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Comparative Evaluation of Dentinal Cracks and Mechanical Failure in ProTaper Retreatment, EndoStar Re-Endo, and ReTreaty Retreatment Files- An In Vitro Study

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ABSTRACT

The long-term prognosis of root canal treated teeth depends on the preservation of dentin of root during nonsurgical endodontic retreatment. The impact of various nickel-titanium (NiTi) retreatment techniques on dentinal crack formation and instrument integrity has not been thoroughly analyzed. The purpose of this study was to assess and compare the mechanical failure and dentinal crack formation related to the ProTaper Universal Retreatment, Endostar RE-Endo, and Retreaty retreatment file systems. Forty-five human single-rooted premolars were extracted, obturated and then randomly selected into three experimental groups of 15 teeth each. The three systems of rotary files were used for retreatment, as recommended by the manufacturers. After instrumentation, the roots were cut horizontally 3 mm, 6 mm and 9 mm from the root apex. Samples obtained were examined under a stereomicroscope to look for dentinal defects or fissures. File characteristics and alterations to the file such as fracture and file deformation were also documented. The statistical analysis was done using one-way ANOVA for continuous variables and Pearson's chi-square test for categorical variables with a significance level of $P < 0.05$. Significant variations were noticed among the three groups among the three groups among the three groups among the three groups. ProTaper Universal Retreatment had the highest frequency of mechanical failure, whereas the Retreaty method had the lowest incidence of dentinal fissures and instrument deformation. Results from Endostar RE-Endo were mediocre. Within the restrictions of this in vitro experiment, Retreaty retreatment files displayed more favorable mechanical behavior and caused fewer dentinal flaws, suggesting its potential as a safer choice for nonsurgical endodontic retreatment.

Keywords: RE-Endo, Retreaty retreatment file systems, Dentinal fissures

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INTRODUCTION

The primary goal of endodontic treatment is to eradicate microbes and their toxic by-products from the root canal system and to subsequently obturate the canal space three-dimensionally, thereby preventing reinfection, ensuring long-term periapical health and functional retention of the tooth. According to Haapasalo et al. in 2005, chemo-mechanical cleaning and disinfection of the root canal system coupled with obscure obturation entraps residual bacteria and coronal or apical microbial leakage, thus making endodontic therapy successful. [1] These principles would lead to healing of the periapical tissues and normal functions of the tooth, when applied appropriately.

In the cases of failure of a root canal treatment, clinicians have two primary approaches to management; surgical (apical surgery) and non-surgical (orthograde) retreatment. It was suggested by Friedman and Stabholz in 1990 that non-surgical retreatment should be used at the earliest any time possible and this is a form of conservative management aimed at getting rid of a persistent infection and regaining canal patency.[5] Non-surgical retreatment aims at eliminating the former obturating material, restoring access to the apical terminus, sanitizing the canal, and three dimensional hermetic closure.[3,4]

To improve the gutta-percha removal while reducing procedural errors, a number of specialized retreatment systems, such as ProTaper Retreatment, Endostar RE-Endo, and the recently released Retreaty Retreatment system, have been developed with unique metallurgical properties, cross-sectional designs, and kinematics.[5] The forces produced during rotational instrumentation may cause dentinal microcracks and lead to instrument deformation or fracture, despite the fact that these devices have shown encouraging retreatment capabilities. The long-term prognosis of retreated teeth may be jeopardized by dentinal abnormalities, which might spread under functional loading and put teeth at risk for vertical root fractures. Similarly, a major procedural issue that could impede canal disinfection and negatively impact treatment results is instrument separation.[6]

The effectiveness of obturating material removal, debris extrusion, or the shaping capacity of different retreatment techniques have been the main topics of prior research. Comparatively fewer investigations have examined their influence on dentinal crack formation and mechanical failure, particularly with recently launched multi-alloy systems such as the Retreaty Retreatment files. Additionally, there is still little data that directly compares the Retreaty Retreatment, Endostar RE-Endo, and ProTaper Retreatment devices under defined experimental circumstances.

