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Comparative evaluation of incidence of dentinal defects after root canal preparation using three different endodontic retreatment systems – An in vitro study

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Abstract

Context: Safe and efficient removal of all root filling materials from the root canal system without compromising radicular dentin structure is essential for optimal nonsurgical retreatment.

Aims: The aim of this study was to evaluate and compare the incidence of dentinal defects caused during root canal filling removal using conventional, rotary, and reciprocating retreatment file systems.

Settings and Design: A detailed protocol explaining purpose and procedures of the study was submitted to the Institutional Ethics Committee and ethical clearance obtained.

Subjects and Methods: Sixty human maxillary permanent central incisors were collected and decoronated to 12-mm standardized length. The canals prepared up to a master apical file size F3 with Protaper hand files, obturated using AH plus sealer, examined under the stereomicroscope (×40 magnification): Group I: Control (n = 15), Group II: Conventional (n = 15), Group III: Protaper Universal Retreatment Files (n = 15), and Group IV: Reciproc Blue (n = 15). After instrumentation, teeth were sectioned at 3, 6, and 9 mm from the apex to evaluate the presence of dentinal defects under the stereomicroscope.

Statistical Analysis Used: Statistics were performed using the SPSS, version, 25 (SPSS Inc., Chicago, IL, USA). Initially, the normality test was done using the Shapiro–Wilk test and data were not normally distributed followed by Kruskal–Wallis test. $P < 0.05$ is considered statistically significant.

Results: Maximum percentage increase in dentinal defects was observed in Protaper Universal Retreatment Files followed by Conventional method and Reciproc Blue.
Conclusions: Significantly Reciproc Blue reduced the incidence of dentinal defects after root canal preparation.
Keywords: AH plus sealer; dentinal defects; ProTaper hand files; retreatment; stereomicroscope

INTRODUCTION

This aim and objective of this study was to assess and compare the frequency of dentinal abnormalities brought on by root canal fillings that involved removing all of the previously utilized endodontic restorative material in order to get rid of the microbial population and necrotic tissues.[2] Following an initial root canal, posttreatment disease may develop as a result of bacteria that have been left in the root canal system by improper cleaning, missing canals, insufficient root filling, or coronal leakage.[3]

Vertical root fractures (VRFs) have a poor prognosis for the affected tooth and should thus be avoided. The foundation of VRFs has been postulated to be local stress concentrations. Dentin defects caused by endodontic procedures can act as stress concentration areas, propagate from repeated stresses caused by subsequent endodontic and restorative procedures, and eventually develop into a VRF. Dentinal defects can be caused by a number of factors, including biomechanical preparation, root filling techniques, retreatment procedures, and post placement. Retreatment procedures necessitate additional mechanical preparation of the root canal, which can result in additional damage to the root canal wall.[4,5]

It has been reported that canal preparation and obturation alone can damage root dentin and cause fracture, so repeating these procedures (retreatment) should increase the likelihood of defects.[6] Because it requires reopening the root canal system by removing the original filling using endodontic hand files, heat instruments, ultrasonic instruments, or engine-driven rotary files, followed by cleaning, shaping, and re-obturation, conventional root canal retreatment is one of the most challenging technical challenges. The use of nickel-titanium (NiTi) rotary devices has been extensively studied as a promising method for root canal retreatment and root filling removal. One significant aspect of this technique is its capacity to eliminate the root filling material without the use of gutta-percha solvents.

