

Operative Torque Analysis to Evaluate Cutting Efficiency of Two Nickel-Titanium Rotary Instruments for Glide Path: An *In Vitro* Comparison

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ABSTRACT

Aim and objective: The aim and objective of this study was to evaluate and compare the cutting efficacy of two different nickel titanium rotary instruments by a novel methodology: the operative torque (torque and time needed to progress toward the apex).

Materials and methods: Ten fresh extracted upper first premolars with two canals were instrumented with a KaVo (Biberach, Germany) and a KaVo 1:1 handpiece at 300 rpm with maximum torque set at 2 N. One canal was instrumented with ProGlider NiTi rotary instruments (Dentsply Sirona Endodontics, Ballaigues, Switzerland), with tip size of 16.02, and the other one with EdgeGlidePath rotary instrument (EdgeEndo, Albuquerque, New Mexico). Mean instrumentation time, mean torque values, and maximum torque values were evaluated for each instrument. The significance level was set at $p < 0.05$.

Results: EdgeGlidePath instruments reached the working length in significantly less time with a significantly smaller amount of torque when compared to ProGlider ($p > 0.05$). No instruments exhibited flute deformation or underwent intracanal failure.

Conclusions: Operative torque is related to the capability to cut dentin and progress toward the apex: the smaller the torque values, the higher the cutting ability (and safety). Operative torque is also dependent on debris removal and irrigation techniques. Nevertheless, both operative torque and instrumentation time are clinically relevant parameters for evaluating instruments' performance (i.e., cutting ability).

Clinical significance: Operative torque during endodontic instrumentation helps understanding the overall performance in terms of both cutting efficiency and safety.

Keywords: Cutting efficiency, Glide path, Nickel-titanium, Operative torque, Rotary instruments.

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INTRODUCTION

The mechanical properties of nickel-titanium (NiTi) endodontic instruments have been widely investigated in the past years, including the cutting efficiency,^{1,2} due to their importance in affecting their clinical performance. It has been shown that because of their capability to efficiently cut and remove dentinal tissue, it is related to many instruments' features as follows: Firstly, it is dependent on design, including tip size and cross-sectional shape, number and depth of flutes, and helical and rake angles.³⁻⁵ Secondly, it is dependent on the properties of the alloy and manufacturing processes, including alloy hardness, electropolishing, heat treatments, and coating of the instruments.^{6,7} Finally, it is dependent on instruments' motion, including speed and torque in continuously rotating or reciprocating motions, amplitude and frequency of pecking motion, and debridement of flutes.^{8,9} Other differences in cutting efficiency may also be related to sterilization processes or more likely to the clinical use, which is known to reduce the sharpening of the blades.

There is no standard method to evaluate the cutting efficiency. In the last decades, it has been evaluated mainly in extracted teeth by measuring the amount of debris generated during instrumentation, by measuring the weight loss of teeth after canal preparation or by radiographically assessing the changes in canals' volumes and/or in the dentin thickness following instrumentation. Other researchers made similar evaluations using plastic blocks, while a few studies

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measured lateral cutting by measuring the indentation depth into a Plexiglas plate produced by a lateral pressure of the rotating NiTi instrument. In the majority of studies, preparation time was also recorded because a more rapid progression toward the apex was considered directly related to a better cutting efficacy.¹⁰⁻¹³

More recently, an *in vivo* study on operative torque was published using an innovative methodology, which proved to be a useful tool to evaluate instruments and techniques during their clinical use.¹⁴ Measuring operative torque (more precisely mean and peak torque values) allowed precise comparison of intracanal progression of different instruments, showing significant differences in both preparation time and instrumentation stresses.

The authors concluded that the device used to measure intracanal torque could be adopted to evaluate the clinical performance of instruments (including cutting efficiency) and other operator-related parameters, such as pecking motions or brushing motion.¹⁵ Hence, in the present study, operative torque and instrumentation time were recorded during the intracanal progression of instruments in extracted teeth as means to evaluate and compare the cutting efficiency of NiTi rotary instruments.

MATERIALS AND METHODS

The whole research has been performed at the Department of Oral and Maxillo-facial Sciences of Sapienza University of Rome. Ten fresh extracted upper first premolars with two canals were selected for the study. After accessing the cavity with a 016 round bur, all canals were negotiated with a K-file size 10, and working length was established visually and radiographically. Teeth with nonpatent canals, severe canal curvatures (>30), or wide or resorbed canals were excluded from the study. In each tooth, one canal was assigned to a first group and instrumented with a ProGlider NiTi rotary instrument (Dentsply Sirona Endodontics, Ballaigues, Switzerland), exhibiting tip size of 16.02, variable progressive taper, and manufactured using m-wire alloy; the other canal was assigned to the second group and was instrumented with a EdgeGlidePath rotary instrument (EdgeEndo, Albuquerque, New Mexico). EdgeGlidePath has a triangular cross-section, with tip size of 19 and 1 mm maximum flute diameter (varying taper), and it is produced with FireWire heat treatment. Both instruments are meant to create a glide path using only one instrument. All teeth were prepared by the same experienced clinician, and the same amount of 5% sodium hypochlorite (NiClor, Ognà, Milan, Italy) was used in each root canal.

