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Original Research Article

Evaluation of Dentinal Microcrack Formation with Endodontic Retreatment Files using Scanning Electron Microscope: An *in vitro* Study

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ABSTRACT

Aim: The aim of this study is to evaluate the incidence of dentinal defects after root canal retreatment with ProTaper Universal retreatment (PTUR) and Hyflex remover file system using scanning electron microscope.
Materials and Method: Sixty extracted single-rooted human teeth were selected and divided into 4 groups of 15 teeth each. In negative control group, teeth were left unprepared. In positive control group, teeth were prepared with ProTaper Next and obturated with no further retreatment. In PTUR and Hyflex groups, teeth were prepared and obturated followed by removal of the filling material with PTUR and Hyflex instruments, respectively. 3 mm of roots were then sectioned at 3 mm from the apex and observed under a scanning electron microscope to detect defects.
Results: PTUR group showed significantly higher (p value <0.05) incidence of defects than the other groups. No significant differences were observed between Hyflex and the positive control group.
Conclusion: Within the limitations of the present study it was concluded that all retreatment instruments used in this study created defects in the root dentin. PTUR instruments showed a significantly higher association with creating dentinal defects than Hyflex remover.

Keywords: Dentinal defects, Hyflex remover, PTUR files, Retreatment

INTRODUCTION

Endodontic treatment aims to restore teeth affected by inflamed or infected root canals to their natural form and function through a meticulous process of mechanical and chemical preparation of the root canal space, followed by sealing with biocompatible materials.[1] Despite these efforts, endodontic failures can occur due to various factors such as coronal leakage, fractures, missed canals, and procedural errors. Such failures often necessitate retreatment, either nonsurgical or surgical, to address persistent infection or discomfort.[2]

Nonsurgical retreatment involves the complete removal of existing filling materials from the root canal system to achieve thorough cleaning, shaping, and re-obturation. Techniques for material removal have evolved significantly, leveraging advancements in tools and methods.[3] Rotary nickel-titanium (NiTi) instruments, such as the ProTaper Universal and Hyflex Remover systems, have emerged as effective tools for this purpose. These instruments are designed with varying tapers and tip geometries to facilitate the removal of gutta-percha and other obturation materials.[4]

The ProTaper Universal retreatment system features specialized files (D1, D2, D3) designed for different aspects of the root canal: initial penetration, middle-third removal, and apical cleaning, respectively. Each file is tailored with specific lengths, tapers, and tip diameters to optimize material removal while minimizing potential damage to the root structure.3 In contrast, the Hyflex Remover file is characterized by a non-cutting tip and a taper that changes along its length, designed to preserve periradicular dentine while effectively removing filling materials.[5]

Despite the advantages offered by NiTi rotary systems in terms of efficiency and precision, concerns about their impact on dentinal integrity have been raised. Studies have shown that instrumentation with NiTi files, including during retreatment procedures, can induce microscopic dentinal defects known as microcracks. These defects, though often subclinical, may compromise the long-term structural integrity of the tooth and potentially contribute to future complications. In addition to NiTi files, obturation procedures have also been linked to dentinal abnormalities.[6] According to Blum et al.'s research, microcrack incidence rises following obturation. Dentinal microcracks are initiated and spread by intraradicular operations like shaping, cleaning, and obturation, according to a recent micro-CT-based study.[7]

This warrants the purpose of this study, which is to investigate the incidence of dentinal defects after using two different rotary retreatment systems: ProTaper Universal retreatment (PTUR) and Hyflex Remover.

MATERIALS & METHODS

Sample power calculation. The G power sample power calculator was used to determine sample power. A sample size of 15 per group would result in a power of 0.96 for generic z tests based on data from earlier in vitro research that showed an effect size of 0.8 for the test groups. For the investigation, a total of 60 specimens were lined up in 4 groups.

Specimen selection and preparation. Sixty human single rooted teeth were removed for purposes unrelated to this investigation.

The following inclusion criteria were applied: straight root, mature apex, single canal, and not filled with root canal material.

Following extraction, the teeth were rinsed with water to eliminate blood and scaled using a scaler to detach any connected periodontal tissue. Plaque and calculus were then submerged in a 5% sodium hypochlorite (NaOCl) solution for two hours to dissolve any superficial soft tissue and sanitize the surface. To make sure the collected teeth were free of calcifications, fractures, craze lines, open apices, root caries, or restorations, preoperative radiographs were employed. Each experimental tooth was sectioned off using a flexible diamond disk (Novo Dental Products, Mumbai, India) in a slow-speed handpiece while submerged in a generous amount of water cooling in order to standardize the teeth. Every tooth's root was measured from the apex to the CEJ and standardized to a length of 16 mm.

