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Assessment of Real-Time Operative Torque during Nickel–Titanium Instrumentation with Different Lubricants

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Featured Application: Evaluate the torque values by nickel–titanium rotary instruments during intracanal instrumentation.

Abstract: The aim of the present study is twofold: to assess ex vivo the role of different lubricants on real-time torque generated during intracanal instrumentation and to check whether two different kinds of torque parameters, operative torque (OT) and average peak torque (APT), could produce similar results. Forty extracted single-rooted teeth were selected for the present study and divided into four equal groups (n = 10): Group A, NaCl 0.2%; Group B, NaOCl 5%; Group C, ethylenediaminetetraacetate (EDTA), and Group D, EDTA and hydrogen peroxide. Afterwards, Edge Taper F2 (Edge Endo, Albuquerque, New Mexico) were rotated clockwise at 300 rpm with 3 Ncm maximum torque by an endodontic torque recording motor. In each sample, mean OT and mean APT were recorded and statistically analyzed with one-way ANOVA and a post hoc Bonferroni between groups ($p < 0.05$). EDTA (12.11 ± 4.45 Ncm) showed statistically significant ($p < 0.05$) lower values compared with the other tested irrigant for both parameters. Overall, the two different parameters were both able to differentiate between the influence of lubricants on torsional loads.

Keywords: endodontics; nickel–titanium; torque; root-canal irrigants

1. Introduction

Nickel–titanium rotary (NTR) instruments gained a primary role in root-canal treatment (RCT). Despite that, NTR instrument failure is approximately 1% of all RCTs [1,2]. Sattapan et al. (2000) reported that torsional stresses are the major responsible of the failure of these files in 55% of the examined cases, while flexural stresses cause 45% of the failure [3]. This ratio could even be changed in recent years, since manufacturers have produced more flexible instruments thanks to the introduction of new heat treatment processes [4–6].

In the literature, many studies evaluated the torsional resistance of an NTR instrument, locking it 3 mm from the tip, whilst the motor rotates at 2 rpm until fracture occurs [7–9]. Despite being easier to perform, static tests do not reflect an instrument's clinical performance during RCTs. Recently developed software and manufacturing allowed the realization of devices able to evaluate and record real-time torque variation. For this reason, thanks to these new devices, previous published studies managed to introduce the idea of an "operative torque" [10]. The "operative torque" (OT) is defined as the amount of torque needed by the instrument to reach the apex. Nowadays, it is obtained by measuring the torque generated by the instrument each 0.1 s and calculating the mean value. Therefore, it can be defined as the mean operative torque (MOT). Thanks to this parameter, it is now possible to evaluate the efficiency of an NTR instrument during RCT. However, despite the importance of introducing a parameter that allows the measurement of the stresses produced during root-canal shaping, operative torque relevance and the methods of calculation are still controversial. It is indeed influenced not only by the time need to perform the RCT but also by the technique used by the clinician.

Despite the primary role of NTR instruments in shaping the root canal, the aim of endodontic treatment is to allow irrigant penetration through the endodontic space, not only focusing on the main canal [11]. Moreover, these irrigants and lubricants are used to emulsify and clean the debris produced by the cutting action of the endodontic instruments, this way facilitating the instruments' progression [12].

Irrigants are produced in two different forms: aqueous and paste-type lubricants. The aqueous irrigants, such as sodium hypochlorite (NaOCl) and ethylenediaminetetraacetate (EDTA) are primarily used as surfactants and to suspend debris [13]. NaOCl is the most used irrigant in endodontics considering its superiority in removing the smear layer.

Chelating agents, such as EDTA, create stable calcium complexes with smear layers and calcific deposits along the dentinal walls [14]. These agents act on calcified tissue by subtracting sodium ions, which in combination with dentine, give a soluble salt with calcium ions. Paste-type substances, such as combinations of EDTA and carbamide peroxide or EDTA and urea peroxide, are marketed by rotary manufacturers and firstly improve hard tissue debridement [15]. The hard tissue debridement allows a lower blade engagement on the dentinal walls and consequently a lower torque generation by the instrument during intracanal instrumentation. Furthermore, the chelating and lubricating actions of EDTA ensure the debris removal from the rotating instrument. Moreover, chemical additives, such as peroxides, could soften the dentinal walls to facilitate instrumentation and instrument progression towards the apex [12].

