

# Microscopic Assessment of Dentinal Defects Induced by ProTaper Universal, ProTaper Gold, and Hyflex Electric Discharge Machining Rotary File Systems – An *in vitro* Study

## Abstract

**Background:** Biomechanical preparation of root canal can damage root dentin leading to the formation of dentinal cracks which can eventually lead to fracture and failure of the treatment. **Aim:** The aim was to investigate the incidence of dentinal defects in root canals prepared with ProTaper Universal, ProTaper Gold, and Hyflex electric discharge machining (EDM) rotary file systems using handheld USB digital microscope. **Materials and Methods:** One hundred and fifty extracted mandibular premolar teeth with single canal were randomly divided into five groups ( $n = 30$ ). Group 1: unprepared (negative control). Group 2: canal preparation done with nickel–titanium hand files (positive control), Group 3: canals prepared with ProTaper Universal rotary system, Group 4: canal preparation done with ProTaper Gold rotary system, and Group 5: canals prepared with Hyflex EDM rotary system. The specimens were sliced at 3 mm, 6 mm, and 9 mm from the apex with a slow-speed saw under water cooling. Digital images of each section were captured at  $\times 40$  magnification with the aid of a microscope. Two independent evaluators assessed the images for the presence of dentinal defects. The number of dentinal defects was recorded and Chi-square test was used for statistical analysis ( $P < 0.05$ ). **Results:** The number of specimens presenting dentinal defects was as follows: Group 3; ProTaper Universal – 9/30 (30.0%), Group 4; ProTaper Gold – 2/30 (6.7%), and Group 5; Hyflex EDM – 1/30 (3.3%). No defects were detected in the negative and positive control groups (Group 1 and Group 2). **Conclusion:** ProTaper Universal showed the highest percentage of defects in comparison to ProTaper Gold and Hyflex EDM.

**Keywords:** Dentinal damage, digital microscope, rotary nickel–titanium

## Introduction

One of the key determinants for successful nonsurgical endodontic therapy is the preparation of the root canal system. Stainless steel hand files were used traditionally which have now been replaced with nickel–titanium (NiTi) file systems. Dentinal cracks or root fractures can occur when the tensile stress in the root canal wall exceeds the tensile stress of dentin during instrumentation.<sup>[1]</sup> With the advancements in metallurgy, new NiTi file systems have emerged. This study was conducted to evaluate the incidence of dentinal microcracks resulting from the use of ProTaper Universal, ProTaper Gold, and Hyflex electric discharge machining (EDM) rotary file systems during root canal preparation.

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## Materials and Methods

One hundred and fifty extracted human mandibular premolar teeth with mature apices and straight root canals were selected and stored in distilled water. Soft tissue and calculus were mechanically removed from the root surfaces. Intraoral periapical radiographs were taken to confirm a single canal [Figure 1a]. The teeth were decoronated with a slow-speed saw under water coolant to obtain a standardized root length of 16 mm. A single layer of aluminum foil was used to cover the root surfaces. Each root was embedded into acrylic resin. The aluminum foil was removed from the root, and a light-body silicon-based material was used to replace the space created and simulate the periodontal ligament. The root was immediately inserted into the impression material. Apical 3 mm of the root was exposed and immersed in water

**How to cite this article:** Devi TP, Kaur A, Priyadarshini S, Deepak BS, Banerjee S, Sanjeeta N. Microscopic assessment of dentinal defects induced by ProTaper Universal, ProTaper Gold, and Hyflex electric discharge machining rotary file systems – An *in vitro* study. *Contemp Clin Dent* 2021;12:230-4.

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Submitted : 14-Jul-2020

Revised : 23-Jul-2020

Accepted : 25-Jul-2020

Published : 21-Sep-2021

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#### Website:

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DOI: 10.4103/ccd.ccd\_631\_20

#### Quick Response Code:



during instrumentation to prevent dehydration. The teeth were randomly divided into five groups of thirty teeth each ( $n = 30$ ). All canals were prepared by a single operator to avoid variables. The canal length was measured by inserting a size 10 K-file into canal terminus and subtracting 1 mm from this measurement. A glide path preparation was achieved. Apical preparation was completed with a size 25 instrument of each system. In all teeth, the canal patency was established with a #10 K file. Three percent sodium hypochlorite solution was used as an irrigant during instrumentation with a 27 gauge needle. Seventeen percent Ethylenediaminetetraacetic acid (EDTA) was additionally used between each sequential instrument in groups with rotary system preparation. All roots were kept moist in distilled water throughout the procedures. In Groups 3, 4, and 5, Endoactivator (Dentsply Tulsa Dental, Tulsa, OK, USA) was used with number 25 tip for 30 s.

