Evaluation of Dentinal Crack Formation by ProTaper Next, HyFlex CM and Wave One Reciprocating File Systems at the Apical and Middle Third of Root in Mandibular Molars - An In-Vitro Scanning Electron Microscope Analysis

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ABSTRACT

BACKGROUND

Advances in root canal instruments have led to lesser frequency of dentinal crack formation. Not many studies have been reported in literature that compare crack formation using instruments based on control memory (CM) and M wire technology. The study intended to evaluate and compare the prevalence of dentinal cracks formed by ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), HyFlex CM (Coltene, Whaldent) and Wave One (Dentsply, Maillefer) reciprocating file systems at the apical and middle third of the mesiobuccal root canal of mandibular molars under scanning electron microscope (SEM).

METHODS

Forty-five extracted sound human mandibular molars were decoronated and mesial roots were retained followed by root canal instrumentation using ProTaper Next, HyFlex CM and WaveOne reciprocating files. Roots were then sectioned perpendicular to the long axis of teeth and viewed under scanning electron microscope to detect the presence of cracks.

RESULTS

ProTaper Next system produced more cracks compared with HyFlex and Wave One ($P < 0.05$) but there was no statistically significant difference between all the three groups. All the file systems showed more incidences of cracks in the apical third compared to middle third.

CONCLUSIONS

All the NiTi instruments produced cracks and the highest incidence of cracks was seen in the apical third compared to middle third region.

KEY WORDS

Dentinal Cracks, HyFlex CM, ProTaper Next, Root Canal, Wave One

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BACKGROUND

One of the critical stages for successful root canal treatment is proper canal shaping. It provides ample space for effective disinfection and filling of root canal materials and medicaments. This is mainly accomplished by instrumenting the dentin of root canal walls with endodontic files manufactured under varied processes with different designs.¹ Although rotary files exhibit enormous advantages over hand files, they exert a larger stress on the root canal walls than manual hand files. Studies have reported that the significantly greater frequency of rotations of rotary files in the canal that facilitate shaping may in turn cause crack formation. Rotary files generate much more stress on the dentine above their normal tensile strength. Thus when the tensile stress in the root canal walls exceeds the flexural strength of dentin, dentinal cracks and root fractures may result.²

The superior results of NiTi instruments can be attributed to its specific geometric design feature, increased flexibility and superelasticity of the NiTi alloy.³ As NiTi rotary instruments vary widely with tip designs, tapers and cutting blades it may lead to stress concentration in dentinal walls and enhanced crack formation.² It was found that improvement in the metallurgy of the alloy to increase the flexibility should be highly beneficial, which in turn renders NiTi instruments of greater taper better ability to negotiate curved canals and reduction of iatrogenic errors while maintaining the original path. Recently, super elastic NiTi alloys have been developed with special heat treatment processes so that these NiTi alloys have a stable martensite phase in different clinical conditions. The various heat-treated NiTi alloys include M-wire, R-phase, and CM wire.³

ProTaper Next utilises M-wire which is essentially a thermally processed NiTi alloy that is stable at body temperature. It was developed via thermo-mechanical processing and contains three crystalline phases: deformed and micro-twinned martensite, R-phase, and austenite. The presence of the martensite phase improves the fatigue resistance of the file. It also exhibits improved cyclic fatigue resistance.³ HyFlex CM utilises Control Memory (CM) wires which have a lower nickel content (52% wt.), as compared to other NiTi files. The special thermo-mechanical treatment renders extreme flexibility and improved shape memory effect. The CM wire has a stable martensite phase because the austenite finishing temperature is above the working temperature. Because of its unique manufacturing process, it has increased resistance to cyclic fatigue as they do not rebound to their original shape.³

Considering the increased amount of crack formation by rotary file systems, new file systems with reciprocating motion were introduced. The Wave One NiTi File System basically works in a reverse "balanced force" cutting motion. It is driven by a pre-programmed motor, which moves the files in a back and forth "reciprocating" motion. The M-Wire technology also improves the fracture resistance, increasing the flexibility and cyclic fatigue resistance of the instruments.⁴ The mesiobuccal canal of mandibular molars may have a significant curvature in the buccolingual plane which could result in higher stress on the instrument and root canal wall thus leading to higher risk of crack formation.⁵

Although several studies have been done regarding crack formation, studies comparing crack formation using NiTi

instruments with M wire and CM wire technology at the middle and apical third of mandibular molars are scarce in literature.

