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# The effect of different retreatment systems and root canal sealers on the fracture resistance of endodontically retreated samples: A laboratory study

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Considering previous literature, it has been thought that different file motions and root canal sealers used during retreatment may affect the fracture resistance of the endodontically retreated teeth. This study aims to compare the fracture resistance values of retreated teeth with two different file systems and re-obturated with gutta-percha and different sealers. Sixty extracted lower premolars were prepared up to ProTaper Universal-F4 (PTU) and filled with resin-based sealer (RBS) and gutta-percha. Thirty teeth were re-prepared with PTU retreatment files and ProTaper Universal-F5. The remaining 30 teeth were re-prepared with Reciproc-50 files. Fifteen teeth from each group were filled with RBS, or calcium silicate-based root canal sealer (CSBS), and F5 or R50 gutta-percha. After the setting of filling materials, a fracture test was performed. Data were analyzed with a two-way ANOVA and chi-square test ($p < 0.05$). There was no significant difference among the groups ($p > 0.05$). The lowest mean was observed in the PTU-CSBS group (277.80 ± 105.47 N), and the highest mean was observed in the PTU-RBS group (335.05 ± 121.05 N). A buccolingual irreparable fracture was common in all groups ($p < 0.05$). Specimens retreated either with rotational or reciprocating files could be re-obturated with a combination of gutta-percha and RBS or CSBS.

**Keywords:** Calcium silicate-based sealer, fracture resistance, ProTaper, Reciproc, resin-based sealer, root canal retreatment.

## Introduction

The primary goal of endodontic treatment is to create a biologically acceptable environment that maintains the health and healing of the periradicular tissue, which is part of the root canal system. Root canal treatment is classically performed with endodontic instruments, irrigation solutions, and root canal filling materials such as gutta-percha and root canal sealers (1). Although initial root canal treatment has high success rates between 86% and 98% (2,3), several reasons, such as complex root canal anatomy, persistent bacteria, insufficient chemo-mechanical preparation, deficiencies during obturations, and/or post-endodontic restoration procedures, could result in failures (3-5). If initial endodontic treatment fails but the tooth is periodontally sound and restorable, the next alternative treatments are non-surgical root canal retreatment (NSRCRT) or surgical retreatment. NSRCRT is a

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frequently preferred method among these alternatives (5). It is important to remove all previous filling materials from the root canal to provide effective disinfection via the contact of irrigation solutions with persistent microorganisms (6). Many different materials are used to achieve this aim, such as stainless-steel files, nickel-titanium (Ni-Ti) hand or rotary instruments alone or in combination with heated pluggers, chemical solvents, ultrasonics, irrigants, and irrigation activation systems (6-8). Ni-Ti rotary instruments due to their superior flexibility and higher cutting efficiency compared to conventional stainless-steel instruments, have become essential for endodontics (9). There are special rotary systems manufactured for the removal of filling materials, such as the ProTaper Universal (PTU) Retreatment System (Dentsply, Germany), which is one of the widely used systems for NSRCRT. This system consists of three convex triangular section files, each produced for one-third of the root canal. Recently, Ni-Ti files that reciprocate in addition to rotation have also been produced for the mechanical preparation of root canals. Researchers have shown that these files produced for mechanical preparation are also effective in NSRCRT (10-12). It has been reported that reciprocating motion increases the resistance of Ni-Ti instruments to cyclic fatigue, and reciprocating files are more effective in removing filling from root canal walls compared to rotary and hand files (11). Recent studies evaluating the gutta-percha removal efficiency of one of these systems, Reciproc (VDW, Germany), have shown positive results (12).