On retreatment therapy, such a film may reduce the action of intracanal medicaments and the adhesion of the root canal sealer to the canal walls. Other advantages of rotary instruments are the non utilization of potential carcinogenic products and the elimination of possible apical extrusion of gutta-percha by excessive dissolution of this material.[7]

The ProTaper Universal Retreatment system is a NiTi rotary instrument that is used for the removal of filling material from the root canal. The instruments have a convex triangular cross section.[5] They have various tapers and diameters at the tip, which are size 30, 0.09 taper, size 25, 0.08 taper and size 20, 0.07 taper. These retreatment files have full lengths of 16 mm for D1, 18 mm for D2, and 22 mm for D3. To remove filling materials from the coronal, middle, and apical parts of the canals, D1, D2, and D3 are recommended. D1 has a working tip that facilitates its initial penetration into filling materials.[8]

The Reciproc blue system consists of three instruments. The Reciproc blue 25 has a tip diameter of 0.25 mm and an 8% taper over the first 3 mm from the tip. The Reciproc blue 40 has a tip diameter of 0.40 mm and a 6% taper over the first 3 mm. The Reciproc blue 50 has a tip diameter of 0.50 mm and a 5% taper over the first 3 mm. This file system is more resistant to cyclic fatigue and has greater flexibility. High efficiency and cutting performance are provided by the ideal combination of specific s-shaped cross section, variable taper, cutting angles, and thermally improved raw material.[9]

Safe and efficient removal of all root filling materials from the root canal system without compromising the radicular dentin structure is essential for the optimal nonsurgical retreatment. The aim of this study was to evaluate and compare the incidence of dentinal defects caused during root canal filling removal using conventional, rotary, and reciprocating retreatment file systems.

SUBJECTS AND METHODS

60 human permanent maxillary central incisors were found to be in good condition, after being extracted due to periodontal issues. Teeth with fractures, calcification, apical resorption, and extreme curvatures were not included. To avoid dehydration, the extracted teeth were gathered and promptly placed in deionized water with a 0.1% thymol solution added. The root length of each tooth was standardized at 12 mm, and all of the teeth were meticulously cleaned by removing the hard deposits and decoronated at the cemento-enamel junction level using a diamond disc and water cooling.

The patency of each canal was confirmed with 15 size K-file and the working length (WL) determined by subtracting 1 mm from this measurement. The canals were prepared to a master apical size F3 with hand Protaper files following step-down technique. Each canal was irrigated with 2 mL of 2.5% sodium hypochlorite (NaOCl) using 27G side vented needle after every instrumentation and 2 mL of 17% ethylenediaminetetraacetic acid for 1 min as a final rinse irrigant and subsequently rinsed with 2 ml of distilled water. AH Plus sealer (Dentsply Maillefer) was coated into the canal using lentulo spiral and obturated with Protaper gutta-percha points and allowed to set. Teeth were radiographed at different angulations to verify the quality of filling procedure and absence of voids. The obturated roots are examined under the stereomicroscope at ×40 to ensure no visible cracks before the commencement of retreatment procedure. All the specimens were stored for 2 weeks at 37°C at 100% humidity to allow complete setting of the sealer. To simulate periodontal ligament space, the surfaces of sixty roots were coated with a silicone impression material. These teeth were then embedded in a tube filled with self-curing acrylic resin.

Sixty teeth were divided into four groups with 15 teeth per group as mentioned below:

- Group I – Control
- Group II – Conventional method
- Group III – ProTaper Universal Retreatment files (Rotary retreatment file)
- Group IV – Reciproc Blue (Reciprocating retreatment file).

Group I – Control group
Teeth in the control group were left undisturbed after obturation.

Group II – Conventional method
Gates Glidden drills size 3 and subsequently size 2 were used to remove the coronal filling material. The canals were then re-instrumented with Hedstrom files to remove filling material until the WL is achieved. After reaching the WL (with a size 15 file), sizes 20, 25, 30, 35, and 40 were used until the WL.

Group III – ProTaper universal retreatment files (rotary retreatment file)

The root filling substance was removed using ProTaper Universal retreatment files (Dentsply Maillefer, Ballaigues, Switzerland). The coronal portion of the root canal filling was removed

using the D1 ProTaper tool (size 30, 0.09 taper). The middle third of the root canal was completed with the D2 ProTaper tool (size 25, 0.08 taper). Lastly, the WL made use of the D3 ProTaper instrument (size 20, 0.07 taper).

