# DIAMOND Cutting efficiency of new endodontic instruments : an in vitro comparative study

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**Abstract**

**Aim of the present study was to analyze the cutting efficiency of two different NiTi systems in all their four most used sizes as proposed by manufacturer in their clinical sequence: ProTaper Gold (Maillefer, Baillagues, CH) and newly released Diamond Edge File (EdgeEndo, Albuquerque, NM) (n=10 for each size). The testing methodology was designed in order to mimic clinical usage and compare the cutting efficiency defined as easier progression to the working length in plastic blocks, using a custom-designed testing system. The system consisted of a sample holder, a motor dedicated to driving endodontic instruments, and a sensor located under the sample holder. Two parameters were recorded to assess cutting efficiency: axial force and operative torque. Mean values and standard deviations of all tests were then statistically analyzed using 1-way ANOVA followed by the post hoc Tukey test with significance set to a 95% confidence level. Results from the present study shows significant differences between the two instruments and the two sequences. When comparing all instruments Diamond Files require less force (measure by torque values) to cut a block and progress to the working length. These data show that they are more efficient at cutting versus ProTaper Gold. On the other hand, they require more force, so called positive force, in order to progress the instrument apically. These last data may seem contradictory when compared to torque values. Moreover Diamond instruments in all sizes showed a statistically significant lower screw-in effect (less negative force) when compared to ProTaper Gold instruments. All these above-mentioned differences were noted in all the four instruments inside the proposed sequence. Overall, the new Diamond files showed very balanced properties and allowed smoother and safer progression to the desired working length as shown by the proposed methodology.**

**Keywords: Endodontic instruments, nickel titanium, cutting efficiency**

## Introduction

In the last years there have been many innovations in the manufacturing of nickel-titanium (NiTi) rotary instruments related to design or heat treatment and there have also been many innovations in the motors and motions for the clinical use of this instrument (1-6). A huge number of new instruments have been commercialized with different features aiming at improving efficiency and safety of the rotary instrumentation



## How to Cite

G. Gambarini, K. Hyeon Cheol
M. Feghali, S. Barre, V. Vincenzi, N. M. Grande.
**DIAMOND Cutting efficiency of new endodontic instruments : an in vitro comparative study.**
Annali Di Stomatologia, 16(1), 54-58. https://doi.org/10.59987/ads/2025.1.54-58



**10.59987/ads/2025.1. 54-58**

(7-12). As a consequence, the traditional ISO testing for the NiTi rotary files are often not sufficient to correctly evaluate and compare these improvements in the performance of NiTi instruments, also because in clinical practice performance can be highly affected by the differences in the canal anatomy (13) and in the hardness of the dentin. More precisely, some properties like cutting efficiency and fatigue resistance became more important parameters to be evaluated for NiTi Instruments (3), while they were less relevant ones for stainless steel manual files.
These last two tests are not regulated by ISO standards, and consequently there has been also an improvements in finding new methodologies for such testing in vitro (14-18), aiming at better understanding how these innovations in design and heat treatments could improve the mechanical properties and clinical performance of the newly developed instruments. Most of the studies, however, evaluate the properties of one single file , mostly addressing to differences also related to sizes and tapers. Nevertheless most of the instruments are used within a sequence and each single evaluation should be inserted in a wider approach, which is the role of each instrument inside a sequence. We know that while instrumenting a root canal not all the instruments do the same job and not all the instruments cut in the same way or in the same portion of the canal, thus resulting in different instrumentation stress and different torsional loading. As a consequence, the value provided from bench testing have to be properly analyzed because the overall performance of the file depends on the relation between the stress and the strength which are applied to a single instrument in the specific case.
Therefore, in the present study, the goal was to analyze the cutting efficiency of two different NiTi systems in all their four most used sizes as proposed by manufacturer in their clinical sequence. Cutting efficiency has not been defined as a test from ISO and consequently there is still a lot of different methodologies that could be used, and this could also probably slightly affect some results because cutting efficiency could be more related to the tip design or to the blade design (which could also be defined as lateral cutting), creating some confusions amongst readers. Therefore, in the present study, a sophisticated automatic methodology was used (Fig. 1). The concept was to analyze the progression of each instrument within a sequence inside a simulated root canal in order to mimic all the factors involved in the cutting efficiency (tip, blades, applied force), and also the screw-in effect. This is a factor more related to safety than efficiency, since a higher tendency of screw-in effect may be a relevant clinical risk, due to the fact that the instrument could more easily become blocked inside the canal and then more easily broken.
Two different kinds of Niti Systems instruments were tested: ProTaper Gold (Maillefer, Baillagues, CH) in a sequence of four instruments and newly released Diamond Edge File (EdgeEndo, Albuquerque, NM) in a sequence of four instruments. These instruments are similar in sizes but not equal: they differ due to design and heat treatment, and also manufacturers instruction for use recommend different speed and torque. Therefore, the testing methodology was designed in order to mimic clinical usage and compare the cutting efficiency defined as easier progression to the working length

## Materials and Methods

Cutting efficiency testing was conducted using a custom-designed testing system (Fig. 1). The system consisted of a sample holder (Fig. 1a), a motor (fig.1b) dedicated to driving endodontic instruments, and a sensor located under the sample holder.

