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The effect of reciprocation versus rotational movement on the incidence of root defects during retreatment procedures

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Abstract

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Aim To compare the incidence of dentinal defects caused by reciprocating and rotary techniques during retreatment procedures.

Methodology One hundred and twenty extracted mandibular premolars with single canals were selected. Twenty teeth were left unprepared. The root canals in the remaining 100 teeth were prepared with K-files up to size 35 and filled with Gutta-percha and AH Plus sealer using a passive cold lateral compaction technique. Twenty canals were filled and received no further treatment. Eighty teeth were divided into four groups ($n = 20$ in each) to undergo the removal of the root filling. In groups 1 and 2, the root filling was removed using ProTaper Retreatment files and Reciproc files, respectively, and the canals were not refilled. In groups 3 and 4, the root filling was removed using ProTaper Retreatment files and Reciproc files, respectively, and the canals were then refilled using a conventional cold lateral compaction technique. The roots were sectioned horizontally at 3, 6 and 9 mm from the root apex and observed under a stereomicroscope at 20× magnification. Defects were categorized as no defect, incomplete defect and fracture. The differences between the groups were analysed using the chi-square exact test ($P = 0.05$).

Results No defects were observed in the unprepared and filled groups, in contrast to the experimental groups. In the coronal thirds, groups 2 and 4 had more dentinal defects than groups 1 and 3 ($P < 0.05$). In the middle thirds, group 4 had more defects than group 1 ($P < 0.05$). In the apical thirds, group 2 had fewer defects than did group 3 and group 4. Also, group 3 had more defects than group 1 ($P < 0.05$). When comparing the experimental groups, there were no significant differences with regard to fracture ($P > 0.05$).

Conclusions Both nickel–titanium systems were associated with dentinal defects during retreatment procedures in extracted premolar teeth.

Keywords: cracks, dentine defects, reciprocation, retreatment, rotary.

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Introduction

The ProTaper Universal Retreatment system (Dentsply Maillefer, Ballaigues, Switzerland) is a NiTi rotary instrument that is used for removal of filling material from the root canal. It comprises three retreatment files, one for each third of the root canal. The instruments have a convex triangular cross-section similar to the ProTaper Universal shaping and finishing files.

Reciproc instruments (VDW, Munich, Germany) have an S-shaped cross-section, two cutting blades and a continuous taper over the first 3 mm of the file followed by a decreasing taper to the shaft (Liu *et al.* 2013). Although Reciproc instruments are fundamentally used for preparation of root canals, studies have

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evaluated their use in the removal of root filling material (De-Deus *et al.* 2010, Zuolo *et al.* 2013). The reciprocating technique was found to be the most rapid method for removing Gutta-percha and sealer, followed by the rotary technique and the hand file technique. Additionally, it was reported that the reciprocating technique removed more filling material from the canal walls than the rotary technique (Zuolo *et al.* 2013).

Vertical root fracture results in a poor prognosis for the affected tooth and often leads to extraction. Root fractures may occur as a result of dentinal defects (i.e. craze lines or microcracks) that propagate with repeated stress application through occlusal forces (Yoldas *et al.* 2012). Several factors may be responsible for the formation of dentinal defects: biomechanical preparation, root filling techniques, retreatment procedures, and post-placement (Barreto *et al.* 2012, Yoldas *et al.* 2012). Retreatment procedures require additional mechanical preparation of the root canal and can thereby cause more damage to the root canal wall (Shemesh *et al.* 2011).

The purpose of this study was to compare the incidence of dentinal defects caused by reciprocating and rotary techniques during retreatment procedures. The null hypothesis was that there would be no significant difference in dentinal defects produced between rotary and reciprocation systems.

Materials and methods

Approval of the ethical board of the research foundation of Erciyes University of Medical Sciences in Kayseri, Turkey, was obtained to conduct this investigation (Ethics Approval Number 570).

Specimen selection and preparation

Single-rooted, human mandibular premolars that had been extracted for periodontal reasons were used. The external root surface was inspected under a microscope (Zeiss Opmi; Carl Zeiss, Jena, Germany) to exclude teeth with external defects or cracks. Radiographs were taken from buccolingual and mesiodistal aspects and the width of canals measured 9 mm from the apex. One hundred and twenty teeth that were comparable in canal width were finally selected and stored in purified filtered water. To ensure standardization, the crowns of the teeth were partially removed to achieve a final 19-mm length for each tooth. Twenty teeth were left unprepared and served as the control group, while the remaining 100 teeth were subjected to canal preparation.

