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EFFECT OF NOVEL ROTARY ROOT CANAL PREPARATION SYSTEMS ON FRACTURE RESISTANCE OF RADICULAR DENTIN

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ABSTRACT

Purpose: to evaluate fracture resistance following root canal instrumentation using different rotary nickel titanium (Ni-Ti) preparation systems (ProTaper Next, Spring Endo files with unheated finish (Spring Endo) and Spring Endo files with heated finish (Spring H)).

Materials and methods: 30 recently extracted human permanent mandibular molars were collected for this study. Decoronation was done, then the mesial roots were separated from the distal ones. The mesial roots were randomly divided into 3 groups (n=10) according to the used instrumentation system; Group I: ProTaper Next system, Group II: Spring Endo system and Group III: Spring H system. (n=10). Roots were mounted in acrylic resin blocks and a vertical load were applied to them using the universal testing machine to apply fracture resistance test. Data were collected and statistically analysed.

Results: ProTaper Next system showed less fracture resistance compared to Spring Endo and Spring H systems with statistical significant difference between them.

Conclusion: Roots prepared with ProTaper next system are more liable to fracture compared to roots prepared with Spring Endo or Spring H files.

KEYWORDS: Fracture Resistance, Spring Endo files with unheated finish, Spring Endo files with heated finish

INTRODUCTION

One of The most undesirable failure symptom of endodontic treatment is crown or root fracture. [1] Dentin criteria such as modulus of elasticity or micro-hardness are affected by loss of vitality following root canal treatment.[2] Resulted tooth fracture after root canal treatment is related to loss of tooth structure which is usually attributed to trauma, caries, previous restorations or different endodontic procedures as access cavity and\or root canal preparations.[3] That's why a precise root

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canal preparation not only increases the fracture resistance of the tooth but also keeps its structural integrity.[4] However, preservation of tooth integrity compared to proper canal debridement represents a controversial issue.

Nowadays, variable modifications applied to nickel titanium (Ni-Ti) instruments design as thermomechanical treatment of the alloy, altered taper or method of fabrication allowed for improvement of the quality of mechanical root canal preparation to keep the balance between the preservation of tooth structure and applying of proper debridement. [5]

One of the fifth generation rotary files are ProTaper Next rotary files which are manufactured from M-wire Ni-Ti alloy. These instruments are characterized by an innovative off-centred rectangular cross section that provides these files a snake-like swaggering movement. The pitch length increases from the tip to the shaft which aids to decrease the screwing effect of the instrument within the root canal. [6]

ProTaper Next instruments are available in multiple sizes and tapers X1(17/0.04); X2 (25/ 0.06); X3 (30, 0.07); X4 (40/0.06); and X5 (50/ 0.06). However, the system taper is progressive along the files working shaft. [6] However, the progressive taper of these files can remove a greater amount of dentin, affecting the strength of teeth. [4]

Spring Endo file is another novel file which is rotary Ni-Ti instrument with an elastic spring on its shaft via laser cutting.[7] The elastic spring on its shaft can make its insertion within the root canals, especially of posterior teeth, easier with less risk of fracture compared to conventional Ni-Ti instruments. It was also suggested that the spring structure buffers the overload applied to the instrument, resulting in an improved resistance to cyclic fatigue, torsional resistance and increased flexibility. Additionally, it improves cutting ability by generating micro-vibration which reduces the screw-in phenomenon into the canal through the blade area. [7]

Spring Endo and Spring H files have identical designs; however, unlike Spring Endo, Spring H is manufactured from a heat-treated controlled-memory wire. It is assumed that the heat treatment of Ni-Ti alloy in addition to the spring design improves the flexibility of these instruments during root canal preparation compared to original Spring Endo files. [8] However, this created a question if this unique design along with its technique of cutting would affect the tooth structure integrity or not?

It was stated that excessive removal of dentin from the root canal walls may lead to fracture. [9] On the other hand, some authors posed that increasing root canal preparation taper -within limits- allowed for better distribution of masticatory forces which in turn would improve the fracture resistance of the affected tooth. [10]

Based on this controversy, this study aimed to assess the fracture resistance of mandibular first molars following root canal mechanical preparation using different rotary preparation systems (ProTaper Next, Spring Endo and Spring H files)

The null hypothesis of this study was that no significant difference between the three rotary file systems used in this study would be observed.