Ten instruments for each of the following sizes and tapers were selected for the present study: S2, F1 , F2 and F3 for Protaper Gold and Slider, F1 , F2, F3 for Edge Diamond.
The rotational speed of the instruments was set according to the manufacturers' specifications: 300 rpm for Protaper Gold and 500 rpm for Edge Diamond. No torque limit was imposed, allowing the sensor to record the actual torque generated during the cutting process. The axial advancement and axial speed were standardized at 1mm per stroke and 0.30 mm/s, respectively, for both instrument systems to ensure a fair comparison.
Two parameters were recorded to assess cutting efficiency: axial force and operative torque.

- Axial force corresponds to the force applied by the practitioner to advance the instrument within the canal. A positive axial force indicates the external force required to reach the working length, and the negative axial force signifies self-advancement of the instrument due to a screwing effect.
- Operative torque represents the resistance encountered by the instrument during cutting. It reflects the energy transferred by the instrument to the dentin during the cutting process. The torque values are recorded directly on the motor. All results were measured in N (newtons)

For this study, endo training blocks were used. The smallest instrument in each sequence was tested on a new block, while subsequent instruments from the same sequence were used on the same block. This approach simulated the progressive removal of material in a clinical setting. Mean values and standard deviations of all tests were then statistically analyzed using 1-way ANOVA followed by the post hoc Tukey test with significance set to a 95% confidence level.

## Results

Results showed that mean operative torque values and SD were the following ones: Protaper Gold S2 2,451N ( SD 0,09) , F1 1,372 N ( SD 0,04) , F2 2,334 ( SD 0,07) and F3 2,376 ( SD 0,08)
Edge Diamond Slider 1,582 N ( SD 0,03) , F1 1,101 N ( SD 0,02) , F2 1,616 N ( SD 0,04), F3 1,546 ( SD 0,03).
Statistical analysis showed significant differences ($p<0.05$) between files of the same size from different manufacturers, with Edge Diamond requiring less operative torque to progress.
Results showed that mean values and SD for applied