No preparation was done in the negative control group (Group 1). Root canal preparation was done with NiTi hand files to apical size # 25 K file in the positive control group (Group 2). Circumferential quarter-turn push-pull filing motion using the crown-down technique with K-files #45–80 was done resulting in preparation with a taper of about 0.05. In Group 3, the teeth were prepared with ProTaper Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland) sequentially using an endodontic motor X-SMART Plus (Dentsply, Maillefer) at the rotational speed of 300 rpm. Sx file was used to enlarge the coronal portion of the canal, followed by S1–S2 files used with a torque of 1.5 N. cm in a brushing motion. The finishing files were used until the working length (WL) was reached with a torque of 2.5 N cm and the canal preparation was completed with # F2 (25/.08) file. In Group 4, teeth were prepared with ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) system in sequential order till F2 at the WL at 300 rpm and torque of 2.5 N cm. In Group 5,

Hyflex EDM files were used in a gentle in-and-out motion with a rotational speed of 500 rpm and 2.5 N. cm torque with CanalPro CL Motor (Coltene). The files were used in the sequence of 25/.12 (orifice opener), followed by 10/.05 glide path file up to the WL and Hyflex EDM 25/~ Onefile (Coltene – Whaledent, Allstetten, Switzerland) for enlargement of the root canal till the WL.

### Sectioning and examination of roots

The roots of all the teeth were sectioned perpendicular to the long axis at 3 mm, 6 mm, and 9 mm from the apex with a slow-speed saw under water coolant. Each section was then viewed through a handheld Universal Serial Bus (USB) digital microscope (Microware) [Figure 1b and c]. Digital images of each section were captured at  $\times 40$  magnification to determine the presence of dentinal defects which were categorized according to Barreto *et al.* [Table 1].<sup>[2]</sup> Two calibrated endodontists who were not involved in the preparation of the specimens determined the presence or absence of dentinal defects. “No defect” was defined as root dentin without any lines or cracks on both the internal surface of the root canal wall and the external surface of the root. “Crack” was defined as all lines observed on the slice that either extended from the root canal lumen to the dentin or from the outer root surface into the dentin.<sup>[3]</sup> Roots were classified as “defected” if at least one of three sections showed either a craze line, partial crack, or a crack [Figure 2]. Results were expressed as number and percentage of defected roots in each group.

### Statistical analysis

The data collected were analyzed with Chi-square test to compare the appearance of defected roots between the experimental groups. All statistical analyses were performed using the software SPSS 17.0 program (SPSS Inc., Chicago, USA).

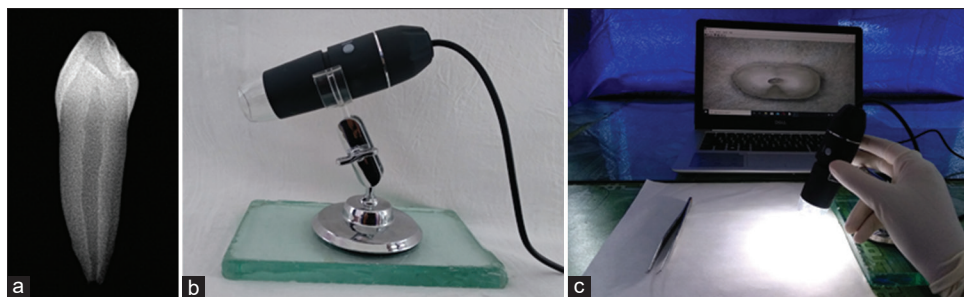


Figure 1: (a) Intra-oral periapical X-ray of a single-rooted mandibular premolar tooth. (b) Handheld USB digital microscope. (c) Examination of the apical section under the microscope

**Table 1: Classification of dentinal defects according to Barreto *et al.*<sup>[2]</sup>**

A	No defect	Root dentin without any lines or cracks on the external or the internal surface of the root
B	Incomplete crack	A line extending from the canal wall into the dentin without reaching the outer surface
C	Complete crack	A line extending from the root canal wall to the outer surface of the root
D	Craze lines	All other lines that did not reach any surface of root or extend from the outer surface into the dentin but did not reach the canal wall

## Results

The number of dentinal defects at apical 3 mm was observed in 9/30 (30.0%) specimens with ProTaper Universal. These defects were found in 2/30 (6.7%) specimens with ProTaper Gold and 1/30 (3.3%) with Hyflex EDM. *P* value (*P* = 0.0003) indicates high significance among the experimental groups at apical third [Table 2]. ProTaper Universal group thus demonstrated a significantly higher number of defects (*P* < 0.05) compared to ProTaper Gold and Hyflex EDM groups. However, no significant difference was observed between the ProTaper Gold and Hyflex EDM groups. No dentinal defects were observed in the unprepared group (Group 1) and with hand files (Group 2). In addition, no statistically significant difference was observed for the presence of dentinal defects in the middle third (6 mm) and coronal third (9 mm) of the root canal [Table 3].

