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An In Vitro Evaluation of Dentinal Crack Formation by Conventional Hand Filing and Three Different Rotary File Systems

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ABSTRACT

Aim: The aim of this study is to evaluate the incidence of root cracks observed in the canal walls after root canal instrumentation with conventional hand filing and 3 different rotary file systems. Method: A total of hundred mandibular incisors were selected. The teeth were divided into five groups (n=20). Group 1-Unprepared(control group), Group 2-Conventional hand files, Group 3-Self adjusting file, Group 4-Neolix NiTi Rotary files and Group 5-Dentsply ProTaper Universal rotary files are used to prepare canals. Roots are then sectioned 3, 6 & 9 mm from the apex and the cut surfaces were observed under a stereo microscope and presence of cracks were noted. Results: The Chi-square test is performed to compare the appearance of cracked roots between the experimental groups. Instrumentation of root canals with stainless steel hand K- files and SAF did not cause damage but rotary systems such as Neolix NiTi, ProTaper Universal instruments can cause damage to the root dentin resulting in cracks and fractures. Conclusion: All rotary files created microcracks in root dentin, whereas the SAF file and conventional hand files showed no dentinal microcracks.

Keywords: Conventional hand files, Dentsply ProTaper Universal rotary files, Self adjusting file, Microcracks, Neolix NiTi Rotary files.

INTRODUCTION

Vertical root fracture (VRF) in endodontically treated teeth is one of the most common complications of root canal therapy. Several factors include remaining dentinal thickness, force generated by spreader during obturation and endodontic post placement leads to dentinal micro-crack formation have been investigated as major causes of vertical root fracture. Root canals shaping procedure and rotary instrumentation also have the potential to induce crack formation, which leads to complete fracture under functional load. Several factors of nickel titanium (NiTi) files such as different heat treatments, cross-sectional shape and kinematics may influence the generation of cracks. Advances in NiTi instruments and their kinematics allow the possibility to well-shaped root canals.[1]

Rotary nickel-titanium (NiTi) instruments could potentially cause dentinal cracks, which may have the potential to develop into fractures. Cracks after canal instrumentation were detected in horizontal sections cut at different levels along roots or at the apical root

surface. Recently a new generation of NiTi files has been introduced with a variable cross sectional design and a different working motion, which completes canal preparation with only one instrument.[2]

Stress concentration in the root canal can cause canal transportation, straightening and deviation which results in thinner areas of remaining dentin thickness thus leads to increased risk for apical crack formation and later converts to VRF. Several studies that use finite element analysis have shown that rotary file systems used in root canal procedures experience the most stress in curved root canals.[3]

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. 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 cracks4. Several studies have found the highest defect ratio when ProTaper was used, whereas no defect was observed with hand files. It has been shown that root canal filling procedures could also create cracks, observed significantly more dentinal defects (micro-cracks) in teeth that were obturated with spreader than when no spreader was used. Retreatment procedures, biomechanical preparation, and obturation techniques could all lead to dentinal damage in different degrees.[5]

Vertical root fracture was defined by Walton et al, as a devastating episode that has poor long term prognosis eventually requires tooth extraction. There is high prevalence of vertical root fracture in endodontically treated teeth due to presence of dehydrated and less elastic dentin.

Many factors are responsible for microcrack formation in root canal walls. Some of them were different designs, number of files, and kinematics of available NiTi systems. These instrumentation-induced dentinal defects act as trigger points for vertical root fractures. Hence this issue requires in depth scientific investigation and reflection.[16]

MATERIAL AND METHOD

.A total of hundred human mandibular central incisors with mature apices from 40 to 60 year old patients extracted for periodontal reasons were selected and kept in distilled water. Soft tissue and calculus were mechanically removed from root surfaces. Proximal radiographs of the teeth were taken, and only single-rooted teeth with a single straight canal were included in the study. Teeth with fracture lines, open apices, curved roots, root caries, resorbed apices or anatomical irregularities were excluded. The coronal portions of all teeth were removed using an isomet low-speed saw under water cooling, leaving roots approximately 12 mm in length. All the roots were inspected under microscope to detect any pre-existing external defects or cracks. Teeth with such defects were excluded from the study. In all teeth, the canal width near the apex was compatible with a size 10 K-file (Mani, Japan). In all the teeth, apical patency was determined by inserting a size 10 K- file into the root canal until its tip was visible at the apical foramen and the working length (WL) was set 1.0 mm shorter of this measurement. The buccolingual and mesiodistal widths of the canals were measured at 10 mm from the apex on radiographs. The homogeneity of the 5 groups with respect to the canal width at the 10 mm level were assessed by using analysis of variance (P = 1.000). Twenty teeth were left unprepared as the control group. The working lengths were established by subtracting 1 mm from the length of a size 10 K-file inserted into the canal until the tip of the file became visible at the apical foramen.