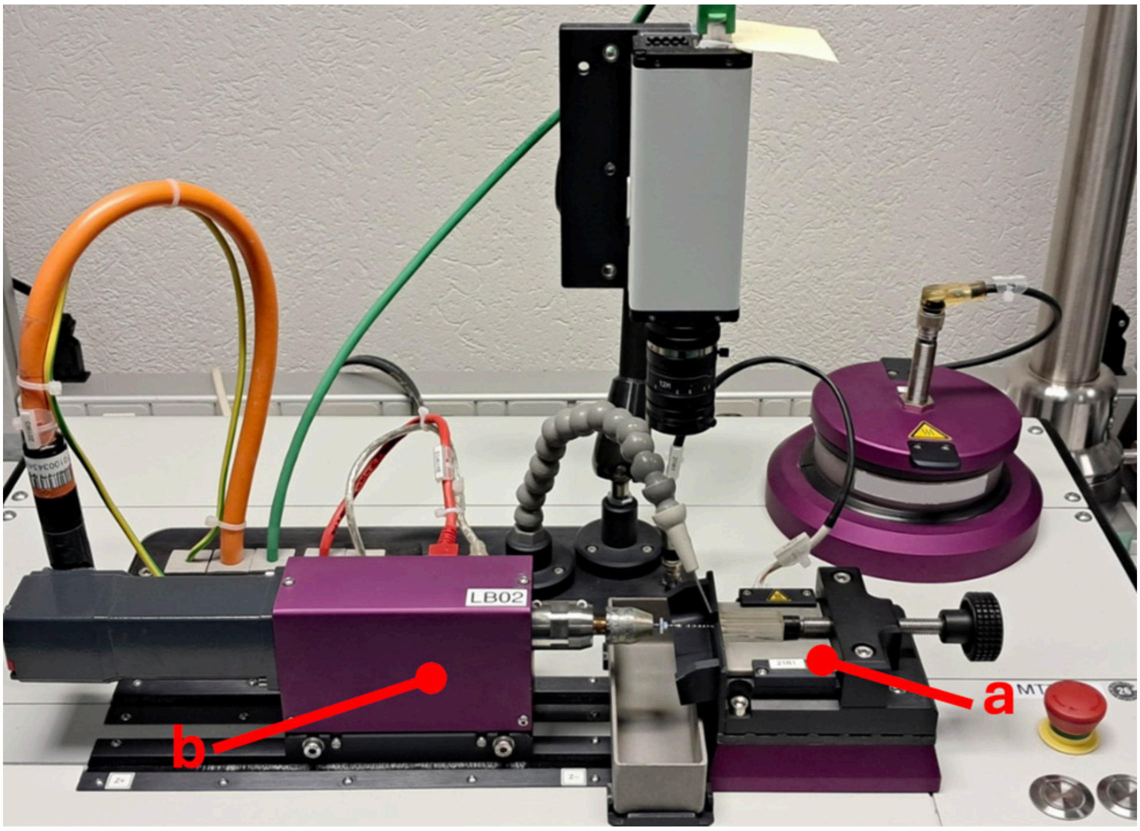


**Figure 1.** The testing devices

positive axial force were the following ones; Protaper Gold S2 1,818N ( SD 0,07), F1 1,276N ( SD 0,04) , F2 2,532N ( SD 0,09)and F3 2,582N ( SD 0,08). Edge Diamond Slider 3,938N (SD 0,09) , F1 3,111N (SD 0,08) , F2 2,692N (SD 0,07), F3 3,612N (SD 0,09). Statistical analysis showed significant differences ($p<0.05$) between files of the same size from different manufacturers, with Protaper Gold requiring less applied force to progress.

Results showed that mean values and SD for applied negative axial force were the following ones. Protaper Gold S2 3,358N (SD 0,09), F1 0,802 N(SD 0,06) , F2 1,392N (SD 0,07) and F3 0,144 N (SD 0,3) Edge Diamond. Slider 0,082N (SD 0,02)., F1 0,036 N(SD 0,02)., F2 0,002N (SD 0,01) , F3 0,002 N (SD 0,01). Statistical analysis showed significant differences ( $p<0.05$) between files of the same size from different manufacturers, with Protaper Gold showing a significant higher screwing-in effect.

Results are also shown by graphs in Figure 2 showing comparative data from all the three tests.

## Discussion

Results from the present study shows significant differences between the two instruments and the two sequences. When comparing all instruments Diamond Files require less force ( measure by torque values) to cut a block and progress to the working length. These data show that they are more efficient at cutting versus ProTaper Gold. On the other hand, they require more force, so called positive force, in order to progress the instrument apically. These last data may seem contradictory when compared to torque values. Moreover Diamond instruments in all sizes showed a statistically significant lower screw-in effect (less negative force) when compared to ProTaper Gold instruments. All these above-mentioned differences were noted in all the four instruments inside the proposed sequence.

These results could be explained by the fact that cutting efficiency is a relatively complex phenomenon to analyze even in vitro, because cutting efficiency is a combination of different factors. In the present study, the progression of the instrument was set equal for all the tested devices and the resulting torque and forces were monitored. The torque is generated by a reaction to the cutting action, meaning that higher torque values show higher effort of the energy that is required to cut. Therefore, it basically shows how efficient an instrument is and how sharp the blades are.

Furthermore, these differences could also be related to the hardness of the metal. Usually a non-heat-treated alloy is harder than a heat-treated one and consequently it is more efficient in cutting. Ideally, the less operative torque, the better it is, because each instrument has a torsional strength, which is related to the maximum torque applied: the lower is the torque value during the progression, the more safe this progression is, because it is less likely that the torque value exceeds the maximum torque values which are withstood by the instrument.

Moreover, if an instrument requires less torque, there is less risk to be blocked inside the root canal. The


