ORIGINAL ARTICLE

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An in vitro evaluation of the removed dentin thickness of different retreatment systems using with and without solvent in the danger zone of mandibular molar teeth

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Purpose: Due to its vulnerable structure in the danger zone, the selection of an endodontic instrument becomes very important to avoid excessive root canal preparation in this area. It was aimed to compare the effect of different retreatment file systems and solvents on the amount of removed dentin thickness in the danger zone of mandibular molar teeth using cone beam computed tomography (CBCT).

Methods: A total of 120 mesiobuccal root canals were prepared and obturated with BioRoot RCS root canal sealer using the single cone technique. Specimens were divided randomly into three groups according to the retreatment system used (n = 40): ProTaper Universal Retreatment (PTUR), Reciproc Blue (RB), and XP-Endo Retreatment (XPR). Thereafter, each group was divided into two subgroups according to whether a solvent was used or not (n = 20). CBCT images were obtained from specimens before and after removing root canal filling materials. The removed dentin thickness was calculated in axial sections obtained from 4 mm below the furcation area. Data were statistically analyzed using two-way ANOVA and Bonferroni tests (p = 0.05).

Results: In terms of removed dentin thickness, no significant difference was found between retreatment systems when used with solvent (p = 0.964), whereas a significant difference was found when they were used without solvent (p = 0.004). The removed dentin thickness in RB was lower than in XPR (p = 0.008) and PTUR (p = 0.018).

Conclusion: Solvent did not affect the amount of removed dentin thickness of XPR and PTUR files. Removed dentin thickness of RB was less when used without solvent than with solvent.

Keywords: CBCT; danger zone; removed dentin thickness; retreatment; XP-Endo retreatment.

Introduction

Endodontic treatment can fail due to bacterial persistence within the root canal system or coronal leakage after root canal treatment. Nonsurgical root canal retreatment is the first clinical option when the initial endodontic treatment fails (1). During endodontic retreatment procedures, several special instruments and solvents can be used to remove the existing obturation materials from the root canal system. The selection of an endodontic instrument may

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become very important to avoid excessive root canal preparation in the root canal system, especially at the thinnest dentin area of roots, which is considered a danger zone.

ProTaper Universal Retreatment (PTUR) (Dentsply Maillefer, Ballaigues, Switzerland) is one of the special retreatment file systems. This system is made of a traditional nickel-titanium alloy (Ni-Ti) and includes three instruments as follows: D1 (30/.09), D2 (25/.08), and D3 (20/.07). These files have a convex triangular cross section and work with a rotational movement (2).

Reciproc files (VDW, Munich, Germany), which are introduced to complete the preparation of root canals with a single instrument, are also recommended by their manufacturers for removing the existing obturation materials from root canals. Reciproc Blue (RB) is produced as a result of some thermomechanical treatment of the alloy. The alloy's molecular structure is modified with a heating and cooling proprietary treatment, which gives the instrument a blue color. According to the manufacturer, this new surface heat treatment makes the file more flexible, with a lower risk of fracture (3). RB files are available in three sizes, namely R25, R40, and R50.

XP-Endo Retreatment system (XPR) (FKG, La Chaux-de-Fonds, Switzerland) consists of three instruments: DR1, XP-Endo Shaper, and XP-Endo Finisher R. The DR1 (30/.10), which has an active tip design, is used to remove the canal filling material in the coronal and middle thirds of root canals. XP-Endo Shaper (30/.01) and XP-Endo Finisher R (30/zero taper) are produced from MaxWire (Martensite – Austenite Electropolish Flex) alloy. At body temperature, the MaxWire alloy shifts from a martensitic phase to an austenitic phase, acquiring a spoon-like shape at its active tip to allow it to reach and clean previously inaccessible areas. It removes the root canal filling materials without changing the original shape of the root canal (4).

Cone-beam computed tomography (CBCT) is used as a nondestructive technique for the evaluation of the root canal system (5). The remaining dentin thickness in the danger zone has been assessed in some studies using CBCT (6-8). In a previous study, in which micro–computed tomographic (μCT) imaging was used as the reference standard, it was shown that dentin thickness can be accurately measured using CBCT imaging after simulated instrument removal (6).

