



EVALUATION OF DENTINAL CRACKS AFTER ROOT CANAL INSTRUMENTATION WITH FOUR DIFFERENT ROTARY NITI FILE SYSTEMS: PROTAPER UNIVERSAL, PROTAPER NEXT, HYFLEX-CM AND WAVE-ONE

Endodontics

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ABSTRACT

Introduction: Aim of the study was to observe and compare the dentinal cracks caused by instrumentation of root canal with rotary Protaper Universal, Protaper Next, Hyflex CM and WaveOne systems.

Methods: One hundred ten mandibular premolars with mature apex and straight single canals ($<10^\circ$) were selected and stored in distilled water. Root canals were divided into control (uninstrumented) group ($n=10$), 4 experimental groups ($n=25$) instrumented with Protaper Universal, Protaper Next, Hyflex CM, and WaveOne. Root canals were stained with 1% methylene blue dye and horizontal sectioning was done at 3mm, 6mm and 9mm from apex and viewed under 30-fold magnification of stereomicroscope and digital images were captured using camera attached to it to determine presence of dentinal cracks. Data was analysed using chi-square test.

Results: The control group showed no cracks. All experimental groups showed presence of dentinal cracks. There were significant difference between Protaper Universal group and Control, Hyflex CM and WaveOne group ($p<0.05$) with Protaper universal group showing maximum cracks and Hyflex CM and Wave One showing least number of cracks. No significant difference was found between Protaper Next, Hyflex CM and WaveOne group ($p>0.05$).

Conclusion: Within limitations of the study, it can be concluded that Protaper Universal, Protaper Next, Hyflex CM and WaveOne systems results in dentinal crack formation after instrumentation in roots canals.

KEYWORDS

Cracks, M-wire, Ni-Ti, Controlled memory.

INTRODUCTION

Successful endodontic treatment depends upon triad of proper diagnosis, thorough biomechanical preparation and 3-D obturation of root canal system.^[1] The main mechanical objective is complete and centered incorporation of the original canals into prepared shape and to retain as much cervical and radicular dentin as possible so as not to weaken the root structure, thereby preventing fractures.^[2] During biomechanical preparation, instrument contact create momentary stress concentration in dentin,^[3] resulting in cracks, craze lines^[4,5,6] propagating to vertical root fracture (VRF).^[4,7] VRF leads to endodontic treatment failure and tooth extraction.^[6] Technological advancement in rotary NiTi instruments has led to easier, faster and better root canal shaping. Difference in design features of NiTi files such as core diameter, cross-sectional shape, rake angle, flute depth and metallurgy may influence generation of cracks.^[8] ProTaper Universal rotary files (Dentsply) are made from conventional NiTi wire, have convex triangular cross-section in their active portion and progressively increasing taper in shaping files that enables active cutting motion and removal of relatively more dentin coronally.^[9,10]

HyFlex CM, controlled memory NiTi files have a symmetrical cross-section, manufactured through a special thermomechanical process, contain slightly lower Nickel content as compared to conventional NiTi controlling the memory of files, making them extremely flexible. These are up to 300% more resistant to cyclic fatigue.^[11]

M-Wire Technology is another recent advancement seen in Protaper Next and Wave One systems which involves drawing the raw wire under specific tension and heat treatment. ProTaper Next (Dentsply) files have an off-centered rectangular design and progressive and regressive percentage tapers on a single file. M-wire technology improves the resistance to cyclic fatigue by almost 400%.^[9]

The Wave One (Dentsply) is single-file system, used on pre-set clockwise-anticlockwise angles in reciprocating endomotor in a balanced force like manner. It consists of 3 single-use files: small

(21/6%), primary (25/8%) for majority of the canals, and large (40/8%) for larger canals.^[12]

The goal of the present in-vitro study is to observe and compare the dentinal cracks in roots after preparation with different Ni-Ti rotary file systems manufactured with different technologies using stereomicroscope in order to find the best file system for root canal preparation.

