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The Influence of a Thermomechanical Treatment on The Cutting Efficiency of NiTi Endodontic Rotary File

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Abstract

This study was designed to evaluate the cutting efficiency of heat-treated endodontic file under two different torque setting 1.5 Ncm as a recommended torque and at a higher torque 4.5 Ncm. Material and method: 40 Race Evo sets of files were used to shape 400 acrylic resin canals with angle of curvature less than 30º a length of 16 mm. Samples were divided into two groups depending on torque. Group A: (20) files tested under recommended manufacture torque 1.5 Ncm. Group B: (20) file were tested under higher torque 4.5 Ncm. Each group was further divided into two subgroups according to number of canals: Subgroup I: (10) Race Evo files were used to shape 8 canals. Subgroup II: (10) Race Evo files were used to shape 12 canals. The difference in the weight loss for each sample was calculated. Data were analyzed by Two-way ANOVA. Results: there was statistically significant difference between 8 canals and 12 canals ($P \leq 0.05$). With recommended torque showed statistically significantly higher mean of weight loss than high torque. With high torque showed statistically significantly higher cutting efficacy with 8 canals. Conclusions: Race Evo files showed higher cutting efficiency with recommended torque than high torque.

Keywords: *Cutting efficiency; Heat treatment; Race Evo; Torque.*

1. `Introduction

The introduction of nickel-titanium (NiTi) endodontic files has greatly improved flexibility in shaping curved canals, thereby minimizing the chances of file breakage and ledge formation compared to older stainless-steel files (1). Despite their greater flexibility and resistance, NiTi files can still unexpectedly break due to cyclic fatigue, which can jeopardize the outcome of root canal treatments (2). Enhancing resistance to file separation has driven improvements in metallurgy and led to innovations in endodontic files design and usage (3).

In 2007, DENTSPLY in Tulsa, USA, developed the M-wire NiTi alloy, which is created through a process involving several cycles of thermal treatment during milling (4). Recently, a specific thermal process has applied to the M-wire alloy after grinding; which resulted in a new Gold alloy (5). The manufacturer declared that this heat treatment enhances the file's strength and flexibility. However, the impact of thermal processing techniques, including the gold finish, on the file's microscopic surface properties and its relationship to fracture incidence remains unclear (6).

Manufacturers have aim to enhancing the resistance of cyclic fatigue of NiTi instruments using heat-treated alloys (7). This technology modifies the phase-transformation temperature to keep the alloy in its martensitic phase at body temperature, enhancing its properties. The Blue treatment, with its unique blue oxide surface layer, and the gold treatment are designed to improve cyclic fatigue resistance (8).

The new electropolished RACE EVO (FKG Dentaire SA, La Chaux de Fonds, Switzerland) with a triangular cross-sectional design, rounded tip and alternating cutting edges, (9). As stated by the manufacturer, RACE instruments provide better cyclic fatigue resistance and greater flexibility, improved cutting efficiency, lesser stress on dentin, and reduced screwing effect. The heat treatment results in a blue color a titanium oxide layer which enhances resistance to cyclic fatigue (10).

Different instrument designs significantly influence cutting efficiency. Cutting ability refers to an instrument's capacity to cut through a specific material, while cutting efficiency denotes the speed at which the instrument performs the cut (11). Both cutting ability and cleaning efficiency are influenced by several Factors such as; metallurgical properties, surface treatment, cross-sectional shaft design, flute design such as the number of flutes, rake angle, helical angle, and tip design (12). Additional factors influencing these efficiencies include lubrication used during cutting, sterilization, resistance to wear and mode of use (13).

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2. Experimental: This was in vitro study performed in the faculty of Dentistry research laboratories, Misr International University in Egypt. his research has received approval from the ethics committee of the Faculty of Dentistry; Misr international university in Egypt, 18/1/2023.

2.1. Sample Selection:

Forty Race Evo sets of files were used to shape 400 acrylic resin canals with simulated canal curvature less than 30º degree and radius of 5 mm and have similar length 16 mm. Forty samples were divided into two main groups. Group A: (20) files tested under recommended manufacture torque 1.5 Ncm. Group B: (20) file were tested under higher torque 4.5 Ncm. Each group were further subdivided into two subgroups: Subgroup I: (10) Race Evo file were used to shape 8 canals. Subgroup II: (10) Race Evo file were used to shape 12canals. The Acrylic blocks' external surfaces were coded in order to identify the canals during the weighing process.