Solvents are used in endodontic retreatment to remove the filling materials, usually the gutta-percha, from the root canal system. Many types of solvents are available, such as chloroform, eucalyptol, orange oil, and xylene (9). To date, no studies have compared the influence of solvents on retreatment files on the removed dentine thickness. Therefore, this in vitro study was conducted to evaluate the amount of removed dentin thickness in the danger zone of mandibular molar teeth after removing the filling materials with PTUR, RB, or XPR systems with and with-

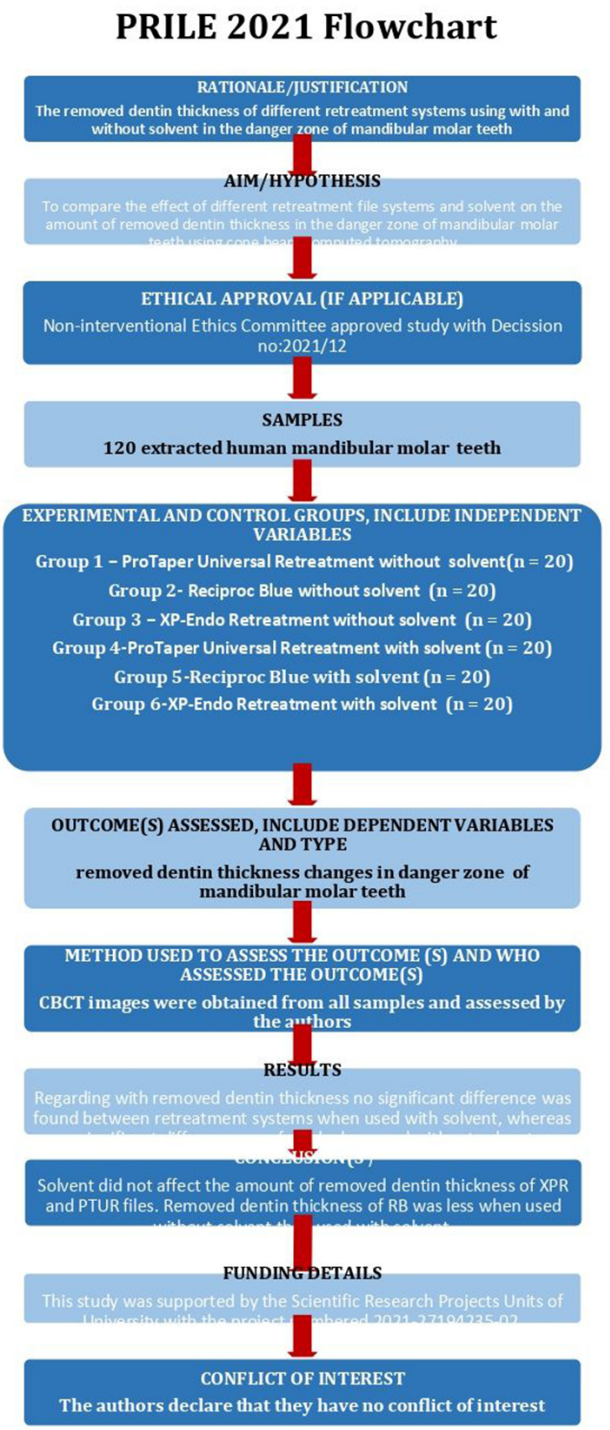

Fig. 1. PRILE 2021 flowchart.

out solvent. The null hypotheses tested were as follows: first, there would be no effect of solvent on the amount of removed dentin thickness; and second, there would be no difference between the amounts of removed dentin thickness of retreatment file systems.