In the current literature, many studies evaluated the different characteristics and molecular pattern of different types of lubricants [16–21]. Most of these studies focused their attentions on the various effects in reducing and eliminating smear layer and debris during RCTs. In the last fifteen years, a small number of studies have tried to investigate the role of lubricants on torque generated during instrumentation. However, these studies tested the instruments in a simulated root-canal system and focused on maximum torque value reached by the instrument during the instrumentation [22,23]. Moreover, to date, no published studies evaluated the efficacy of different irrigants on reducing operative torque. Therefore, the aim of the present study is twofold: to evaluate the role of different lubricants on real-time torque generated during intracanal ex vivo instrumentation and to propose a new methodology to assess real-time operative torque.

2. Materials and Methods

A total of forty extracted single-rooted teeth were selected for the present study to perform operative torque test. The single-rooted teeth were extracted for periodontal and orthodontic reasons. After the extraction procedures, teeth were immediately stored in saline water 0.2% until examination. Teeth presenting root caries, restorations, deformation such as resorption, immature apex, root fractures, and calcification were discarded. The inclusion criteria were as follows: teeth presenting one canal with a class I according Vertucci's classification and a curvature smaller than 30° according Schneider's criteria [24,25]. As showed in Figure 1, to clearly investigate the root-canal anatomy, the teeth were previously analyzed through the use of cone beam computed tomography (CBCT) in axial, coronal, and sagittal sections [26].

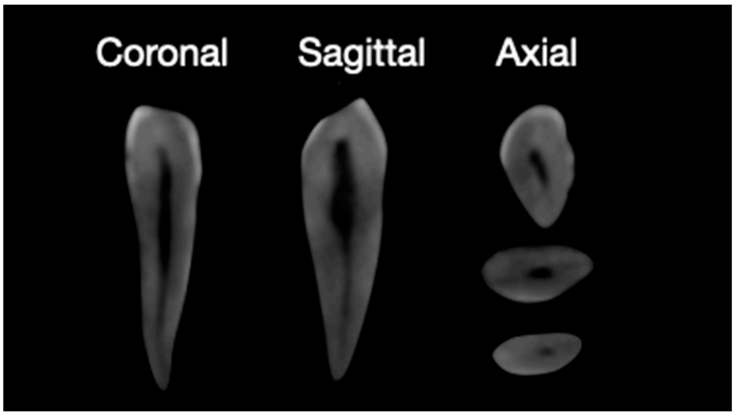

Figure 1. Cone beam computed tomography (CBCT) evaluation of the extracted teeth.

An endodontic access and a manual glide path with a #15 K-file (Dentsply, Maillefer, Tulsa, OK, USA) to the working length was performed on all the extracted teeth [27].

The forty extracted teeth were randomly divided into four different groups (n = 10).

To perform the operative torque test, a brand-new endodontic file was utilized for all the tests. The files utilized in the present studies were the Edge Taper F2 (Edge Endo, Albuquerque, NM). These files present as shaped cross-sectional design, with tip 25 and taper 0.06. Before the instrumentation, each of the NTR files were inspected with a ×20 microscope to detect any sign of deformation.

For each group, different endodontic irrigants were selected: Group A, aqueous saline solution (NaCl 0.2%, OGNA, Milano, Italy); Group B, aqueous sodium hypochlorite (NaOCl 5%, OGNA, Milano, Italy); Group C, aqueous ethylenediaminetetraacetate (EDTA), and Group D, paste-type combination of acetyl alcohol, EDTA, and hydrogen peroxide (RC PREP, OGNA, Milano, Italy). Before proceeding with the instrumentation of the canal, a total of 1mL of the selected irrigant was introduced into the canal with the use of a 30-gauge syringe. Afterwards, files were rotated, according to the manufacturer recommendation, clockwise at 300 rpm with 3 Ncm maximum torque by an endodontic torque recording motor (Kavo, Biberach, Germany) [28]. This endodontic torque recording motor ensure a real-time evaluation every 1/10 s. The operative torque test was concluded when the file reached the apex [29].

