

A comparison between clinical operative torque and in vitro torsional resistance

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Abstract

Operative torque indicates the real-time stresses exerted on Nickel-Titanium Rotary Instruments (NTRs) during clinical application, whereas torsional resistance denotes a file's maximum capacity to withstand torsional stresses prior to fracture. A comprehensive understanding of both parameters is essential for enhancing instrument safety and informing the development of next-generation rotary systems. Consequently, the present study aimed to evaluate the "in vivo" operative torque values of new NiTi rotary instruments (I-file, Henry Schein Endodontics, China) and to compare these with the in vitro torsional resistance of each instrument. Twenty instruments, representing the following sizes (i-File 25.07, I-Follow 15.04, and I-Finish 25.04), were selected and divided into two groups. The first group (n=10 for each size) was evaluated for torsional resistance in accordance with ISO Standard 3630-1. The second group involved instruments used clinically to prepare a molar case. Data were collected and subjected to statistical analysis. The results demonstrated statistically significant differences among the three files in both tests; however, their behavior was similar. No values exceeded the torsional strength, indicating a proper balance between the two properties. The findings of the study confirmed an ideal distribution of intracanal operative loading, with all instruments exhibiting operative torque values below the maximum torque at failure.

Keywords: torque, torsion, fracture, nickel-titanium instruments

Introduction

Nickel–titanium rotary files (NTRs) are extensively employed in endodontics owing to their flexibility, shape memory, and cutting efficiency. They facilitate more efficient and expedited shaping procedures owing to their high rotation speed and superior debris removal capabilities. Consequently, NTRs have established themselves as the gold standard in endodontic instrumentation. Nevertheless, the fracture of NTRs remains a significant challenge, often occurring unexpectedly and potentially jeopardizing treatment outcomes (1-4). Two primary mechanisms responsible for file separation are cyclic fatigue and torsional failure. Cyclic fatigue is associated with repetitive tensile and compressive stresses encountered in curved canals, whereas torsional failure transpires when the instrument tip becomes lodged in dentin while the shank continues to rotate (5-9). In such instances, the torque exerted by the motor— which



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aims to maintain a consistent rotational speed— may substantially exceed the NTR's strength, leading to intracanal separation.

Operative torque represents the rotational force produced during instrument interaction with dentin during canal preparation. It fluctuates continuously based on canal anatomy, file design, and operator technique (10-13). Excessive operative torque predisposes an instrument to torsional stress accumulation, plastic deformation (typically flute elongation), and eventual fracture.

Numerous factors can influence operative torque in clinical practice (14-18). To be more precise.

1. The anatomy of the canal—characterized by being narrow, curved, and calcified—enhances the contact between the dentin and the file, thereby increasing the torque requirement.
2. The design of the file—including its cross-sectional shape, taper, and cutting efficiency—affects the magnitude of the torque produced. Moreover, the tip design is of utmost importance, as a non-cutting tip requires greater torque to progress and cut.
3. Heat-treated NiTi alloys with improved flexibility typically produce lower torque values, despite a slight decrease in their cutting efficiency.
4. Motor Settings – Torque-controlled motors can limit rotational stress by reversing or stopping rotation upon reaching a preset torque threshold. Moreover, differences in torque are present when NTRs are used with continuous rotation or reciprocating motions,
5. The clinical technique—comprising pecking motions, gradual progression in small steps, enhanced glide path preparation, and the implementation of improved irrigation protocols—could potentially diminish torque loads.

Torsional resistance represents the maximum torque a file can endure before undergoing plastic deformation or fracture (19-20). Standardized testing protocols, such as ISO 3630-1, assess the torque at the point of fracture through securing the file tip and applying

rotational force until separation occurs. The principal factors affecting torsional resistance are as follows:

1. The core diameter—larger core areas effectively resist torsional stress; however, they consequently diminish flexibility.
2. Cross-sectional geometry—whether triangular or square—distributes stress differently compared to S-shaped or off-centered configurations.
3. Alloy processing—thermomechanical treatments enhance flexibility; however, they may variably influence torsional resistance. Additionally, these treatments frequently increase the propensity for flute deformations.
4. Surface treatments, such as electropolishing and coating, serve to diminish surface irregularities and enhance resistance to crack initiation.

Operative torque indicates the real-time stresses exerted on NTRs during clinical procedures, whereas torsional resistance signifies a file's maximum capacity to withstand torsional stresses prior to fracture. A comprehensive understanding of both parameters is essential for enhancing instrument safety and guiding the development of next-generation rotary systems. Consequently, this study aimed to evaluate the “in vivo” operative torque values of novel Niti rotary instruments (I-file, Henry Schein Endodontics, China) and compare them with each instrument's in vitro torsional resistance.