Access cavities were prepared using a diamond bur (Brasseler USA, Savannah, GA, USA) under water cooling on all teeth except the control group. A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed in the canal until it was visible at the major apical foramen, and the working length (WL) was determined by subtracting 1 mm from this measurement. A silicon impression material was used to coat the surface of the roots to simulate periodontal ligament space. The teeth were then embedded in tubes filled with self-curing acrylic resin (Imicryl, Konya, Turkey) at the cemento-enamel junction level. The canals were prepared to a master apical size 35 with K-files (Dentsply Maillefer) using the balanced force technique as described by Roane *et al.* (1985). Step-back instrumentation was performed using sizes 40–70 K-files. Each canal was irrigated with 2 mL of 2.5% sodium hypochlorite (NaOCl) between each file using a syringe and a 27-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). After completion of the preparation, the canals were irrigated with 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) for 1 min and subsequently rinsed with 2 mL of distilled water. The root canals were then dried with paper points (Dentsply Maillefer). One hundred roots were filled using the passive technique, as previously described (Souza *et al.* 2008). Master Gutta-percha cones size 35, .02 Taper (Dentsply Maillefer) were coated with AH Plus sealer (Dentsply Maillefer) and placed into the root canal to the WL. Additional Gutta-percha cones were placed without using a spreader to the depth at which resistance was met. A heated plugger was used to remove excess Gutta-percha coronally, and the access cavities of all specimens were filled with temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). The specimens were stored for 2 weeks at 37 °C at 100% humidity to allow complete setting of the sealer. Twenty teeth with root fillings were left filled, and no retreatment was performed. Root canal preparation, filling and retreatment procedures were performed by a single operator to avoid variability.

Experimental groups

Group 1: The removal of filling material with ProTaper retreatment instruments (n = 20)

In this group, ProTaper Universal retreatment (PTUR) instruments (Dentsply Maillefer) were used to remove

the root filling material. The PTUR instruments were used with a motor (X-Smart; Dentsply Maillefer) at the torque and speed recommended by the manufacturer. The PTUR instruments were used at a constant speed of 500 rpm for D1 and 400 rpm for D2 and D3, with a torque of 3 Ncm. The D1 ProTaper instrument (size 30, .09 taper) was used for the removal of the coronal third of the root canal filling. The D2 ProTaper instrument (size 25, .08 taper) was used in the middle third of the root canal. Finally, the D3 ProTaper instrument (size 20, .07 taper) was used at the WL. The retreatment procedure was concluded with the use of ProTaper instrument F4 (size 40, .06 taper) at a speed of 300 rpm and a torque of 2 Ncm.

Group 2: The removal of filling material with Reciproc instruments (n = 20)

In this group, the canal filling material was removed using the Reciproc R25 instrument (size 25, .08 taper). The instrument was introduced into the canal, activated by a VDW Silver electric motor and applied in a reciprocating motion. It was then moved towards the apex using an in-and-out pecking motion with an amplitude of approximately 3 mm. Gentle apical pressure was combined with a brushing action against the lateral walls, according to the manufacturer's instructions. This procedure was repeated until the instrument reached WL. The retreatment procedure was concluded with the use of an R40 instrument (size 40, .06 taper).

Group 3: The removal of filling material with ProTaper retreatment instruments and refilling

In this group, the removal of root canal filling material was performed as it was in group 1. However, the root canals were then refilled using a conventional cold lateral compaction technique. A size-40 master point coated with AH Plus sealer (Dentsply Maillefer) was introduced into the canal, condensed with size 25, .02 taper and size 20 .02 taper finger spreaders (Dentsply Maillefer), followed by the placement of accessory Gutta-percha points, with sealer. Excess Gutta-percha was removed using a heated plugger, and the filling was vertically compacted.

Group 4: The removal of filling material with Reciproc instruments and refilling

In this group, the removal of root canal filling material was performed as in group 2. The root canals were then refilled with a conventional lateral compaction technique as in group 3.