Root canal preparation

Root canal shaping procedure were performed with four different file techniques (conventional hand files, SAF, Neolix NiTi files, Dentsply ProTaper Universal) according to the manufacturers' instructions of each system with slow pecking motion and light apical pressure. Each instrument was used in 5 canals and operated with a low-torque motor. After each instrument insertion, the teeth were irrigated with 2 ml of 3% sodium hypochlorite (Coltene/Whaledent AG) using a syringe and a 30-G endo irrigation needle single side vent (Transcodent, Kesselort,Germany) place 1 mm from the working length. After completion of the procedure, canals were rinsed with 2 ml distilled water. To avoid any discrepancy by dehydration, all roots were kept moist

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in distilled water throughout the experimental procedures.

A total of 100 extracted teeth were divided into 5 groups.

Group 1 was left untreated and served as a control group.

In Group 2, the BMP was done with Conventional hand files (K- files Mani) sizes 10 to 40 in a circumferential quarter- turn push- pull filing motion, using balance force crown down and step- back 1 mm increments with K- files sizes 45–80, resulting in a preparation with a taper of about 0.05.

In Group 3, the BMP was done by self adjusting file system (SAF) with 25 mm length & 1.5mm diameter. The hand-piece used for the system is RDT. The RDT hand-piece head provides the SAF with a 0.4 mm impact movement and up to 5,000 rpm drive speed required for performing endodontic treatment.

In Group 4, the BMP was done by Neolix NiTi A1 file with 21 mm length used at speed 350-500 rpm and 1.5 N cm torque.

In Group 5, the BMP was done with ProTaper Universal rotary files (Dentsply Maillefer) that were used sequentially from Sx to F3 at the speed of 300 rpm with a torque of 1.5 N cm to prepare the canals.

The Roots were embeded in auto-polymerizing epoxy resin blocks to prevent roots from shrinking because of dehydration.

Microscopic evaluation

The roots were sectioned at 3, 6 and 9 mm from the apex with a low-speed saw under water cooling. (fig.1)

The slices were then view through a stereo microscope (Model: XTL 3400E, Magnification: 25X). (fig.2)

The samples were photographed with a reflex camera (Nikon D90; Nikon Tokyo, Japan) attached to the stereo microscope to determine the presence of micro-cracks. (fig.3)

Assessment of dentinal damage

To avoid confusion, observations were divided into four categories:

(1) no defect (root dentin devoid of any lines or cracks where both the external surface of the root and the internal root canal wall had no defects)

(2) defect (all lines observed on the slice that extended either from the outer surface into the dentin or from the root canal lumen to the dentin)

(3) fracture (line extending from the root canal space to the outer surface of the root)

(4) fracture and defect (where both were seen)

Statistical analysis

Statistical analysis was done with Statistical Package Social Sciences (SPSS version 20, IBM, USA). A cracked root was determined when a crack is found at 1 or more levels. The result is express as the number and percentage of cracked roots in each group. The chi-square test is performed to compare the appearance of cracked roots between the experimental groups.

When compared between the groups, P value for the Chi- square test is lesser than that of 0.05 in apical, middle and cervical third which indicates that there is significant association between the groups at the apical, middle and cervical levels.

When compared within the groups, P value for the Chi- square test is lesser than that of 0.05 which indicates that there is significant association between apical, middle, and cervical thirds for Group 5. Whereas, P value being greater than 0.05 for Group 4 indicates no significant association between their apical, middle and cervical thirds.

No statistics are computed because Group 1, Group 2 and Group 3 are constant.

RESULTS

The unprepared canals (the control group), the HF group and SAF group presented no defects. Defects were found in all NiTi rotary file groups (Neolix NiTi, ProTaper Universal).The percentages of roots with defects in each groups at coronal, middle and apical thirds are shown in tables 1 and graph 1.

In the coronal third section, Group 5 showed maximum number of fracture cases (13) and Group 4 showed lesser number of cases (6). While, Group 3, Group 2 and Group 1 showed no fracture cases (0).