Hence the objective of this in-vitro study was to evaluate and compare the prevalence of dentinal crack formation by three file systems- ProTaper Next, HyFlex CM and WaveOne reciprocating file systems at two different sites-the apical and middle third of the mesiobuccal root canal of mandibular molars using scanning electron microscope (SEM). The null hypothesis stated that there is no significant difference in the dentinal microcrack formation when the three different file systems are used at both apical and middle third of the root.

METHODS

This in-vitro study was done among extracted mandibular molars. The study was approved by the Ethical committee for Postgraduate Studies, Dayananda Sagar College of Dental Sciences, Bangalore, and was conducted for a period of six months from February 2016 to August 2016. Forty-five permanent mandibular molars extracted for various reasons were collected from the Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Bangalore. Intact mandibular molars with fully formed apex were included. Teeth with fracture, open apices, calcified canals, internal resorption and with a history of previous restoration or endodontic treatment were excluded. Infection control protocols as well as the entire procedure followed occupational safety and health administration (OSHA) and the centre for disease control and prevention (CDC) recommendations and guidelines.

Armamentarium included Airtor handpiece (NSK), Straight hand piece (NSK), Diamond disc, Burs – Endo access and Endo Z bur, K-files (Mani), ProTaper Next files (Dentsply), HyFlex CM files (Coltene-Whaledent), Wave One Reciprocating files (Dentsply), Xsmart and Xsmart Plus (Dentsply), 0.1 % Sodium hypochlorite (DEOR), Distilled water, 17 % EDTA solution (Smear off –DEOR), RC Help (Prime Dental), Luer lock syringe, Aluminium foil, Polysiloxane impression material (Aquasil, Dentsply), Self-cure acrylic (DPI-RR Cold cure) and scanning electron microscope.

- 45 permanent molars were cleaned and decoronated 2 mm above cemento-enamel junction (CEJ) with a diamond disc to ensure straight line access and to provide a reference plane.
- Distal roots were sectioned and discarded; mesial roots pre-checked for existing cracks at magnification of 12.5 X under operating microscopes.
- Mesial roots were wrapped with aluminium foil, separating medium was applied before embedding it in the self-cure acrylic.
- The space created by the foil was replaced with polysiloxane impression material to simulate periodontal ligament.
- Patency of apical foramen was established by inserting a size 10 K file till it was visible at the apical foramen.
- Working length 1mm from the apex was calculated for each tooth and recorded. The teeth were instrumented with 15 K file up to the working length.

The samples were randomly divided into the following 3 groups for cleaning and shaping:

Groups	Instrument Used	Method of Instrumentation
Group 1 (N = 5)	ProTaper Next (PTN) rotary Ni-Ti files	Instrumentation done with 17/0.04 rotary file followed by 25/0.06 file using Xsmart endomotor with a torque 4 - 5.2Ncm and speed of 300 rpm.
Group 2 (N = 5)	HyFlex CM rotary Ni-Ti files	Instrumentation done with 20/0.04 followed by 25/0.04 file using Xsmart endo motor with a torque 2-3Ncm and speed of 500 rpm.
Group 3 (N = 5)	WaveOne reciprocating rotary Ni-Ti files	Instrumentation done with 25/0.08 file only using Xsmart plus endo motor with a torque 2-3 Ncm and speed

Table 1. Distribution of Study Samples Based on the Method of Instrumentation

Each instrument was used with a pecking motion for three times per canal. Throughout the preparation the canals were irrigated with 1ml of 1 % sodium hypochlorite. The instruments were lubricated using RC help. After the instruments were used for three roots, they were substituted with new ones to avoid any deceptive effect of worn files. Final irrigation was done with 2 ml 17 % EDTA and 2 ml distilled water. The samples were then stored in distilled water. After preparing the root canal, all the roots were sectioned perpendicular to the long axis of the teeth at 3 mm and 6 mm from the apex using low speed saw with water cooling. Slices were then viewed under SEM (Zeiss sigma VP, Zeiss Oberkochen, Germany) to detect the presence of cracks. In this study, crack was defined as, those lines seen on the slice of teeth that extended from the root canal lumen to dentin.⁶ The data was spread into Microsoft excel sheet and it was analysed statistically using SPSS 15 software. Descriptive statistics and inferential statistics involving Fischer exact test were employed. A P value of less than 0.05 was considered to be statistically significant.