## Discussion

Root canal preparation with rotary NiTi endodontic instruments can significantly weaken the root by generating stresses in root dentin leading to microcracks or craze lines.<sup>[3]</sup> These stresses are generated from inside the

root canal and more along the walls and higher stresses in the apical third.<sup>[4]</sup> Dentinal defects are considered as stress concentrators and a predisposing factor to vertical root fracture. The contact stress levels are determined by the design (cross-sectional and longitudinal) of the instruments and its kinematics.<sup>[5]</sup> The mechanical response of the periodontal ligament to external stress is nonlinear and viscoelastic which dissipates the stress in a clinical scenario.<sup>[6]</sup> Silicone impression material with similar characteristics was used to mimic the bony socket and hold the specimens during canal preparation and to dispel the applied forces in the present study. Extracted mandibular premolar teeth were used in this study since these teeth are prone to be influenced by forces during root canal preparation as a result of their smaller dimensions and thin dentinal walls.<sup>[7]</sup> The specimens were stored in hydrated environment at all times to prevent dehydration and avoid artifacts.<sup>[8]</sup> Similar apical preparation was done using all file systems (#40) in a crown-down manner. Glidepath was achieved with all the systems to preserve canal anatomy and reduce instrument binding in the canal since the possibility of dentinal defects might increase due to excessive instrument binding and maximum contact between file

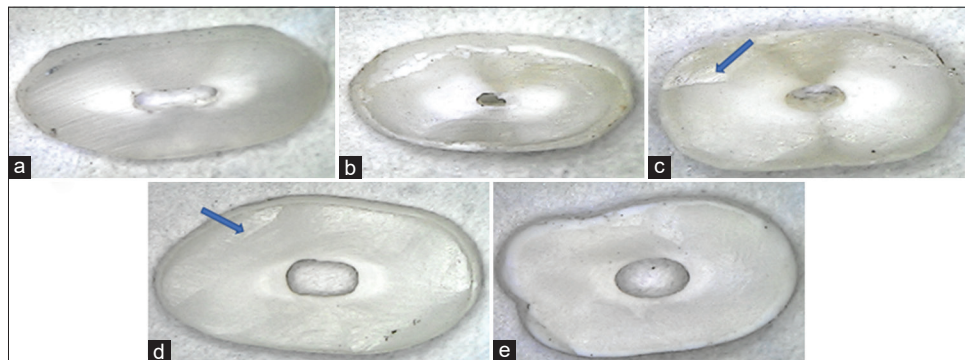


Figure 2: (a) Apical third unprepared section depicting no crack (Group 1: negative control). (b) Apical third section prepared with hand file depicting no crack (Group 2: positive control). (c) Apical third section prepared with ProTaper Universal file depicting crack (Group 3). (d) Apical third section prepared with ProTaper Gold file depicting incomplete crack (Group 4). (e) Apical third section prepared with Hyflex electric discharge machining file depicting no crack (Group 5)

**Table 2: Dentinal defects in the experimental groups**

	ProTaper Universal (Group 3), n (%)	ProTaper Gold (Group 4), n (%)	Hyflex EDM (Group 5), n (%)	Total
No defect	21 (70.0)	28 (93.3)	29 (96.7)	78
Defects	9 (30.0)	2 (6.7)	1 (3.3)	12
Total	30	30	30	90

*P*=0.0003

**Table 3: Dentinal defects at apical third, middle third and coronal third**

Group	3 mm	6 mm	9 mm
Hand K files	0	0	0
ProTaper Universal	9	5	4
ProTaper Gold	2	2	2
Hyflex EDM	1	2	2
$\chi^2$	18.5185	6.12613	4.2857
<i>P</i>	0.0003 (significant)	0.1056 (not significant)	0.2322 (not significant)

