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RESEARCH ARTICLE

Comparison of fracture resistance of teeth with prepared protaper next, protaper gold, and hyflex CM rotary files

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ABSTRACT

Preparation of the root canal system is a crucial step in root canal treatment. Endodontically treated teeth differ structurally from healthy, untreated teeth. This can lead to root cracking by creating pressure on the canal wall, reducing the fracture resistance of the tooth. Different designs, including cross-sectional shape, tip, taper, flute, radial land, helix angle, rake angle, and pitch, can influence the outcome of the root canal preparation and the risk of root fracture. The purpose of this study was to evaluate the fracture resistance of teeth after root canal preparation using three different NiTi rotary files: ProTaper Next (PN), ProTaper Gold (PG), and HyFlex CM (HC). Thirty premolars with a single and straight root canal were decoronated at the cementoenamel junction, leaving 14 mm of the root. The subjects were divided into 3 groups. Group 1 (n = 10) was prepared using PN, group 2 (n = 10) was prepared using PG, and group 3 (n = 10) was prepared using HC. After instrumentation and irrigation, the specimens were subjected to a continuous vertical compressive force (crosshead-speed of 2.28 mm/sec) in order to record the force (in newtons) until root fracture. To describe the surface characteristic of the dentinal root after the preparation, a section fragment from the apical third of the specimens was observed using a scanning electron microscope (SEM) at 2500x magnification. The micrographs were analyzed according to the Hulsman's method. The results demonstrated that there was a statistically significant difference in root fracture resistance among the three groups. (p = 0.043). The LSD post hoc test indicated that HC showed a higher root fracture resistance (p < 0.05) compared to both PN and PG. In conclusion, the different file systems of PN, PG, and HC instruments generate different root fracture resistance of teeth. In comparison to PN and PG, HC instruments tend to result in increased fracture resistance.

Keywords: endodontics; fracture strength; root canal preparation; rotary files

INTRODUCTION

The preparation of the root canal system is one of the most important stages in a root canal therapy. Effective root canal instrumentation is essential for ensuring the long-term success of the root canal therapy. The purpose of root canal instrumentation is to eliminate any residual bacteria, pulpal remnants, and other debris while preserving the structural integrity of the root canal walls.[1] Endodontically treated teeth differ structurally from healthy, untreated teeth. Old dentin and endodontically treated dentin have greater values of modulus of elasticity and hardness, indicating a rise in the deposition of transparent dentin and, consequently, a reduction in the difficulty of crack propagation.[2] Due to the higher risk of fractures in these instances, meticulous planning and innovative treatment procedures are required.

One potential complication of root canal preparation is the crack of the root canal wall. During biomechanical preparation, the interaction of the preparation instruments with the dentin walls shapes a canal. The interactions cause several transient stress concentrations in the dentin, which might induce dentinal flaws and microcracks or craze lines.[3] When the root canal wall is cracked during a root canal preparation, it can reduce the fracture resistance of the tooth.[4] In terms of clinical outcome measures, these fractures may impair the prognosis of endodontic treatment and reduce the long-term survival rate of the tooth.[5,6]

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They may lead to vertical root fractures that become a serious clinical problem as an outcome of endodontic treatment, which often leads to tooth extraction.[7] Technological advances in rotary nickel-titanium (NiTi) tools have resulted in novel design concepts and easier, faster, and more precise root canal shaping in recent decades. NiTi endodontic instruments were developed using a variety of proprietary processing techniques, including machining procedures, to improve mechanical properties. (e.g., twisting, electrical discharge machining), specific thermomechanical treatments such as controlled memory wire (CM wire), memory wire (M-wire), electrical discharge machining (EDM), and surface finishing techniques.[8-10]

ProTaper Next™ (PN, Dentsply Sirona Balligues, Switzerland) was introduced as an off-center rectangular file with multiple progressive and regressive taper concepts. Taper variation reduces the connection between the file and the dentin, lowering screw impression and undesirable taper lock.[11] Compared to the previous generation, namely ProTaper Universal™(PU), PN was introduced with a clear advantage over the previous rotary systems, such as safer preparation in curved canals, instrumentation duration, and fracture resistance[12] and has a unique swaggering movement.[13] ProTaper Gold™ (PG, Dentsply Sirona Balligues, Switzerland) is the latest generation of PU, which uses the same sequence and design but a different NiTi alloy, and a shorter handle allows improved accessibility to teeth. According to the manufacturer, this rotary system is manufactured using a complex heating-cooling process that results in a gold-coloured titanium oxide coating on the surface of the instrument.[14] HyFlex® CM (HC, Coltène Whaledent, Altstätten, Switzerland) is manufactured in a special thermomechanical procedure that aims to increase flexibility. Because it does not return to its original shape, it may reduce the risk of failure due to ledge formation, canal transportation, or perforation.[15,16] Clinical and experimental investigations indicate that the fatigue resistance of these new Hyflex® CM rotary instruments is exceptional.[17] The controlled memory effect enables the file to retain the geometry of the canal after it has been removed from the canal. This property is responsible for preventing procedural errors like ledge formation, transportation, and perforations, which is highly advantageous in cases involving curved canals.[18] In their study, Leski et al[19] concluded that HC is more flexible than PN. However, other studies found no significant differences to apical transportation.[20] All of those properties would influence the fracture resistance of the teeth.