Thus, the current in vitro study uses the ProTaper Retreatment, Endostar RE-Endo, and Retreaty Retreatment file systems to compare the frequency of dentinal cracks and

mechanical failure (instrument deformation and fracture) after retreatment. The results of this study may help doctors make well-informed clinical decisions by offering evidence-based recommendations about the mechanical performance and safety of these modern retreatment devices.

MATERIALS AND METHOD

Study Design

Study was conducted at the Department of Conservative Dentistry and Endodontics. The main goal was to compare three nickel-titanium rotary retreatment file systems used for nonsurgical treatment in terms of the frequency of dentinal crack formation and instrument-related mechanical failures.

Calculating Sample Size

The formula was used to estimate the sample size in accordance with the methodology outlined by Aly et al.

$$n = (2S^2 (Z_{(1-\alpha)}+Z_{(1-\beta)})^2)/\delta^2$$

Based on this computation, a total of 45 teeth were needed; assuming a 95% confidence level and 90% statistical power, 15 specimens were assigned to each experimental group.

Sample Selection

The study comprised 45 human single-rooted premolars that had just been extracted for periodontal or orthodontic reasons.

Inclusion Criteria

- Single root with a single canal
- Freshly extracted, non-carious, intact premolars
- Root length of 21 ± 1 mm
- Fully formed apices

Exclusion Criteria

- Teeth with root caries
- Developmental anomalies
- Internal or external resorption
- Root fractures
- Previously endodontically treated teeth
- Teeth with curved canals
- Multiple canals
- Open apices
- Dilacerated roots

Preparing the Specimen

To remove any remaining soft tissues and surface calcifications from the root surfaces, ultrasonic scalers were used. To prevent dehydration, the samples were kept in normal saline at room temperature following thorough cleaning.

Each tooth was vertically inserted in self-cured acrylic resin blocks that were 25 mm tall and 15 mm in diameter after being covered with a 0.2–0.3 mm layer of utility wax to replicate the periodontal ligament. To know the presence of only one canal and to make sure the canal curvature fell between 0° and 10°, standardized preoperative radiographs also used in both buccolingual and mesiodistal projections.

Root Canal Preparation

Using a No. 2 round diamond bur (Mani, Japan) in a high-speed handpiece under water coolant, traditional oval-shaped access cavities were created.

A size #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was used to create canal patency. The working length was measured radiographically and standardized to 21 ± 1 mm, which is 1 mm below the radiological apex.

The ProTaper Universal rotary system (Dentsply Maillefer, Switzerland) and the crown-down method up to F3 were used for biomechanical preparation.

Two milliliters of 2.5% sodium hypochlorite were used to irrigate each canal during instrumentation, and five milliliters of normal saline were administered following each instrument.

The final irrigation included: • 177 EDTA 2 mL of 2 mL of 2 mL of 2 mL of 17%

- Two milliliters of sodium hypochlorite (2.5%)
- Five milliliters of saline

The canals were dried using sterile paper points.

Obturation of the Root Canal

Radiographs were taken to confirm the apical fit of an F3 gutta-percha cone that was chosen as the master cone. The heated vertical compaction method was then used to obturate the root canal using F3 cones and AH Plus resin sealer. A temporary restorative substance was used for sealing of coronal access cavities, and all teeth were kept at 37°C and 100% humidity for ten days to allow the sealer to fully set. The post-obturation of the post-obturation of the post-obturation of the root filling.

Group Allocation

The forty-five specimens were randomly assigned into three experimental groups (n = 15).

Group I: ProTaper Universal Retreatment file system

Group II: Endostar RE-Endo Retreatment file system

Group III: Retreaty Retreatment file system

Retreatment Procedure

Retreatment was carried out in accordance with each file systems.