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In the middle third, Group 5 had maximum number of fracture cases (7) while Group 4 showed lesser number of fractures (6). Group 3, Group 2 and Group 1 did not show any fracture cases (0).

In the apical third, Group 4 had maximum number of fracture cases (6) while Group 5, Group 3, Group 2 and Group 1 showed no fracture cases.

However, maximum defects were seen in group 5 (ProTaper Universal) followed by Group 4 (Neolix NiTi). However, no significant difference was detected among group 1, 2, 3 i.e. no defects($p>0.05$)

DISCUSSION

Clinical endodontics encompasses a number of treatment options but perhaps, the most important is treating pulp and root canal systems so that patients can retain their natural teeth in function and esthetics.

The predisposing factors for fracture formation in endodontically treated teeth include:

1. The loss of healthy tooth substance as a result of caries or trauma

2. Moisture loss in pulpless teeth.

3. Previous cracks in dentin.

4. Loss of alveolar bone support.

Bier et al (2009) also suggested that fractures did not occur immediately after canal preparation. However, craze lines occurred in 4%–16%, which may develop into fractures. In this regard, root canal preparation with NiTi rotary systems and every following additional procedure in endodontics can create fractures or craze lines.[7]

Over the last few decades, endodontics has undergone a complete revolution with the introduction of the NiTi alloy for the manufacture of manual instruments initially and then the rotary endodontic instruments. Studies have shown that defects appear on root dentin wall after the initial treatment with NiTi rotary instruments. Tooth type, canal wall thickness, root canal diameter, cross- sectional shape, root canal preparation instruments and preparation methods might all be involved in the increased risk for tooth fracture during and subsequent to endodontic therapy.

Therefore, the aim of this study was to evaluate the defects in root dentin after root canal preparation. Samples were stored in distilled water. This medium was previously recommended for investigation of human dentin (Saber SE and Schafer E. 2016) as it causes the smallest changes in dentin over time.[17]

Crown portion removal of all the specimens was done using low- speed saw with water coolant. It eliminates some variables, such as the anatomy of the coronal area and access to the root canals allowing a more reliable comparison between endodontic treatment techniques.

In all the teeth, canal patency was established with size 10 K- file (Mani). Thereafter, canals were prepared with Neolix NiTi, ProTaper Universal rotary (Dentsply,Maillefer) using a torque control motor (NSK Endomate DT, Dentsply Maillefer). Each canal was irrigated with 2 ml of 3% solution of sodium hypochlorite between each instrumentation. After completion of the procedure, canals were rinsed with 2 ml of distilled water. All roots were kept moist in distilled water throughout the procedure.

Conventional hand files had been used for BMP in many previous studies. K- files up to size 40 were used followed by step- back preparation till size 80. Although the use of hand files is more time consuming, it results in cleaner canal walls in the apical third as compared with the engine- driven NiTi rotary systems.

We used crown- down technique of instrumentation for the rotary group as it is said to provide increased cutting efficiency and faster instrumentation and prevents the binding and the separation of the instrument in the canal. It also facilitates adequate irrigation and obturation of the canals.

Yoldas et al (2012) in their study stated that the tip design of rotary instruments, cross- sectional geometry, constant or variable pitch, and taper, flute form could all be related to crack formations in the root dentin.[5]

In the present study, we have used three rotary systems as follows:

1. SAF system

2. Neolix NiTi system

3. ProTaper Universal system.

The Self Adjusting System (ReDent, Raanana, Israel) a hollow file designed as an elastically compressible,

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thin-walled pointed cylinder, composed of a thin nickel-titanium lattice.

The SAF is available in three standard lengths: 21 mm, 25 mm and 31 mm and two diameters: 1.5 and 2 mm. The file is surface treated by sandblasting, enabling it to file dentin from the canal's interior surface. It has Self abrasive surface. The handpiece used for the system is RDT. The RDT (KaVo type connector RDT3;ReDent) handpiece head provides the SAF with a 0.4 mm impact movement and up to 5,000 rpm drive speed required for performing endodontic treatment. The irrigation system used is VATEA system. The VATEA is an irrigation system with an integral pump that can be adjusted to different flow rates (1-10 ml/min). The SAF's hollow design allows for continuous irrigation of the root canal through its lumen. The endodontic file's movement within the canal helps to continuously exchange the irrigation solution throughout the procedure by its agitation.

