Original Research

Comparative Evaluation of Microcrack Formation in Different Kinematics Using Rotary and Reciprocating File Systems: An In Vitro Study

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Abstract

Aim and objective: To compare root microcrack formation after root canal preparation using ProTaper Next in rotation or forward reciprocation and Waveone gold in reverse reciprocating motion.

Materials and methods: Buccal roots of 60 maxillary premolars with mature apices were selected, for different instrumentation techniques and divided into three groups. Coronal access was achieved and the canals were confirmed for apical patency. The canals were then instrumented using the following instrumentation techniques: ProTaper Next in rotation or forward reciprocation or Waveone gold in reverse reciprocation. The tooth was then subjected to sectioning using a diamond saw under water cooling and then was visualized under the stereomicroscope for dentinal microcrack.

Results: The results showed that the maximum dentinal microcrack formed at apical 3 and 6 mm was in Waveone gold in reverse reciprocation followed by ProTaper Next in forward reciprocation and rotation. However, the p value was found to be not significant at 3 and 6 mm (p value—0.082 and 0.23).

Conclusion: Nickel titanium rotary instruments tend to induce varied degrees of root dentinal damage during canal instrumentation. ProTaper Next files in rotation as well as forward reciprocation presented with minimal microcrack defects when compared with Waveone gold.

Clinical significance: Root canal preparation, when performed by manual or engine-driven techniques, has shown to produce structural defects in the root dentin. One of the causes of failures in root canal treatment is because of fracture in the dentin that occurs due to these procedures. Though all the motion kinematics caused microcracks in this study, it was seen that rotational motion produced the least structural damage to the dentin.

Keywords: Dentinal microcrack, Kinematics, ProTaper Next, Reciprocation, Waveone gold.

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Introduction

The success of endodontic therapy can be achieved by bacterial elimination, unexpurgated debris removal, and a complete three-dimensional obturation.1

Vertical root fractures are a common complication that results after root canal therapy often leading to extraction of the tooth.2 The root fracture might occur as a result of a microcrack or craze line that is propagated with repeated stress application by occlusal forces.3

Over the past few decades, new nickel titanium rotary systems have been developed and was preferred due to their advantages such as resistance to flexural and torsional failure as well as improved cutting ability. Root canal instrumentation with continuous rotation and reciprocating motion is reported to cause dentinal microcracks, regardless of the technique or kinematics used.3–5

In 2008, Yared proposed a canal preparation technique using F2 ProTaper in reciprocation and this has shown to maintain the original root canal anatomy with least possible distortion.6 The ProTaper Next rotary system, which consists of instruments with variable taper, has an off-centered rectangular cross-sectional design.7

The flexibility of rotary instruments as a result of heat treatment has been stated as a significant reason for microcrack formation. The Waveone gold rotary system has an offset parallelogram-shaped cross-section with a semiactive tip.7,8

Conclusion:

Nickle titanium rotary instruments tend to induce varied degrees of root dentinal damage during canal instrumentation. ProTaper Next files in rotation as well as forward reciprocation presented with minimal microcrack defects when compared with Waveone gold.

Clinical significance: Root canal preparation, when performed by manual or engine-driven techniques, has shown to produce structural defects in the root dentin. One of the causes of failures in root canal treatment is because of fracture in the dentin that occurs due to these procedures. Though all the motion kinematics caused microcracks in this study, it was seen that rotational motion produced the least structural damage to the dentin.

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There are very few reported studies that evaluate the rate of microcrack formation with different reciprocating kinematics. Research on relationship between tooth structural integrity and instrumentation techniques and kinematics is certainly required. Therefore, the aim of the study was to evaluate microcracks formed after canal preparation using Waveone gold (WOG) in reverse reciprocating motion and the ProTaper Next (PTN) file system in a sequential manner in rotation or forward reciprocating motion.
The null hypothesis was that there would be no significant difference in the formation of dentinal microcrack between ProTaper Next in rotation or forward reciprocating motion and Waveone gold in reverse reciprocating motion.

MATERIALS AND METHODS
The present study was carried out in the Department of Conservative Dentistry and Endodontics and Nano Sciences, Kochi, India. Sixty human maxillary premolars indicated for extraction due to orthodontic reasons with moderately curved buccal roots (curvature <10°) with mature apices according to the Schneider method were selected for the study. The curvatures of the roots were determined using the CBCT (CS 9300) 3D imaging software. The extracted teeth were stored in distilled water. The cusps were flattened using carbide disks to maintain the tooth length to 20 mm. The roots of all teeth were inspected with transmitted light and stereomicroscopy under 12× magnification to detect any preexisting craze lines or cracks if present, if so, were excluded from the study group. A rubber-based impression was made and all the roots were embedded in acrylic blocks. After achieving coronal access, the apical patency of the canals was confirmed using a 10 K size file (Dentsply Maillefer, Switzerland). The samples were randomly divided into three groups as follows:

Group I
PTN–R—ProTaper Next in continuous rotation (n = 20)
ProTaper Next files (Dentsply Maillefer, Switzerland) were introduced into the canal in the following sequence using a torque-controlled endodontic motor (X-Smart plus, Dentsply Maillefer, Switzerland) at a speed of 300 rpm and a torque of 2.5 N cm. X1 file (17/0.04) followed by X2 file (25/0.06) was used in a brushing outstroke motion till the working length.

Group II
PTN–FR—ProTaper Next in forward reciprocation (n = 20)
The instrumentation order was similar to that of group I. The files were used in forward reciprocating motion (150°CW and 30°CCW) using a torque-controlled cordless endodontic motor (Endomax, Dentamerica) at a speed of 300 rpm and a torque of 2.5 N cm.