Various complications, such as ledge formation, stripping, and transportation of the apical foramen, may occur during the initial treatment and NSRCRT (13). These complications may cause the weakening of the root. The formation and progression of cracks in root canals are complications that can cause root fractures. The prognosis of a root canal with a root fracture is very poor, and tooth extraction or resection of the affected root is almost always required. Depending on the amount of dentin removed during the initial endodontic treatment and NSRCRT, tooth cracks may occur (14). It has been reported that manual files and reciprocating files can produce cracks during preparation, but these cracks are less common compared to rotary files (15). On the other hand, an ideal root canal filling material should be bonded to the root canal dentin and strengthen the remaining tooth structure against fracture to increase the long-term success of the endodontically treated tooth (16). In this context, root canal sealers may play an important role, as gutta-percha cannot bind to root canal walls. Resin-based root canal sealers, which are accepted as the "gold standard" in endodontics due to their properties such as long-term dimensional stability, reduced solubility, high bond strength, and low toxicity, are the most commonly used sealer group in root canal treatments with gutta-percha (17,18). Apart from this group of sealers, calcium silicate-based root canal sealers have started to gain popularity recently. It has been reported that pastes have improved physical and chemical properties compared to conventional mineral trioxide aggregate (MTA) (19). According to the manufacturers, these sealers use the bioactivity of MTA to interact with dentin, causing intratubular calcium and silicate incorporation and the formation of tag-like structures, thus enhancing adhesion and sealing (20,21).

Considering previous literature, it has been thought that different file motions and root canal sealers used during NSRCRT may affect the fracture resistance of the endodontically retreated teeth. For this purpose, the fracture resistance of teeth filled with gutta-percha and resin or calcium silicate-based sealers following two different removal techniques was evaluated. The null hypothesis of the present study was that the file systems and sealers used during NSRCRT did not affect fracture resistance.

## Materials and Methods

### Sample Preparation

The manuscript of this laboratory study has been written according to the Preferred Reporting Items for Laboratory Studies in Endodontology 2021 Guidelines (22) (Fig. 1). After the approval of the non-interventional ethics committee (Decision No. GO 21/1329), 60 same-sized, single-rooted, and single-canalled lower premolar teeth were used according to the sample size calculation ($p = 0.05$, statistical power 80%) based on previous studies (23,24). Radiographs were taken from the samples in buccolingual and mesiodistal directions. The crowns of the teeth were removed, and the roots were adjusted to 15 mm to standardize the length of the specimens. Following decoronization, the mesiodistal and buccolingual widths of the coronal part of the samples were measured with a caliper in order to standardize specimens. The average mesiodistal and buccolingual widths were calculated. Samples with a difference of 20% from the average were excluded (25). Teeth with caries, cracks, previous root canal treatment, and immature apices were excluded during sample selection. Working length was established with a #15 K file (Dentsply, Germany) that was 1 mm short from the apical foramen for all samples. Then, samples were prepared up to the PTU F4 file (respectively with SX, S1, S2, F1, F2, F3, and F4 files of the PTU system) and obturated with ProTaper F4 gutta-percha and resin-based root canal sealer (AH Plus, Dentsply, Germany). Between each file, the ca-

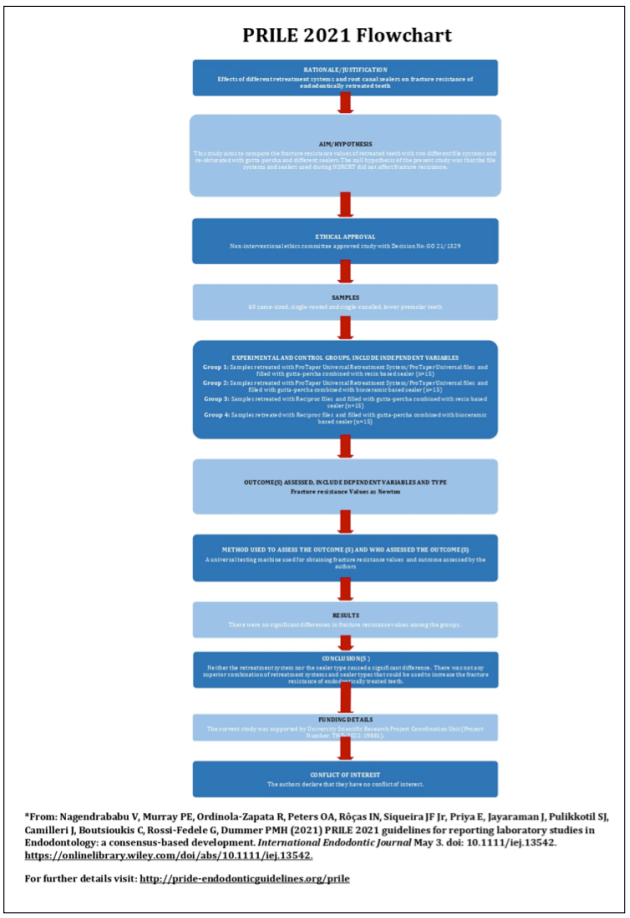


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**Fig. 1.** PRILE 2021 flowchart.

nals were irrigated with 3 mL of 2.5% sodium hypochlorite (NaOCl). As the final irrigation, each sample was irrigated with 3 mL of 2.5% NaOCl, 3 mL of a 5% EDTA solution to remove the smear layer, and 3 mL of distilled water. The samples were kept at 100% humidity and 37°C for 2 weeks to allow the sealers to set.