MATERIAL AND METHODOLOGY

Extracted human mandibular premolars with straight single roots were selected for the study. Teeth with open apices or anatomic irregularities were excluded. All roots were observed in a stereomicroscope under 10X magnification to exclude teeth with any external defects or cracks. Mesiodistal and buccolingual radiographs were taken to verify the presence of a single canal and width of the canal on both angles was measured at 9 mm from the apex. 110 roots with comparable canal widths were finally selected and stored in distilled water throughout the study. Decoronation of selected teeth perpendicular to their long axis using a diamond-coated disc was done under water cooling, leaving approximately 15 mm root length. All roots were covered with aluminium foil, embedded in autopolymerizing acrylic resin, and periodontal ligament simulation was performed using vinyl polysiloxane impression material after removal of foil.

TOOTH PREPARATION

Ten teeth were left unprepared and served as the control group (GROUP I). The remaining 100 teeth were randomly divided into 4 experimental groups of 25 teeth each. Canal patency was established with a size 10 K-file and biomechanical preparation was done till 20-K file. Thereafter, root canal preparation was performed according to manufacturer's guidelines:

GROUP II (Protaper Universal):

Canals were prepared in crown down fashion using SX, S1, S2, F1, F2 files at 250 rpm according to the library settings programmed in endomotor in gentle in-out motion.

GROUP III (Protaper Next):

Canals were prepared in sequence SX, X1(17/0.4), X2(25/0.06) at 300 rpm, 2Ncm in gentle in-out motion.

GROUP IV (Hyflex CM):

Canals were prepared in sequence 25/0.08,20/0.04,25/0.04 at 500 rpm, 2.5Ncm in gentle in-out motion.

GROUP V (WaveOne):

Canals were prepared with primary file 25/0.08 in a reciprocating, slow in-and-out pecking motion until reaching the full working length using reciprocating endomotor (Orikam) (30°/ 150°).

Recapitulation was done using 20-K file in between instrument change. The root canals were irrigated with 3% sodium hypochlorite after each instrument change using syringe and 30G needle. A total of 12 mL 3% sodium hypochlorite was used in each canal and final rinsing with 5 ml distilled water was done.

Sectioning And Microscopic Examination:

All root canals were stained with 1% methylene blue dye, washed and sectioned perpendicular to the long axis at 3, 6 and 9 mm from apex using a low-speed diamond disc under water cooling. Sections were viewed under stereomicroscope and digital images of each section were captured at x30 magnification using a digital camera attached to stereomicroscope to determine the presence of dentinal cracks. The cracks were classified depending on the following criteria:

Score 0 : Root dentin devoid of any lines or cracks.

Score 1 : An incomplete crack extending from the canal wall into dentin without reaching the outer surface or a line extending from outer surface into dentin but not reaching canal lumen.

Score 2 : A complete crack extending from root canal wall to outer surface of the root.

Statistical Analysis

Statistical analysis was done using SPSS version 16. The data was tabulated as number and percentage of cracks in each group. The association of cracks with various groups was done using Chi-square test. The level of significance for the present study was fixed at p<0.05.

RESULTS

A complete fracture was observed in apical third of Protaper Universal group. Figure 1 shows the percentage of roots with cracks. Control group showed no cracks. There was a statistical significant difference between Protaper Universal group and Control, Hyflex CM, WaveOne group (p < .05). Among the NiTi file groups, the least number of cracks were observed in the WaveOne group and Hyflex CM, whereas maximum number was observed in the ProTaper Universal group. No significant differences were noted between the WaveOne, Hyflex CM and ProtaperNext group (p>0.05)

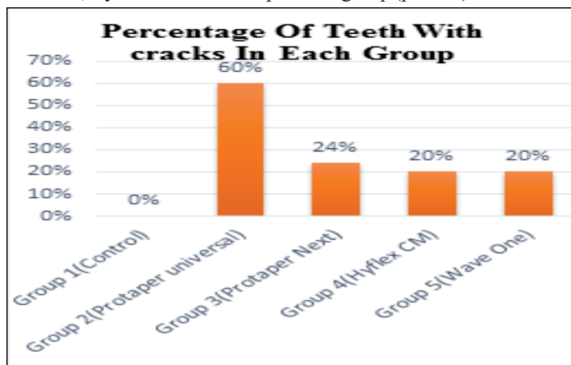


Figure 1: Percentage Of Teeth With Cracks In Each Group

Table 1: Absolute Number Of Cracks At Different Levels In Each Group And Total Cracked Roots Per Group