RESULTS

The frequency of crack formation at the apical and middle third of mandibular molars using the three different instruments is shown in Table 1.

- Apical third region: Highest occurrence of crack formation was observed at the apical third with ProTaper next in 9 (60 %) of the samples. It was found to be least with WaveOne which when used crack formation was found in 6 (40 %) samples, followed by HyFlex CM with a crack formation in 7 (46 %) specimens. (Table 1, Figure 1)
- Middle third region: Highest occurrence of crack formation was observed at the middle third with ProTaper Next 8 (54 %) of the samples. It was found to be least with WaveOne which when used crack formation was found in 5 (33 %), followed by HyFlex CM with a crack formation in 6 (40 %) specimens. (Table 1, Figure 2)

As the p value is found to be not significant with the presence of crack at apical and middle third using the three different instruments, the null hypothesis is accepted.

Files	Cracks at Apical Third	P Value	Cracks at Middle Third	P Value
ProTaper Next	9(60)	0.284*	8 (54)	0.278*
HyFlex CM	7(46)		6(40)	
Wave One	6(40)		3(33)	

Table 2. Crack Formation at Apical and Middle Third Using Different File Systems

*Fischer exact test

Figure 1. Cracks at Apical Third Using Different File Systems

Figure 2. Cracks at Middle Third Using Different File Systems

DISCUSSION

The present study aimed to compare the dentinal crack formation in the apical and middle third of mesiobuccal root canal of mandibular molars after the instrumentation with ProTaper Next, HyFlex CM and WaveOne reciprocating files. As many studies have not included the three instruments, comparisons are given wherever possible. The degree and extent of root canal defects after instrumentation depend on tip design, cross sectional geometry, taper, pitch and flute form of the instrument. The specific anatomy of root canal, post preparation dentinal wall thickness and canal diameter are other contributing factors related to stress concentration.⁷

The ProTaper Next (PTN) system was selected for this study because it is one of the commonly used file systems in the field of endodontics. In the present study, the highest percentage of crack formation was seen in this group with 60 % at apical and 54 % in the middle third. However, according to results these were no statistically significant differences in the presence of cracks between the groups. The offset mass of rotation of PTN file system which generates a mechanical

wave of motion similar to the oscillation was noted along a sinusoidal wave. This results in cutting off a bigger envelope of motion as compared to a similar sized file with a symmetrical mass and axis of rotation. The manufacturing material properties of ProTaper Next might be one of the reasons for the high incidence of cracks.⁸ The taper of the instrument is a contributing factor in inducing dentinal microcracks. All tapered nickel titanium file systems available till date have shown an incidence of 18 - 60 % in inducing dentinal microcracks compared to the stainless-steel files having a taper of 2 %. The ProTaper Next files used in the present study had an apical taper of 6 %. Both X1 and X2 files of ProTaper Next utilizes both an increasing or decreasing percentage tapered design on a single file whereas the PTN X3, X4, and X5 files have a fixed taper from D1-D3, than a decreasing percentage tapered design over the rest of their active portions.⁹

Manufacturing of instruments with greater taper resulted in increased stiffness of rotary instruments and less fatigue resistance and increased risk of crack formation. In this study, apical preparation till size 25 with different taper of these systems was followed. The apical enlargement was made same for all groups which allowed comparisons with the instrument taper. Because of the increased core diameter added with progressive and regressive tapers on a single file, instrumentation might have resulted in a wider preparation of the canal walls.¹⁰ It is reported that in the apical root dentin, higher stress concentrations are generated by stiffer file designs, that in turn could pose greater risk of crack initiation.¹¹

The cutting action of ProTaper Next is mainly due to the off centred rectangular K shaped blade design which results in a two-point contact with the canal walls.⁹ This instrument is characterized by active rotating movement which is capable of producing a mechanical wave of motion travelling along the active length of the file. This leads to a higher level of stress concentrations in root canal walls which can also lead to crack formation.¹² ProTaper Next files have a higher torque value of 4 - 5.2 Ncm compared to other file systems (2 - 3Ncm).¹³ The higher crack formation in the group of high torque settings may be related to greater stress on the dentinal surface. In the present study, HyFlex CM files showed 46 % presence of cracks in the apical third and 40 % in the middle third.