Two weeks later, randomly assigned 30 samples were re-treated and re-prepared with PTU Retreatment files (D1, D2, and D3, respectively) and PTU files (F4 and F5), while the remaining 30 samples were re-treated and re-prepared with Reciproc 25, Reciproc 40, and Reciproc 50 (VDW, Munich, Germany) files up to the working length. Retreatment procedures were performed by a single operator. The files were used with the help of the X Smart Plus (Denstply-Sirona, Germany) endomotor under the manufacturer's instructions. A total of 10 mL of 2.5% NaOCl was used during retreatment procedures; 3 mL of 5% EDTA solution was used again to remove the smear layer, and 3 mL of distilled water was used to remove irrigant remnants. Samples were dried with paper points, and randomly assigned 15 samples from each group were re-obturated with F5 or R50 gutta-percha cones combined with resin- (AH plus) or calcium silicate-based sealers (Sure Seal Root, Sure Endo, South Korea). Radiographs were further taken to evaluate obturation quality. Then, all samples were kept at 100% humidity and 37°C for 2 weeks to allow the sealers to set one more time.

## Fracture Resistance Test

After the abovementioned period, melted wax up to 2.0 mm below the cement-enamel junction (CEJ) was used to cover samples to simulate the periodontal ligament in vitro. Then, a plastic ring (25 mm in diameter and 20 mm high) filled with self-curing acrylic resin (Imicryl, Konya, Turkey) was utilized to embed samples vertically. A 2-mm gap was left between the top of the acrylic and the CEJ on the buccal and lingual aspects to simulate the physiologic relationship between the bone crest and the tooth (26). After acrylic resin polymerization, the teeth were removed from the resin, and the wax was removed using warm water. Then, the resin sockets were filled with vinyl polysiloxane impression material (Variotime, Heraeus Kulze, Hanau, Germany), and the teeth were re-embedded into their respective sockets. Consequently, the impression material filled the space formerly occupied by the wax, hence providing a simulated periodontal membrane (27). The specimens were mounted in a universal testing machine (Marestek, Istanbul, Turkey). A vertical compressive loading (rate: 1 mm/min) was applied via a spherical steel tip (diameter: 2 mm) to the decoronized surfaces of roots until the fracture occurred. The peak load to fracture was recorded in Newtons (N). Fracture types were also classified according to their direction and their restorability as follows: buccolingual, mesiodistal, oblique, repairable (fractures above or at the CEJ), and non-repairable, respectively.

## Statistical Analysis

Analysis of the data was performed in SPSS (Version 20, IBM, Armonk, NY, USA) program. The variances were homogeneous according to Levene's test, and the data were normally distributed according to the Shapiro-Wilk test. A two-way analysis of variance was used to compare the data. The Chi-square test was used to compare the percentages of fracture types. The level of significance was determined as $p < 0.05$ in all analyses.

## Results

There were no significant differences in fracture resistance values among the groups ($p > 0.05$). The results took place in Fig. 2. The mean fracture resistance values of the groups are aligned as follows: PTU-CSBS<REC-CSBS<REC-RBS<PTU-RBS. Table 1 shows the distribution of fracture types. According to the Chi-square test,

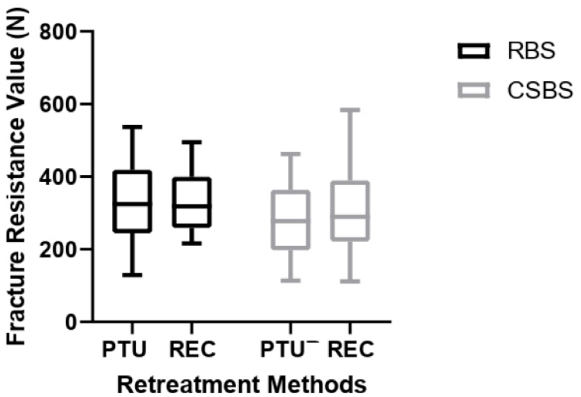


**Fig. 2.** Box-line graph showing the results of the fracture resistance test of the groups in Newton. PTU: Protaper Universal Files; REC: Reciproc Files; CSBS: Calcium silicate-based sealer; RBS: Resin-based sealer.

buccolingual non-repairable fracture types were observed significantly more in all groups ($p < 0.05$).