MATERIALS AND METHODS

To calculate the proper sample size for this study, a suitable earlier investigation carried out by Hegazi et al., [11] was chosen for this investigation, because the power sample size was greater than 80%, the significance threshold was 0.05, the confidence interval was 95%, and the actual power was 96.7%. the computer program used for sample calculation was G Power version 3 where sample size equation was:

$$n = N \times p(1-p) / [[N-1 \times (d^2 \div z^2] + p(1-p)]$$

Where:

n= sample size

N= population size

Z = Z value (1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal

d = error proportion (0.05)

1-p= 0.984

The actual size of the tested sample was oversized to 30 to ensure the authenticity of the research.

The ethical authorization for this study was yielded by Research Ethics Committee of Faculty of Dentistry, Tanta University. A statement and full explanation about the purpose and details of this clinical trial corresponding to the standards on human research rendered by the Research Ethics Committee at Tanta University's Faculty of Dentistry were discussed with the selected patients before obtaining their informed consent to use their extracted teeth in this study.

The chosen samples for this study were freshly extracted human permanent mandibular first molars with mature separated roots were obtained for this study. Any attached calculus or remnant soft tissue to the collected teeth was eliminated using sharpened hand scalers. Then they were cleaned with distilled water and then dispensed in sterilized normal saline solution (4°C) till the time of their handling. The selected teeth were used within two to three months maximum after their extraction. [12]

The inclusion criteria for the samples of this study involving lower first molars provided that the cause of their extraction is irrelevant to this research as periodontal diseases for instance. They had two discrete mesial canals and mature roots with fully formed closed apices. All included molars showed a similar range of mesial canals curvature (20^{o}-40^{o}) which was confirmed by digital radiography using digital intraoral sensor *then the degree of root canal curvature was calculated using Schneider's methodology. [13]

All molars were decoronated and the length of the remaining roots was standardized to be 14 mm. Teeth were then sectioned through the furcation using a diamond disc to separate the mesial and distal roots. Mesial roots were then disinfected and restored in saline.

An independent trained investigator not involved in the study handled the randomization and concealment process. Random sequence generation was achieved using a computer random allocation program and concealed from the operator using the sequentially numbered opaque sealed envelope (SNOSE) technique. Then a closed envelope containing the instructions to use either ProTaper Next**, Spring Endo*** or Spring H[3] rotary preparation systems was selected.

The mesial roots were randomly allocated into three equal groups (n=10). Group I: ProTaper Next system[2], Group II: Spring Endo system[3] and Group III: Spring H system[3].

A glide path using a stainless steel K-hand file #15 was done in both root canals of the mesial roots. For **group I:** ProTaper Next files were used up to master apical file X3 (30 / 0.07), at 300 rpm rotational speed and 2 NCM torque values using a 20:1 gear reduction hand piece driven by a torque-limited endodontic motor****. Each file was utilized in a circumferential brushing motion against the root canal walls.

For **group II**: The Spring Endo rotary file system was used in the following sequence 10/0.02, 15/0.04, 20/0.04, 25/0.06 till master apical file (30 /0.06) using the same hand piece and endodontic motor[4] as group I. Crown-down manner was used throughout the sequential preparation at 200 rpm and torque 0.8 NCM in accordance with the manufacturer's specifications.

