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Fracture Resistance of Roots Prepared with XP-endo Shaper Using a Higher Rotation Speed

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Abstract
The aim of this study is to evaluate the effect of root canal preparation with XP-endo Shaper (XPS) used at high rotation speed on the fracture resistance of roots. Fifty mandibular canine teeth were decoronated to obtain a standard root length of 14 mm. They were randomly divided into 4 experimental groups and 1 control group (n=10): no preparation, preparation with XPS at 1000 rpm and 3000 rpm, preparation with XPS at 1000 rpm and 3000 rpm and filling with cold lateral compaction. Data were statistically analysed using 1-way analysis of variance (P=.05) The highest fracture resistance was observed in the control group, followed by the group with root canal preparation and root canal filling at 3000 rpm. The use of the XPS at 1000 rpm and 3000 rpm, or filling the root canals with epoxy resin-based sealers had no significant effect on the fracture resistances of the roots.

Keywords: *Fracture Resistance; High Rotation Speed; XP-Endo Shaper; Root Fracture*

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I. Introduction

Vertical root fracture (VRF), which is an important cause of endodontic failure, is a serious clinical problem that results in tooth extraction or the resection of the affected root (1,2). It has been stated that endodontically treated teeth are more susceptible to VRF (3,4). It is reported that VRF are mostly caused by operative procedures applied to root canals during root canal treatment. There are several factors such as loss of tissue during the preparation of root canals, dentin dehydration, effects of irrigation solutions on dentin, application of excessive force during the root canal filling process, and intra-canal post-application, among others (3-5). In addition to these, Bier *et al* (6) reported that during root canal preparation performed using rotary nickel-titanium (NiTi) systems, the file may induce microcrack formation with the accumulation of the momentary stress on the dentin and increase the amount or size of existing microcracks. These dentinal microcracks may later cause VRF (7). Studies have determined that the stress level in dentin during root canal preparation depends on numerous factors such as the alloy properties of the files used, their cross-sectional and longitudinal designs, torque settings, number of rotations, and kinematics (7,8).

Recent developments in NiTi files have led to the development of single-file systems as an alternative to multiple file systems in order to increase clinical efficacy and shorten the working time (9,10). XP-endo Shaper (XPS; FKG, La Chaux-de-Fonds, Switzerland) is the only snake-shaped design structure file system produced using the MaxWire (FKG Dentaire SA) alloy structure. The file has a size/initial taper of 30/.01 in its martensitic phase when it is cooled, but, upon exposure to body temperature (35°C), the taper changes to .04 (9). The design of XPS enables the instrument to adapt the root canal system 3-dimensionally during operation at body temperature, which expands or contracts according to the root canal morphology to improve cleaning and shaping. The manufacturer recommends using the XPS file system with a continuously rotating endodontic motor at 800 or 1000 rpm and 1 Ncm settings (11).

One of the factors affecting the cutting efficiency and the amount of dentin removed in the root canals of NiTi file systems is the rotation speed of the file (number of rotations per minute [rpm]). Various reasons exist to use low speeds with NiTi rotaries (e.g. below 300 rpm), including longer time to fatigue failure and less incidence of taper lock (12). Weber *et al* (13) have reported that using the XPS at 3000 rpm in the root canals ensures a more effective preparation and that less deformation is observed on the file compared to its use at 1000 rpm. There were no studies found in the literature investigating the effect of using XPS at high rotation speed on the fracture resistance of roots. Therefore, our study aims to evaluate the effect of root canal preparation with XPS used at high rotation speed on the fracture resistance of roots. The null hypothesis of our study is that using XPS at high or low rotation speed will not affect the fracture resistance of roots.

II. Materials And Methods

This study was approved by the Institutional Committee of Ethics in Research (Ref no: 2021/37).

Study Design: Invitro study

Study Location: This study done in Department of Endodontics, Hatay Mustafa Kemal University, Hatay, Turkey

Study Duration: January 2021 to September 2021.

Sample size: Fifty straight, single-rooted mandibular canine teeth without caries, extracted for periodontal reasons, were included in the study.

