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EFFECT OF TWO THERMALLY-TREATED ROTARY NICKEL-TITANIUM FILES WITH AND WITHOUT ROOT CANAL FILLING ON FRACTURE RESISTANCE OF TEETH, AN EX-VIVO STUDY

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ABSTRACT

Aim: To assess the effect of chemo-mechanical root canal preparation using ProTaper Next and Videya N rotary files with and without root canal filling on the fracture resistance of roots.

Methodology: A total of 40 freshly extracted mandibular premolars were decoronated and randomly divided into 5 equal groups (n=8) according to the files used as follows; group 1 prepared using ProTaper Next files without filling; group 2 prepared using ProTaper Next files and filled with gutta percha and Totalfilbioceramic sealer; group 3 prepared using Videya N files without filling; group 4 prepared using Videya N files and filled with gutta percha and Totalfilbioceramic sealer; and group 5 without preparation or filling as a control. All roots were subjected to load using universal testing machine till fracture and load needed was recorded in Newtons. The data were statistically analyzed using one-way ANOVA test, and post hoc analysis.

Results: The 4 experimental groups significantly lowered the roots' fracture resistance compared to the control group without a statistically significant difference between the experimental groups. The filled groups showed a non-statistically significant increased fracture resistance compared to the non-filled ones.

Conclusion: Chemo-mechanical root canal preparation decreases the roots' fracture resistance. Root canal filling using bioceramic sealers might enhance the roots' fracture resistance.

KEYWORDS: Bioceramicsealers, fracture resistance, nickel-titanium, rotation.

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INTRODUCTION

Fracture resistance of teeth is a critical aspect of endodontic treatment and can be affected by several factors, including the type of file system used for canal preparation. Nickel-titanium (NiTi) files have become popular in recent years due to their high flexibility, excellent cutting efficiency, and reduced risk of file separation compared to stainless steel files (1).

During root canal preparation, NiTi files during canal preparation can increase the fracture resistance of teeth. This is because NiTi files have a super-elastic property that allows them to bend without permanent deformation. This property reduces the risk of inducing microcracks in the tooth structure during preparation, which can compromise the fracture resistance of the tooth (2).

The ProTaper Next system features a unique design that allows for greater flexibility and precision during the procedure. The ProTaper Next files have a variable taper design that allows them to gradually widen the canal as they are used. This design helps to reduce the risk of file separation and allows for better control of the instrument during use. Additionally, the files have a non-cutting tip, which helps to reduce the risk of damage to the root canal walls. It shows an off-centerd rectangular cross section made of M wire(3).

Videya N rotary file system has been recently launched in the market mimicking the design features of the ProTaper Next file system. Yet, it is manufactured from CM wire rather than the M wire with different thermal treatment(4).

Bioceramic root canal sealers are characterized by the ability to bond chemically to root canal dentine by the formation of hydroxyapatite-like structures and an interfacial layer. This unique property might be of value in improving the fracture resistance of root canal treated teeth (5).

Videya N rotary file is relatively a novel file, up to our knowledge no studies have been performed to assess its effect on the root's fracture resistance. Therefore, the current study sought to determine how root canal preparation with ProTaper Next and Videya N files, both with and without root canal filling, affected the roots' resistance to fracture. The null hypothesis is that there is no statistically significant difference in the fracture resistance of the roots between the two files examined with and without a root canal filling.

MATERIALS AND METHODS

Ethical approval:

The local ethical committee gave its blessing to the study's protocol and assigned it approval number (04-2023-300065).

Sample size calculation:

In order to apply a statistical test to the null hypothesis—that there is no difference between the tested groups regarding fracture resistance—a power analysis was created. Based on the findings of Kilic et al. (1), the anticipated minimal sample size (n) was a total of 40 samples using an alpha level of (0.05), beta of (0.2) (i.e., power=80%), and effect size (f) of (0.595). (i.e, 8 samples per group). G*Power version 3.1.9.7 was used to calculate sample size.