2.2. Weighing procedure:

Before preparation, all blocks were weighed (wt. pre) by a five-digit scale (Kern 770 KERN, Germany) high precision balance sensitive scale. Each sample was weighed preoperatively before mechanical preparation and after being air-dried for 24 hours. After preparation; The acrylic blocks were dried using paper point and then left to air dry for 24 hours. After preparation, the blocks were reweighed. The operator was tabulated the measurements in a chart; for later use in subtractive analysis to compare between the cutting efficiency of the files [14].

2.3. Sample preparation:

The acrylic resin canal was explored with glide path 15/.04 to the working length. All canals were irrigated with distilled water after each instrument during canal instrumentation. The mechanical preparation done in crown down manner according to manufacture instruction. The canals were shaped by file size 25/.04 followed by file size 25/.06 Race Evo file using speed 800 rpm and torque 1.5 Ncm in (group A) and torque 4.5 Ncm in (group B) with same speed 800 rpm. Each set of files used once to shape 8 canals or 12 canals before discarded.

2.4. Evaluation:

Data were recorded as a delta weight (Δwt = wt pre – wt post) and tabulated [15].

2.5. Statistical Analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Weight loss data (Δwt) showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values. Two-way Analysis of Variance (ANOVA) was used to study the effect of torque, number of canals and their interactions on mean (Δwt). Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

2. Results:

The results indicated that torque had a statistically significant impact on mean weight loss, irrespective of the number of canals. Conversely, Number of canals regardless of torque there was no statistically significant effect on mean weight loss. The interaction between the variables had a statistically significant effect on mean weight loss. Since the interaction between the variables is statistically significant, so the variables are dependent upon each other.

a. Comparison between torque types After usage in 8 canals; there was no statistically significant difference between the two torque types (Pvalue = 0.792, Effect size = 0.0002). After usage in 12 canals; recommended torque showed statistically significantly higher mean Δwt (higher cutting efficiency) than high torque (P-value

b. Comparison between number of canals with recommended torque, there was no statistically significant difference between mean Δwt after usage in 8 or 12 canals. With high torque, usage in 8 canals showed statistically significantly higher mean Δwt (higher cutting efficiency) than usage in 12 canals (P-value = 0.015, Effect size = 0.015.

Tables and figures

Table (1). The mean, standard deviation (SD) values and results of two-way ANOVA test for comparison between Δwt values (g) with different interactions of variables:

Number of canals	**Recommended torque**		**Amplified torque**		***P*-value**	**Effect size *(Partial Eta Squared)***
	Mean	**SD**	**Mean**	**SD**		
8 canals	**0.00874**	**0.00057**	**0.00871**	**0.00071**	**0.792**	**0.0002**
12 canals	**0.00882**	**0.00068**	**0.00845**	**0.00092**	**<0.001***	**0.034**
***P*-value**	**0.477**		**0.015***			
Effect size *(Partial Eta Squared)*	**0.001**		**0.015**			

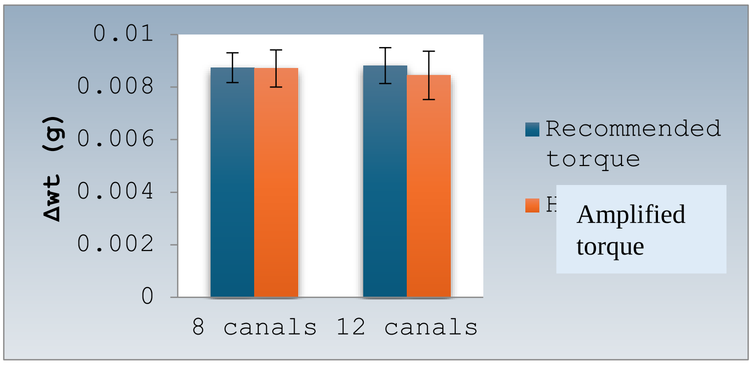

Figure (1): Bar chart representing mean and standard deviation values for Δwt with different interactions of variable.

4. Discussion:

The effectiveness of root canal treatment primarily depends on accurate root canal preparation. The introduction of nickel-titanium (NiTi) alloy carried new possibilities to endodontics due to its superelasticity. These superelastic of NiTi endodontic instruments can provide central alignment within the root canal, allowing for proper preparation even in severely curved canals while respecting the canal's anatomy, thus leading to a better prognosis [(16)].