* Dr.Suni plus Digital Intraoral Sensor, Suni Medical Imaging, Inc.,Sanjose, USA

** Dentsply/Maillefer, Ballaigues, Switzerland

*** DenFlex, Seoul, South Korea

**** E-CONNECT, Changzhou City, China

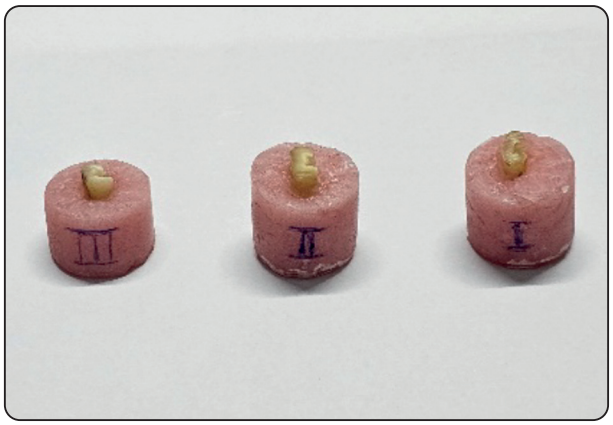

Fig. (1) Acrylic blocks with embedded mesial roots

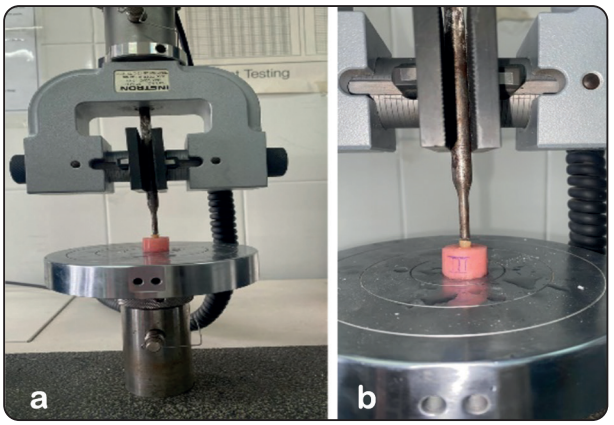

Fig. (2) (a) The universal testing machine, (b) Load application at the center of the root

For **group III:** Root canals were prepared with the Spring H rotary system till master apical file (30 / 0.06) using the same motor and hand piece devices as in group 1.

Application of Glyde™ [2] lubricant was limited to one application for each file and was separated from sodium hypochlorite* (NaOCl) irrigation by 2ml of saline to prevent their unfavorable interaction. Following each root canal preparation, each file was carefully examined, and once any deformity was detected within the file shaft, it was excluded at once. Moreover, each file was used maximally for preparation of 3 root canals and then discarded even with non-apparent distortion. Before and after applying each instrument, 3ml of immediately prepared 2.5% NaOCl solution was used to irrigate each root canal using a sterile disposable plastic syringe with a closed-end needle of 30-gauge. At the end of the preparation, 3 ml of sterile normal saline solution were used to rinse the root canals. The exact irrigation protocol was applied to all tested groups. All specimens were kept moist throughout the instrumentation procedure and were restored in normal saline after completing the instrumentation procedure.

Roots were placed into acrylic resin molds** (Fig 1). Before testing, all specimens were transmitted and dispensed in distilled water. A vertical compressive loading at the center of the canal orifices using a universal testing machine*** by a round-end ball at a crosshead speed of 1 mm/min was applied.[14] (Fig 2)

For statistical evaluation of the collected data, SPSS**** software version 21 was used. One-Way Analysis of Variance (One-Way ANOVA) were used to detect statistically significant differences among the groups, along with Tukey's test which was used to apply pairwise comparisons between each two groups of the tested groups including the control group. The statistically significant difference was set at p-value <0.05.

RESULTS

Table 1 presented the comparisons of fracture resistance mean values of the three groups. The mean fracture resistance values of the mesial roots were 501.348 ± 37.026 for group I (ProTaper Next), 975.287±10.013 for group II (Spring Endo) and 979.277±11.033 for group III (Spring H) with a statistically significant difference between the three groups (P<0.001). Tukey pairwise comparison test revealed a statistically significant difference between both group I versus II and I versus III (P<0.001) while there was no statistical significance between group II and III (P=0.952). (Table 1 and Fig.3)

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** Acrostone; Dent Product, Egypt
*** Instron, Norwood, MA
**** SPSS Inc. Chicago, USA

TABLE (1) Fracture resistance values of the three groups

Fracture resistance	Groups (mean ± SD)			One way ANOVA	TUKEY'S Test comparison of the 3 groups		
	Group I	**Group II**	**Group III**	**P-value**	**I&II**	**I&III**	**II&III**
Mesial roots	501.348 ± 37.026	975.287 ± 10.013	979.277 ± 11.033	<0.001*	<0.001*	<0.001*	0.952