Group III
WOG—Waveone gold in reverse reciprocation (n = 20)
A reciprocating Waveone gold file having a size 25 and a Taper of 0.07 was used in an endodontic motor (X smart plus, Dentsply Tulsa Dental) with pecking motion up to the middle third and last 3 mm was by in and out motion until the working length was reached. After three pecking motions, the file was withdrawn and then cleaned and inspected before being reused. This procedure was repeated until the file reached the desired working length.

During instrumentation, the canals were irrigated with 2 mL 3% sodium hypochlorite and distilled water in each group. K-file of size 10 was used to confirm the patency of the canal. The sectioning of each embedded specimens at 3 and 6 mm from the apex was carried out immediately after instrumentation.

Sectioning and Microscopic Observation
All roots were horizontally sectioned at 3 and 6 mm from the apex with a low-speed saw (Isomet 5000; Buehler) under water cooling. Slices were then subgrouped as group Ia—PTN-R at 3 mm, group Ib—PTN-R at 6 mm, group IIa, IIb—PTN-FR at 3 and 6 mm, group IIIa, IIIb—WOG at 3 and 6 mm. The specimens were viewed through a stereomicroscope (Zeiss Stemi SV6, Carl Zeiss) using a cold light source (KL 2500 LCD, Carl Zeiss). Digital images of each section were recorded at a magnification of 30× using a digital camera that was attached to the stereomicroscope.

All the specimens were observed by a single examiner for presence of dentin microcracks (Figs 1 to 3). The results were expressed as whether cracks were present or absent at apical 3 and 6 mm (Tables 1 and 2).

Statistical Analysis
The results regarding the presence of dentinal microcracks were expressed as the number and percentage of samples within each group. The statistical analysis was performed with the SPSS software (Version 20). The analysis of the data was done using the Chi-square test.

RESULTS
The three groups examined showed the presence of dentinal microcracks at apical 3 and 6 mm (Figs 1 to 3). In the current study,
The presence of microcrack at 3 mm was found to be 30% in both group I and II. However, microcrack was comparatively more in group III (60%) (Table 1). About 30% of group I, 35% of group II, and 55% of group III showed presence of microcrack at 6 mm (Table 2). The presence of microcrack was detected in all three groups; however, there is no significant difference between the three groups in 3 and 6 mm sections ($p$ values 0.082 and 0.23).

**DISCUSSION**

When rotational forces are applied onto the canal walls using nickel titanium instruments, microcracks are formed in the root dentin. Even after meticulous shaping and cleaning with various versions of rotary or hand instrumentation, microcracks occur.

Vertical root fracture (VRF) may result as a gradual propagation of microcracks within the tooth structure and a delayed effect of root canal therapy. The effect of root canal preparation techniques and kinematics has been found to induce the formation of microcracks, resulting in VRF.

According to the results of the present study, microcrack formation occurred independent of the kinematics and the type of instrument used. The single-file reverse reciprocating system (group III) showed maximum dentinal microcrack when compared to the sequential file system in continuous rotation or forward reciprocation (groups I and II). The results were consistent with previous studies, which demonstrated that no method could completely prevent crack formation. The obtained differences may be due to the preparation technique, the cross-sectional...
design, the taper of the instruments, and kinematics used such as continuous rotation and forward and reverse reciprocating motion.15,16

The cross-section of Waveone gold is a parallelogram with two 85° cutting edge, alternating with a patented off-centered cross-section where only one cutting edge will be in contact with the root dentinal wall. The tip of WOG is semiactive, which helps in improving its penetration into any secure canal with a smooth and reproducible glide path, eliminating the need to push the file apically. During a 360° rotation, the WOG single file with a cross-section that alternatively touches the dentinal wall might increase the contact of the instrument with the dentinal wall, thus promote the formation of dentinal defect.17

Liu et al. reported that the use of Reciproc files caused less microcrack than the ProTaper universal file in a sequential file system.10 However, Priya et al. had reported that the use of single-file reciprocating motion in the root canal may result in higher levels of stress in the root dentin.12

The PTN file system is a M wire technology and has an off-centered mass with rectangular cross-section reducing the screwing effect. The cross-section design with a two-point contact onto the dentinal wall serves to reduce the engagement between the files and dentin and also the torque over the file.15,18

Deveci et al. reported that the rate of microcrack formation was observed more in Reciproc than ProTaper Next.15 Capar et al. had reported that PTN caused less microcrack than ProTaper universal and hyflex.19 Cassimiro et al. stated that kinematics is not related to the formation of microcracks.20

However, in the present study the files used in forward reciprocation were found to cause less microcrack compared to ones in reverse reciprocation, though the results were not statically significant. Therefore, taper and kinematics used for root canal preparation need to be taken into consideration while instrumenting the root canals. Images of dentinal microcracks were captured using a digital camera attached to the stereomicroscope. However, the limitation of the study is that there are high chances that these imaging procedures may develop heat, leading to dehydration of samples inducing cracks, which might affect the results of the study. Therefore, future studies using other methods like microcomputed tomography or optical coherence tomography will eliminate the sectioning procedure and hence could be less detrimental.

This is the first study to assess the presence of microcrack when forward reciprocation motion was used with the ProTaper next system. The presence of microcrack was observed to be similar when PTN was used in forward reciprocation as in rotation.

**Conclusion**

Nickle titanium rotary instruments tend to induce varied degrees of root dentinal damage during canal instrumentation. ProTaper Next files in rotation as well as in forward reciprocating motion represented satisfactory results with minimal microcrack defects when compared with Waveone gold in reverse reciprocation.

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