The crystallographic phase transformations in NiTi instruments can compromise their strength, leading to unpredicted breakage flexural fracture caused by internal structure's defects of the metal alloy, without any external structure distortion [(17)]. The recently introduction of blue heat-treated RACE EVO files, claimed to have high cyclic fatigue resistance [(18)]. The thermal heating-cooling treatment process applied to RACE EVO improved the resistance, and results in a blue titanium oxide layer on the file's surface, enhancing its flexibility [(19)].

This process impacts the crystallographic state by achieving a high austenite transformation finish temperature (Af temperature) close to human body temperature, this ensure that the file stays in the martensitic phase at body temperature, thus improving its mechanical properties by integrating the dependable features of the original RaCe with proprietary heat treatment and enhancing rotation speed capability [(20)].

RACE® EVO instruments provide an optimal combination of durability, strength and control. With exceptional resistance to cyclic fatigue, optimized but non-intrusive cutting efficiency, and a minimal screwing effect [(21)]. The sharp-edged triangular design of RACE EVO, combined with higher rotation speed; results into 1.5 times greater cutting efficiency [(22)].

Different materials with varying hardness levels have been used as substrates to assess the cutting efficiency of various endodontic instruments [23]. Simulated resin canals were used to standardize the study groups [24], ensuring consistent performance and a high degree of reproducibility in terms of hardness, dimensional stability, fixed angle of curvature [25]. Consequently, using simulated canals helps eliminate the morphological and dimensional variations found in extracted human teeth canals [26].

In this study, all samples were mechanically prepared according to the manufacturer instruction using the crown-down technique. A 3ml distilled water using side vented plastic syringe was used as the root canal irrigant. The external surfaces of the blocks were numbered for canal identification during the weighing process. Blocks were randomly selected from each group and weighed before and after instrumentation to calculate weight loss, thereby assessing cutting efficiency [14]. Cutting efficiency is an important mechanical property as it influences the ability of instrumentation to safely prepare the root canal system [27]. Various factors influence the cutting ability of NiTi instruments, including rake angle and helical angle, groove depth and number, cross-sectional design and tip configuration, chip elimination capacity, kinematics, and manufacturing processes like heat treatments [28].

Cutting efficiency is defined as the ratio of the work done to the input energy delivered to the file [29]. A highly efficient file, with enhanced cutting ability, requires less time, torque, and pressure to enlarge the canal. This reduction in pressure, torque, and time helps prevent file failure [30].

The method used to assess the cutting efficiency of the instruments used in this study measuring the amount of weight loss; this approved with chi 2016[31]. This remains a reliable approach for evaluating the cutting efficiency of the file, which directly impact their performance. This agreed with the Bergmans' observation [32] that cutting efficiency and cleaning effectiveness of NiTi instruments are closely related.

The cutting efficiency of files diminished after repeated use, showing higher cutting efficiency with 8th uses than the 12th uses, with no statistically significant difference between the 8th and 12th regarding to the number of canals. The decrease in the cutting efficiency of the instruments could be alternation in the cutting edges [33]. Moreover, the rotational bending of instrument within the canal leads to the formation of surface microcracks, which eventually combine to form fatigue cracks [34].

Endodontic files experience varying degrees of torque. If the applied torque reaches or exceeds the threshold for deformation or breakage, the instrument will either bend or break. Low torque control motors help prevent instrument failure by stopping rotation or reversing the direction when the torque matches the set level on the motor. This reduces the risk of instrument failure. Torque significantly affects the fracture resistance of the file; when used with high torque, the file becomes more active, increasing the likelihood of instrument locking, deformation or separation [36].

Results showed that there was statically significant difference after usage in 12 canals regarding to torque. Recommended torque 1.5Ncm showed statistically significantly higher mean of weight loss (higher cutting efficiency) than high torque 4.5 Ncm. This clarify the impact of a blunted blade during instrumentation [37]. The loss of sharpness extends the operative time and increase torque on the file during instrumentation [38]; because of decrease in the instrument's cutting efficiency after repeated use [39,40].

5. CONCLUSION:

Within the study limitations, the following could be concluded that the Torque and the number of canals adversely impacted the cutting efficiency of thermomechanical treated NiTi files (Race Evo sets).

6. Conflicts of Interest:

The authors declare that they have no conflict of interest.

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