In the negative control group, the teeth received no treatment. In the other 3 groups, using an endoaccess bur (Dentsply Maillefer, Switzerland) in a high-speed handpiece, coronal access was prepared, and a #10 K-file (Dentsply Maillefer, Switzerland) was used to assess canal patency. The #15k file was used to measure the working length. An X Smart endomotor

(Dentsply Maillefer, Switzerland) was used to clean and shape the root canals using ProTaper rotating Ni-Ti files up to F3 (#30/09) at a speed of 300 rpm. After each instrumentation, the canals were irrigated with 2 ml of 3% NaOCl using a syringe and a 27-gauge side vented needle. 2 ml of 2% NaOCl, 2 ml of 17% ethylenediaminetetraacetic acid (EDTA), and 2 ml of distilled water were used for the final irrigation.

Canal filling. The technique of cold lateral compaction was used to obturate the teeth. The size 40 gutta-percha cones with taper 2% (Dentsply-Maillefer) were introduced as the master cone after the canals were dried using absorbent paper points (Dentsply-Maillefer). The apical 5 mm of the cones were then coated with sealer (EugeSeal, Safe Endo). A size M spreader (Dentsply-Maillefer, Ballaigues, Switzerland) was used to laterally condense accessory medium-fine cones until the gutta-percha cones could no longer be compressed at a depth greater than 5 mm into the root canal. As a pilot, a few teeth were radiographically examined to guarantee the quality of the obturation.

The teeth in the positive control group underwent no retreatment treatments after being prepped and obturated.

Retreatment procedures.

PTUR group. Using a D1 (size 30, 0.09 taper) to form a reservoir for the solvent material, the filled canals were first retreated. To soften the gutta percha, a drop of Guttasolv (Septodont, France) was then put into each canal. The working length was then attained by using D2 file (size 25, 0.08 taper) and D3 file (size 20, 0.07 taper) in brushing motion at speed of 600 rpm.

Hyflex group. To soften the gutta percha, a drop of Guttasolv (Septodont, France) was inserted into each canal. The Hyflex Remover files were then utilized for the whole working length and kept there for a further thirty seconds.

2% NaOCl was used in both retreatment groups to irrigate the root canals in between each filing. 2 ml of 2% NaOCl and 2 ml of 17% EDTA were used for the final irrigation, which was then followed by 5 ml of distilled water. Radiographs taken from below were used to confirm that the root filling materials had been removed.

2.5 Evaluation. 3 mm of roots were cut horizontally at 3 mm from the apex using a low-speed, 100 mm-diameter saw (Novo Dental Products, Mumbai, India) 0.5 mm thick diamond blade cooled by water. The scanning electron microscope was then used to take pictures of the root sections, which were then examined for any defects.

STATISTICAL ANALYSIS

The types of dentin defects found in each root sample were recorded, and the statistician tallied and statistically assessed the percentage of defects for each group. Using the cross-tabs function, the Odd's ratio and the relative risk of microcrack occurrence were determined, and Mann-Whitney U tests were employed to compare the defects found in the various groups with each other.

RESULT

Following root canal retreatment, a total of 15 defects were noted in the four groups simultaneously. The Hyflex (n = 4), positive control (n = 2), and negative control (n = 0) groups were all considerably lower than the PTUR group (n = 9). Table 1 shows the distribution of three types of defects (Type A - No defect, Type B -Fracture line, and Type C - Partial Crack) across four distinct groups: Negative control, Positive control, PTUR group, and Hyflex group.

The "Count" column specifies the number of occurrences for each defect type within each group, while the "Column%" columns provide the percentage distribution relative to the total count in each column.

This table shows that the PTUR group, in particular, shows a higher susceptibility to fractures and partial cracks compared to other groups. The positive control group and Hyflex group also exhibits some impact, while the negative control group maintains a low incidence of defects. PTUR was found to have considerably more faults than Hyflex when post hoc comparisons across the groups were performed (Mann–Whitney U = 80.500, p = 0.037). Hyflex did not differ significantly from either the negative control group (Mann–Whitney U = 82.500, p = 0.035) or the positive control group (Mann–Whitney U = 96.500, p = 0.341).

Table 1: Presence of defect is listed in the table; however, both presence and absence are used for the calculation of Kruskal–Wallis.