Sample size calculation: Based on III.tissue residues on the teeth, teeth presenting with intracanal calcification, internal resorption, previous endodontic treatment, as well as teeth with root curvature (> 5°), were excluded from the study. The buccolingual and mesiodistal diameters were measured with a digital caliper at a distance of 7 mm from the anatomical apex, and teeth with similar values were included in the study.

Procedure methodology

Teeth were stored in a 0.9% saline solution containing 0.1% thymol at room temperature until they were used in the study. Teeth crowns were removed from the cervical enamel junction using diamond discs under water cooling, to obtain a standard root length of 14 mm. The pre-existing cracks or craze lines in the teeth were evaluated under x 10 magnification using a stereomicroscope, and teeth without crack and craze lines were included in the study.

A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the canal until its tip was visible at the major apical foramen and working length (WL) was determined by subtracting 1 mm from this length. Roots were randomly divided into 4 experimental groups and 1 control group using a computer software (www.random.org). (n = 10).

Control Group

Root canal preparation and root canal filling were not performed for 10 teeth.

Preparation Protocols

A new instrument was used for the mechanical instrumentation of each new root canal, and all these procedures were performed by a single experienced endodontist inside a glass cabinet, with the temperature adjusted to 37°C using a heater. This was done to simulate the body temperature for the XPS to undergo the phase change.

Group 1: Xps-1000 Rpm Group

A manual glide path was established up to a size 15-K file for 20 root canals. The XPS was operated at 1000 rpm and 1-Ncm torque, applying a vertical pecking motion until reaching the WL, followed by 1 set of 10 long strokes to complete the canal shaping. After each set, the instrument was cleaned, and apical patency was confirmed with a 15-K file. A gutta-percha cone size 30/.04 was placed inside the canal, and the preparation was considered complete when this cone reached the WL.

Group 2: Xps-3000 Rpm Group

A manual glide path was established up to a size 15-K file. The XPS was operated at 3000 rpm and 1-Ncm torque, and all instrumentation procedures were performed as described previously.

Irrigation was performed with 1 mL 2.5% NaOCl between each instrument for both groups. A final rinse was performed with 2 mL 2.5% NaOCl for 1 min, 2 mL 17% EDTA for 1 min, and 10 mL distilled water using a 30-G side vented needle (Ultradent Products Inc, South Jordan, UT). After the irrigation was completed, the root canals were dried with paper points (Dentsply Maillefer).

Root Canal Filling

Group 3: Preparation With Xps At 1000 Rpm And Filling With Cold Lateral Compaction

After the root canals were prepared as described in group 1, the root canals were filled with gutta-percha cones and AH Plus sealer (Dentsply De Trey, Konstanz, Germany) using the cold lateral compaction technique. Periapical radiographs were taken to confirm the quality of the root canal filling. The coronal access of specimens was filled with a temporary filling material (Cavit; 3M ESPE, Seefeld, Germany).

Group 4: Preparation With Xps At 3000 Rpm And Filling With Cold Lateral Compaction

After the root canals were prepared as described in group 2, the root canal filling procedure was conducted in the same manner as group 3.

Following the root canal preparation of all teeth and completion of the root canal filling procedure, they were stored at 37°C and 100% humidity for 7 days.

Fracture Testing

Each apical root ends were embedded vertically 3-4 mm inside an acrylic resin block (with a height of 13 mm, and diameter of 15 mm), and left for 24 hours to allow the resin block to fully polymerize. The Universal Testing Machine (Testometric Micro 500, Testometric Co. Ltd., Rochdale, UK) was used to measure the force required for the root fracture.

The resin blocks were fixed to the metal square-shaped holder of the device, and the spherical tip was positioned at the center of the root canal. The spherical tip (r = 1.5 mm) on the testing machine moved vertically toward the

center of root canal and contacted it (Fig. 1). The ball dropped at a speed of 1 mm/min until the root fractured. The root fracture was detected by observing a sharp drop in force on the screen of the test machine. Moreover, the software automatically terminates the test procedure as soon as the sharp drop is detected. The fracture value was recorded as Newtons (N).