The Neolix NiTi (France) is EDM [Electric Discharge Machining] file. It is single file system. Available as C1, GPS(#15), A1(#20,#25,#40). C1 available in 15 mm length while GPS & A1 available in both 21 mm and 25 mm lengths. It is suitable for complex, J-shaped and S-shaped canals. It's has high resistance for fracture, having high cutting efficiency, efficient to remove debris. It has complete curettage till apex.

The ProTaper system (Dentsply/Maillefer, Ballaigues, Switzerland) introduced in 2000 was used for instrumentation of the teeth in the Rotary Group IV. ProTaper Universal system consists of a set of six instruments (three shaping files – Sx, S1 and S2 for the crown- down procedure and three finishing files – F1, F2, and F3 for apical shaping) with progressive taper. In 2006, two new files, F4 and F5 were added for apical finishing. It allows the operator to achieve cleaning and shaping of the canal using less number of files. It has been claimed that progressive taper prevents a "taper- lock" situation as seen in other systems. Instruments are triangular cross- sectionally, reducing the contact area between the file and dentin. They have modified guided tips, varying tip diameters, varying helical angles and pitches and available in 21 mm lengths. The ProTaper system has shaping files with partially active tips while the finishing files have noncutting tips as stated in the study done by Sanghavi and Mistry.[16]

Berutti et al (2003) reported in their study that ProTaper Universal system is shown to have a lower risk of instrument separation when compared to other system due to its triangular file design. It has been suggested that the variable taper design of ProTaper lowers the screw- in effect causing less apical transportation and has better canal centering ability.[17]

In our study, rotary ProTaper F3 file has been used which has a larger apical taper of 0.09 which could explain the higher incidence of damage observed in this group as compared to any other group which is on similar lines with the study done by Rahman et al, Barreto et al and Liu et al (2013)[10] stated that ProTaper Universal finishing files (F1, F2, and F3) have more taper (0.07, 0.08 and 0.09 respectively) compared to the other rotary systems, thus explaining the higher incidence of cracks observed in the ProTaper Universal group which correlates with the findings of the current study. Furthermore, Shemesh et al (2009)[7] and Liu et al (2013)[2] in their study when compared the incidence of dentinal defects using different Ni–Ti rotary files observed that ProTaper Universal resulted in the maximum number of defects which is in accordance with this study.[17]

In permanent mandibular central incisor teeth, root canals are comparatively wider and oval than other permanent teeth. Circular canals showed lower and more uniform stress distributions than oval canals in which greater stresses were recorded at the cervical and middle thirds leading to higher risks of fractures, which were shown in a study by Versluis et al that was conducted on permanent mandibular incisors using ProTaper Universal rotary system; thus, this explains the cause of increased fracture formation in the coronal thirds of our study.

CONCLUSION

Within the limitations of the current study, with exception of the control group, conventional hand files and self adjusting files (SAF) group, rest of all groups showed microcrack formation. Even though this in vitro study did not reflect the clinical settings, we can conclude that maximum number of cracks seen at coronal third of root dentin followed by middle and less cracks in apical third of root dentin.

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Fig.1: Specimen sectioned horizontally at 3 mm, 6 mm and 9 mm from apex

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(a) Front view (b) Side view

Fig 2: Stereo Microscope (Model: XTL 3400E, Magnification: 25X)