	3mm	6mm	9mm	Total cracked roots per group
Control (Group I)	0(0) ^a	0(0) ^a	0(0) ^{a,b}	0(0) ^a
Protaper Universal (Group II)	3(12) ^a	5(20) ^a	7(28) ^b	15(60) ^b
Protaper Next (Group III)	3(12) ^a	2(8) ^a	1(4) ^{a,b}	6(24) ^{a,b}

Hyflex Cm(Group IV)	3(12) ^a	2(8) ^a	0(0) ^a	5(20) ^a
Wave One(Group V)	5(20) ^a	0(0) ^a	0(0) ^a	5(20) ^a
p-value	0.187	0.100	<0.001	0.001

DISCUSSION

Root canal preparation using endodontic files is often associated with the formation of some dentinal cracks.¹³¹ These cracks may propagate into VRF, which is perhaps the most undesirable experience for a clinician.¹³¹ Even in VRF absence, mere presence of cracks can compromise the outcome of endodontic treatment. Dentinal cracks occur when tensile strength of dentin is exceeded by tensile stresses while instrumentation.¹⁶¹ More the root dentin is removed while preparation, the more likely is the presence of root fracture, as speculated by Wilcox et al.¹⁴⁴ A fracture could communicate in between adjacent sections of canal as concluded by Onnink et al.¹⁵¹

In this study, all rotary systems resulted in crack formation while control group didn't show any cracks. Instrumented roots with Protaper Universal, ProTaper Next, Hyflex CM and WaveOne rotary files, showed the incidence of cracks as 60%, 24%, 20% and 20% of total roots respectively.

The major number of cracks were observed in apical sections for all the tested instruments except for Protaper Universal, which is in agreement with previous studies.^{164,17,181} Protaper Universal shaping files S1,S2 have progressively increasing taper design which increases stiffness and facilitates active cutting motion and remove relatively more dentin in coronal third and hence, more cracks.¹⁹¹ The maximal stress concentration occur in apical third of root because of successive instrumentation or of lower capability of thinner, more fragile apical dentin to withstand these stresses.¹⁷¹ Using an initial instrument with greater taper and size may explain why more cracks occurred at 3mm level. Preparing canals without performing a wide pathway with smaller hand files or path finder files may result in more cracks at 3mm level.

ProTaper Universal group was the only group where complete crack was noted at apical third. In Wave One group; single file was used for canal preparation, in Protaper Next and Hyflex CM group; three files were used while in ProTaper Universal group- five files were used. Finishing and manipulating the root canal with more files might explain why ProTaper Universal caused more cracks than other system. It was supported by Liu et al study in which there were more dentinal cracks in Protaper Universal group as compared to single file systems.²⁰¹ Taper of instrument is directly proportional to amount of dentin removed, compromising the root which is more likely to get dentinal cracks, as confirmed by Kesim et al.²¹¹ Protaper Universal F2 file has greater apical taper of 0.08 which might have resulted in more complete dentinal cracks.¹⁴¹ Liu et al, observed 50% cracks in roots instrumented with Protaper in accordance to our study.²⁰¹ More cracks in Protaper Universal group are due to more amount of material in core design, more increasing and decreasing taper on single file, making it strategically less flexible, triangular cross-section resulting in less space for collection of dentin chips, thus generating stresses on root wall.⁹¹