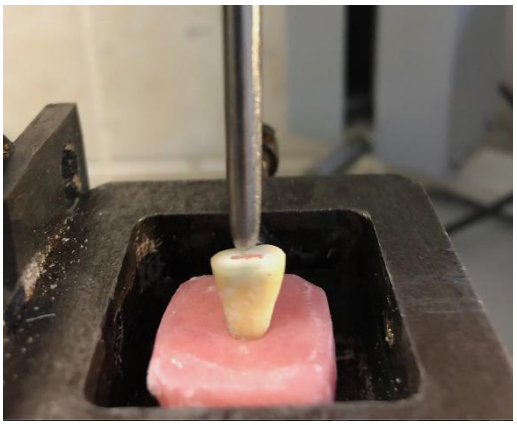

Figure 1. Specimen placed in a universal testing machine

Statistical Analysis

The statistical analyses were performed using SPSS software, ver. 20.0.1 (SPSS, Chicago, IL, USA). The normality of the variables was analyzed using the Shapiro-Wilk test. Therefore, the fracture resistance of the groups was statistically compared by one-way analysis of variance (ANOVA). The level of significance was determined as 5% ($p < 0.05$).

IV. Results

All teeth in the experimental and control groups were fractured in the labiolingual direction during the test. The fracture resistance differences among the groups were not statistically significant at the 95% level of confidence (P =.929). The highest fracture resistance value was observed in the control group, followed by the group with root canal preparation and root canal filling at 3000 rpm. The lowest value was observed in Group 1 (preparation at 1000 rpm without root canal filling) (Table 1). No file fracture occurred in any of the files used in all groups.

Table 1: Mean ± SD of force loads at fracture in Newton (N)

Groups	Force (N)
Control	578.8 ± 55.7^{a}
XPS-1000 rpm	518.3 ± 149.6^{a}
XPS-1000 rpm filling	537.5 ± 160.9^{a}
XPS-3000 rpm	533.9 ± 136.6^{a}
XPS-3000 rpm filling	556.5 ± 92.1^{a}

The same superscript letters indicate statistically no significant values (P >.05).

V. Discussion

The success of endodontic treatment depends on performing all stages in accordance with the literature. The preparation of the root canals affects the prognosis of the teeth by affecting the microhardness, elasticity, and fracture resistance of the dentin (14,15). The contacts formed between the files and the dentin walls during root canal preparation cause many momentary stress concentrations on the dentin surface and the high stress formed may increase the amount of dentinal defect and the risk of VRF accordingly (8,16).

In literature, studies conducted on the resistance of teeth to fracture examine the incidence of microcrack formation in teeth (17), stress analysis on the dentin surfaces (8), and the presence of defects and fractures seen in teeth under constant mechanical forces (18). Standardization of the samples is an important parameter in fracture resistance studies using extracted human teeth. It is generally accepted that the fracture resistance of an endodontically treated tooth is directly related to the amount of remaining undamaged tooth structure (19,20). In order to ensure standardization, teeth with similar length and diameter characteristics were included in the study.

According to the results we obtained in our study when the root preparations of the XPS at 3000 rpm and 1000 rpm rotation speed were compared, no statistically significant difference was observed between the groups in terms of the fracture resistance of the teeth (p>.05). When we look at the literature, there were no

