RESEARCH

Dentinal crack formation after root canal preparation: Rotary versus reciprocal instrumentation

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ABSTRACT

Dentinal crack formation after root canal preparation: Rotary versus reciprocal instrumentation

Background: The aim of this study was to compare the incidence of dentinal crack after instrumentation with full-sequence rotary (ProTaper Universal and ProTaper Next) and reciprocating (Reciproc and WaveOne) files.

Methods: Seventy-five mandibular central incisors were selected and stored in distilled water until use. Fifteen unprepared teeth were served as a negative control group and the remaining 60 teeth were prepared by using full-sequence rotary and reciprocating files. After instrumentation, the teeth were horizontally sectioned at 3 ,6 and 9 mm from the apex with a low-speed saw under water-cooling. All slices were viewed through a stereomicroscope and pictures were taken. The presence of dentinal crack was noted and analyzed by used the chi-square test.

Results: The control group had no dentinal crack. All root canal instrumentation with both rotary and reciprocating files resulted in dentinal crack. ProTaper Universal produced significantly more dentinal crack than the other groups in 3 mm level. ProTaper Next produced significantly more dentinal crack in 6 mm level than the other levels.

Conclusion: All the files used in this study were related to the formation of cracks in the canal walls.

KEYWORDS

Dentinal crack, ProTaper, reciprocal, rotary instrument

ÖZ

Dönme ve resiprokal hareket yapan eğe sistemlerinin kök kanal tedavisi sonrası dentin çatlağı oluşumuna etkisi

Amaç: Bu çalışmanın amacı resiprokal ve dönme hareketi yapan eğe sistemlerinin preparasyon sonrası dentin çatlağı oluşumuna etkilerinin kıyaslanmasıdır.

Gereç ve Yöntemler: 75 adet mandibular santral kesici diş seçilmiş ve distile su içerisinde çalışmada kullanılıncaya kadar muhafaza edilmiştir. 15 adet diş preparasyon yapılmaksızın negatif kontrol grubu olarak ayrılmış, geri kalan 60 diş dönme (ProTaper Universal ve ProTaper Next) ve resiprokal (Reciproc ve WaveOne) hareket yapan sistemler kullanılarak prepare edilmiştir. Sonrasında bütün dişlerden, apekslerinden itibaren 3, 6, 9 mm mesafelerden su soğutması altında düşük hızlı testere ile yatay olarak kesitler alınmıştır. Bütün kesitler stereomikroskop yardımı ile incelenmiş ve görüntüler kaydedilmiştir. Üzerinde çatlak bulunan dişler not edilmiş ve ki-kare testi kullanılarak analiz edilmiştir.

Bulgular: Kontrol grubundaki örneklerin hiçbirinde çatlak yoktu. Prepare edilen diğer gruplarda ise çatlak varlığı tespit edildi. 3 mm'lik kesitlerde PU grubunda diğer gruplara kıyasla daha fazla çatlak tespit edildi. PN grubunun 6 mm'lik kesitinde diğer kesitlerine kıyasla daha fazla çatlak tespit edildi.

Sonuç: Bu çalışmada kullanılan bütün eğe yöntemlerinin kanal duvarlarında çatlak oluşturduğu tespit edilmiştir.

ANAHTAR KELİMELER

Dentin çatlağı, ProTaper, resiprokal, dönen alet

Root canal instrumentation is one of the most important stages in successful root canal treatment. Stainless steel hand files, several rotary nickel titanium (NiTi) file systems have been introduced for the preparation of root canals. NiTi files provide many advantages compared to conventional files. Increased flexibility, and shortened working time are the major advantages of NiTi files.[1,2] Different tip design, taper, and cutting blade configuration of NiTi file systems, stress on the root canal walls may arise[3] and these can result as microcracks or craze lines,[4] because of the repeated stress application by occlusal forces these microcracks and craze lines may develop into vertical root fractures (VRF).[4,5]

VRF is one common complication associated with root canal instrumentation which usually leads to tooth loss.[4,6] Furthermore, some other cofactors that promote VRF have been discussed such as the tooth anatomy,[7] the use of high concentrations of sodium hypochlorite,[8] the placement of prosthetic posts[9,10] and different filling techniques.[11]