## Discussion

Completing treatment without further surgical procedures protects the tooth's integrity. However, additional mechanical preparation during NSRCRT may compromise the mechanical properties of teeth by causing additional defects, microcracks, and material loss in the root canal dentin (14). Endodontically treated teeth showed significantly reduced resistance to fracture, and this was positively correlated with increased root dentin loss during NSRCRT (23,28). When the literature was examined, it was observed that there was limited information on the effects of both the kinematic movements of the files and the effects of different sealers on the fracture resistance strength of teeth exposed to NSRCRT. Therefore, this study aimed to evaluate the fracture resistance of teeth retreated with Ni-Ti rotating and reciprocating files (PTU Retreatment System/PTU files and reciprocating files) and further obturated with gutta-percha in combination with different resin-based root canal sealers (resin-based AH Plus sealer and calcium silicate-based Sure Seal Root).

The effects of rotating and reciprocating files on the fracture resistance of initially treated teeth were evaluated several times (24,29-33). There were conflicting results regarding the effects of these files; mainly, it has been reported that there were no statistically significant differences between the fracture resistance values of samples treated either with rotating or reciprocating files (24,29-31). There was no statistically significant difference in fracture resistance between samples prepared with PTU and WaveOne or Reciproc and obturated with a resin-based sealer/gutta-percha combination (24). Another study reported that samples prepared with WaveOne resisted fracturing more than samples prepared with PTU (32). In a recent study using premolars, it was found that the samples prepared with ProTaper Next or ProTaper Gold fractured with higher forces in comparison to samples prepared with WaveOne (33). Studies evaluating the effects of additional preparation during NSRCT on fracture resistance strength are limited (23,28). In a previous study, samples filled with resin-based sealer (AH Plus) and lateral condensation of gutta-percha were retreated after 30 days with rotary (ProTaper Next) or reciprocal files (WaveOne) used in combination with the PTU Retreatment (PTUR) and refilled again with resin-based sealer (AH Plus) and gutta-percha and exposed to a fracture resistance test. PTUR, one of the rotating systems manufactured especially for NSRCT, is widely used for root canal filling removal but requires the use of an additional system for further preparation (23). It has been reported that the PTUR+WaveOne group revealed statistically higher fracture resistance values compared to the PTUR+ProTaper Next group. However, in the present study, there were no statistically significant differences between samples retreated with rotating or reciprocating files and obturated with a resin-based sealer (AH Plus) and gutta-percha combination. The procedural differences between the two studies could be the reason for this conflict. In the present study, initial treatment of all samples was completed with rotating files, and the retreatment was completed either with rotating or reciprocating files and solvent was not used during the retreatment step. However, in the previous study, initial treatment was com-

**Table 1.** Types of fractures and their percentages per group

| Types of fractures | Buccolingual fractures | | Mesiodistal fractures | | Obliquely fractures |
|---|---|---|---|---|---|
| Groups | Repairable (%) | Non-repairable* (%) | Non-repairable (%) | Repairable (%) | Non-repairable (%) |
| PTU-CSBS | 0 | 73.33 | 20 | 6.67 | 0 |
| PTU-RBS | 0 | 66.67 | 6.67 | 20 | 6.67 |
| REC-CSBS | 6.67 | 86.67 | 0 | 0 | 6.67 |
| REC-RBS | 0 | 66.67 | 26.67 | 0 | 6.67 |

PTU: ProTaper universal files; REC: Reciproc files; CSBC: Calcium silicate-based sealer; RBS: Resin-based sealer.

pleted either with rotating or reciprocating files, and the retreatment step was completed further either with rotating or rotating+reciprocating files and solvent was used during the retreatment step. These variables could result in different conclusions.