Materials and Methods

The manuscript of this laboratory study has been written according to the Preferred Reporting Items for Laboratory Studies in Endodontology 2021 Guidelines (10) (Fig. 1). This in vitro study was approved by the Non-interventional Ethics Committee of the University (approval no: 2021/12). The sample size was calculated based on a previous study's data (8). It was found that 19 samples would be sufficient for each group (type I alpha error = 5%, effect size = 0.431, power = 95%). To compensate for possible dropouts during the treatment, 20 samples were assigned to each group. The inclusion criteria for the mandibular molars were: straight mesial root with a degree of curvature of 5° or less according to Schneider's classification (11); 12 ± 1 mm in length and type IV (two separate and distinct root canals extend from the pulp chamber to the apex) mesial root canals according to Vertucci's classification (12); intact root structure, closed apex, and no history of endodontic treatment. The exclusion criteria were: incomplete root formation; open apex; obliterated root canals; root resorptions; root fractures. The cusps were flattened to standardize the teeth to 16 mm in length. After access cavity preparation, apical patency was checked with a size 10 K-file. The working length (WL) was determined by subtracting 1.0 mm from the measured length after the tip of the instrument was visible through the apical foramen.

To calculate the removed dentin thickness, root canals were scanned in two steps: before obturation of root canals and after removing filling materials. The initial dentin thickness (IDT) in the danger zone was measured after preparation of root canals with ProTaper X1 and X2 (before obturation) to avoid misreading caused by scatters of gutta-percha (Fig. 2).

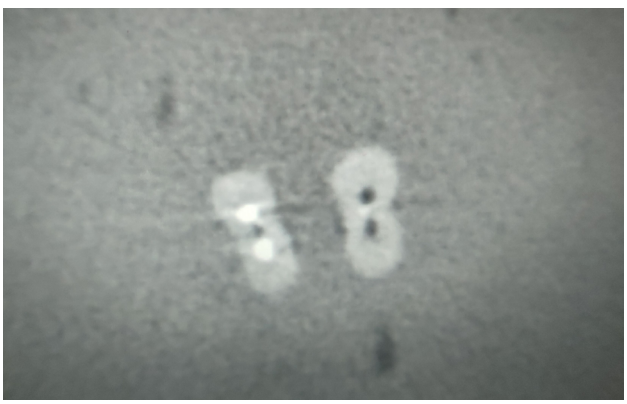

Fig. 2. Representative axial section shows the scattering caused by gutta-percha.

Root Canal Preparation

Mesiobuccal root canals were prepared using ProTaper Next X1 and X2 files with an X-Smart Plus endomotor (Dentsply-Sirona, Germany). During the preparation of the root canals, a total of 5 mL of 2.5% NaOCl was used. For final irrigation, 5 mL of 2.5% NaOCl, 5 mL of 17% EDTA, and 5 mL of distilled water were used. Root canals were dried with paper points.

CBCT analysis before obturation

Before obturation of prepared root canals, teeth were embedded in custom-made silicone molds (Zetaplus; Labordental, São Paulo, Brazil). CBCT images were obtained using a CBCT device (Veraviewepocs 3D R100; J. Morita Corp., Kyoto, Japan) with the following parameters: voxel size of 0.125 mm, FOV 81 mm high x 51 mm diameter, 9.3-s exposure, X-ray output of 90 kV, and 5 mA. Initial dentin thickness (IDT) in the danger zone (4 mm below the furcation) was calculated by measuring the minimum distance from the edge of the root canal to the external surface of the distal root concavity in sections (Fig. 3). This measurement was repeated three times, and the mean thickness was recorded.

Root Canal Obturation

Mesiobuccal root canals were filled with ProTaper Next X2 gutta-percha and a bioceramic root canal sealer (BioRoot RCS) using the single cone technique and stored at 37°C for one month. Specimens were assigned into three groups according to the retreatment system used (n = 40): ProTaper Universal Retreatment (PTUR), Reciproc Blue (RB), and XP-Endo Retreatment (XPR). Thereafter, each group was divided into two subgroups according to whether a solvent was used or not (n = 20). Randomization of root canals was done using the Research Randomizer Program (available at http://www.randomizer.org) by one of the investigators.