Group IV – Reciproc blue (reciprocating retreatment file)

Reciproc Blue (VDW, Munich, Germany) consists of Reciproc R25 instrument (size 25, 0.08 taper) was used to remove the root filling material. This procedure was repeated until the instrument reaches the WL. The retreatment procedure was concluded with the use of R40 instrument (size 40, 0.06 taper). Each rotary, reciprocating, and hand instruments were discarded after being used in 1 sample. During retreatment, root canals were constantly irrigated with 1 mL 1% NaOCl at each instrument change. The retreatment procedure was considered complete when no gutta-percha or sealer is detected on the instrument surfaces or inside the root canal or dentinal walls.

The silicone impression material was removed, and all roots were cut horizontally at 3, 6, and 9 mm from the apex with a low-speed saw under water coolant. A total of 45 slices were examined in each group. The sectioned tooth was evaluated for the presence of dentinal defects under the stereomicroscope with ×40 magnification. Photographs were taken with a digital camera attached to a stereomicroscope.

Root defects fall into three different groups, which are categorized as follows:[10]

• "No defect" refers to root dentine that is free of lines or cracks and where there are no defects on the root's exterior or inside the root canal wall. [Figure 1], Fracture [Figure 3], and incomplete flaws [Figure 2]

• "Incomplete defects" refers to lines that do not extend from the root canal to the outer root surface (for example, a partial crack, a line that extends from the canal walls into the dentine without reaching the outer surface, or a craze line, which extends from the outer surface into the dentine but does not reach the canal lumen);

• "Fracture" refers to a line that extends from the root canal space to the outer surface of the root.

Statistics was performed using the SPSS, version, 25 (SPSS Inc., Chicago, IL, USA). Initially, normality test was done using Shapiro–Wilk test and was found that the data are not normally distributed. Then Kruskal–Wallis test was used to compare the groups. $P < 0.05$ is considered statistically significant.