ProTaper Universal (PU) rotary files (Dentsply Maillefer, Ballaigues, Switzerland), which have been used for years, have a convex triangular cross-sectional design and various percentage tapers that enable an active cutting motion and the removal of relatively more dentin coronally.[12]

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ProTaper Next (PN) (Dentsply Maillefer) is a later introduced NiTi rotary system manufactured using M-wire NiTi alloy (Sportswire, Langley, OK). The PN system has variable tapers and an off-centered rectangular cross section design and requires working with a rotational movement. This off-centered rectangular cross section design is intended to reduce torsional stress on the instrument (www.tulsadentalspecialities.com).

The new single-file NiTi systems Reciproc (R) (VDW, Munich, Germany) and WaveOne (WO) (Dentsply Maillefer) are able to prepare canals with only one file, thereby requiring less time than rotary full-sequence systems.[13] These files are made of a special NiTi alloy called M-wire.[14] This M-wire alloy provides increased flexibility and improved resistance to cyclic fatigue of the files.[15,16] The reciprocating movement relieves stress on the file[13] and it is conceivable that they could relieve stress on root canal walls as well.[17]

The aim of this investigation was to compare the incidence of dentinal cracks after preparation with full-sequence rotary (PU and PN) and reciprocating (R and WO) files. The null hypothesis was that there would be no differences in crack formation among the groups.

MATERIALS AND METHODS

Seventy-five mandibular central incisors with mature apices and straight root canals (<5°) that had been extracted for periodontal reasons were selected and stored in distilled water until use. Mesiodistal radiographs of the teeth were taken to verify the canal configuration, and only teeth with a single canal were included in the study. The coronal portions of all the teeth were removed by diamond coated bur with water cooling, leaving roots approximately 13 mm in length. All the roots were observed with a stereomicroscope (Novex, Arnhem, The Netherlands) with X12 magnification to detect any preexisting external defects or cracks. Roots with such defects were excluded from the study.

Fifteen teeth were left unprepared and served as negative control, and the remaining 60 teeth (4 experimental groups) were subjected to the procedures described later. The canal length was measured by inserting a size 10 K-file into the canal until the tip of the file became visible at the apical foramen. The distance between the tip of the file and the reference plane was defined as the canal length. The working length (WL) was established by subtracting 1 mm from this length. A glide path was performed via a size 15 K- file. During the experimental procedures, roots were covered with 4 mm x 4 mm gauze and kept moist to avoid drying. A silicon based impression material (Zetaplus putty, Zhermack, Italy) was used for coating the cemental surface of roots to simulate periodontal ligament space. Then, all roots were embedded in acrylic blocks to simulate alveolar bone. The PU, PN, WO and R were used in 4 experimental groups;

Group 1. ***(Control Group, C):*** Fifteen root canals were left unprepared and served as control.

Group 2. ***(ProTaper Universal, PU):*** The root canals were instrumented with PU files at 300 rpm with 2 Ncm tourque (X-Smart Plus; Dentsply, Maillefer, Ballaigues, Switzerland). Each file was used according to the manufacturer's instructions using a gentle in-and-out motion. The instrumentation sequence was SX at half of the WL; S1 and S2 at two thirds of WL; and then F1 and F2 at the WL.

Group 3. ***(ProTaper Next, PN):*** PN files were used to the WL according to the manufacturer's instructions using a gentle in and out brushing motion. The PN files were used in the sequence PU SX and then PN X1 and X2 at a rotational speed of 300 rpm and 2 Ncm torque.

Group 4. ***(WaveOne, WO):*** A WO Primary reciprocating file with a #25 tip was used in a reciprocating in-and-out pecking motion, according to the manufacturer's instructions.

Group 5. ***(Reciproc, R):*** A R25 file was used in a reciprocating slow in and out pecking motion (full WL) according to the manufacturer's instructions.

In PU and PN groups after each file, in WO and R groups after three pecks 2 mL NaOCl was used as irrigant. Each root canal was irrigated with a total of 12 mL of 2.5 % NaOCl.