Group I (ProTaper Universal Retreatment)

Retreatment was carried out using D1, D2, and D3 files at the manufacturer's recommended speed and torque until complete removal of the obturating material.

Group II (Endostar RE-Endo)

It was performed using the four-file Endostar RE-Endo rotary system according to the manufacturer's recommended sequence, rotational speed, and torque.

Group III (Retreaty Retreatment)

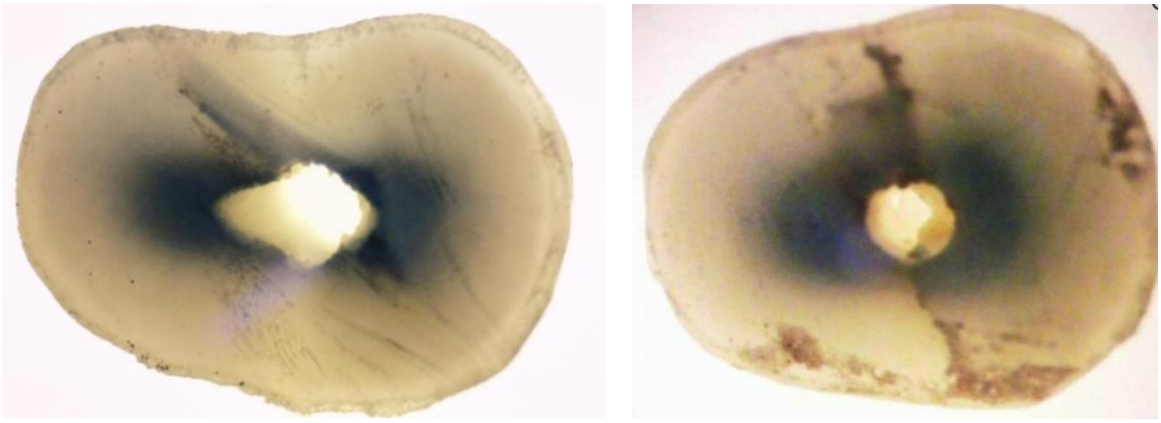
Retreatment was carried out using the five-file Retreaty system (Bull-Y, Skinn-Y, Shap-Y1, Shap-Y2, and Shap-Y3) according to the manufacturer's recommended kinematics and sequence.

No chemical solvents were used during retreatment.

Assessment of Dentinal Cracks

Sectioning and Microscopic Analysis: Slow-speed under cooling of water, each specimen was sectioned perpendicular to the long axis from the apex done under magnification of X25 (Carl Ziess)

Dentinal microcracks were defined using two distinct categories: "no crack" and "crack" [Figure 1a,b]. They were separated into two groups in order to prevent the confusing description of root cracks:



No crack 1(a) : The term "no crack" refers to root dentin that is free of craze lines or cracks on either of the surfaces of the root canal wall.

Crack 1(b) : Cracks were observed as any lines on the slice that either extended from the root canal lumen to the outer surface or from the outside root surface into the dentin.[9]

Assessment of Mechanical Failure

During the procedure, mechanical performance of the retreatment instruments was continually monitored. The instruments were thoroughly examined after every use for any