In all experimental groups, 0.2 mL of eucalyptol was used to soften the Gutta-percha in the root canal orifice. Each ProTaper and Reciproc instrument was discarded after being used in one canal. During the removal of canal filling material, the root canals were irrigated with 10 mL of 2.5% NaOCl. The removal of canal filling material was considered complete when no Gutta-percha or sealer was detected on the instrument surfaces or inside the root canal or dentinal walls. A dental operating microscope (Zeiss Opmi; Carl Zeiss, Jena, Germany) was used throughout.

Examination of roots

The silicon impression material was removed, and all roots were sectioned perpendicular to their long axis at 3, 6 and 9 mm from the apex with a low-speed saw (Isomet 1000; Buehler, Lake Bluff, IL, USA) under water cooling. Slices were then viewed through a stereomicroscope (BX60; Olympus, Tokyo, Japan) at a magnification of 20×. Pictures were taken with a digital camera (DP-70; Olympus). The images were then inspected for defects by two operators who were blinded to the technique used to retreat the canal. A total of 60 slices were examined in each group. Three distinct categories of root defects were defined, and the defects were classified as follows (Shemesh *et al.* 2009):

- 'No defect' – root dentine devoid of any lines or cracks and where both the external surface of the root and the internal root canal wall had no defects (Fig. 1a).
- 'Incomplete defects' – lines that did not extend from the root canal to the outer root surface (e.g. a craze line, a line extending from the outer surface into the dentine but that did not reach the canal lumen, or a partial crack, a line extending from the canal walls into the dentine without reaching the outer surface) (Fig. 1b).
- 'Fracture' – a line extending from the root canal space to the outer surface of the root (Fig. 1c).

Statistical analysis

A chi-square exact test was performed to explore the difference between the groups and the influence of root level (apical, middle and coronal) on the appearance of defects. The significance level was set at $P < 0.05$. Multiple comparisons were performed with z-test adjusted by the Bonferroni correction. All statistical analyses were performed using the IBM Statistics

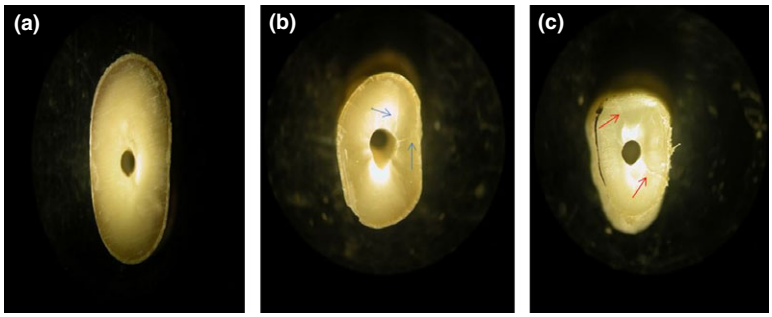

Figure 1 Representative images (a) no defect, (b) incomplete defect (*blue arrows*) and (c) fracture (*red arrows*).

SPSS 21.0 for windows (IBM Corp., Armonk, NY, USA). Interexaminer agreement was analysed using kappa statistics.

Results

Interexaminer agreement evaluated with the kappa test for all the groups, and significance set at 0.5, showed satisfactory values of 0.9 and above for each group.

Table 1 summarizes the defect incidence for each group. The unprepared and filled-but-no-retreatment groups had no defects, but defects and fractures were found in all experimental groups.

In the coronal root thirds, there were significant differences amongst the groups ($P = 0.004$). Groups 2 and 4 had significantly more dentinal defects than groups 1 and 3 ($P = 0.01$). In the middle root thirds, group 4 had significantly more defects than group 1 ($P = 0.02$). There were no significant differences amongst the rest of the experimental groups ($P > 0.05$). In the apical root thirds, group 2 had significantly fewer dentinal defects than group 3 and group 4. Also, group 3 had significantly more defects than group 1 ($P = 0.01$).

The experimental groups had significantly more fracture formations than the control and filled-but-no-retreatment groups ($P = 0.01$). However, there were no significant differences amongst the experimental groups in terms of fracture formation ($P > 0.05$).