Retreatment protocols

Solvent-free Groups

ProTaper Universal Retreatment (PTUR) group

D1 (30/.09), D2 (25/.08), and D3 (20/.07) files were used respectively at 500 rpm speed and 2 Ncm torque with full rotational motion via an endodontic motor (X Smart; Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer's recommendations. The coronal, mid-

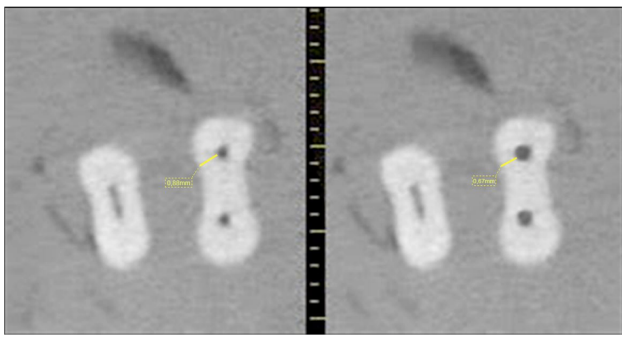

Fig. 3. Representative axial section shows the measuring of thinnest dentin thickness in danger zone in initial and final CBCT scans.

dle, and apical portions of the root canals were retreated with D1, D2, and D3 files, respectively, with a brushing action against the canal walls in a crown-down direction, until the working length (WL) was reached.

Reciproc Blue (RB) group

Reciproc Blue R25 (25/.08 taper) files were used in reciprocal motion via an endodontic motor with 3 mm of forward and backward movements until the R25 file reached the working length.

XP-Endo Retreatment (XPR) group

The DR1 (30/.10) file was used to remove the coronal third of the root canal filling material by operating with an endodontic motor in accordance with the manufacturer's instructions. Thereafter, the XP-Endo Shaper and XP-Endo Finisher R file systems were used respectively at 1000 rpm and 1.0 Ncm with slow and gentle 7–8 mm lengthwise movements up to the working length, according to the manufacturer's instructions.

Solvent-used Groups

In the solvent-used groups, each retreatment file system was used with the aforementioned protocols. Additionally, 0.1 mL of eucalyptol was injected into the coronal part of the root canals. In all groups, apical patency was achieved by introducing a #10 K file to a point 1 mm beyond the working length (WL). The criteria for the completion of removing filling materials were the absence of visible gutta-percha on the root canal walls and files. A radiograph was also taken to confirm the completion of the retreatment procedures. A total of 5 mL of 2.5% NaOCl was used during retreatment procedures. For final irrigation, 5 mL of 2.5% NaOCl, 5 mL of 17% EDTA, and 5 mL of distilled water were used.

CBCT analysis after removing filling material

Roots were scanned with the same exposure parameters as at the time of initial imaging. The remaining dentin thickness (RDT) in the danger zone was calculated in axial sections as described in the initial analysis (Fig. 3). This measurement was repeated three times, and the mean thickness was recorded. The percentage of removed dentin thickness was calculated as follows: (IDT-RDT/IDT) x 100 by the author GG, who was blinded to the groups.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 19.0 (Armonk, NY: IBM Corp.). After analysis of normality with the Kolmogorov-Smirnov test, data were analyzed using two-way ANOVA and Bonferroni tests ($p = 0.05$).

Results

The descriptive values for the removed dentin thickness are shown in Table 1. In the solvent-used groups, no significant difference was found among file systems ($p = 0.964$). In the solvent-free groups, a significant difference was found among file systems ($p = 0.004$); Reciproc Blue removed significantly less dentin than PTUR ($p = 0.018$) and XPR ($p = 0.008$). In terms of the effect of solvent, a significant result was found only in the RB retreatment system. The removed dentin thickness was less in the RB without solvent group than in the RB with solvent group ($p = 0.005$).

Discussion

Due to the vulnerable structure of the danger zone, the selection of an endodontic instrument may become very important to avoid excessive root canal preparation in this

Table 1. The mean, standard deviation, and p values of the amount of removed dentin thickness in experimental groups (%)

Groups	Solvent		p
	Without	With	
ProTaper Universal Retreatment	20 ± 10^{aA}	21 ± 11^{aA}	0.735
Reciproc Blue	10 ± 5^{aB}	20 ± 15^{bA}	0.005
XP-Endo Retreatment	21 ± 10^{aA}	20 ± 15^{aA}	0.879
p	0.004	0.964	

*The significant differences are shown with different superscript capital letters and lowercase letters in column and row, respectively.

area. This in vitro study evaluated the removed dentin thickness in the danger zone of mandibular molar teeth after using PTUR, RB, and XPR retreatment systems with and without solvent using CBCT.

