uses.

Table 4: Scores attributed by the different examiners.

Commercial brands	Average score	K-S P value
Densell™	0.8667	> 0,05
Dentsply-Maileffer™	2.6000	> 0,05
FKG™	2.0000	> 0,05

Instrument wear

Regarding the use of optical microscopy for qualitative evaluation of the files samples, it is important to emphasize that other studies also used the visualization of endodontic files with the use of microscopy[2,15,24-26]. However, they did not use the optical microscopy associated to the Image J program, using the Focal Reconstruction Technique which provided good quality micrographs in colour.

The results show that there are significant differences between commercial brands Densell™ in relation to Dentsply-Maileffer™ and FKG™ (P value < 0.05). In contrast, there is no difference between FKG™ and Dentsply-Maileffer™ (Pvalue > 0.05) (Table 5). As for the mean scores attributed, it was observed that the Dentsply-Maileffer™ instruments were the ones that presented greater wear on their surfaces (2.60 considered as medium wear), followed by the FKG™ instrument. The Densell™ instrument was the one that presented less wear in its cutting blades, with presence of minimum wear (Figure X).

Table 5: ANOVA test: one criterion, TUKEY between the scores of the three commercial brands.

Commercial brands	P value
Densell™ X Dentsply-Maileffer™	< 0,05
Densell™ X FKG™	< 0,05
FKG™ X Dentsply-Maileffer™	> 0,05

Although there was a greater cutting capacity for the Densell™ file, from a qualitative point of view, it was the instrument that wore its cutting blades less. Probably, such difference can be attributed to the alloy composition of this instrument although the cutting surfaces and the cross section of the three instruments are similar. It is believed that for this reason, the instruments presented good and similar cutting capacities, occurring, moreover, surface wear in all instruments.

Conclusions

From the results obtained and based on the methodology used in the present investigation, it seems fair to infer that the instruments of the Dentsply-Maileffer™, Densell™ and FKG™ commercial brands presented similar cutting capacities. Regarding the wear of the instruments, it was found that the Densell™ brand blades deformed less than the Dentsply-Maileffer™ and FKG™ brand instruments.

Acknowledgements

We are grateful to José Arauto Ribeiro and Ewandro Luiz Nohara, PhD (Laboratório de Materiais, Tratamentos de Superfície e Nanotecnologia do Departamento de Engenharia Mecânica da Universidade de Taubaté) for technical assistance, and Luis Rogério de Oliveira Hein, PhD (Laboratório de Materiais e Tecnologia, Universidade Estadual de São Paulo).

Conflict of Interest

The authors declare no conflict of interest.

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Citation: de Medeiros JMF, da Rocha Souza APB, Sakane FK, da Rosa LCL, de Carvalho PL, Alves Claro APR, Pedron IG. “Comparative Study of Cutting Capacity and Wear in 3 Commercial Brands of Ni-Ti Manual Endodontic Files”. *SVOA Dentistry* 2022, 3:5, 235-242.