Discussion

There are a number of limitations present in previous studies evaluating dentinal defect formation: (i) it is possible that the defects occurred during the extraction of the teeth (Shemesh *et al.* 2009), (ii) it is possible that the defects occurred during the sectioning procedure (Bier *et al.* 2009), (iii) it was not possible to evaluate at which point during the instrumentation procedures the cracks were produced (iv) it is possible that the same defects extended to different levels of the root and were counted as separate defects (Onnink *et al.* 1994), and (v) it is not possible with the current methodology (root sectioning and direct observation by optical microscopy) to detect pre-existing defects. Micro-CT imaging has a much higher definition than stereomicroscopy, and a large number of sections can be analysed per tooth without creating defects. De-Deus *et al.* (2014) reported that micro-CT

Table 1 Number/percentage of defects in the different slices

	Number of incomplete defect/percentage of samples with incomplete defects				Number of fracture/percentage of samples with fracture			
Group	3 mm	6 mm	9 mm	Total	3 mm	6 mm	9 mm	Total
Control	0/0%^{a}	0/0%^{a}	0/0%^{a}	0/0%	0/0%^{a}	0/0%^{a}	0/0%^{a}	0/0%
PFNR	0/0%^{a}	0/0%^{a}	0/0%^{a}	0/0%	0/0%^{a}	0/0%^{a}	0/0%^{a}	0/0%
ProTaper R	2/10%^{ac}	1/5%^{a}	0/0%^{a}	3/5%	0/0%^{a}	1/5%^{ab}	0/0%^{a}	1/1.7%
Reciproc	1/5%^{a}	2/10%^{ab}	5/25%^{b}	8/13.3%	0/0%^{a}	5/25%^{b}	2/10%^{a}	7/11.7%
PTR+refilled	6/30%^{b}	3/15%^{ab}	1/5%^{a}	10/16.6%	2/10%^{a}	1/5%^{ab}	1/5%^{a}	4/6.6%
Rec+refilled	5/15%^{bc}	4/20%^{b}	6/20%^{b}	15/25%	2/10%^{a}	2/10%^{ab}	3/15%^{a}	7/11.7%

PFNR, Prepared and filled-but-no-retreatment, PTR: ProTaper R, Rec:Reciproc. The same superscripted letters indicate no significant differences ($P > 0.05$).

image technology was accurate and a nondestructive method that allows the assessment of the specimens before instrumentation.

In previous studies, it was reported that initial root canal preparation performed with NiTi rotary instruments generated dentinal defects (Yoldas *et al.* 2012, Bürklein *et al.* 2013). Contrary to this, initial root canal preparation performed with hand files did not show any dentinal defects (Bier *et al.* 2009, Yoldas *et al.* 2012, Ashwinkumar *et al.* 2013). For this reason, in the present study, initial root canal preparation was performed with hand files to determine with more precision the number of defects that occurred during retreatment.

It has been stated that the technique used during root filling may affect the generation of dentinal defects (Versluis *et al.* 2006, Shemesh *et al.* 2009). Souza *et al.* (2008) described a passive compaction technique that does not create additional force or dentinal defects during the filling process. Similarly, several reports showed that the passive filling technique did not cause dentinal defects (Shemesh *et al.* 2009, Topcuoglu *et al.* 2014). Although the passive filling technique is not a common technique for root canal filling, it was used to avoid creating dentinal defect before the removal of the root filling material. In the present study, the passive filling technique did not cause any dentinal defect, as opposed to studies using active filling techniques (Shemesh *et al.* 2009, 2010). One limitation of the current study is that the use of a passive filling technique was associated with a reduced propagation of cracks during the initial filling. However, the pressure required for the removal of the Gutta-percha is lower in the passive filling technique than in active filling techniques, and this could be the reason for the reduced formation of dentinal defects. This benefit should not be ignored during the interpretation of the results of the present study. Also, in the present study, one of the most preferred filling techniques (cold lateral compaction) was used for refilling the root canals. This was carried out with the aim of evaluating the effect of an active filling technique on dentinal defect formation during the retreatment procedure. The results showed that the refilling groups (groups 3 and 4) had significantly more incomplete dentinal defects than did the nonrefilling groups (groups 1 and 2) in the apical root thirds. During the filling procedure, the techniques associated with pressure caused more dentinal defects than did the passive techniques (Barreto *et al.* 2012). The forces generated with spreaders, during lateral compaction, could be responsible for the increase of dentinal defects.

It has been proposed that the remaining filling material could be minimized by means of further canal enlargement beyond the initial root canal size (Friedman *et al.* 1992, Marques da Silva *et al.* 2012). In the present study, this additional instrumentation was performed with ProTaper F4 and Reciproc R40 files to minimize the amount of residual filling material on the root canal walls.