After instrumentation, the teeth were horizontally sectioned at 3, 6 and 9 mm from the apex with a low-speed saw (Isomet 1000; Buehler, Lake Bluff, IL, USA) under water-cooling. To avoid any artifacts by dehydration, the teeth were kept moist in purified filtered water throughout all experimental procedures. All slices were then viewed through a stereomicroscope (Novex, Arnhem, The Netherlands) at 25X magnification and pictures were taken.

Each specimen was checked by 2 operators and classified into 2 categories: ''no cracks'' and ''cracks.''

1. 'No cracks' was root dentin without any lines or cracks on the external or the internal surface of the root (Figure 1).

2. 'Cracks' was defined if any lines, microcracks, or fractures were present in root dentin (Figure 2).

Chi-square test was used for statistical analysis of differences between the groups at a 95 % confidence level ($P<0.05$).

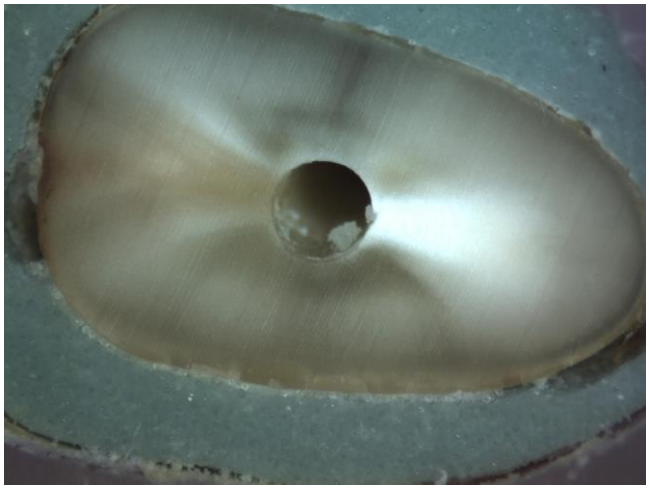

Figure 1.

Cross sectional image showing no crack

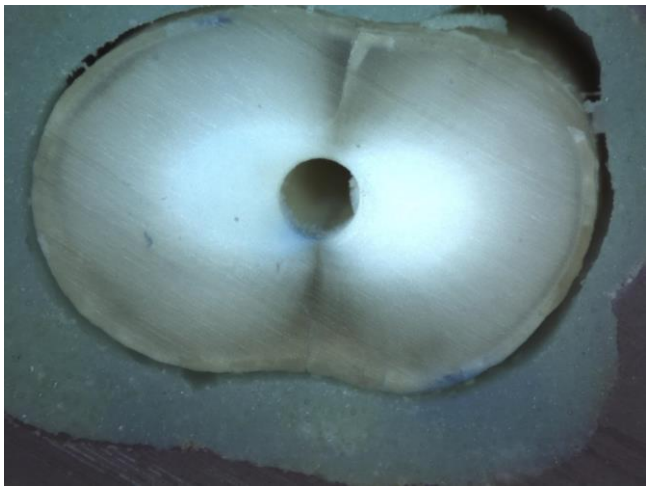

Figure 2.

Cross sectional image showing crack

RESULTS

The quantity of each dentinal crack for each group at different section is shown in Table 1. Control group had no dentinal crack. PU produced significantly more dentinal cracks than control and experimental groups in 3 mm level ($P<0.05$). There was no statistically significant difference among the experimental groups in 6 mm level ($P>0.05$). In 9 mm section, there was no statistically significant difference control group and experimental groups ($P>0.05$). In each experimental group, there was no significant difference at all levels except for PN group ($P>0.05$). The PN group produced significantly more dentinal crack only in the 6 mm level than 3 and 9 mm levels ($P<0.05$).

Table 1.

The quantity of each dentinal crack for each group at different section

Groups (n=15)	3 mm		6 mm		9 mm	
	C	NC	C	NC	C	NC
Control Group (C)	0	15	0	15	0	15
ProTaper Universal Group (PU)	10	5	8	7	4	11
ProTaper Next Group (PN)	3	12	6	9	0	15
WaveOne Group (WO)	4	11	5	10	3	12
Reciproc Group (R)	4	11	8	7	3	12

'C', 'NC' are the acronyms for dentinal crack.