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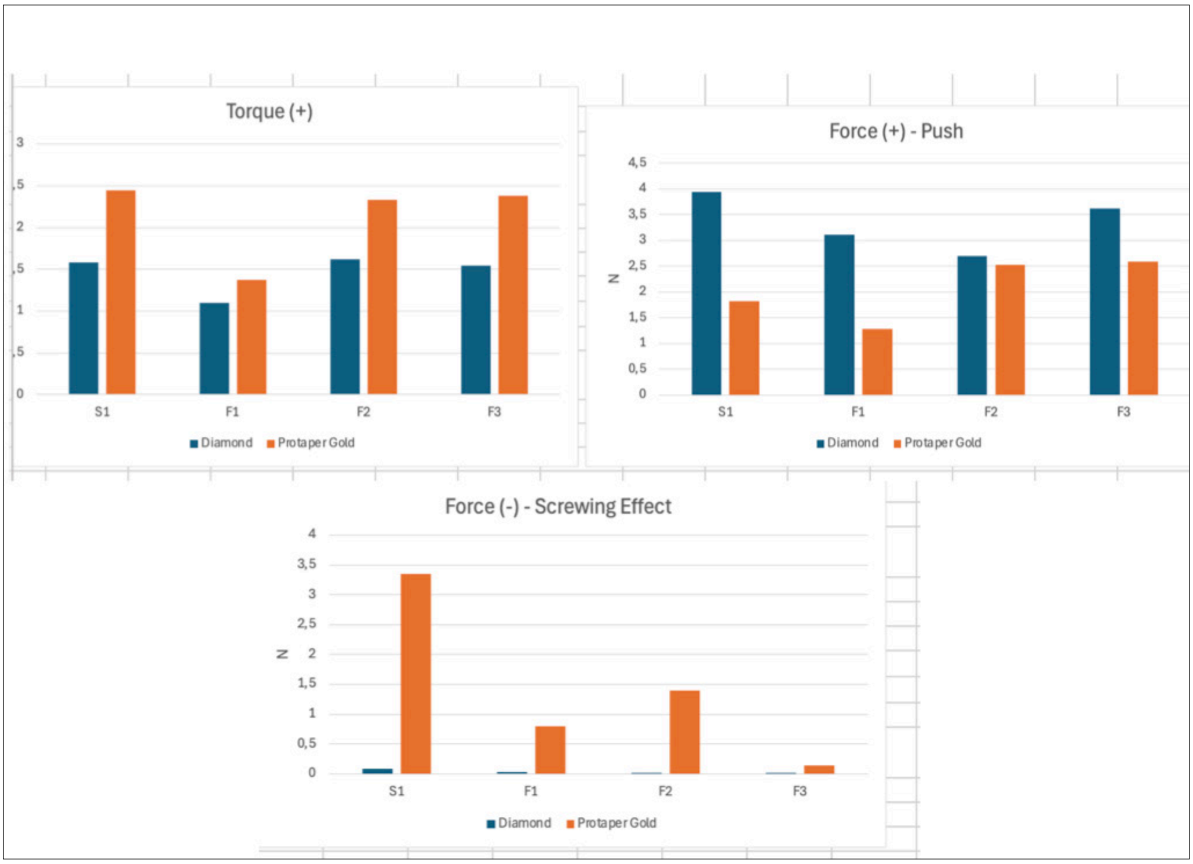


**Figure 2.** Comparison of operative torque, positive and negative axial force

applied forces are mainly linked to the helix angle of the instrument. For example file design with a large helix angle may induce more screw-in effect and, thus, needing less pushing action to reach a predetermined cutting efficiency, as shown by tests of the present study. On the opposite, a drill design with a low helix angle has a little screw-in effect and more pushing is required to the same predetermined distance, as shown by Diamond files in our tests. Ideally, cutting efficiency should be a proper mix of both tip and blade design and a correct choice of the hardness of the alloy in order to reduce the screw-in effect but still not require too much pushing action. Furthermore, the tip also plays a relevant role because a cutting tip will obviously help progression but, in case of pushing action, the tip must follow the root canal. If not, it may lead to heterogenic errors like zipping and latching, mainly when using the most rigid or bigger instrument in curved canals

In the present study, Diamond instruments showed a more balanced in vitro performance between cutting efficiency and screw-in effect. They also showed a little bit higher force to instrument canal but, overall, a very good combination of all the above-mentioned properties. Such a balance could allow, in clinical practice, to have a smoother progression to the working length with increased safety and less risk of iatrogenic errors. The data from the present study are interesting, even if it is not very easy to correlate them with clinical practice because other factors, like the complexities of the root canals and the hardness of dentine, may also influence significantly the performance of the instruments. However, the proposed in vitro testing we able to provide useful and significant information comparing different performance of the instruments when we compare one instrument sequence with the other.

In vitro studies which simulate clinical performance can be extremely useful in order to evaluate how the instrument could work inside canals, which are the weak or strong features of any instrument and also of each sequence. Theoretically, operative loads should be equally distributed among the different instruments and ideally not having instruments that are much more stressed, because this could be a danger in clinical practice. Overall, Diamond files showed very balanced properties and allowed smoother and safer progression to the desired working length as shown by the proposed methodology.

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