In previous studies, it was reported that the minimal dentin thickness of mesial roots of mandibular molars was affected by the root length (13, 14). Therefore, in the present study, teeth with roots 12 ± 1 mm in length were selected. The location of the danger zone of mandibular molar teeth was determined to be 4 mm below the furcation area, based on previous research by De-Deus et al. (15). Although µCT is the most exact imaging technique for evaluating root canal anatomy (15), CBCT is currently the common imaging technique applied in clinical practice (15-17). The advances in voxel size and field of view make CBCT an admissible technique to assess root canal anatomy (18) and to compare dentin thickness pre- and post-procedures (19). In the present study, to calculate the amount of removed dentin thickness, roots were scanned in two steps (before obturation and after removing filling material) using CBCT. To avoid misreading caused by artifacts related to gutta-percha, root canals were scanned after preparation with ProTaper Next X1 and X2 instruments (before obturation) and saved as measurements of initial dentin thickness.

To the authors' knowledge, this is the first study to evaluate the effect of solvents and retreatment file systems on the amount of removed dentin thickness. In the present study's intragroup comparison, it was found that the amount of removed dentin thickness of retreatment files was similar when they were used with or without solvent, except for RB. RB removed less dentin when used without solvent. In the present study, RB operates in reciprocal motion, while PTUR and XPR systems work with rotation. The criteria for the completion of removing filling materials were no evident visualization of any gutta-percha on root canal walls and files. During the retreatment process in solvent-used groups, chemical plasticization of gutta-percha might create a superficial layer adhered to the root canal wall. Therefore, it can be concluded that Reciproc Blue (reciprocal motion) cuts more superficial layers of dentin when used with solvent than without, in order to remove the layer of residual filling material on the canal walls. On the other hand, in the intergroup comparison, the amount of removed dentin thicknesses of retreatment files was similar when used with solvent, whereas when used without solvent, Reciproc Blue removed less dentin than PTUR and XPR. Therefore, the null hypotheses tested were rejected. Reciproc Blue is a single file system, whereas XPR and PTUR retreatment systems are multi-file rotary systems. In the XPR group, DR1 has a 0.10 taper; in the PTUR group, D1 has a 0.09 taper. On the other hand, R25 has a 0.08 apical taper (at 3mm) then reduces towards the coronal ends. It can be concluded that the number and taper of these files might enable the systems to cut more superficial layers of dentine than R25 during root filling removal when used without solvent.

In the literature, there is no study that evaluated the removed dentin thickness of the tested retreatment files after removing filling material with or without solvent. However, a few studies evaluated the removed dentin thickness of Reciproc Blue in primary root canal treatment (7, 20, 21). In the study by Sousa et al. (7), the results revealed that Reciproc Blue showed similar safe thickness values for preparation with ProTaper Next, BioRace, and WaveOne Gold instruments in MB and ML root canals. de Carvalho et al. (21) reported that Reciproc Blue removed increased dentine thickness in unnecessary regions of root canal due to its larger taper and the shape memory effect that tends it to return to its original shape compared to R-Motion size 30, 0.04 taper (FKG Dentaire), HyFlex CM (HFX) size 30, 0.04 taper (Coltène Whaledent), and XP-endo Shaper size 30, 0.01 taper. Silva et al. (20) reported that no significant difference was found between Reciproc Blue and ProTaper Gold rotary systems in the amount of remaining dentin thickness in curved canals. Lim and Stock (22) suggested that 0.3 mm of minimal thickness of canal walls is required to provide fracture resistance to the root canal. In the present study, in all groups the remaining dentin thickness was greater than that value and can be considered a safe thickness as reported by Sousa et al. (7).

In this study, only simple teeth (with straight root canal) were assessed. The degree of difficulty in the removal of root fillings may be directly affected by some features of the selected teeth, such as curvature, length, and shape of the root canal. Future studies using more challenging canals are necessary to confirm and identify this topic.

Conclusion

The use of solvent only affected the amount of removed dentin of RB. In the absence of solvent, RB removed less dentin than PTUR and XPR files in the danger zone.

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Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Zonguldak Bülent Ecevit University Ethical Board of Clinical Trials and Non-interventional Research Ethics Commitee (date: 23.06.2021, protocol no: 2021/12).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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