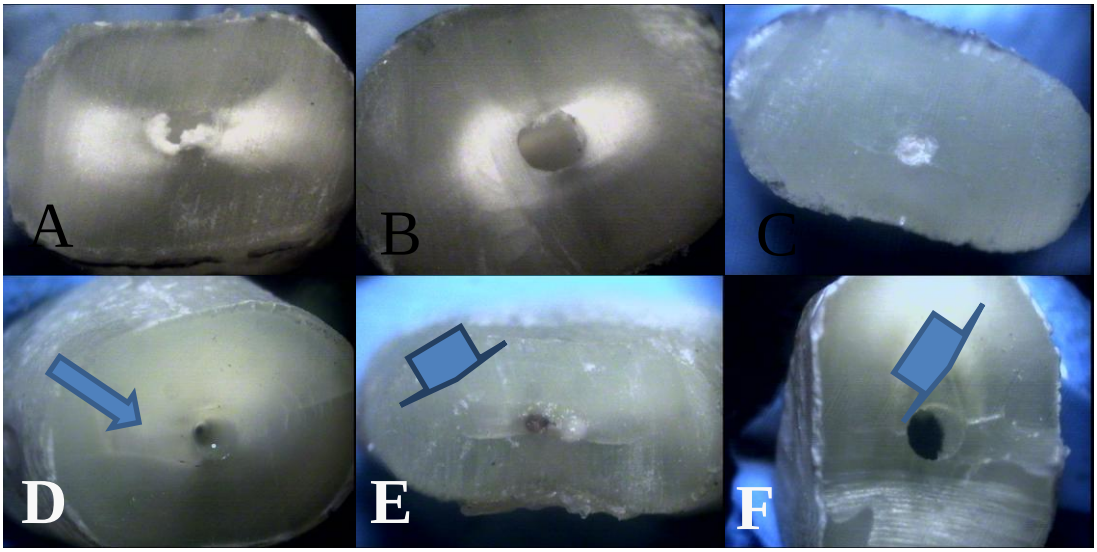

Fig.3: Root sections showing no defects (A, B, C) and arrow showing defects (D, E, F)

Table 1: Comparison of defects among all study groups at different levels.

Groups	Number of cracks			Total no. of roots (%)	P value
	3 mm	6 mm	9 mm		
Control (unprepared)	0(0.0)	0(0.0)	0(0.0)	20(100)	

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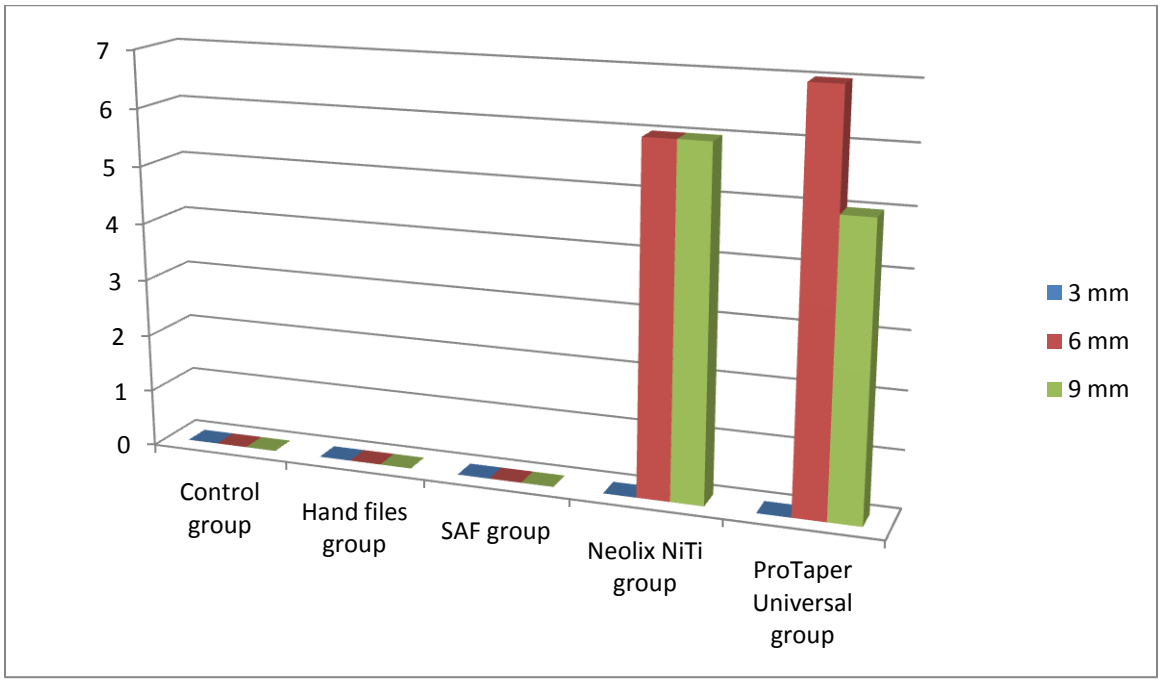
Conventional hand files	0(0.0)	0(0.0)	0(0.0)	20(100)	0.001*
Self adjusting files	0(0.0)	0(0.0)	0(0.0)	20(100)	
Neolix NiTi files	0(0.0)	6(30)	6(30)	20(100)	
ProTaper universal rotary files	0(0.0)	7(35)	13(65)	20(100)	

* indicates significant at p<0.05

Graph 1: Comparison of defects among all study groups.



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