	Type A (No defect)		Type B (Fracture line)		Type C (Partial Crack)	
	Count	Column%	Count	Column%	Count	Column%
Group 1 (Negative control group)	15	33.33	0	0.00	0	0.00
Group 2 (Positive control group)	13	28.89	1	16.67	1	11.11
Group 3 (PTUR group)	6	13.33	4	66.67	5	55.56
Group 4 (Hyflex group)	11	24.44	1	16.67	3	33.33

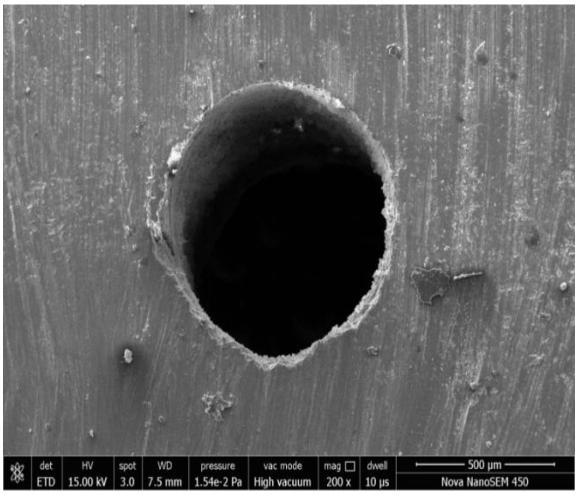


Figure 1: Type A (No defect)

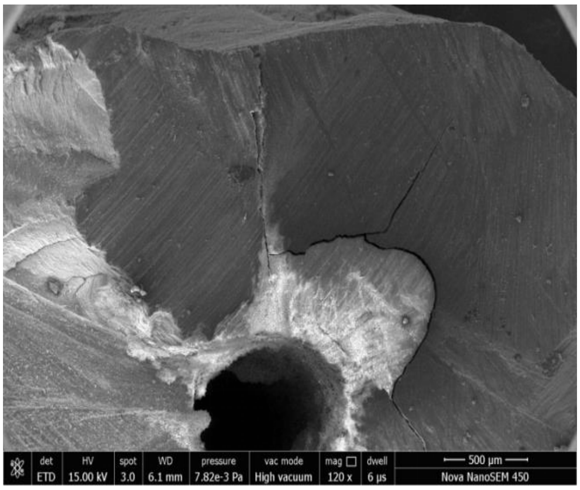


Figure 2: Type B (Fracture)

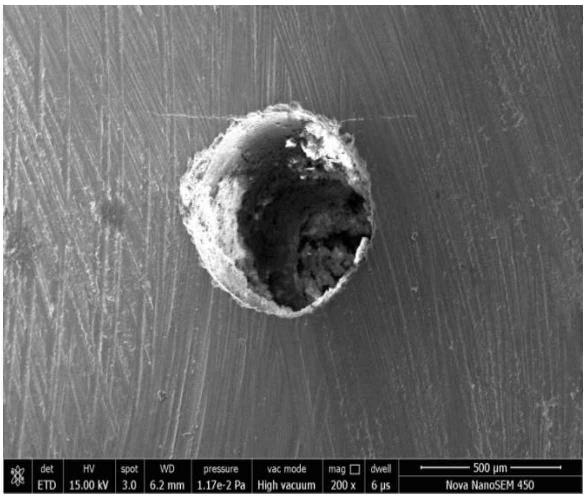
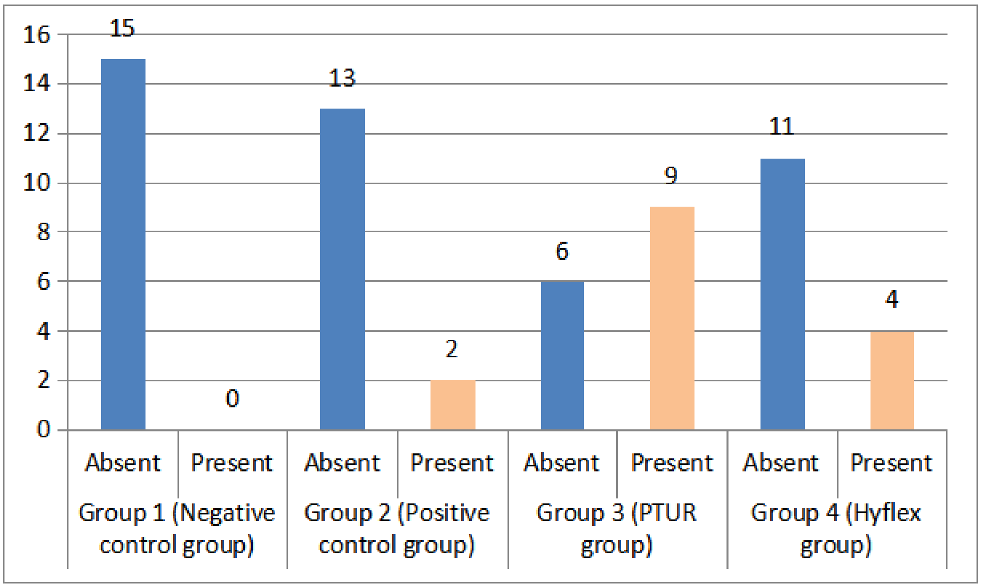