Root canal sealers are indispensable for endodontic treatment and retreatment. They contribute to the three-dimensional, hermetic root canal obturations. There are several sealers classified according to their constituents. Resin-based sealers are widely preferred and accepted as the gold standard. They interact chemically with the root dentin collagen network through covalent bonds between the epoxy rings and amine groups exposed in the collagen network (18). Recently manufactured calcium-silicate sealers have been reported to own the property of chemically bonding to mineralized tissues such as dentin (19,20). The contribution of different sealers to the fracture resistance following NSRCT is not well-investigated; however, in a recent meta-analysis that included 17 studies, it was reported that epoxy resin-based root canal sealers showed higher bond strength to root canal walls than calcium silicate-based root canal sealers in paste formation, regardless of the evaluated root canal third (20). Although the positive correlation between bond strength and fracture resistance is not clear, it is generally accepted that successful adhesion of the materials to the root dentine increases their reinforcing effect (27). Contrary to this, however, a recent systematic review reported that there were conflicting results regarding the superiority of resin-based sealers in comparison to calcium silicate-based sealers in increasing fracture resistance values of initially root canal-treated samples, according to six studies (16). There are studies evaluating the effect of the sealer type used in initial treatment on the penetration (34,35) or bond strength (36) of sealers used after retreatment rather than the fracture resistance. In a recent study, Eğemen and Belli (34) reported that resin-based sealers used in initial treatment affected the penetration of calcium silicate-based sealers into the dentinal tubules used during NSRCT adversely, and the use of resin-based sealers might be advantageous in NSRCT. Furthermore, it has been reported that zinc oxide-eugenol-based root canal sealer adversely affects the bond strength of resin-based sealer to the root canal walls, regardless of the NSRCT techniques used (36). On the other hand, it was reported that the use of resin-based sealer in the first treatment did not affect the penetration of calcium silicate-based sealer used during NSRCT (35). Although there was no statistical difference among the groups in the current study, the fracture resistance of the samples retreated with rotating or reciprocating files and re-obturated with resin-based sealer or gutta-percha was found to be higher than samples re-obturated with calcium silicate-based sealer or gutta-percha. It is thought that this might be since the sealer used in the initial treatment was a resin-based sealer.

There are several limitations to fracture resistance studies. Obtaining samples that resemble each other regarding cross-section, anatomy, storage duration and environment after extraction, age, and the forces (chewing or traumatic) to which the teeth are subjected before or during extraction is a really difficult task. All these variables may affect the results of the study and are especially important for mechanical testing (37). Premolars were extracted for periodontal reasons without cracks, and caries was included in the current study. Radiographs were obtained buccolingually and mesiodistally to use samples with similar anatomical features, and the buccolingual and mesiodistal widths of the samples were measured before the initial preparation. Simulating periodontal tissues during fracture resistance experiments is another issue of debate. It has been reported that periodontal ligament simulation has an impact on fracture resistance values and fracture modes (38); therefore, a periodontal ligament was simulated in the current study. Considering the fracture modes, it was observed that most fractures were in the buccolingual direction, and this result is consistent with other studies in the literature where vertical forces were applied to the samples (29,30). Also, it is important to mention that in the current study, a single vertical load parallel to the long axis of the tooth was applied to assess fracture resistance (29,30). However, loads and forces exist in different directions during chewing. Controls in fracture resistance experiments consisted of teeth that were neither prepared nor obturated, prepared but not obturated, and prepared and obturated only with gutta-percha (16). However, in this study, there was no control group. This may be one of the limitations of the present investigation. It is well known that intact samples resist fracture (23,29,31) and that the presence of control groups is beneficial. On the other hand, the primary objective of the study was to compare the effects of distinct variables, such as the sealer and the file system, with each other rather than with a control group.

## Conclusion

Within the limitations of this study, it was observed that re-preparing the root canals with PTU Files or Reciproc Files and refilling with gutta-percha combined with resin- or calcium silicate-based root canal sealers did not reveal a statistically significant difference in the fracture resistance of teeth initially prepared with PTU Files and obturated with gutta-percha combined with resin-based root canal

sealer. For this reason, the initial hypothesis of the study was accepted. The use of resin-based sealers could be recommended during NSRCT, but additional studies are needed for more precise results.

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