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Evaluation of the cutting efficiency of a martensitic recently introduced file and an austenitic counterpart: an in vitro study

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ABSTRACT

Background and Objectives. Since their introduction, NI-Ti instruments have been and still are widely studied and compared. Among all the parameters to be taken into consideration, the cutting efficiency is the less observed, as there is a considerable difficulty in making the in vitro tests reproducible and as close as possible to clinical reality. The aim of this study is to evaluate the cutting efficiency of a new martensitic file (EdgeFile X7 ®) compared with its austenitic counterpart.

Materials and Methods. A total of 30 instruments (15 martensitic and 15 austenitic) were tested using a device analogue to another already validated in a previously published study.

Results. The martensitics files showed a mean cutting depth of 1.57 +- 0.47mm, while the austenitic files showed a mean cutting of 6.13 +- 1.53 mm

Conclusions. Since the tested instruments are identical in every feature and differ only in the heat treatment, we can infer that it is responsible for the significant differences in cutting efficiency between the two groups.

Keywords: Endodontics, Nickel-titanium; Cutting efficiency, Mechanical evaluation

Abbreviations:

-Root canal treatment (RCT)

-Nickel-titanium (NiTi)

-Stainless steel (SS)

INTRODUCTION

The introduction of Nickel titanium rotary instruments completely modified the root canal treatment (RCT). Despite that, the goals defined by Schilder in the late 60s of reaching a chemo mechanical disinfection and a stable filling of the root canal, have not been modified in the years [1,2]. On the other hand, the way these goals can be achieved has been drastically modified. Indeed, the introduction of the nickel-titanium (NiTi) rotary files improved the effectiveness speediness of the treatment [3–5]. To be more specific, the NiTi rotary files have replaced the stainless steel (SS) manual files in most of the steps of the RCTs. The widespread use of NiTi rotary instruments derives from two main characteristics: Superelasticity and shape memory effect. The superelasicity is the ability of the alloy to store stress up to 8% without being plastically deformed, remaining in the elastic region of deformation. The shape memory effect is defined as the ability of the alloy to memorize a pre-imposed form and return to it on work. These characteristics are due to the changes in the crystallographic phase of the NiTi [6–8]. The mechanical behavior of the NiTi alloy is represented by the stress/deformation graph. This graph could be divided in three different areas, related to the crystallographic phases of the NiTi alloy: the austenitic region in which the alloy is austenitic phase, the austenitic/martensitic region (also called R-phase) in which there is a partially transformation of austenite in martensite, the martensite region in which the total amount of austenite is transformed in martensite above certain loads. These phases also describe and justify the behavior of the nickel titanium rotary instruments under stress condition [9].

Indeed, the properties and peculiarity of each phase has been deeply described in the literature. The cyclic fatigue resistance is positively influenced by the amount of martensite, and the same statement can be affirmed for the bending ability. Both characteristics increase as well as the martensite percentage increase. Instead, the torsional resistance of the files is negatively affected by the martensite. Indeed, a more austenitic file is more resistant to torsional stresses. Despite the literature agrees on the effect of crystallographic phases on the above-mentioned properties, it is less clear the effect of martensite and austenite percentage on the cutting efficiency of the rotary files. The EdgeFile X7 are instruments made of a nickel-titanium alloy subjected to proprietary thermal treatment which results in a proprietary wire called FireWire™ (Figure 1A). The manufacturer recommends a speed between 300 and 500 rpm and a torque between 2.5 and 4 Ncm. The EdgeFile X7 shows a triangular cutting section. For the current study the manufacturer has also developed for experimental purpose a purely austenitic counterpart of this file, with a blue coating to recognize the austenitic one (Figure 1B). The file made for this study is therefore equal in every characteristic to the EdgeFile X7 currently present on the marketplace, except for heat treatments. The aim of this work is to verify the importance of heat treatments in the cutting capacity of Ni-Ti instruments excluding every confounding factor derived from the geometrical differences of the files.

MATERIALS AND METHODS

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3 Sample size calculation was based on a pilot study. Considering a test power of 0.80 (G*Power 3.1.9.2 software, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with α = 0.05 and β = 0.95, the minimum sample size was established at 15 instruments for each group (*n* = 15). Therefore, in the present study, 30 X7 25.06 instruments were used, 15 thermally treated and 15 austenitic (figure 1). The set speed for the test is 300 RPM and the torque is 2.5 Ncm, as recommended by the manufacturer.

All instruments were subjected to side cutting tests using 3mm red dental wax as a substrate. To ensure the amount of wax was the same, a 3D printed metal mold was used to cut the wax sample. The test was performed using a device similar to the one used by Pedullà et al, driven by a weight of 200 gr that ensured the movement at constant force, for a time of 30 seconds for each measurement [10,11]. The machine presented the same characteristics, therefore with a crankshaft that transmitted the rotation from the step-by-step motor to two chucks between which the tested instrument is held. Thus, when the engine is switched on, the two chucks and the instrument rotated simultaneously and with a U-shaped support located on a mobile platform, which was linked to and moved by the above-mentioned weight (figure 2).

This automatic system allows to remove the bias problem induced by the operator's movement. The analysis of the cutting capacity was performed by measuring the mm of wax cut from the substrate with a digital caliber with a sensitivity of ± 10^{-1} mm. Each measurement was repeated twice, therefore 30 values for each instrument have been obtained.