Figure 3: Type B (Partial crack)

Graph 1: Presence or absence of defects among the groups. PTUR shows significantly greater presence of defects



DISCUSSION

In this investigation, single-rooted teeth were analyzed to check for any exterior flaws. According to studies, the extraction process itself may result in this kind of problem.[8] Nonetheless, the lack of any defect in the negative control group suggests that the teeth were intact, which is in line with findings from prior investigations. The teeth in this investigation were sectioned and subsequently inspected using a scanning electron microscope. Despite the possibility that the sectioning process would harm the specimens, the negative control group's specimens showed no defects.[9]

Numerous experiments conducted over the years using different methods have documented the development of cracks during NiTi rotary instrumentation. It has been found that obturation procedures may also result in dentinal defects in addition to NiTi filings.[10] In their investigation, Blum et al. came to the conclusion that microcrack incidence rises following obturation. Dental microcracks are initiated and propagate as a result of intraradicular processes such shaping, cleaning, and obturation, according to a recent micro-CT-based study.[7] In order to prevent any excessive stresses during obturation, a light compaction was done in the current investigation using a finger spreader.

It is also important to remember that, in order to replicate clinical settings, all retreatment procedures were carried out at body temperature (37° C).[11]

Using Hyflex remover and ProTaper Universal Retreatment (PTUR) tools, the incidence of defects was examined following the retreatment. Defects were found using sectioning and a scanning electron microscopic examination approach. The study's null hypothesis was rejected when it was discovered that dentinal defects were caused by both file systems, with the group of PTUR showing a considerably higher occurrence (p value <0.05).

The literature has thoroughly examined the link between dentinal defects and the usage of NiTi rotary files. While the majority of published research focused on the initial root canal treatment, a small number also assessed the impact of these treatments on retreatment procedures; these are summarized here.

Microscopic evaluation was used to compare three different NiTi rotary retreatment files: Mtwo, R-Endo (Micro-Mega, Besancon, France), and D-Race. All examined groups had root dentin defects, with no significant differences found (p > 0.05). this served as the foundation for the current study's null hypothesis. The two examined retreatment files produced defects, according to the current investigation; still, a statistically significant difference was observed.[10]

Reports from micro-CT scanning have revealed that PTUR files have a higher incidence of dentinal abnormalities than other studied files. The new study's findings are in line with theirs, which showed that PTUR files had more defects than hyflex remover.[12]

Shemesh et al. employed stereomicroscope inspection to examine the crack formation following the use of PTUR files in contrast to the use of hand Hedstrom files. They discovered that, although there was no discernible difference between the retreatment groups, the retreatment procedures produced more defects than the initial treatment.[13]

Hyflex remover's efficacy in removing root canal fillings has been assessed in a number of trials, but its role in the development of dentinal defects following retreatment has not been examined. However, studies that assessed the frequency of dentinal defects associated with hyflex files following first root canal therapy found that their use did not cause any new dentinal microcracks.

The design and geometry may be two of the reasons for the hyflex group's lower defect incidence in the current investigation as compared to the PTUR group. The tip diameters and tapers of the PTUR instruments (D1, D2, and D3) are different; they are size 30, 0.09 taper, size 25, 0.08 taper, and size 20, 0.07 taper, respectively.[14] Hyflex remover is characterized by a single file with a taper of 7% and an apical diameter size of 30. The file is equipped with a 1 mm wire that is minimally intrusive and is recognized for its high efficiency without requiring any solvent.[15] Comparing the PTUR instruments to the Hyflex remover, the former are more rigid and tapered. This may also account for the PTUR group's increased frequency of defects.

The variation in metallurgical characteristics of the instruments that were evaluated is another factor. NiTi in the austenite phase is the primary material used to make PTUR instruments.[16] The modified triangular cross-sectional shape of the HyFlex Remover retreatment files. This form lacks radial lands and has three distinct cutting edges. As such, these files are designed with the express purpose of preventing entry into the canal wall and effectively removing any excess dentin removal.[15]

CONCLUSION

There are a few limitations to this study: the sectioning procedure may have exposed the specimens to additional mechanical stress; it was not possible to evaluate the dentin's inner preoperative state; and it was not possible to evaluate cracks that occurred along the root's longitudinal axis.

Within the limitations of this study, it was concluded that all retreatment instruments created defects in root dentin. However, teeth retreated with Hyflex remover file showed less dentinal microcrack formation when compared to teeth retreated with ProTaper Universal retreatment files. Further clinical research or better methods are required that can replicate the clinical setting to answer several remaining questions about the development of and the role of dentinal defects in endodontics.

Declaration by Authors

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