Materials and methods

Twenty instruments corresponding to the following sizes (i-find 25.07, I-follow 15.04, and I-finish 25.04) were selected and categorized into two groups. Instruments in the first group (n=10 for each size) underwent torsional resistance testing (MTAF maximum torque at failure) in accordance with ISO standard 3630-1, utilizing a device previously developed by the authors (19-20) for torsional assessments (see Figure 1). The second group was employed clinically to prepare a molar case in accordance with the manufacturer's Instructions for Use (IFU). Instruments were rotated using a

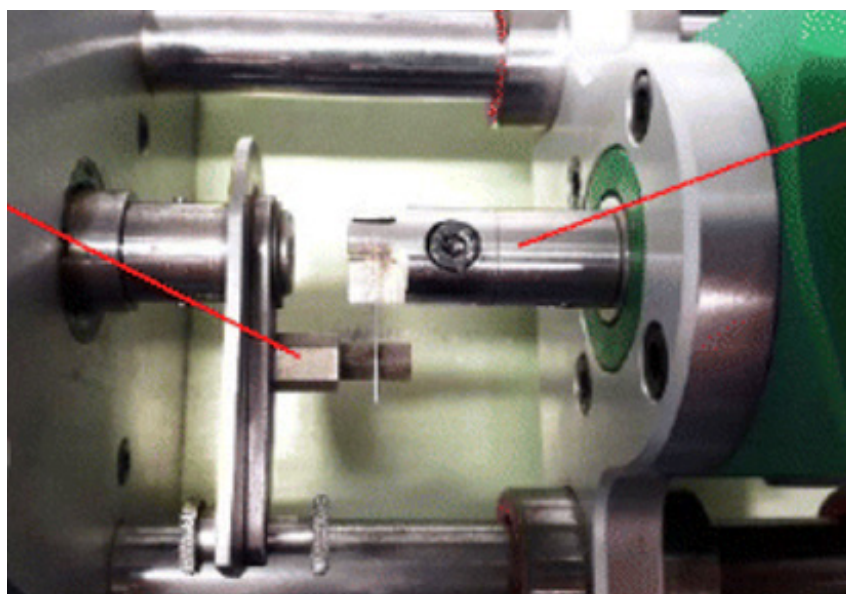


Figure 1. Test apparatus for torsion as per ISO 3630-1.



Figure 2. Presents the mean MOT values for each instrument, the motor employed, and a clinical case conducted during the study.

novel motor (EndoMaster, Perfect, Shenzhen, China), which permitted the recording of intracanal operative torque (MOT, maximum operative torque). In a private practice setting, ten cases were completed utilizing new instruments in each instance. The maximum torque value (MOT) (Figure 2) was documented for every case and instrument. All data—including mean values and standard deviations—were subjected to statistical analysis using one-way ANOVA followed by the post hoc Tukey test, with the level of significance established at 95% confidence.

Results

The mean values and standard deviations for MOT were as follows: I-find 0.84N (SD 0,15), I-follow 0.26N (SD 0,005), and I-finish 0.54N (SD 0,1). The mean values and standard deviations for MTAF were as follows: I-find 1,14 N/cm (SD 0,2), I-follow 0,56 N/cm (SD 0,01), and I-finish 0,82 N (SD 0,1). Results indicated a statistically significant difference among the three files in both tests, although they exhibited similar behavior. The operative torque was notably higher for the instruments labeled I-find, which demonstrated the greatest resistance in vitro. Conversely, the operative torque was markedly lower for the instruments designated I-follow, which showed the least resistance in vitro. No values surpassed the torsional strength, indicating an appropriate balance between the two properties. Furthermore, no instrument exhibited intracanal deformation or breakage.

Discussion

Operative torque pertains to the real-time rotational force exerted by a nickel-titanium (NiTi) instrument during root canal shaping. It is continuously measured—generally every 0.1 seconds—by advanced endodontic motors and indicates the dynamic stress necessary

to cut dentin and progress toward the working length. The ISO torsional test 3630-1 (for endodontic files) is a standardized procedure employed to determine an instrument's torsional resistance. Ideally, a well-balanced clinical performance of both parameters is essential for enhancing NTRs, cutting efficiency, progression, and safety, thereby guiding clinicians toward more controlled and effective procedures. Torque-controlled motors were proposed to reduce the risk of intracanal failure by preventing instruments from reaching torque values—usually determined by ISO torsional tests—that could lead to breakage if instruments become obstructed within canals. However, if preset values are excessively low (to maximize safety), the instruments may not cut effectively or progress smoothly. Therefore, when new NiTi rotary instruments (NTRs) and sequences are marketed, a preliminary study should be conducted to evaluate both parameters: operative torque and torsional resistance. These parameters facilitate more precise definition and selection of preset values for clinical application. Furthermore, this approach could also determine whether the sequence is well balanced in distributing operative stress among the instruments. The study's results confirmed an ideal distribution of intracanal operative loading, with all instruments exhibiting operative torque values below their maximum torque at failure. Such data substantiate that emerging technologies—such as adaptive motion motors, torque-sensing handpieces, and innovative NiTi alloys—hold the potential to enhance clinical safety while maintaining or improving efficiency. Further clinical validation is necessary to develop evidence-based guidelines for optimizing torque control. Moving forward, additional in vitro and clinical studies that combine torque monitoring with fatigue testing under dynamic conditions—simulating clinical performance more accurately—are required.

Conclusion

Operational torque and torsional resistance are interdependent parameters that substantially impact the clinical efficacy and safety of NiTi rotary endodontic files. A comprehensive understanding of their interaction, along with appropriate technique and instrument selection, is crucial to minimize fracture incidence. Innovations in alloy technology, instrument design, and torque-controlled devices are expected to further enhance the reliability of rotary endodontic instrumentation.

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