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Comparison of root microcrack formation after root canal preparation using two continuous rotational file systems and two reciprocating systems –An Invitro study

[1]Arjun B Ravi,[2]Prabath Singh V P,[3]Sreeram SR,[4]MadhuHariharan, [5]Razdan TR

[1,2,3,4,5]*Department of Conservative Dentistry and Endodontics, Amrita School of Dentistry; Amrita Institute of Medical Sciences; Kochi; India*

Abstract:
Aim:*To compare the incidence of dentinal defects after preparation with reciprocating (Reciproc and WaveOne) and fullsequence rotary ProTaper Universal and Protaper Next instruments.*
Materials and methods:*One hundred human mandibular premolars were randomly assigned to 5 groups (n = 20 teeth per group). The root canals were instrumented by using the reciprocating single-file systems Reciproc and WaveOneand the fullsequence rotary protaper universal andProTaper nextinstruments.One group was left unprepared as control. Roots were sectioned horizontally at 3, 6, and 9 mm from the apex and the sections were then observed under a stereomicroscope. The absence/presence of cracks was recorded, and the data were analysed with a chi-square test. The significance level was set atP= .05.*
Results:The control group Protaper universal, protaper next, waveone and reciproc caused cracks in 0%, 50%, 35%, 15% and 20% of samples, respectively. A statistically significant difference was found between the reciprocating file groups(WaveOne and reciproc) and the continuous rotation group (ProTaper universal and protaper next) (P< .05). However, no significant difference was found among the 2 reciprocating file groups and 2 continuous rotation group(P >.05).
Conclusions:*Dentinal micro cracks are produced irrespective of motion kinematics andsuch an incidence is less with instruments working in reciprocating motion compared with those working in continuous rotation.*
Key words:*Dentinal defects, nickel-titanium instruments, reciprocation, root canal preparations.*

I. Introduction

Vertical root fracture (VRF) in endodontically treated teeth is one of the most frustrating complications of root canal therapy, which results in tooth or root extraction(1). Because its effects are catastrophic, identifying the etiologic factors of VRF in an endeavour to improve its prevention becomes important(2).

During biomechanical preparation, a canal is shaped by the contact between instruments and dentin walls. These contacts create many momentary stress concentrations in dentin. Such stress concentrations may induce dentinal defects and micro cracks or craze lines(3). These, in turn, were associated with increased VRF susceptibility because applied stresses caused by root canal obturation, retreatment, and repeated occlusal forces can be exponentially amplified at the tip of those defects and can initiate or propagate into cracks (3).

In the last decade, advances in nickel-titanium (NiTi) instruments have added a new dimension to root canal treatment. Recently, single-file systems in rotary and reciprocating motion were introduced(4). Various file systems differing in their design features such as the NiTi core diameter, cross-sectional shape, rake angle, and flute depth may affect the behaviour of the file and, therefore, may influence the generation of cracks(5).ProTaper rotary files (DentsplyMaillefer, Ballaigues, Switzerland) are popular instruments that are characterized by an increasing taper design, convex triangular cross-section throughout their active portion, and a negative rake angle(6). Their design facilitates active cutting motion and removes relatively more dentin coronally compared with other systems. ProTaper rotary files were reported to create more dentin damage than other rotary instruments(7).

Recently, ProTaper Next (DentsplyMaillefer) instruments have been introduced that have an off centered rectangular design and progressive and regressive percentage tapers on a single file, which is made from M-Wire technology. Having an off-centered rectangular design decreases the screw effect, dangerous taper lock, and torque on any given file by minimizing the contact between the file and the dentin(8).

The Reciproc and WaveOne files are used in a reciprocal motion that requires special automated devices. Reciproc files are available in different sizes (ie, 25.08, 40.06, and 50.05), whereas WaveOne consists of the sizes 21.06, 25.08, and 40.08. The reciprocating movement relieves stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements and, therefore, reduces

the risk of cyclic fatigue caused by tension and compression. The angles of reciprocating are specific to the design of the particular instruments (9).

Single file endodonticsand reciprocating motion are the two major modifications inmodern endodontics but their bearing on the root canal wall is not fully elucidated.Hence a study was designed which was aimed to compare the incidence of dentinal defects after preparation with reciprocating (Reciproc and WaveOne) and fullsequence rotary (ProTaper Universal and Protaper Next) instruments.