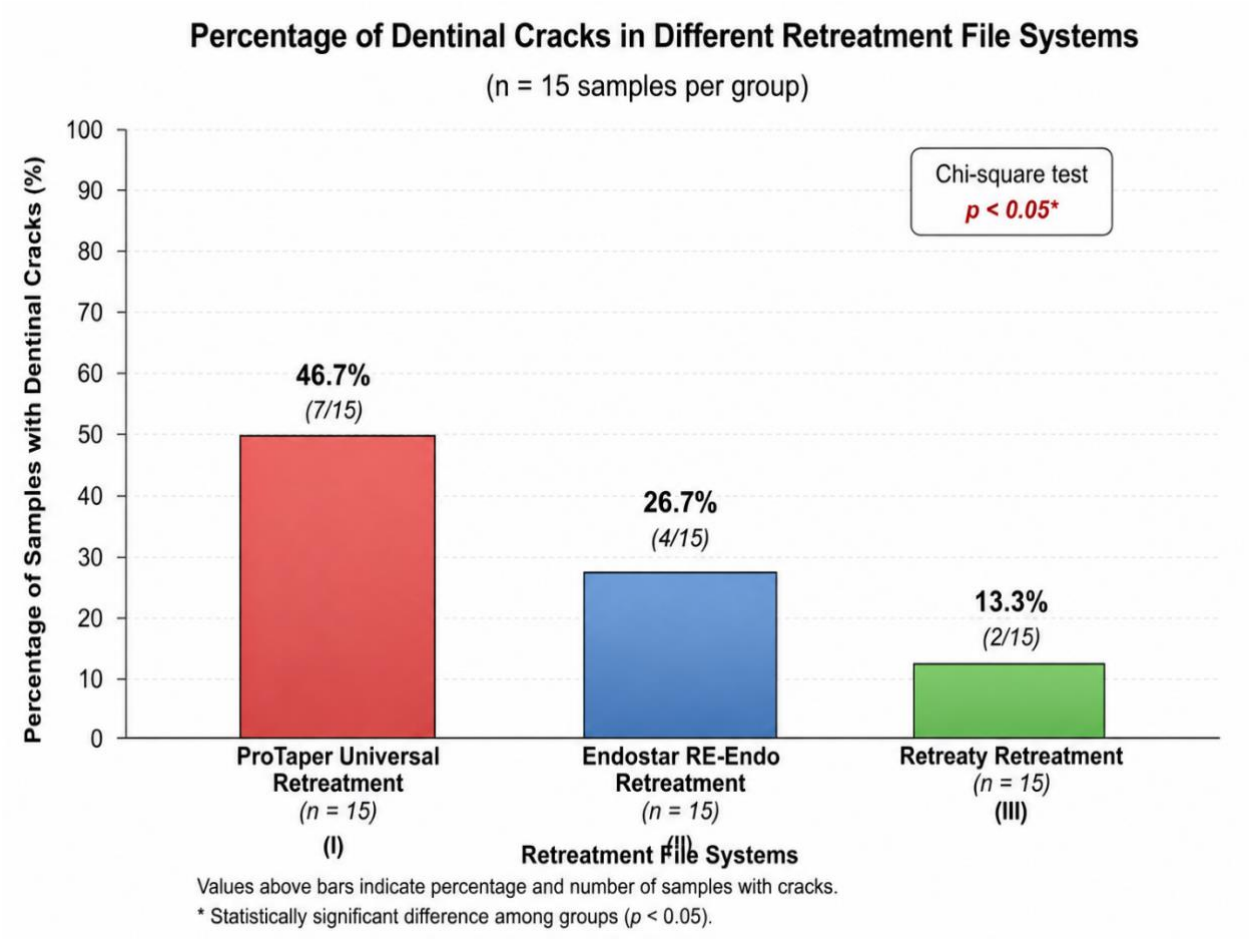
signs of deformation, distortion or fracture. All instruments with visible defects and/or separation were discarded and all such events were recorded for later statistical analysis.

Statistical Analysis

Data collected were analyzed for their distribution by the Shapiro–Wilk test for normality. Quantitative data were reported as mean + standard deviation and categorical data were reported as frequencies and percentages. One-way analysis of variance (ANOVA) was performed for the quantitative parameters when comparisons were undertaken between the groups. Appropriate post hoc analysis was performed when applicable. Pearson's chi-square test was used for the analysis of categorical variables like dentinal cracking and instrument separation. Results with P values <0.05 were deemed significant.