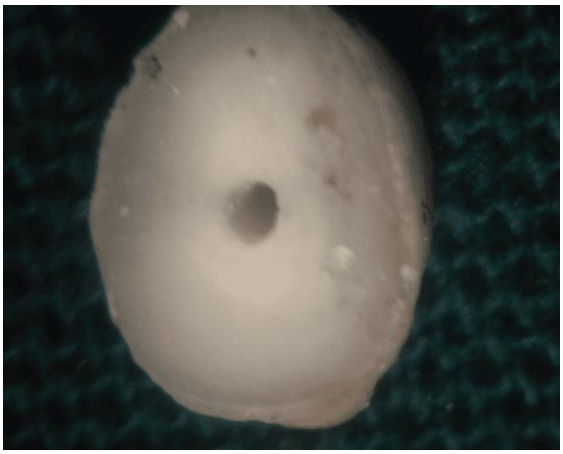

Figure 1: Stereomicroscope evaluation showing no defect

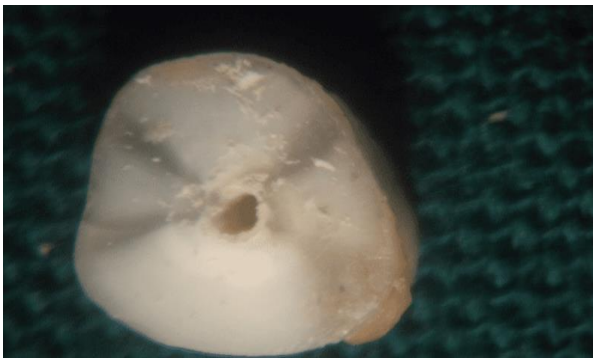

Figure 2: Stereomicroscope evaluation showing incomplete defects

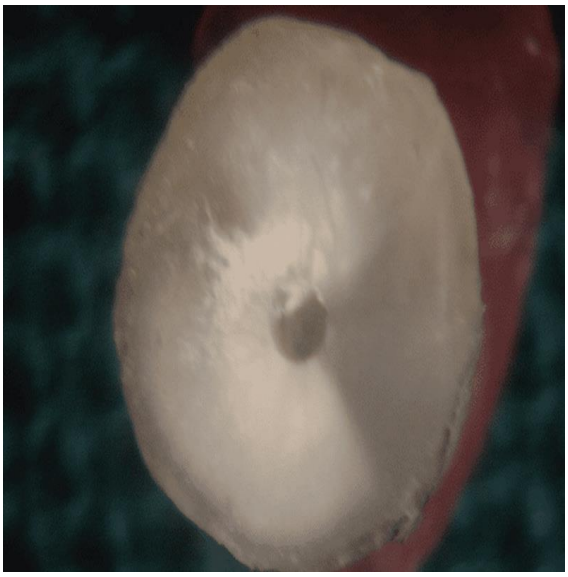

Figure 3: Stereomicroscope evaluation showing fracture

RESULTS

Maximum percentage increase in dentinal defects was observed in Group III (Protaper Universal Retreatment Files) followed by Group II (Conventional method) and Group IV (Reciproc Blue) [Table 1].

Table 1: Comparison within experimental groups at 3mm,6mm and 9mm from apex.

Groups	Subgroups	n(mm)	Mean rank	Median	P
Control	3 6 9 Total	15 15 15 45	24.50 21.50 23.00	0.133 0 0.067	0.351
Conventional	3 6 9 Total	15 15 15 45	23.5 20.4 25.1	0.333 0.067 0.467	0.326
Protaper	3 6 9 Total	15 15 15 45	26.23 21.20 21.57	0.6 0.2 0.267	0.318
Reciproc Blue	3 6 9 Total	15 15 15 45	24.47 21.43 23.10	0.267 0.067 0.267	0.562

The incidence of defects was among the groups in the descending order [Graph 1].

Group III >Group II >Group IV >Group I.

When comparison was done for defects at 3 mm, 6 mm, and 9 mm, no statistical difference ($P < 0.05$) was observed: 3 mm from apex >9 mm from apex >6 mm from apex.

Statistically significant difference ($P < 0.05$) was observed in Group II, Group III, and Group IV as compared to Group I.

DISCUSSION

Endodontics places a high priority on tooth fracture resistance since these fractures can lower long-term survival chances.[11] Dentinal deformities are thought to be a risk factor for VRF and a stress concentrator. The instruments' kinematics and cross-sectional and longitudinal designs dictate the contact stress levels.[12] The invention of rotary endodontics aimed to shorten treatment durations while improving root canal preparation accuracy and efficiency.

Root canal preparation with various rotary NiTi endodontic instruments can cause stress and strain, which can result in the formation of microcracks or craze lines in the root dentin.[13]

Reciprocating motion has several benefits, including increased durability, resistance to cyclic fatigue, and centred root canal preparation. This motion is also associated with clockwise and counterclockwise rotation, which aids in the release of the file when it is engaged in the radicular dentin during the preparation process.[14] As retreatment requires further mechanical manipulations in the canal, this can cause further damage to the root canal wall. Topçuoğlu *et al*.[3] who concluded that there was significant increase in the number of dentinal cracks after retreatment procedure.[15]

To prevent dehydration and to avoid artifacts, the samples were stored in a hydrated environment.[12,16] Decoronation of all the specimens was done using a diamond disc with water coolant. By sectioning of samples which allowed to evaluate of the effect of root canal treatment procedures on the root dentine by direct inspection of the root canal wall and dentinal defects such as craze lines and incomplete cracks.[10,12]

In order to simulate the periodontal ligament, which may have an impact on the distribution of forces during the root canal preparation process, the roots in the current investigation were encapsulated with an elastomeric impression material and acrylic resin. Soros et al. claim that there is no synthetic substance that can absorb the stresses on teeth, just like the natural periodontal ligament. Nonetheless, the existence of the periodontal ligament and efforts to replicate it may help introduce artificial shifts in the force distribution in the clinical setting.