In the present study, the effect of two different NiTi systems, working with different motions, on the incidence of dentinal defects during the retreatment procedure was evaluated. According to the results, the Reciproc system created more dentinal defects than did the ProTaper Retreatment system in the coronal and middle thirds. However, there was no statistically significant difference amongst the groups in the apical thirds. The ProTaper retreatment system works in a continuous rotation motion and consists of 3 retreatment files: D1, D2 and D3. The D1 instrument is designed to remove the filling material from the coronal third and to facilitate the working of the next instrument (D2). The D2 instrument removes the Gutta-percha from the middle root third and creates a space for entry to the apical third by the D3 instrument. However, the Reciproc system is a single-file system, working with a reciprocating movement. Specifically, the Reciproc system does not incorporate an instrument that shapes the coronal and middle thirds of the root canal system initially, which will facilitate working in the apical third of the root canal system. This could mean that the instrument encounters more stress during the retreatment procedure in the coronal and middle thirds of the root canal system.

In the present study, the retreatment procedure was performed with the Reciproc R25 instrument at WL, followed by the R40 instrument. It has been stated that the reciprocal motion seems to enhance debris transportation towards the apex during root canal preparation (Bürklein & Schäfer 2012) and may increase torsional forces (Bürklein *et al.* 2013). However, in the present study, the effect of the Reciproc system on dentinal defect formation during the retreatment procedure was evaluated.

According to the results, a greater number of dentinal defect formations were observed in the Reciproc group in the coronal and middle root thirds than in the ProTaper retreatment group. The amount of debris formation that occurred during the retreatment

procedure may be greater than the amount of debris accumulated during the initial root canal preparation. Hence, the additional torsional forces that occur with the instrument could be the reason for dentinal defect formations on the root canal walls. Shemesh *et al.* (2011) evaluated the effect of retreatment procedures on the appearance of defects on the root canal wall and found that both hand files and the ProTaper retreatment system caused dentinal defects. Similar to this study, the ProTaper retreatment group was associated with more dentinal defects during the retreatment procedure.

Bürklein *et al.* (2013) stated that when using only one instrument to complete preparation, more stress is generated during mechanical instrumentation compared to canal instrumentation using full-sequence systems. They evaluated the incidence of dentinal defects after root canal preparation with reciprocating instruments (Reciproc and Wave-One) and rotary instruments (ProTaper and Mtwo) and determined that instrumentation with Reciproc files was associated with significantly more complete cracks compared to Mtwo and ProTaper. Although the current study evaluated the effect of retreatment procedures on the incidence of dentinal defects, the findings were similar to those in the study by Bürklein *et al.* (2013). This may be due to increased stress on canal walls during the use of a single file for the retreatment procedure in the Reciproc group.

Several authors reported that various factors such as tip design, cross-section geometry, constant or progressive taper design, constant or variable pitch, and flute form could be responsible for dentinal defect formation (Yoldas *et al.* 2012, Ashwinkumar *et al.* 2013). Topcuoglu *et al.* (2014) evaluated dentinal defect formation during retreatment procedures using several NiTi rotary systems and hand files and reported that all systems caused dentinal defects without significant differences amongst the systems. Additionally, they stated that there may not be any correlation between NiTi retreatment file design or degree of taper and the incidence of dentinal defects. The current study evaluated the effect of NiTi systems (ProTaper retreatment and Reciproc files) on the incidence of dentinal defects. The findings showed that there was a difference between the retreatment groups in the coronal and middle thirds, but not in the apical third. Bürklein *et al.* (2013) stated that when using only one instrument for complete preparation, more stress will be generated during mechanical instrumentation compared with canal instrumentation using full-sequence systems. Therefore, it could be concluded that the incidence of dentinal defects might be increased compared with preparations using full-sequence rotary systems. The results indicate that there might be an association between the designs and motions of the NiTi systems used in the present study and the incidence of dentinal defects.

Conclusions

NiTi systems, both with reciprocating and rotational movement caused dentinal defects during retreatment procedures. Additionally, the Reciproc system was associated with significantly more cracks in the middle and coronal part of the roots than the ProTaper system. Therefore, the null hypothesis was rejected.

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