All nickel-titanium rotary instruments were used only in one canal. They were gently inserted with a slight pecking motion until they reached the working length and were used according to manufacturers' instructions (rotated at 300 rpm with maximum torque set at 2 N), avoiding forcing them apically. Rotary instrumentation was performed by prototype motor provided by KaVo (Biberach, Germany) and a KaVo 1:1 handpiece, as described in previous *in vivo* researches.^{14,15} All the tested instruments were able to reach the apex. During intracanal progression of the instruments, torque values were recorded automatically by the above-mentioned motor every 0.1 second (Table 1 and Fig. 1). At the same time, all measurements were

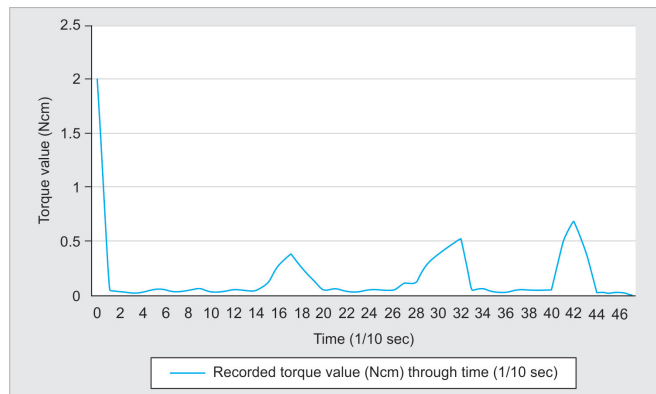


Fig. 1: Data from Table 1 are represented in a graph that shows torque trend during instrumentation

Table 1: The registered torque parameters for the first tooth negotiated with the EdgeGlidePath instrument are resumed in each column: timing (1/10 of seconds), recorded torque values (N/cm), set torque values, recorded speed values (rpm), and set speed (rpm)

| 1/10 sec | Torque | Set torque | Set speed |
|----------|--------|------------|-----------|
| 0 | 2 | 2 | 300 |
| 1 | 0.04 | 2 | 300 |
| 2 | 0.03 | 2 | 300 |
| 3 | 0.02 | 2 | 300 |
| 4 | 0.03 | 2 | 300 |
| 5 | 0.05 | 2 | 300 |
| 6 | 0.04 | 2 | 300 |
| 7 | 0.03 | 2 | 300 |
| 8 | 0.04 | 2 | 300 |
| 9 | 0.06 | 2 | 300 |
| 10 | 0.03 | 2 | 300 |
| 11 | 0.03 | 2 | 300 |
| 12 | 0.05 | 2 | 300 |
| 13 | 0.04 | 2 | 300 |
| 14 | 0.04 | 2 | 300 |
| 15 | 0.11 | 2 | 300 |
| 16 | 0.28 | 2 | 300 |
| 17 | 0.38 | 2 | 300 |
| 18 | 0.25 | 2 | 300 |
| 19 | 0.13 | 2 | 300 |
| 20 | 0.04 | 2 | 300 |
| 21 | 0.06 | 2 | 300 |
| 22 | 0.03 | 2 | 300 |
| 23 | 0.03 | 2 | 300 |
| 24 | 0.05 | 2 | 300 |
| 25 | 0.04 | 2 | 300 |
| 26 | 0.04 | 2 | 300 |
| 27 | 0.11 | 2 | 300 |
| 28 | 0.11 | 2 | 300 |
| 29 | 0.28 | 2 | 300 |
| 30 | 0.38 | 2 | 300 |
| 31 | 0.45 | 2 | 300 |
| 32 | 0.52 | 2 | 300 |
| 33 | 0.04 | 2 | 300 |
| 34 | 0.06 | 2 | 300 |
| 35 | 0.03 | 2 | 300 |
| 36 | 0.03 | 2 | 300 |
| 37 | 0.05 | 2 | 300 |
| 38 | 0.04 | 2 | 300 |
| 39 | 0.04 | 2 | 300 |
| 40 | 0.04 | 2 | 300 |
| 41 | 0.49 | 2 | 300 |
| 42 | 0.69 | 2 | 300 |
| 43 | 0.39 | 2 | 300 |
| 44 | 0.03 | 2 | 300 |
| 45 | 0.02 | 2 | 300 |
| 46 | 0.03 | 2 | 300 |
| 47 | 0 | 2 | 300 |

saved on a memory card, and an Excel file was used to calculate the mean instrumentation time, mean torque values, and maximum torque values. For all tested instruments, the following parameters were analyzed statistically using one-way analysis of variance (ANOVA) test (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, New York: IBM Corp.): mean instrumentation time, mean torque values, and maximum torque values. The significance level was set at $p < 0.05$. Visible signs of instrument deformation or fracture, if any, were recorded.