.[17,18] Control Group A: When examined under a stereomicroscope before sectioning, samples revealed no cracks on the external surface. No cracks were discovered even after sectioning. This suggests that the study's sectioning approach did not cause any cracks. Hence, cracks in other groups should be related to the root canal preparation process.[13]

In a study examining how enlargement with Ni-Ti files affected VRF, Kim et al. [19] discovered that higher stress led to more dentin defects and that these defects were linked to the level of the transverse section (apical, middle, and coronal thirds). Sections from the root's middle and coronal thirds were subjected to three times as much stress as those from the apical third, according to Versluis et al. [20]. Likewise, dentinal abnormalities were found to be more common in the coronal third of roots by Üstün et al. [21].

Similarly, Bier *et al*.[22] and Yoldas *et al*.[23] reported no micro-cracking in specimens instrumented with hand-operated files. When coronal enlargement was performed with Gates-Glidden drills, micro-cracks have been observed in some studies. Through the effect of the burs on the dentine and the excessive removal of root structure that weakens the root, they may also play a role in the development of root defects during preparation.[17]

When compared to other rotary NiTi systems used in this study, the ProTaper Universal system was linked to the highest rate of microcrack formation, particularly in the apical root area with subsequent crack initiation. This was because of the system's relative stiffness, which resulted in increased stress generation and concentration, as well as the creation of microcracks in the root dentin due to the rotational force that NiTi rotary instruments applied to the root canals.[24] Because the extreme flexibility of the alloy creates less pressure during

instrumentation as well as less stress on the root canal walls, highly flexible endodontic instruments have been linked to less dentinal flaws.

ProTaper Universal files reduce debris efflux during enlargement due to their convex triangle shape in the transverse plane. In addition, these files have no radial area, which increases deviation from the center of the root. This characteristic may increase micro-crack formation by exerting more stress on the dentin. Due to taper design difference between hand and rotary files, preparation with rotary Ni-Ti files requires more rotations in the canal which contribute to the formation of dentinal defects.[25]

Liu et al. [26] found that the ProTaper Universal and OneShape systems caused more microcracks than the Reciproc and self-adjusting file systems. In our investigation, specimens created using Reciproc rotary files showed less microcrack formation than specimens prepared using the ProTaper Universal system. Compared to using numerous files, using a single file during expansion may reduce the formation of microcracks.[12, 27]

The incidence of dentinal flaws in RECIPROC blue was observed to differ statistically significantly from Group II and Group III in the current investigation. The reason for this outcome is that, in contrast to RECIPROC instruments, which are made of M-Wire NiTi alloy, RECIPROC Blue is a reciprocating file with an S-shaped cross-section design, two cutting edges, and an identical taper that is fixed at the apical 3 mm. The file also has a regressive taper. When compared to conventional M-Wire and superelastic NiTi alloy, Blue NiTi alloy, which is made using a proprietary thermomechanical process, performed better overall. It showed reduced microhardness, increased flexibility, and produced a NiTi alloy that is softer and more ductile than the conventional one. Highly flexible endodontic instruments were associated with fewer dentinal defects since high flexibility of the alloy generates not only less stresses on the root canal walls but also less pressure on the instrument is required during instrumentation.[28]

Considerable impact on fracture resistance and dentin defect formation as a result of root canal instrumentation, according to Kumaran et al. [29].Furthermore, the canal morphology may have an impact on the development of dentinal defects at various levels of the root canal wall; the narrow thickness of the canal in the apical area increases the likelihood of crack formation because it is less able to tolerate the stresses created during instrumentation. The findings suggest that the occurrence of dentinal defects and the designs and motions of the NiTi systems employed in this investigation may be related.[5, 28]

CONCLUSIONS

Given the limitations of this investigation, it can be said that craze lines were also found in relation to uninstrumented roots and that dentin defects would be more common if extra treatment was administered during the gutta-percha removal technique. The greatest percentage increase in the frequency of dentinal flaws was caused by Protaper universal retreatment files, which were followed by H-file and RECIPROC Blue.

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Conflicts of interest
There are no conflicts of interest.

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