Sample selection

Forty, freshly extracted, human mandibular premolar teeth were extracted at the oral and maxillofacial surgery department, Dentistry Faculty, Assiut University. The teeth were extracted from patients older than 55 years old for periodontal problems not related to this study. The inclusion criteria were as follows:

- Single rooted teeth with complete apical formation.
- The absence of any cracks when examined under the dental operating microscope (Zeiss,

Oberkochen, Germany) at 25X magnification.

- The degree of root curvature was less than 10° by Schneider's method.
- The teeth had approximately the same dimensions.

The teeth were checked radiographically from the mesiodistal and buccolingual views to evaluate:

- The presence of single root canal with single apex.
- The absence of any calcification or resorption.
- The mesiodistal and buccolingual dimensions. Roots with dimensions of 5.1±0.5 mm bucco-lingually and 4.3 ± 0.5mm mesiodistally were selected. Any root that deviates from these dimensions was discarded.

To eliminate any debris, an ultrasonic equipment was used to clean the teeth. After 5 days in a 0.1% thymol solution, the teeth were then preserved in saline solution until they were used. The crowns were divided into 15 millimeter-long sections using a diamond disc (Brasseler Dental Products, Savannah, Georgia). K-file size 10 was inserted into the canal until it reached the level of the apical foramen, at which point the working length was determined by deducting 1 mm from the file's length.

Classification and root canal preparation

Using a computer technique, the roots were divided into five groups of ten (n), at random (www.random.org).

Group 1: Instrumentation with ProTaper Next files without root canal filling

The ProTaper Next file (PTN) was used to prepare the root canals (Dentsply Maillefer, Ballaigues, Switzerland). According to the manufacturer's recommendations, it was utilized with a gently in and out pecking motion with an amplitude of roughly 3 mm utilizing a ZX J. Morita endodontic rotary motor (Corp, Tokyo, Japan) with a contra angle (16:1 reduction).

PTN X1 and X2 were used in order to prepare the root canal. The trash was taken out of the instruments' flutes after every three pecking motions. After three uses, the device was abandoned. To irrigate the root canal, 2 mL of a 2.6% NaOCl solution was flushed through it. In order to avoid binding, a 30-gauge needle NaviTip (Ultradent, UT, USA) was introduced as deeply as feasible into the canal. Following root canal preparation, a final rinse was used, consisting of 5 mL of distilled water, 5 mL of 2.6% NaOCl, and 5 mL of 17% EDTA (ethylene diaminetetraacetic acid) for 1 minute.

Group 2: Instrumentation with ProTaper Next files with root canal filling

The PTN files used in group 1 were used for the root canal preparation. After that, paper points were used to dry the root canals. Using the single-cone approach, the root canals were filled with gutta-percha 25/.06 and Totalfill BC bioceramic root canal sealant.

Group 3: Instrumentation with Videya N Rotary Files (Heat-activated blue) without filling :

The root canals were prepared using Videya N Rotary Files (Huizhou Videya Technology, China) using a ZX J. Morita endodontic rotary motor (Corp, Tokyo, Japan) with a contra angle (16:1 reduction) was used at 300 rpm and 2 N/cm according to the manufacturer's instructions. A gentle in and out pecking motion with amplitude of about 3 mm was applied. The first file used was # 17/0.4 followed by file #25/0.6.

Group 4: Instrumentation with Videya N Rotary Files (Heat-activated blue) with root canal filling :

With the same Videya N Rotary Files as the preceding group, the root canal preparation was carried out. After that, paper points were used to dry the root canals. Using the single-cone approach, the root canals were filled with gutta-percha 25/.06 and Totalfill BC bioceramic root canal sealant.

Group 5: Control group

Unprepared root canals were left.

Following the preparation and filling of the root canals, the roots underwent a 7-day preservation period at 37 °C and 100% humidity.

Fracture Resistance Testing:

After 7 days, the apical 6 mm of all roots wascovered with light body silicone impression material to obtain a 0.2- to 0.3-mm-thick to simulate the periodontal membrane space. The roots were embedded vertically in a plastic ring (10 mm in height and 20 mm in diameter) containing self-cured acrylic resin. Only 9 mm of the root was embedded inside the acrylic resin while the remaining 6mm was left exposed. A dental surveyor was used to provide ideal vertical mounting of the roots. After the setting of the acrylic resin, the samples were removed from the plastic ring.