Mean values of torque generated during intracanal instrumentation (Ncm) were recorded for all the groups taken in exams. In addition, the quantity and the maximum value of all peaks (average peak torque) were recorded for all instrumentation. Afterwards average peak torque (APT) mean value were calculated for each instrument. Data for all the groups were recorded and analyzed using a SPSS 17.0 software (SPSS Incorporated, Chicago, IL, USA). One-way ANOVA was performed for all the tests with a level of significance set at $p < 0.05$. Afterward, a post hoc Bonferroni between groups test was performed.

3. Results

Table 1 shows mean values for operative torque test and for average peak torque. In terms of mean OT, the results showed statistically significant difference ($p < 0.05$) between EDTA (0.29 ± 0.07 Ncm) and both saline solution (0.52 ± 0.04 Ncm) and sodium hypochlorite (0.47 ± 0.08 Ncm). Despite this, no significant differences ($p > 0.05$) were found between EDTA and RC PREP (0.42 ± 0.07 Ncm).

On the other hand, results in terms of mean APT (MAPT) showed significant difference compared to the operative torque test. Indeed, EDTA (12.11 ± 4.45 Ncm) showed a significant ($p < 0.05$) lower mean APT compared with the all the irrigants taken in exams.

Table 1. Mean values of operative torque test and average peak torque mean values (Ncm). One-way ANOVA ($p < 0.05$) and a Bonferroni post hoc test were performed. The superscript uppercase letter shows that the post hoc test was significant otherwise the superscript lowercase shows a non-significant post hoc test.

	Mean Operative Torque (MOT)	Mean Average Peak Torque (MAPT)
Saline Solution	0.52 ± 0.04^{ABC}	23.01 ± 3.48^{aBc}
Sodium Hypoclorite	0.47 ± 0.08^{ADe}	22.79 ± 3.51^{aDe}
Ethylenediaminetetraacetate (EDTA)	0.29 ± 0.07^{BDf}	12.11 ± 4.45^{BDF}
Hydrogen Peroxide (RC PREP)	0.42 ± 0.07^{Cef}	20.04 ± 2.61^{ceF}

4. Discussion

In the present literature, the evaluation of torsional behavior of NTR is mostly assessed with torsional resistance test [30,31]. This test could only evaluate the resistance to torsional stresses concentrated in a given point of the instrument under static condition. Therefore, in recent years, many studies tried to investigate the role of torsional stresses dynamically, in order to reproduce the real application of NTR during intracanal instrumentation.

Recently, the concept of operative torque was introduced in the literature [10,29]. The operative torque test ensures a precise recording of the multitude of torsional stresses along all the surfaces of the whole tested instrument. Moreover, this test evaluates the instrument dynamically, taking into account the stresses developed during intracanal instrumentation, from the orifice towards the apex. On the other hand, this real-time measurement is constantly influenced by the time needed and technique used to reach the working length. In the literature, several studies indicate that the anatomy of the root canal can influence the RCTs [32]. During intracanal instrumentation, calcifications, zips, perforations, and resorption significantly lengthen the operating time. In these cases, the mean operative torque (MOT) test could not be the correct evaluation method, as an increase in operating times with low torque values reached could reduce the mean amount of torque to reach the apex [33]. The MOT test evaluation process usually includes a graph that shows all the torque values reached during the RCT (Figure 2).

Indeed, as showed in Figure 2, numerous areas with high peaks are noted in the graph. Each peak is the torque records related to one pecking motion. This correspondence between torque recorded and file motion could be described as a rising area, corresponding to the inward action of the file; an apex corresponding to the maximum torque reached by the pecking action; a descend area corresponding to the backward action. It is clear that, evaluating these areas, while the values that rise to reach the peak are gradual, the values that descend from the peak are decreasing in a very short time. These characteristics depend on the technique used. Indeed, while the inward motion is gradually performed due to dentinal wall resistance to the cutting action of the file, the outward motion of the file is faster and safer.