and dentin.<sup>[9]</sup> Sodium hypochlorite being alkaline in nature can alter the chemical structure and mechanical properties (elastic modulus and flexural strength) of dentin decreasing microhardness of dentin and affecting crack propagation.<sup>[10]</sup> However, 3% sodium hypochlorite was used for irrigation in all the teeth in the present study and no dentinal defects were noticed in the negative and positive control groups. Therefore, it may be considered that irrigation using sodium hypochlorite in this study did not contribute to the appearance of dentinal defects. Decoronation of all the specimens was done using a low-speed saw with water coolant. Decoronation eliminates variables such as the anatomy of the coronal area and access to the root canals allowing a more reliable comparison between endodontic treatment techniques.<sup>[11]</sup> A portable handheld USB digital microscope was used in the present study to evaluate dentinal defects using hand files, traditional NiTi rotary instrument (ProTaper), a novel heat-treated NiTi rotary instrument (ProTaper Gold), and EDM process file (Hyflex EDM) due to unavailability of stereomicroscope. It consists of HD color CMOS sensor, 24 bit DSP, optimum resolution of  $640 \times 480$ , digital measurement software, and calibration ruler compatible with USB 1.1, USB 2.0, and USB 3.0 and contains eight light-emitting diode bulbs as light source. It has the advantage of low-cost, portable design, easy to use, and can be connected to a computer for data processing and analysis.<sup>[12]</sup> Dentinal defects as a consequence of canal preparation were first reported by Onnink *et al.*<sup>[13]</sup> No dentinal damage was observed with the hand files. This can be attributed to less taper (0.02) and lesser aggressive movements as compared to the rotary instruments, which is in accordance with the previous reports by Yoldas *et al.*<sup>[14]</sup> and Hin *et al.*<sup>[15]</sup> Dentinal defects can also occur as a result of sectioning. However, since no defects were observed in the control and hand file group, it can be concluded that the defects present were not due to the sectioning procedure. ProTaper Universal rotary files demonstrated 30% dentinal defects as compared to ProTaper Gold (6.7%) and Hyflex EDM (3.3%). This significant difference can be attributed to the progressive taper design of ProTaper Universal rotary files with increased stiffness and active cutting.<sup>[16]</sup> The taper of ProTaper file F2 is 0.08 which could explain the higher incidence of damage. Bier *et al.* reported cracks in the horizontal sections of 16% of roots instrumented with the ProTaper system.<sup>[17]</sup> Liu *et al.* observed cracks in 25% of the roots instrumented with ProTaper at the apical root surface.<sup>[18]</sup> The ProTaper Gold rotary system has identical architecture as the ProTaper Universal system. However, it has a 2-stage specific transformation behavior and high austenite finish temperature similar to controlled memory (CM) wire. These metallurgical characteristics impart greater flexibility and fatigue resistance to the files.<sup>[19]</sup> The Hyflex EDM is a continuous rotation single file system produced by EDM. The EDM process results in extremely flexible and fracture-resistant files. The built-in

shape memory prevents stress during canal preparation by changing their spiral shape and following the anatomy of the root canal, thus preventing the formation of microcracks and root dentin defects. Hyflex EDM file has a tip size of 25 with a constant 0.08 taper in the apical 4 mm which reduces up to 0.04 taper in the coronal portion. It has three different cross-sectional zones: quadratic at the tip, trapezoidal in the middle, and triangular toward the shaft. It was reported that this variable cross-sectional design contributes to lesser dentinal cracks' formation.<sup>[20]</sup>

The higher incidence of cracks in ProTaper Universal can thus be attributed to its relative stiffness which led to more stress generation and concentration of stress, especially in the apical root area with subsequent crack initiation as compared to other rotary NiTi systems used in this study. Highly flexible endodontic instruments were associated with fewer dentinal defects since the high flexibility of the alloy generates not only less stresses on the root canal walls but also less pressure during instrumentation.<sup>[21]</sup> This finding is in accordance with the findings of Pedullà *et al.*,<sup>[22]</sup> Pereira *et al.*,<sup>[23]</sup> and Peters *et al.*<sup>[24]</sup> concluded in their respective studies that endodontic instruments manufactured with M-wire alloy and CM NiTi exhibit more flexibility than conventional NiTi rotary instruments. Since Hyflex EDM instruments are manufactured from M-wire alloy, they exhibit high flexibility and would have thus contributed to a lesser number of cracks. The limitation of the present study is that a handheld USB digital microscope was used to examine the sections. Furthermore, the samples included only teeth with straight and single root canals. The use of different speeds and torque settings for each file system was another limitation. The force used during instrumentation could not be standardized as well. Further studies are needed to evaluate the dentinal defects in susceptible roots and curved canals such as mesial roots of mandibular molars and mandibular incisors using a stereomicroscope which aids in providing the depth of the section and hence a three-dimensional view.

## Conclusion

Within the limitations of the present study, it can be concluded that

1. ProTaper Universal showed the highest percentage of dentinal defects in comparison to ProTaper Gold and Hyflex EDM
2. The defects were present more in the apical third (3 mm) as compared to 6 mm (middle third) and 9 mm (coronal third) sections
3. No significant difference was observed between the groups of ProTaper Gold and Hyflex EDM in terms of the presence of defects.

The results also suggest that heat-treated file systems may be less likely to cause microcracks as compared to traditional NiTi systems. Prudent selection of file system

for instrumentation is of utmost importance for long-term endodontic success.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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