The access of the root canal was modified to receive loading fixture using carbide bur.

As depicted in figure 1, the mounted cylinders were sequentially inserted into the universal testing device Model 4502 (Instron, Canton, MA, USA). On the machine's lower plate, the acrylic blocks were positioned with their roots vertically aligned. The device's upper plate had a circular tip with a 4 mm diameter. The coronal surface of the specimen was touched by this rounded tip. Until an audible fracture occurred, each specimen was subjected to a vertical force that gradually increased by 1 mm per minute. The data were reported in Newtons.

Statistical Analysis

The mean value and standard deviation (SD) value for numerical data were displayed. Testing for normalcy was done using the Shapiro-Wilk test. Using Levene's test, the homogeneity of variances was examined. Data were examined using a one-way ANOVA test followed by a Tukey's post hoc test because they were parametric and exhibited variance homogeneity. For all tests, the significance level was set at p 0.05. JASP statistical analysis software for Windows, version 0.16.0.0, was used to conduct the statistical analysis.

RESULTS

Table 1 displays the fracture loads of the roots across all categories. During testing, each root was broken vertically in the buccolingual orientation. When compared to all the experimental groups, the control group demonstrated the greatest fracture load (352.00230.7796), which was statistically significant. The findings from each experimental group were not statistically different from one another.

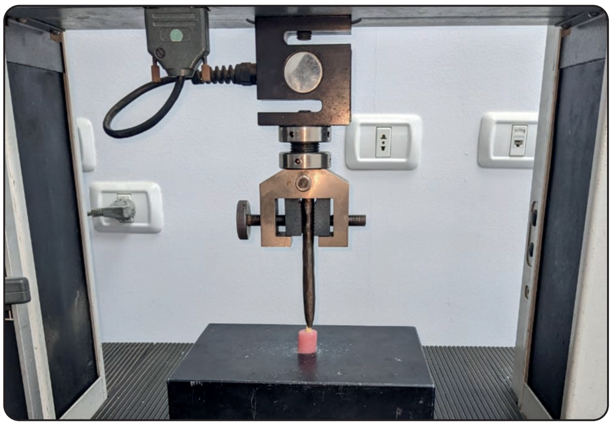

Fig. (1) Root sample embedded in mold being tested using the universal testing machine.

TABLE (1): Mean and standard deviation values for the load to fracture of all groups in Newtons.

Load to fracture (Mpa) (Mean±SD)					f-value	p-value
PTN without filling	PTN with filling	Videya without filling	Videya with filling	Control		
216.26±14.6835^{B}	241.1±66.5431^{B}	243.005±28.3498^{B}	274.465±62.2178^{B}	352.002±30.7796^{A}	13.50224	<0.00001*

Means with different superscript letters within the same horizontal row are significantly different; *significant (p<0.05)

DISCUSSION

The goal of the current research was to determine how root canal filling and PTN and Videya N chemo-mechanical preparation affected the roots' resistance to fracture.

The selected teeth were of old aged patient with narrow canals. The initial file, used, was K file size #10. It was sufficient to end the preparation at rotary file size #25.

Standardization of the extraction time was done through the use of freshly extracted teeth and using thymol 1% as a storage media.

The fracture resistance testing used in the present study following Madarati et al.[6]who used a metal cylinder with a 4 mm steel ball attached to its end. This ball produced a wedging action thus producing vertical fracture. This was done through increasing the amount of vertical force gradually. This created high stress concentration areas at site of incomplete crack line. Propagation of crack took place until fracture occurred.