II. Materials and Methods

Extracted human mandibular premolars with straight roots were selected for this study. Teeth with open apices or anatomic irregularities were excluded. All roots were observed in a stereomicroscope under 25xmagnification (Stemi SV6; Zeiss, Jena, Germany) to exclude any external defects or cracks and were discarded if any of these characteristics were found.Mesiodistal and buccolingual radiographs were taken to verify the presence of a single canal. The width of the canal on both angles was measured at 9 mm from the apex. According to these criteria, 100 mandibular premolars were selected. To ensure standardization, the teeth were sectioned under water cooling with a low-speed saw (Isomet; Buehler Ltd, Lake Bluff, IL) 16 mm from the apex. As suggested previously (10), the root was covered with a single layer of aluminium foil and inserted in acrylic resin (Imicryl, Konya, Turkey) set in an acrylic tube. The root was then removed from the acrylic tube, and the aluminium foil suspended from the root surface. A light body silicon-based material (Oranwash; ZhermackSpA, Rovigo, Italy) was used to fill the space created by the foil and to simulate the periodontal ligament, and the root was replaced to the impression material. Twenty teeth were left unprepared as the negative control group, and the remaining 80 teeth were assigned to 1 of 4 root canal shaping groups.

The working length of the canals was determined by inserting a size 10 K- file(VDW, Munich, Germany) into the root canal terminus until the file was just visible through the foramen and subtracting 1 mm from this measurement. A glide path was performed via a size 15 K file (VDW, Munich, Germany). The apical preparation was completed with respective instruments corresponding to size 40.Each instrument was used in 5 canalsand the root canals were irrigated with 1% solution of sodium hypochlorite between each instrument change.A 27-G needle was used for irrigation. Around 12 mL sodium hypochlorite solution was used for each root. After completion of the procedure, canals were rinsed with 2 mL distilled water. All roots were kept moist in distilled water throughout the experimental procedures. A single experienced operator performed all the procedures. The root canal shaping procedures were performed according to the manufacturer's instructions for each instrument system as follows:

1. **Group 1:** For each ProTaper Universal file, Canals were prepared in a crown-down fashion with the aid of an XSMART motor (DentsplyMaillefer) with rotational speed (250 rpm) and the torque limit programmed in the file library of the motor were used. The sequence was as follows: SX, S1, S2, F1, F2, F3, and F4. The first 3 shaping files were used with a brushing motion away from the root concavities before light resistance was encountered, and the last 4 finishing files were used until the working length was reached.
2. **Group 2:**The ProTaper Next files were usedwith the aid of an XSMART motor (DentsplyMaillefer)with rotational speed and the torque limit programmed in the file library of the motor.Thefiles were used in the sequence ProTaper Universal SX followed byProTaper Next X1, X2, X3, and X4. Each file was used with a brushing motion similar to that used with the ProTaper Universal files.
3. **Group 3:** A primary reciprocating WaveOne file with a tip size of 40 and a taper of 0.08 was used in a reciprocating, slow in-and-out pecking motion until reaching the full working length according to the manufacturer's instructions. The flutes of the instrument were cleaned after 3 in-and-out-movements (pecks). Reciprocating motor (VDW Silver; VDW, Munich, Germany) with the manufacturer's configuration setup for wave one files was used.
4. **Group 4:**A R40 Reciproc file with size 40 at the tip and taper of 0.06 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion until reaching the full working length according to the manufacturer's instructions. The flutes of the instrument were cleaned after 3 in-and-out-movements (pecks).

III. Sectioning and microscopic observation

All of the roots were sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex using a low-speed saw (Isomet; Buehler Ltd, Lake Bluff, IL) under water cooling. Digital images of each section were captured at 25x magnification using a digital camera attached to a stereomicroscope (Stemi SV6; Zeiss, Jena, Germany). In each group, a total of 50 slices were blindly examined for cracks. To define crack formation, 2 different categories were made (ie ''no crack'' and ''crack'') to avoid the confusing description of root cracks.

''No crack'' was defined as root dentin without cracks or craze lines either at the internal surface of the root canal wall or the external surface of the root. ''Crack'' was defined as all lines observed on the slice that either extended from the root canal lumen to the dentin or from the outer root surface into the dentin (11).

IV. Statistical Analysis

Results were expressed as the number and percentage of defected roots in each group. A chi-square test was performed to compare the appearance of defective roots between the experimental groups by using the SPSS/PC version 15 (SPSS Inc, Chicago, IL). The level of significance was set at 0.05.

V. Results

No complete fracture was observed in any of the samples tested.Figure 1shows the percentage of roots with defects. Unprepared canals (ie, the control group) showed no roots with defects Figure 2 (A). There was a statistically significant difference between NiTi file groups and the control group, which presented no defects (P< .05). Among the NiTi file groups, the least number of craze lines and partial cracks (‘‘other defects’’) were observed in the WaveOne group, whereas the maximum number of such defects was observed in the rotary ProTaper universal group Figure 2 (B).The Reciproc and WaveOne instruments caused less cracks than the ProTaper and ProTaper Next files and there was statistically significant difference in crack formation between the groups(p<.05).

There was no statistically significant difference between the Reciproc and Waveone group and also between the protaper universal and protaper next groups (P> .05).