Up to date, the interpretation of this graph has only taken into account the mean operative torque. This calculation takes into account all the torque values reached during instrumentation and is obtained by adding up these values [34]. Besides, since "the apex of the peak" is already a sum of all the previous values, this interpretation could be misleading. For this reason, in the present study, a new concept based on the above-mentioned premises has been proposed—the average peak torque value. This numerical value is the mean obtained from the apex value of each peak shown in the graph. Since "the apex of the peak" value could be considered as the resultant of all the values preceding it, the APT is the mean of each significant value recorded during root-canal instrumentation (Figure 3). Therefore, the proposed concept could be a more representative record of clinical motion of the files, since it is not influenced by the time needed to perform the treatment and is not influenced by a less torque-consuming outward brushing motion. Moreover, it could be considered a good representation of the real difficulties of the root-canal treatment performed and of the amount of stress accumulated by the instruments. Furthermore, since one of the main issues of operative torque is that its measurement is influenced by factors, such as time and technique used, the above-explained concept of APT could be proposed as a possible solution to this problem.

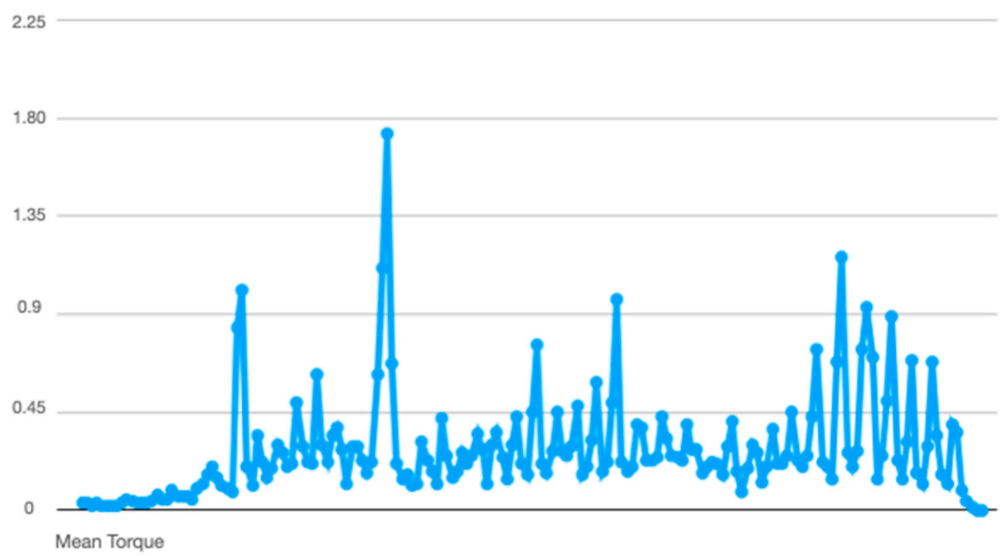

Figure 2. Operative torque test graphical evaluation.