RESULTS

Table 2 shows mean torque values recorded in the two different canals, and instrumentation meantime. Data were normally distributed (Shapiro-Wilk's test, $p > 0.05$), and there was homogeneity of variance (Levene's test, $p > 0.05$). One-way ANOVA revealed a significant difference between the groups regarding the mean and maximum (peak) torque ($p < 0.05$). There was also a significant difference in mean instrumentation time ($p < 0.05$). Overall, the EdgeGlidePath instruments reached the working length in significantly less time with a significantly smaller amount of torque when compared to ProGlider. No instrument exhibited flute deformation or underwent intracanal failure.

Table 2: Comparison between the two instruments

| | n | ProGlider | | EdgeGlidePath | |
|----------------------------------|----|-----------|------|---------------|------|
| | | Mean | SD | Mean | SD |
| Mean torque | 10 | 0.41 | 0.21 | 0.25a | 0.19 |
| Maximum torque | 10 | 1.56 | 0.53 | 1.21b | 0.27 |
| Mean instrumentation time, speed | 10 | 14.87 | 5.49 | 9.25c | 2.58 |

Mean torque values and mean instrumentation time recorded during intracanal progression to the apex with the two tested instruments in the two canals of the same extracted tooth. The highest registered torque value (max torque) is also displayed. Different superscript letter indicates statistical significance ($p < 0.05$)

DISCUSSION

Glide path instruments were selected for this study because they are the first NiTi rotary instruments used by many clinicians, and their performance is not affected by previous instrumentation. Results showed a significant difference between the two instruments for all the parameters tested: mean instrumentation time, mean torque values, and maximum torque values. Since all instruments were operated in similar canals with the same parameters (speed, torque, and motions), differences could be related to different design, manufacturing process, or dimensions. The proposed innovative methodology (measurements of operative torque) allowed detailed visualization and excellent comparison of instrument progression toward the apex, showing detectable differences in both time and torque values. In addition, less instrumentation torque means lower stress during intracanal instrumentation, thus increasing not only performance (due to increased cutting ability) but also safety.

The two tested glide path instruments have a similar tip size (size 16 vs size 19). In a lateral cutting test, usually the greater the diameters, the greater is the cutting efficiency. In the present study, cutting efficiency was assessed by measuring the operative

torque, if more efficient instrument needs less torque and less time to progress and reach the apex. It has been demonstrated that instrument design and manufacturing play a role³ in determining performance; for example, wider cutting blades contacting more dentine on the canal wall increase the lateral resistance. Heat treatments may produce a more ductile alloy, with increased deformation of the cutting blades and greater contact with dentinal walls. All these factors may increase the torque generated during intracanal instrumentation.

Instruments with greater tapers and dimensions need more operative torque to cut and progress toward the apex, avoiding the taper lock effect in their middle and coronal parts.¹⁶ Therefore, the lower torque values required by EdgeGlidePath instruments are probably related to one or all these factors: design, manufacturing process (including heat treatment), and taper. It is difficult to precisely analyze the influence of each of the above-mentioned factors because both heat treatments and tapers are not clearly disclosed by manufacturers.¹⁷⁻¹⁹

It is not easy to correlate data from the present study with similar studies because the instruments are different, in terms of design, dimensions, and clinical use; moreover, the proposed novel methodology is very different from the *in vitro* tests performed in other studies.¹⁰⁻¹³ More specifically, the proposed novel methodology is closer to the real clinical use of the instruments, and with some approximation, it could be compared with studies evaluating instrumentation time. Indeed, studies about instrumentation time are difficult to compare because they are highly influenced by variations in canal anatomy, curvatures, canal diameters, hardness of dentine, etc. Differences in the latter parameter (surface hardness), however, are common limitations in all cutting tests; this can probably explain why there is no international approved standard test for cutting efficiency.

Operative torque is also related to the capability to remove debris because debris entrapped among flutes can increase torque and reduce cutting ability. A possible limitation of the present test is because of the fact that operative torque is assessing cutting efficiency not exclusively since it is also dependent on flutes' debris removal and irrigation techniques. Moreover, it is a comprehensive test, which cannot distinguish which part of the instrument is efficient in cutting; the latter evaluation could be useful to test *in vitro* modifications in the instruments' design. Nevertheless, both operative torque and instrumentation time are clinically relevant parameters because they evaluate performance in a way very similar to the clinical use of the instruments.²⁰⁻²²

CONCLUSION

Under the experimental conditions of the present study, EdgeGlidePath instruments reached the working length in significantly less time with a significantly smaller amount of torque when compared to ProGlider, thus exhibiting an overall better cutting efficiency, with less risk of overstressing the instruments. The instruments were similar in their clinical use and dimensions but different in design and manufacturing. However, it was not possible to assess which factor (design, manufacturing process, or dimensions) played a major role in determining these results. Future studies, by comparing instruments with only one parameter different, may help to precisely assess the role of each parameter in determining cutting efficiency.

CLINICAL SIGNIFICANCE

Operative torque during endodontic instrumentation helps in understanding overall performance in terms of both cutting efficiency and safety.

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