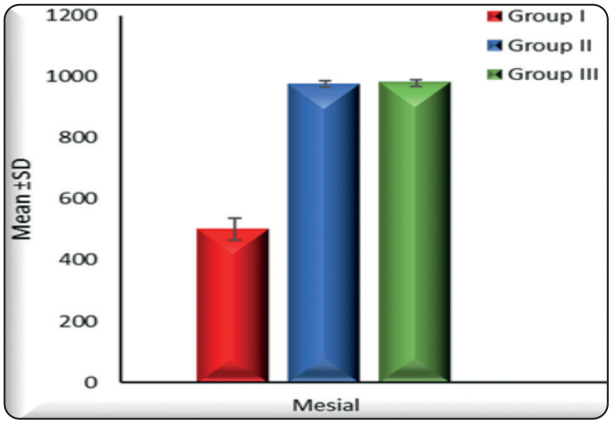

Fig. (3) Bar chart representing fracture resistance of the three groups in mesial roots

DISCUSSION

Successful endodontic treatment outcomes are attributed to efficient chemo-mechanical root canal preparation. However, different preparation techniques have created a risk of root fracture.[15] The prolonged contact between the endodontic cutting instrument and root canals walls during preparation creates immediate stresses in dentin surfaces which may encourage root fractures.[16] Moreover, mechanical preparation of the root canal using Ni-Ti files may result in the development of microcracks within the root canal dentinal walls.[16]

The tested specimens used within this study were standardized for accurate fracture resistance evaluation.[17] Therefore, similar teeth with equal root lengths following decoronation were used. In this study, mandibular molars were used because they are the most common teeth presented for root canal treatment due to its early eruption within the oral cavity in addition to its susceptibility to different forces during the mechanical preparation of root canal treatment specially their mesial roots due to their small dimensions, thin dentinal walls with average curvature which cause them to be ideal candidates for this study.[18]

Moreover, 3 ml of 2.5% NaOCL was used as a standardized irrigant regimen for all groups during root canal preparation to limit the negative effect of NaOCl as an irrigant on the physical properties of dentin by using the lowest available concentration with minimum amount.[19]

Tested roots were vertically placed in acrylic blocks to imitate the real position of the teeth within the oral cavity when they are subjected to mastication forces and stresses as possible for more precise evaluation.[20]

Due to its simplicity and easiness of use, an Instron universal testing machine was selected for this study to apply tooth fracture resistance test.[21]

According to this study, it was revealed that mesial roots of mandibular molars prepared with ProTaper Next rotary system showed less fracture resistance compared to Spring Endo and Spring H rotary systems with a statistically significant difference between the ProTaper Next group versus other both groups. These results can be explained by different tapers of these rotary files as ProTaper Next group ended with 7% taper compared to 6% taper of other two groups. In addition, the type of file motion associated with ProTaper system inside the canal (brushing motion) may have created

additional stresses on the dentinal walls of the roots. Moreover, the aggressive file sequence of ProTaper Next system (X1(17/0.04); X2 (25/ 0.06); X3 (30, 0.07)) in contrast to Spring Endo and Spring H groups (10/0.02, 15/0.04, 20/0.04, 25/0.06, 30/0.06) during root canal preparation has created more compression forces and stresses on the root canal walls specially at the apical area. [11,22]

In addition, the added unique feature of both Spring Endo and Spring H rotary files which is the spring added on their shafts may have created more flexibility with more free movement of the file during canal preparation which was reflected in the form of less stresses created on dentinal walls. [7,8]

Furthermore, Spring H rotary system manifested higher fracture resistance compared to Spring Endo system without any statistical significance between them which may be owing to heat treatment of the alloy from which Spring H rotary files are manufactured (controlled memory wire) as it was found that higher flexibility acquired from heat treatment might be related to the diminished occurrence of dentinal cracks within the root canal walls. [12]

Smoljan et al., [23] concurred with the obtained results as they concluded that smaller taper preparations lead to more fracture resistance than wider progressive taper preparations.

In addition, another study adopted similar results as the current study as they stated that ProTaper Next files caused weakening of the tooth structure due to excessive apical dentin removal owing to the larger apical tip diameter ending with reduced fracture resistance of these teeth. [24]

On the contrary, Milani et al., [25] objected the current results as they declared that root canal preparation with ProTaper Next rotary files didn't affect the fracture resistance of the teeth prepared with them.

CONCLUSIONS

The teeth prepared with Spring H or Spring Endo rotary systems have higher fracture resistance than the teeth prepared with ProTaper Next rotary system.

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