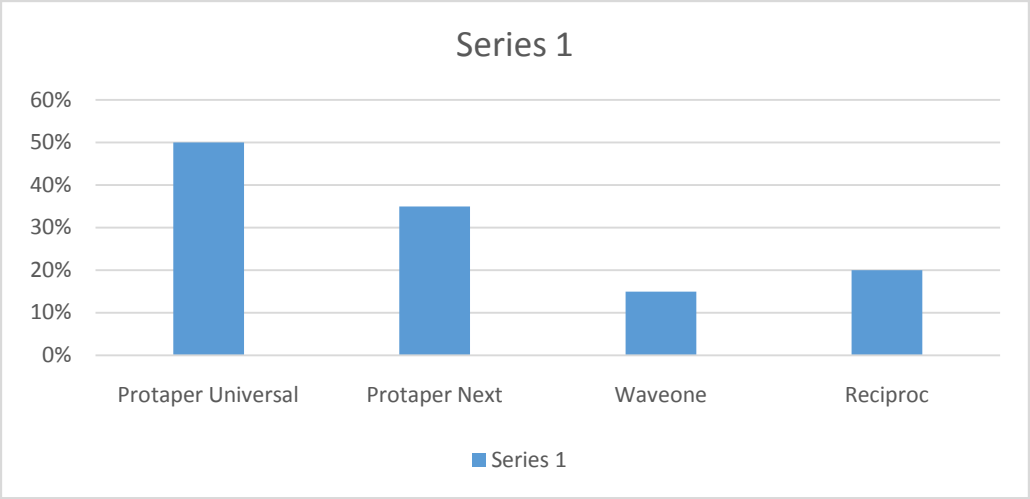
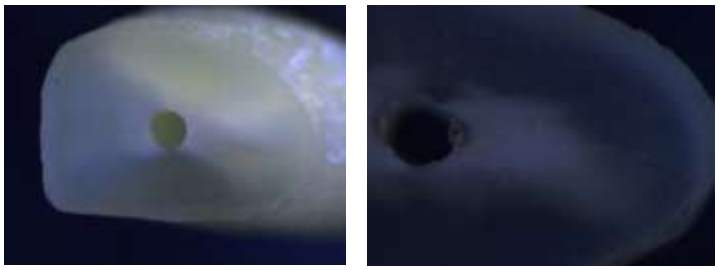


Figure 1



(A) (B)

(A) Cross section at the 6-mm level without anydentinal defects.(B)partial/incomplete crack

VI. Discussion

VRF of endodontically treated teeth is perhaps the most undesirable/frustrating clinical experience. Root canal–treated teeth present with greater probability of VRF. Predisposing factors include the loss of healthy tooth substance as a result of caries or trauma, moisture loss in pulpless teeth, previous cracks in dentin, or loss of alveolar bone support (2). Moreover, previous studies have reported an insignificant difference in the moisture content and mechanical properties of vital and endodontically treated teeth (12). Mostly, VRF is a result of the gradual propagation of tiny cracks in tooth structure and not an immediate effect of root canal therapy. Various canal instrumentation techniques have been found to induce the formation of such cracks, resulting in VRF during sustained function (5,13).

This ex vivo study compares the incidence of dentinal crack formation with reciprocating single-file systems and continuous rotation file systems. The final apical diameter achieved with the 4-instrument system used were similar(ieupto size 40),and this standardisation improved the reliability of the results. The

methodology used was adapted from previous published research(4). Periodontal ligament simulation is important because it acts as a major stress absorber and should influence the outcome of such studies(14). The current study revealed no defects in the control group, and this implies that the methodology adopted did not induce damage. All 4 instrumentation techniques used in this study led to the development of dentinal cracks. Under the present experimental framework, the WaveOne and Reciproc files resulted in significantly less dentinal cracks compared with the continuous rotationalProTaper universal and Protaper Next systems. Active rotating movement results in a high level of stress concentrations in root canal walls that may result in higher incidence of crack formation(15).

Reciprocating motion was found to be more centered in the canal(16), and by repeating the CW and CCW rotation, reciprocating motion allows continuous release of the file when it is engaged in the inner surface of the root canal during the cutting and shaping procedure(17). Furthermore, flexural and torsional stresses acting on the dentin are also reduced as the CCW motion disengages the instrument blades and reduces stresses (15).

WaveOne presented with the least number of dentinal cracks in this study. M-wire technology imparts more flexibility to WaveOne instruments and that might contribute to lesser dentinal cracks in this group (15). Also, the investigated WaveOne files have a noncutting modified tip and a unique cross-sectional design along the length of their active portions (a modified convex triangular cross-section at the tip end and a convex triangular cross-section at the coronal end) (18).

Sectioning could induce damage, but in the present study we speculated that it did not induce such defect because no cracks was found in the control group. However, future studies using advanced methods like optical coherence tomography or infrared thermography will possibly eliminate the sectioning procedure and would be less destructive.

VII. Conclusion

Though the exact duplication of in vivo conditions is difficultwithinthe limitations of this investigation, it could be concluded that dentinal micro cracks are produced irrespective of motion kinematics andsuch an incidence is less with instruments working in reciprocating motion compared with those working in continuous rotation.

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