The foundation of the present investigation is that rotational systems create dentinal flaws that can result in root fractures. A distinct rotational mechanism could make it difficult for a practitioner to select and perform a root canal treatment. A comparison of several rotary systems can help us select the appropriate instrument for a certain patient and treatment strategy. In addition, it will help reduce the occurrences of root canal failure due to improper canal shaping. The objective of this study was to evaluate the resistance to root fracture after root canal preparation with ProTaper Next, ProTaper Gold, and HyFlex CM.

MATERIALS AND METHODS

The study protocol for this study was approved by the Ethics Committee Faculty of Dentistry Universitas Gadjah Mada (letter number: 00454/KKEP/FKG-UGM/EC/2020). Thirty extracted human maxillary or mandibular premolars with mature apices, no calcification, no cracks, no fracture lines on the surface outside the root were selected. A stereomicroscope (Olympus 241790) and radiographs were taken to examine the condition of the specimens. Afterwards, only single-rooted teeth with a single and straight canal and without obstruction were included in the study.

The premolar teeth were selected and decoronated, leaving 14 mm of the root. The working length was determined by inserting a #15 K-file into the root canal tip and subtracting 1 mm from the measured length. After randomly dividing the teeth into three categories (n=10), the root canals were instrumented using three NiTi rotary systems, i.e., PN, PG, and HC with the settings provided by the manufacturer. All the procedures were performed by only one experimenter. The root canal of each tooth was instrumented using a crown-down technique with pecking motion. To gain an identical master apical file size, the latest preparation was determined to #25. The root canals were rinsed with 2 mL of 2.5% NaOCl and saline between the use of the file and then rinsed with 1 mL of 17% EDTA, 2 mL of 2.5% NaOCl, and by final irrigation with 2 mL of 2% chlorhexidine.

The resistance to root fracture was evaluated using a universal testing machine. The specimens were placed on the bottom plate of the universal testing machine. A continuous vertical compressive force was applied at a crosshead speed of 1 mm/min.[21] All the specimens were loaded until fracture. The maximum breaking loads by the universal testing machine were recorded in Newtons (N) with PC software connected to the loading machine.

To evaluate the cleanliness of the root canal walls after the instrumentation using PN, PG, and HC, SEM observation was conducted. Photomicrographs were taken at apical one-third at a magnification of 2500x. These photomicrographs were qualitatively evaluated using the following criteria based on Hulsmann:[22]

Score 1: No smear layer, dentinal tubules open.
Score 2: Small amount of smear layer, some (more than 50%) dentinal tubules open.
Score 3: Homogenous smear layer covering the root canal wall, only few (less than 50%) dentinal tubules open.
Score 4: Complete root canal wall covered by a homogenous smear layer, no open dentinal tubules.
Score 5: Heavy, non-homogeneous smear layer covering the complete root canal wall
The observations were carried out by an examiner who was blind in respect of all experimental groups and who underwent a training process with reference to the scoring system of the SEM evaluations.

RESULTS

The fracture resistance of the prepared root was tested and measured using a Universal Testing Machine. The results of testing the fracture resistance on the roots prepared by using the three different NiTi design instruments, namely PN, PG and HC, are shown as mean and standard deviation in Table 1. The highest fracture resistance was observed in the root prepared using HC (1875.46 ± 598.52 N). The one-way ANOVA test showed a statistically significant difference (p = 0.043) in the fracture resistance in all the three experimental groups as seen in Table 2.

Table 1. The Means and deviation standard of the roots prepared by using three different Ni-Ti design instruments (PN, PG and HC)

Group	n	Means (Newton)	Std.
PN	10	1399.18	357.14
PG	10	1385.66	338.69
HC	10	1875.46	598.52

Table 3 shows no significant difference (p=0.043) in the fracture resistance based on the LSD post hoc test among the three experimental groups (between PG with PN, PN with HC, PG with HC). The result indicated that the root fracture resistance after the preparation using PN and PG had no significant difference, while HC showed a higher root fracture resistance compared to both PN and PG.