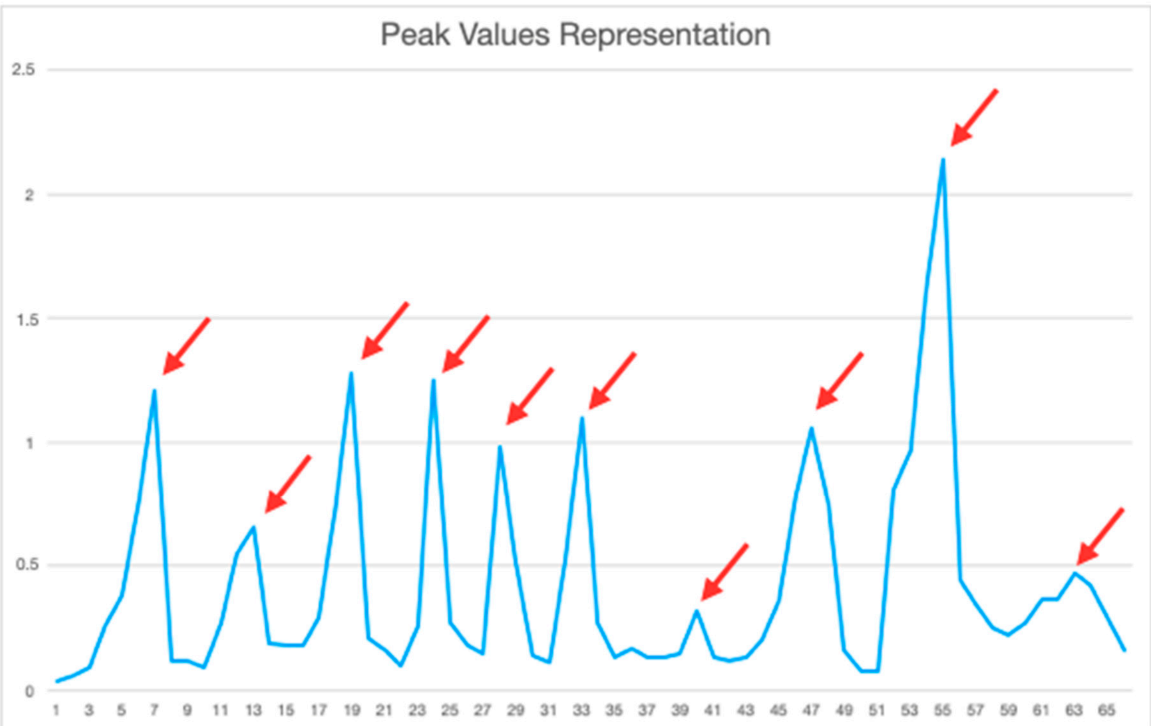

Figure 3. Peak values representation. On the axes are the torque values reached during instrumentation (Ncm) and the instrumentation time (1/10 s). The red arrows indicates peak values.

In the literature, the role of irrigants regarding the torque generated during intracanal instrumentation has been poorly evaluated. The role of different irrigants on torque developed during ex vivo instrumentation has never been evaluated before.

According to the in vitro studies of Peters et al. (2005) and Boessler et al. (2007), the paste-type lubricants showed significantly more torque accumulation during simulated root-canal instrumentation than the aqueous irrigants [22,23]. The method of torque calculation used in the two above-mentioned papers is really different from the current experimental condition. Indeed, both Peters et al. (2005) and Boessler et al. (2007) take into account maximum torque reached as the only torque value. Despite that, their results seem to confirm the findings of the present study. Mousavi SA et al. (2012) showed that there is an increased risk of failure of Ni-Ti rotary files without irrigation [35]. The result of the present study showed statistically different values regarding the different irrigants, partially in agreement with the in vitro previously published studies. Indeed, as shown in Table 1, mean operative torque test results showed a significant difference comparing saline solution and NaOCl or RC PREP. On the other hand, using the mean APT evaluation, the differences were not significant between saline solution and NaOCl or RC PREP. This difference could be related to the influence of inward progression time on the mean operative torque values. Anyway, both evaluations performed in the present study MOT and MAPT showed a significant reduction in torque generated using aqueous EDTA. Therefore, it could be stated that the primary role in the reduction in torque stresses is played by the chelating action of the ethylenediaminetetraacetate, while the aqueous form seems to only slightly influence the stress generation during RCT.

5. Conclusions

According to the result of the present study, the MAPT evaluation could be considered as a reliable method of torsional stress evaluation of NTR during RCT. Moreover, this evaluation could represent the real torque behavior during intracanal instrumentation. The present study seems to demonstrate the influence of lubricants and their physic state on ex vivo torque generated. Anyway, further studies are needed to deeply investigate the in vivo role of lubricants on torsional stress of Ni-Ti instrumentation.

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