'C' means dentinal crack, 'NC' represents no dentinal crack.

DISCUSSION

The results of the current study revealed that dentinal cracks in all experimental groups occurred independent of the type of files used (rotary systems or reciprocating files). The control group had no dentinal crack. Besides in the apical parts of the canals PU caused significantly more crack formation than the other groups. Previous studies[18-20] have shown that dentin cracks due to mechanical preparation of root canals are inevitable. Ashwinkumar et al.[21] observed that PU rotary files produced the most microcracks at all the 3 levels of the root canals when compared with the other groups (NiTi hand K-files, ProTaper hand files, WO reciprocating files). Conversely, Burklein et al.[22] stated that at the apical level of the canals, reciprocating files (R and WO) caused significantly more incomplete dentinal cracks than full-sequence rotary systems (Mtwo and PU).

Capar et al.[23] investigated the effects of PN, PU and HyFlex files on crack formation in dentin and found that all groups, except the control group, were associated with crack formation. Ustun et al.[24] inspected the dentinal microcrack formations occurred by different preparation techniques in mandibular incisors. They found that all groups showed microcrack formations except for the control group and hand instrumentation group. Karatas et al.[25] compared the incidence of root cracks after root canal instrumentation with the TF Adaptive, WO, PN and PU systems. It was found that except the control group all the experimantal groups caused dentinal microcracks and there was no statistically significant difference amoung the experimental groups. Similary in the present study all the experimental groups were related to the formation of cracks in the canal walls.

Kim et al.[26] found that file design affected apical stress and strain concentrations during instrumentation, which was linked to an increase in dentinal defects and canal deviation. R has an identical S-shaped cross-sectional design with sharp cutting edges whereas PU and W are characterized by a triangular cross section that results in a lower cutting efficiency and less chip space.[13] In addition to all of those, PN has an off-centered rectangular design which decreases the screw effect, dangerous taper lock, and torque on any given file by minimizing the contact between the file and the dentin.[27]

Bier et al.[20] stated that the taper of the files could be a contributing factor in dentinal crack formation. PU F2 file, WO Primary file and R R25 file have the same apical taper (0.08). However, the apical taper of PN X2 file is 0.06. Due to the difference in the taper of the files, it may be that PN caused less dentinal damage than the others in this study, although there was no significant statistical difference amoung experimental groups.

In the present study while WO and PU have the same taper and cross section, the highest amounts of cracks were generated by PU at the apical level. Because of the fact that continuous rotational force and constant torque which is applied by the NiTi rotary file on the root canal walls causes considerably escalated microcrack formation. Furthermore, the reciprocating movement minimizes torsional and flexural stresses and reduces the taper lock within the root canal.[28]

Versluis et al.[29] found that stresses in the middle and coronal thirds were 3 times more than at the apical level. In the present study, the files of experimental groups produced similar numbers of cracks in the 6 and 9 mm sections. The maximum number of cracks was found in the 6 mm section whereas the 9 mm section had the least number of microcrack.

In the present study, bone and periodontal ligament were stimulated using acrylic blocks and silicone impression material. Wilcox et al.[4] reported that teeth were covered with single-layer aluminum paper to stimulate the periodontal ligament, then these samples were embedded into the acrylic resin to stimulate the bone. Although these interventions are insufficient to mimic tooth anatomy and biology,[30] Bortoluzzi et al.[31] stated that imitation of the periodontal ligament is necessary in studies that investigated the formation of cracks.

The teeth were examined under a stereomicroscope and non-cracked teeth were included in the study. After sectioning, there were no cracks or fracture formation in the control group. This is compatible with other studies.[19,20,32] Therefore, that sectioning method does not affect crack formation can be argued.

CONCLUSION

All the files used in the study were related to the formation of cracks in the canal walls. At the apical level PU produced significantly more dentinal cracks compared with the others groups. Hence, the null hypothesis is rejected.

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