RESULTS AND DISCUSSION

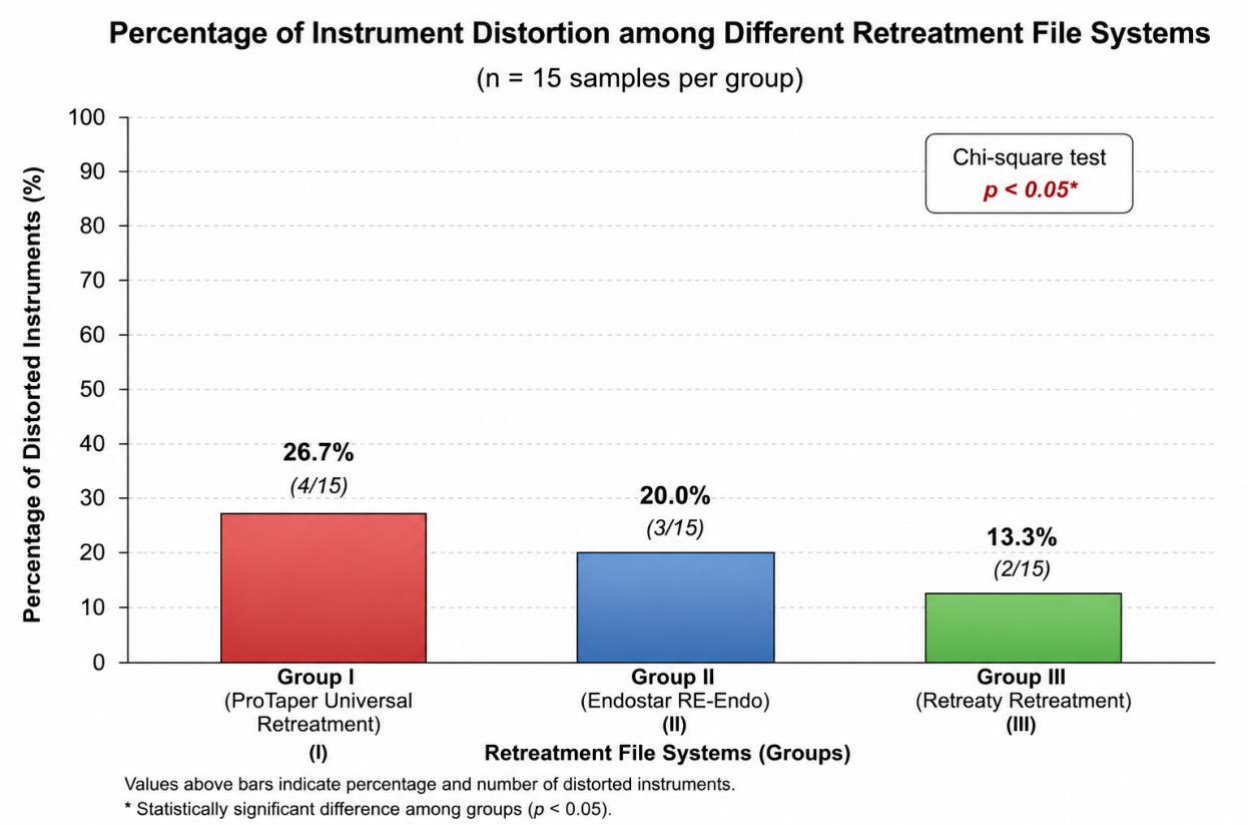
After completing the retreatment process, every specimen was added to the final analysis. For each of the three experimental groups, the frequency of dentinal cracks and mechanical failure (instrument breakage and deformation) was assessed.



Mechanical failure was assessed by analyzing instrument deformation and fracture after each use. Table 2 summarizes the frequency of instrument breakage and deformation within the three groups. The incidence of mechanical failure varied significantly amongst the studied retreatment file systems, according to statistical analysis (P < 0.05).