The mean and standard deviation by type of instrument was then calculated using an excel spreadsheet. All values were then statistically analyzed using the t-student test.

RESULTS

The results of the test have been illustrated in table 1. The X7 austenitic shows a higher cutting efficiency compared to the same file in martensitic form, with statistically relevant results. To be more precise, the martensitic EdgeFile® X7 showed a mean cutting depth of 1.57 +- 0.47mm, while the austenitic files showed a mean cutting of 6.13 +- 1.53 mm.

DISCUSSION

Cutting capacity is an important parameter in NiTi root canal instruments. Indeed it allow the removal of dentine and facilitate root canal preparation [12]. Moreover, it also influences the risk of fracture of NiTi instruments. To be more precise, endodontic instruments with superior cutting efficiency generate a lower friction with the dentin walls, therefore less torsional stress and less risk of torsional fracture [13].

However, there are no international standards for its evaluation. Therefore, the comparison between the different published papers on the subject could be difficult to perform, avoiding obtaining an undoubtful evaluation of the cutting efficiency of martensitic and austenitic instruments. The standardization of testing conditions between the different studies is the most complex factor to obtain since the testing device and the instruments have different characteristics that can impact on the cutting capacity.

First, cutting efficiency could be evaluated in two different ways: axially and laterally. The axial cutting efficiency is the capability to penetrate in a standardized artificial canal and its evaluated measuring the penetration depth [14]. The lateral cutting efficiency measures the instruments pushed laterally on a chosen substrate [10,12,15]. About the substrate, several studies have discouraged testing cutting efficiency using human or bovine teeth dentine because of their variable hardness and water content [16–18]; consequently, in other studies, the cutting efficiency of endodontic NiTi instruments was tested using Plexiglass samples due to their standardized production [17,18]. However, the hardness of Plexiglass has been reported to be lower than dentine [19], whilst gypsum hardness is more comparable with dentine [11,20]. Despite that, in the current study the use of gypsum was discarded because of its properties really influenced by the operator mixing skills, the environmental temperature and the liquid powder ratio

[20]. Therefore, in the current study a red dental wax has been used, to completely standardize the experimental procedures. Despite the different hardness between the dentin and the wax, the stable experimental conditions allow to obtain a reliable evaluation of the two tested files between each other.

Moreover, no published studies have evaluated the cutting efficiency of two files completely equal for cross sections, taper, tip dimension, grounding machine and raw material, with the only difference of the thermal treatment.

Therefore, since the above-mentioned experimental conditions tend to reset the influence that can be obtained by using different files, the current study compare the cutting efficiency of two EdgeFile® X7 with only different thermal treatment. This allows to evaluate and quantify the differences held by cutting from using a martensitic or austenitic instrument [21].

Austenitic X7s were shown to cut more than martensitic EdgeFile® X7s by a factor of 3.92 during testing. Since the two types of tools are the same in all respects except for heat treatments, we can say that thermal treatment is the reason of the difference in cutting capacity [22,23].

The heat treatments, however, alter various characteristics of the alloy, including the elasticity of the instrument in dealing with root canal curvatures. A more martensitic instrument will tend to adapt better to the canal surface respecting the curvatures more and this could affect the greater cutting capacity clinically found in austenitic instruments.

Another important difference between the previously published study with the same machine or with similar machine [11,17], is the point of evaluation of the cutting which was at least at 10mm from the point in the previous studies and 3 mm from the point in the current study, resulting in a value more translatable to clinical performance of the file, this could partially explain the result of the current study.

There are no studies on cutting efficiency of EdgeFile X7 and no studies with so severe testing conditions, and for this reason, the present results cannot compare directly with previous studies.

On the other hand, the wax does not allow to simulate the dentin accurately and on the other hand the test machine does not simulate an instrumentation carried out by a real operator for which this work, although it allows to quantify the difference in cutting capacity induced by heat treatments, does not allow to simulate and quantify the influence that these have at a purely clinical level for which it requires further study in this sense.

CONCLUSION

The evidence described in this paper indicates that an austenitic EdgeFile X7 instrument statistically has a cutting efficiency approximately 3.92 times higher than a martensitic EdgeFile® X7 tool. This highlights the importance of heat treatments in influencing an essential factor such as the cutting capacity of an instrument.

CONFLICT OF INTEREST

I undersign, certificate that I do not have any financial or personal relationships that might bias the content of this work.

AUTHOR'S CONTRIBUTIONS

Conceptualization, M.S and L.T.; methodology, M.D.A.; software, R.R.; validation, M.S., L.T., A.Z.; formal analysis, M.D.A.; investigation, M.D.A.; resources, G.G. and R.R.; data curation, M.D.A.; writing—original draft preparation, M.S. and A.Z.; writing—review and editing, M.D.A. and A.Z.; supervision, R.R.; project administration, L.T. and R.R.; funding acquisition, G.G. and L.T. All authors have read and agreed to the published version of the manuscript.

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TABLES

Table 1. Cutting efficiency of EdgeFile X7 austenitic and martensitic in mm.

	X7 Martensitic	**X7 Austenitic**
Mean ± SD	1.57 ± 0.47	6.13 ± 1.53

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FIGURES

Figure 1. The martensitic X7 currently present on the market (A) and the austenitic replica made for experimental purpose with its blue coating (B).

Figure 2. View of the customized machine for the cutting efficiency, previously validated.