studies found on the fracture resistance of roots prepared with XPS. XPS is the only snake-shaped design structure file system made-produced using the MaxWire alloy structure (11). The instrument has a narrow taper of 0.01 along the entire length of the instrument with a tip size of #27 (11). The XPS file system represents a new generation of rotary instruments that better adapt to the 3-dimensional structure of the root canals (9). Such advanced systems seem to overcome the taper and size increase of conventional rotary files to contact more canal walls. It has been reported that XPS provides superior preparation compared to other solid core rotary instruments by contacting more canal walls as it expands inside the canal (21). Bayram *et al* (17) compared the incidence of microcrack formed by the XPS on mandibular premolar teeth with the ProTaper Universal (PTU; Dentsply Maillefer, Ballaigues, Switzerland), Protaper Gold (Dentsply Maillefer), and Self-Adjusting File (ReDent Nova, Ra'anana, Israel) files through Micro-Computed Tomography (Micro-CT) imaging. According to the results they obtained, new micro crack formations were observed only in the PTU group imaging before and after the preparation. The authors attributed the fact that the XPS was not cause new micro cracks to the snake-shaped design of the file and its higher flexibility compared to other files even when operating at a high rotation speed (800 rpm). In a study comparing the relationship of the use of files featuring different design characteristics (Profile-constant taper [Dentsply Maillefer], Protaper- increasing taper [Dentsply Maillefer] and LightSpeed- without taper [Lightspeed Technology, Inc, San Antonio, TX]) to having the same tip diameter (# 30) in root canal preparation with vertical root fracture through Finite Element Analysis, researchers stated that all three file systems induce stress formation in the apical area, but the LightSpeed file system displayed the lowest stress formation due to the lack of taper (8). In our study, we observed that the use of the XPS at 1000 or 3000 rpm did not have a statistically significant negative effect on the fracture resistance of the roots compared to the control group. We consider that this may be due to the fact that the XPS presents less dentin wall contact during preparation with its MaxWire alloy structure, small taper feature, and snake-shaped design. Additionally, in studies in the literature comparing single file systems with multi-file rotary systems, it is reported that single file systems cause a lower incidence of microcrack formation (22,23). The XPS having no negative effect on the fracture resistance of the teeth may be explained by the fact that it is a single file system.

The use of files in root canal preparation by increasing the speed is included in many studies (13,24,25). In their study evaluating the centering ability of the Protaper Next file (Dentsply Maillefer) at high speed, Maki *et al* (25) reported that the file used at high speed exhibited better centering ability compared to use at low or medium speed. Webber *et al* (13) compared the shaping properties of XPS at 1000 and 3000 rpm by Micro-CT. In this study, while the researchers found no significant difference in root canal volume after preparation in the use of the file at two different speeds, they observed that the taper formed in the middle and apical third of the root increased when the speed was increased to 3000 rpm (13). Furthermore, the authors reported that the file used at 3000 rpm reached the WL in a shorter time with less pecking motion, and thus reduced the contact time with the dentin walls, causing less stress on the dentin (13). The increased taper observed in the apical and middle third with the use of XPS at 3000 rpm, might bring to mind that it may have a negative effect on the fracture resistance of the teeth. However, in our study, no significant increase was observed in fracture resistance in the 3000 rpm group. We think that this may have occurred due to the reduction of the dentinal stress as a result of the shorter time to reach the WL with the file used at high speed.

According to our results, no significant difference was observed in terms of the fracture resistance of teeth between teeth with a root canal filling and the control group with no treatment other than root canal preparation ($p > .05$). In the literature, it has been reported that root canal filling was no increase the fracture resistance of teeth in canals whether or not they were filled with the resin-based sealer AH Plus (26-28). Similar to the results of these studies, in our study, it was determined that performing the root canal filling with a resin-based paste had no significant effect on the fracture resistance of teeth when compared to the control group containing prepared teeth without root canal filling ($P > .05$).

In our study, no file fracture was encountered as a result of using XPS at 1000 and 3000 rpm. In their study investigating the cyclic fatigue effect of using XPS at two different speeds (1000 rpm, 3000 rpm), Azim *et al* (24) have reported that there is no difference in terms of the cyclic fatigue values of the files at both speeds. In addition, Weber *et al* (13) also stated that the use of the XPS at 3000 rpm caused less deformation on the file compared to use at 1000 rpm.

The limitation of our study is the fact that the methodology we applied fails to fully reflect the clinical conditions. It has been reported in the literature that the capacity of teeth to tolerate radicular dentin damage decreases with age (29). Hence, it is considered that the age of the patients from whom the teeth used in in-vitro studies are obtained may also affect the results. Furthermore, the teeth are surrounded by the periodontium within the alveolar bone, which can absorb the forces on them to a certain extent. Therefore, the relationship between fracture resistance and clinical values in our study should be interpreted with caution. Under these circumstances, the results obtained can only be a reasonable prediction of clinical performance, and further studies are needed.

VI. Conclusion

Within the limitations of this study, the use of the XPS at the rotation speeds of 1000 and 3000 rpm, or filling the root canals with epoxy resin-based sealers had no significant effect on the fracture resistances of the roots.

In this portion, the main problem, selected in the study should be discussed with the relevant earlier literature and the proposed method or solution. Proper references should be used in support to the content.

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