These control memory files show a martensite active crystal structure which when heated transforms temporarily into austenitic phase, this enables the file to regain its original shape before cooling down. During autoclaving, shape and strength of the files with straightened spirals can be restored. The files are capable of regaining their shape after sterilization and reuse. This property of CM wire technology helps in more flexibility and easy movement of files through the root canal especially in the curved roots.¹⁴ The less taper (4 %) and core diameter with increased flexibility of HyFlex CM would have led to a lesser number of cracks than ProTaper Next files. The triangular cross-sectional geometry of HyFlex instrument produces only a single point contact with the root canal walls during instrumentation. The better cutting efficiency and decreased rate of transmission of torsional forces onto the dentin might have contributed to lesser number of cracks in HyFlex.¹⁴ In this study least incidence of cracks was seen with WaveOne reciprocating file system with 33 % in middle third and 40 % in apical third.

The higher flexibility and fracture resistance of the instrument is attributed to the M wire technology. The WaveOne file system works in a reverse "balanced force" cutting motion which produces less cracks. The counterclockwise motion disengages the instrument blades and reduces stress. Thus, repetitive clockwise and counterclockwise rotations result in reduced flexural and torsional force on dentin.¹⁵ The reciprocal motion can enhance debris transportation towards the apex that can increase the torsional forces leading to higher incidence of cracks in the apical third (40%) than middle third (33%). The modified triangular cross section causes lower cutting efficiency and less chip space.¹⁶

WaveOne showed better results among others which can be attributed to the reciprocating motion, reverse cutting action, modified convex triangular cross section at the tip end and a convex triangular cross section at the coronal end. This specific design improves the overall flexibility of the instrument. The tips of the instruments are modified to follow canal curvature precisely. More safety is offered by the variable pitch flutes along the length of the instrument.¹⁷ Even though, WaveOne reciprocating files had a taper of 8 % they showed lesser number of cracks because of the reciprocating motion which compensates for the increased taper. HyFlex CM files had the least taper of 4 % and showed lesser cracks than ProTaper Next files.

In each group, cracks at the apical third of the root canal were higher than the middle third. The reduced dentine thickness in the apical region of the root has resulted in more number of cracks, compared to middle region. Hence, all the NiTi instruments tested in the present study produced cracks irrespective of the manufacturing process, cross section, type of rotation, taper, torque, speed, and other instrument characteristics. In the present study, ProTaper Next showed more number of cracks than HyFlex CM and the results are in line with another study reported in literature.¹⁸ On comparing ProTaper Next and WaveOne, the latter showed lesser number of cracks which was found to be similar to that in another study.¹⁹ The frequency of crack formation follows the order ProTaper Next > HyFlex CM > Wave One reciprocating files. Among each group, instrumentation in the apical third produced more cracks than the middle third. But, the presence of cracks between the experimental groups was not statistically significant.

The results obtained in this study, suggest that root canal instrumentation with NiTi rotary files can potentially cause cracks in the apical and middle third of root dentin regardless of the file design. The clinical relevance of the results is that, when an external force is applied, the incomplete cracks in dentine changes into high stress concentration areas, from which the crack propagates gradually to the canal surface. These cracks have the potential to propagate further resulting in gross tissue loss eventually. The newer innovation of M wire and CM wire technology and advances produced in the instrument rotation, taper, speed, torque, cross section has resulted in lesser number of cracks.

CONCLUSIONS

Within the limitations of the study, the following conclusions can be drawn:

- Root canal instrumentation with all the three NiTi rotary file systems tested in this study produced cracks in the apical and middle third of the root canal.
- The percentage of occurrence of cracks were in the order ProTaper Next > HyFlex CM > Wave One reciprocating files. However, the difference was not found to be statistically significant.
- Instrumentation in the apical third produced more cracks than in the middle third amongst all the groups tested in the study.
- Further research should focus on the long-term clinical performance of the tested instruments to give reliable evidence for endodontists.

Limitations

This study is not free from limitations. Dental age of the patient and other factors affecting stress distribution inside the root canal might have confounded the results. Hence further studies are recommended to give insight in this aspect.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.

Financial or other competing interests: None.

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