The cleanliness of the preparation was tested using a Scanning Electron Microscope (SEM) in 2500x magnification and determined based on the Hulsmann's scoring system. This analysis was done to observe the presence of a smear layer resulting from the root canal preparation and dentinal tubules condition on the root canal walls. The open dentinal tubules and the presence of smear layers were used as indicators to assess the cleanliness of the root canal walls. Score 2 and 3 were observed in all the three experimental groups (PN, PG, and HC) as seen in Figure 1 and 2, while score 1 and 4 were not found in all the groups in this study.

DISCUSSION

Mechanical forces are required when using instruments to remove infected tissue, including pulp and dentin, from the root canal. These

Table 2. The One-Way ANOVA result of root fracture resistance after the preparation by using PN, PG and HC

Variables	Sum of squares	df	Mean squares	F	Sig.
Fracture Resistance Difference	1543920.88	2	771960.44	3.669	0.043*

Note: p = probability
*= significant differences (p < 0.05)

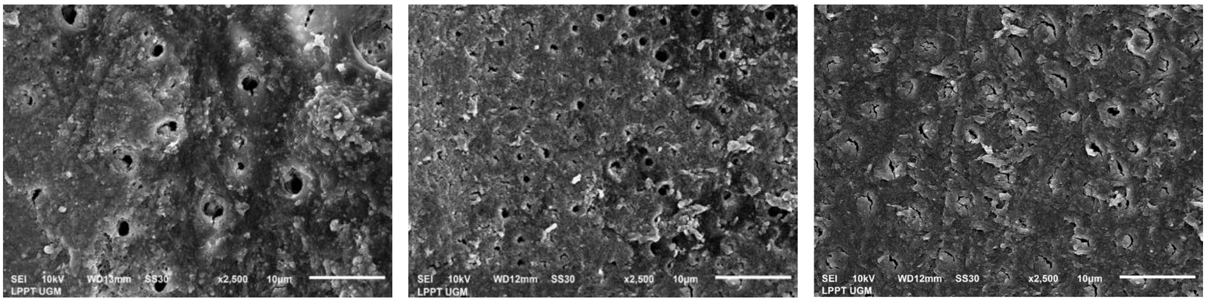
Table 3. The Post Hoc LSD analysis of root fracture after preparation using PG, PN and HC

	Group	p
PN	PG	0.915
	HC	0.026*
PG	HC	0.032*

mechanical forces acting on endodontic files always have a reactive effect on the dentin and root structure.[23] Root canal preparation with rotary NiTi endodontic instruments can significantly weaken the root and cause microcracks or cracks in the root dentin. Depending on the geometries, dimensions, or alloy of the instruments, the forces and the risk or occurrence of dentin damage can cause micro-cracks or crack lines in the root dentin. Depending on the instrument geometries, dimensions, alloys, and forces, the risk or occurrence of dentin damage may vary between instrument systems.

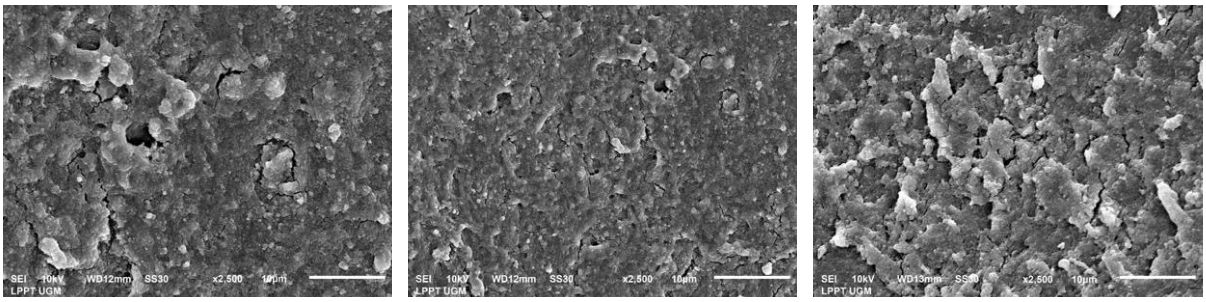
This study investigated the effect of different NiTi rotational systems on the tooth's ability to resist fracture after biomechanical preparation. Many studies have evaluated how rotating instrument systems affect dentinal cracks.[24-27] While Milani et al have argued that resistance to root fracture is more concise and clinically relevant than counting dentin cracks, El Nasr and Abd El Kader[28] stated that analysis of dentinal cracks is a good tool that can indicate root fracture. This study revealed differences in the fracture resistance between teeth prepared using three different instrumentation systems ($p < 0.05$). Multiple factors, including those related to the instruments, may influence the fracture resistance of the teeth that have undergone endodontic treatment, according to some reports. It has been found that the tip design of rotating instruments, cross-sectional geometry, constant or variable pitch and taper, and flute can be associated with cracking.[29] The findings of this study support the findings of that study. The fracture resistance of these three instruments is thought to be influenced by their different cross-sectional shapes and taper sizes. The Hyflex CM has a combination of triangular-square cross-sections with a fixed taper size, whereas the Protaper Next has a rectangular cross-section with a variable taper size. Protaper Gold has a convex triangular cross-section and an increased taper size.[8]