Standardization of the direction of force was done through mounting of the samples using dental surveyor. The dental surveyor allowed proper vertical position of the samples in the acrylic block thus allowing homogenous distribution of forces from the testing machine during static loading[7]. The use of thin layer of silicone impression material was performed to mimic the peridontal ligament[1]

Regarding fracture resistance, there was a significant disparity between the control and experimental groups. The fracture resistance of the tooth structure may be affected by a number of variables, which could account for this. Because the remaining dentin thickness is reduced during root canal preparation, the tooth's structure is weakened and its susceptibility to fracture is increased.[8]. Because more root dentin is removed when using rotary files with greater taper, the root's resistance to fracture may be reduced.[9].

Another factor that may reduce the fracture resistance of the root is the use of 2.6% NaOCl in conjugate with 17%EDTA.This may be attributed to their destructive effect on the intratubular dentine near the surface of the root canal thus reducing the root dentin mechanical strength[10]. The use of rotary files with increased taper may reduce the fracture resistance of the root due to increased removal of root dentin[9].

Another factor affecting the fracture resistance may be the rigidity of the file. The increase in the rigidity of the file increased the stresses on the dentinal wall, thus creating more crack. This point of view may explain our results. The fracture resistance of samples prepared with Videya N files were higher, though insignificant, than samples prepared with PTN files.

The CM wire used to make the Videyea files is primarily martensite with varying amounts of austenite phase [11]. A thermally-treated NiTi endodontic alloy known as controlled memory (CM) wire was first introduced in 2010, and it lacks super-elastic characteristics at neither body temperature nor room temperature [11]. Instruments made of CM Wire may deform as a result of modifications in phase makeup due to the rearrangement of the martensite variants (12). CM Wire instruments therefore appear to not completely straighten during the preparation of curved root canals, in contrast to austenitic NiTi files. The manufacturer suggests that this controlled memory impact will lessen the likelihood of endodontic errors. The austenite finish temperature of CM Wire instruments is greater than intracanal temperature (between 47 and 55 °C), according to DSC analysis (13).

Protaper files were created using M wire, which is primarily austenitic with traces of martensite and R-phase (14). A Nitinol composition with a starting composition of 55.8 1.5 wt% nickel (Ni), 44.2 1.5 wt% titanium (Ti), and trace elements less than 1 wt% is used to heat treat M-Wire (2). The austenite finish temperature of M-Wire was shown to be between 43 and 50 °C (15, 16), which is higher than Af of ordinary NiTi and body temperature and suggests that M-Wire is not totally produced of austenite under clinical settings.This is supported by the findings of numerous metallurgical laboratory techniques, including DSC, XRD, and SEM, which demonstrate that at body temperature, M-Wire comprises austenite phase with trace amounts of martensite and R-phase (17). M-Wire is therefore in a superelastic state (18).

The austenite alloys are more rigid than martensite alloys. During preparation, the root canal geometry was done by various momentary contact between the file and the wall of the root canal creating craze line and incomplete cracks. The craze lines and the incomplete cracks become high-stress concentration areas that gradually propagate to the root canal surface(19).The propagation of the cracks resulted in vertical fracture(20).

Totalfill BC sealer-filled samples produced higher, albeit not statistically significant, outcomes than empty samples. This could be explained by the sealer's chemical attachment to the dentinal wall as hydroxyapatite forms during the setting process. Another factor was that it has a lower contact angle due to its hydrophilic nature, which makes it easier to disseminate across the entire root canal walls (21).

The fracture resistance of teeth that had been sealed with TotalFill BC sealer may have been improved by this chemical bonding. A study of the dentinal tubule penetration of four distinct sealers—iRootTM SP (now known as TotalFill BC Sealer), GuttaFlow Bioseal, AH Plus, and MTA-Fillapex—disproved a claim made by certain authors that small particle size easily penetrates dentinal tubules (5). The little discrepancy might be caused by the main core's usage of gutta-percha, which has a number of drawbacks, including a reduced ability to conform to canal walls and a lack of stiffness that reduces its capacity to fill irregularities, voids, and lateral canals (22).

CONCLUSION

The fracture resistance of the roots is strongly impacted by the chemomechanical root canal preparation. The fracture resistance of the roots may be improved by the application of bioceramic sealers.

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The authors deny any conflicts of interest related to this study.

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