Table 2: Percentage of Instrument Distortion among Different Retreatment File Systems

Group	File System	Distorted Instruments	Percentage
I	ProTaper Universal Retreatment	4/15	26.7%
II	Endostar RE-Endo	3/15	20.0%
III	Retreaty Retreatment	2/15	13.3%



The long-term structural strength of the canal wall depends on radicular dentin being preserved during nonsurgical endodontic retreatment. Although contemporary nickel–titanium (NiTi) retreatment systems have improved the efficiency of gutta-percha removal, the stresses generated during instrumentation may cause formation of dentinal defects, which can lead to vertical root fractures under mechanical forces. Therefore, examining the influence of different retreatment procedures on dentinal wall cracks and instrument integrity remains clinically relevant.

The literature has extensively examined dentinal abnormalities related to root canal instrumentation. According to Bier CA et al. (2009), rotational NiTi instrumentation may produce dentinal abnormalities due to the forces that are transferred to the canal walls during preparation, especially in the apical area.[10] Similarly, H. Shemesh et al. (2009) showed that retreatment and canal preparation techniques might both lead to dentinal abnormalities, highlighting the fact that recurrent instrumentation puts more mechanical stress on radicular

dentin. These results imply that retreatment techniques should minimize needless dentin loss while achieving efficient filling material removal.[11]

The mechanical behavior of retreatment instruments is significantly influenced by their design features. The amount of stress imparted to the dentinal walls during instrumentation is determined by the instrument taper, cross-sectional geometry, rake angle, alloy treatment, and flexibility. While more flexible instruments tend to better follow the original canal anatomy while reducing unnecessary dentin removal, O. A. Peters et al (2004) highlighted that instruments with larger tapers and increased cutting efficiency may remove canal wall and consequently increase stress concentration within canal.

The mechanical performance of endodontic instruments has been significantly enhanced by developments in heat-treated NiTi metallurgy. When compared to traditional NiTi alloys, thermomechanically treated alloys show improved flexibility, superior cycle fatigue resistance, and greater resistance to torsional stress. Heat-treated NiTi instruments have better metallurgical qualities, which may lessen stress transmission to root dentin during instrumentation, as shown by Y. Shen and colleagues (2011). These features have prompted the creation of more advanced retreatment systems intended to increase both effectiveness and security.[13]

During retreatment, instrument deformation and breakage continue to be significant procedural issues. If the instrument is kept in use, distortion—which is typically seen as an early sign of metal fatigue—may occur before instrument separation. Improvements in NiTi alloy processing have greatly increased cycle fatigue resistance, which lowers the risk of irreversible deformation and fracture during clinical usage, according to H. P. Lopes et al. (However, elements including torque settings, rotational speed, operator technique, canal anatomy, and frequent instrument use still affect how long an instrument lasts.[14]

The effectiveness of filling material removal, residual debris, apical extrusion, and shaping ability have been the main focus of earlier studies comparing various retreatment systems; relatively few studies have assessed dentinal crack formation and mechanical failure concurrently. Furthermore, it is challenging to compare research directly due to variations in study design, specimen selection, obturation processes, canal shape, imaging methodologies, and crack evaluation criteria. Therefore, in order to provide meaningful comparisons across recently introduced retreatment systems, standardized experimental techniques are required.

The inherent limitations of laboratory studies should be taken into consideration when analysing them. The biological and biomechanical parameters found in the oral environment cannot be fully replicated in in vitro studies. Temperature variations, long-term clinical aging, functional occlusal loading, and the lack of bone physiology may together cause impact over

emergence and spread of dentinal abnormalities. As a result, laboratory study results should be carefully evaluated and verified by carefully planned clinical investigations and long-term follow-up research.

Overall, the choices for nonsurgical retreatment have increased due to ongoing advancements in NiTi metallurgy and device design. Future studies utilizing finite element analysis, micro-computed tomography, and long-term clinical evaluation may shed more light on the connection between dentinal defect generation, clinical success, and instrument design.

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