Being in line with Milani et al,[21] who showed that all of the ProTaper systems did not show different fracture resistance, this study revealed that preparation with the ProTaper systems (PN and PG) did not affect the fracture resistance of the teeth. Nonetheless, the fracture resistance of the teeth prepared using both systems was lower than that using HC. Hyflex CM has a high degree of flexibility, allowing it to respond to pressure, torsion, and resistance by extending the pitch to avoid binding in the root canal and increase instrument fracture resistance. Further, it rotates at 500 rpm and has a torque of 2.5 Ncm, and can return to its original shape after being heated in an autoclave.[19] Besides, this could be due to the theory that the larger the helical angle, the better the dentin preparation, the higher the likelihood of cracking. It has been known that instruments with a rectangular cross-section have a helical angle of 18.5°, instruments with a convex triangular section have a helical angle of 19.1°, and instruments with a combined rectangular cross-section have a helical angle of 8.3°.[30] As previously mentioned, a higher incidence of dentin cracks leads to a higher fracture resistance of the teeth.



(A) (B) (C)

Figure 2. Micrographic Image using SEM with 2500x Magnification in PN (A), PG (B), and HC (C) showing few smear layers and >50% exposed dentinal tubules (Score 2)



(A) (B) (C)

Figure 3. Micrographic Image using SEM with 2500x Magnification in PN (A), PG (B), and HC (C) showing smear layers and <50% exposed dentinal tubules (Score 3)

In addition to the helical angle, the taper of the file instrument can be concerning due to the effect of increased tooth structure removal on fracture resistance.[31] ProTaper Gold has a progressive taper, PN consists of variable taper, while HC is characterized by a constant taper. Based on the result, it can be speculated that the progressive taper may significantly weaken the roots due to greater dentinal removal. However, it should be highlighted that tooth fracture results from the interaction between multiple factors with intrinsic aspects of the canal.

In this research, the rotating speed and torque were determined by following the guidelines provided by the manufacturer. The instrument with a 500 rpm rotation speed (HC) produced the highest fracture resistance when compared to the two instruments with a 300 rpm rotation speed (PN and PG). This demonstrates that instruments with a rotating speed of 500 rpm are superior to those with a speed of 300 rpm when it comes to their ability to cut effectively. In addition, the taper of the file will have an effect on the dentin integrity. According to the findings of several studies, the preparation of the roots using instruments with a larger taper resulted in a significant weakening of the roots.[31] The constant taper of HC resulted in higher fracture resistance compared to PN and PG which have progressive and variable tapers.

A root canal preparation results in the formation of a smear layer that can contain a variety of dental components, including dentin, microorganisms, and any remaining pulp tissue. Particularly in the apical third, it is difficult to completely remove the smear layer from the root canal; as a result, any remaining microorganisms have a chance to recolonize after the preparation.[33] Based on the systematic review conducted by Gambarini, et al.,[34] smear layer removal could improve the outcome of a root canal therapy for teeth with initial clinical symptoms or pulpal

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necrosis. Following the evaluation of fracture resistance, we also evaluated the cleanliness of the apical third of the root canal walls in this study. Based on the Hulsman's criteria,[22] the scanning electron micrograph revealed that PN, PG and HC resulted in scores of 2 and 3. The effect of different file rotary systems on the cleanliness of the apical third of the root canal walls after the preparation requires further investigation.

Notably, the specimen preparation and force application in this study were different from clinical conditions; consequently, any direct correlation between fracture load values and clinical reality should be interpreted with caution. The present results can only serve as a reasonable predictor of clinical performance under the given condition.

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CONFLICT OF INTEREST

The authors declare no conflict of interest with the data contained in the manuscript.

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