Karatas et al observed that Protaper Next causes less dentinal cracks at apical section than Protaper Universal and Wave One. It is in accordance with our study, where Wave One showed more incomplete apical cracks, and Protaper Universal showed more complete cracks than Protaper Next and Hyflex CM group. The apical taper for Protaper Next X2 file is less i.e. 0.6 and hence, less crack formation than Protaper Universal F2 and Wave One primary file which has taper of 0.08.²²¹ Also, less cracks might be contributed to M-wire technology of Protaper Next.²³¹ The off centered rectangular design of Protaper Next files generates a swaggering motion, which decreases the screw-in effect, dangerous taper lock and torque by minimising contact between the file and dentin and hence, reduced cracks.⁹¹

In our study, cracks caused by Hyflex CM is 20%. Reason for less number of cracks may be due to its 300% more resistance to cyclic fatigue. This controlled memory metallurgy makes it highly flexible but without the shape memory. A study done by Capar et al compared dentinal crack produced by ProTaper Universal, ProTaper Next and Hyflex CM and concluded that cracks were present in 28% of roots prepared with Hyflex CM and ProTaper Next whereas the ProTaper Universal showed 56% of cracks.⁹¹ The increased number of cracks in their study might be due to use of teeth with different root canal anatomy and also because of the preparation to larger apical size i.e. 40/.04. Peters OA et al stated that increased rotational speed is

associated with increased cutting efficiency.^[24] Because of extended fatigue resistance,^[25] the recommended speed of Hyflex CM has been increased to 500rpm and this increased speed lead to reduced number of cracks in Hyflex CM group.^[9]

Wave One file system showed cracks in 20% of instrumented roots. This result is coherent with the study done by **Kansal R et al**^[31] in which Wave One and Protaper F2 files in reciprocating motion produced significantly less cracks as compared to conventional rotational Protaper technique. This might be due to reciprocating motion which is more centered in the canal^[26], and by repeating clockwise and counter-clockwise rotation, it allows for continuous release of the file when it gets engaged on inner surface of canal during preparation.^[27] Furthermore, flexural and torsional stresses acting on the dentin gets reduced as the counter-clockwise motion disengages the blades of file.^[28]

Reciprocating files produce significantly more incomplete cracks than full sequence rotary files as speculated by **Burklein et al**. It is in accordance to our study as more cracks are evident in apical third than other groups.^[29] Wave One has a taper of 0.08. When shaping with only single file of larger taper as in Wave One Primary file, the instrument and root canal are subjected to significant stresses, which may be the reason of more incomplete cracks at apical third in Wave One group.^[29] Manufacturing alloy of instrument is more important factor than its motion in determining the damaging potential of single file instrument as stated by **Nasr et al**.^[30] In their study, Wave One system produces less cracks than Protaper F2 system. It might be attributed to the M-wire technology which makes it more flexible.^[28]

Dentinal cracks might be induced by the sectioning but the study conducted by **Kansal R, Capar ID, and Karatas E et al** reported that sawing action could not result in dentinal cracks, because no cracks were found in the control group.^[3,9,22] Similar findings were present in our study, with no influence of sectioning on crack formation. Also, to avoid any false positive results, instrumented roots were stained with methylene blue dye before sectioning. Hence, the dye only stained the cracks actually produced by instrumentation and not by sectioning. Closed environment system i.e acrylic moulds and polyvinylsiloxane impression material were used to simulate bone and periodontal ligament respectively, to mimic clinical conditions.^[3,7,22] At a depth of 500 µm from the lumen, 6% NaOCl has a greater effect on dentin microhardness than 3% NaOCl. Therefore, it is advisable not to use higher concentrations of NaOCl, so as not to alter the physical properties of dentin—and jeopardize the tooth. Hence, 3% Sodium hypochlorite was used in our study.^[31]

The results obtained concludes that instrumentation with NiTi rotary files can potentially cause cracks on the root surface regardless of the file system used. Newer advancements like M-wire technology and Controlled memory wire results in relatively less cracks than conventional Ni-Ti. So, it would be most beneficial for us to choose a file system that causes minimal or no cracks. Overall, the discrepancy in results can be explained by the differences in size between sample teeth, methodological design, different sectioning levels, periodontal ligament simulation, and different types and sizes of instruments, which precludes a direct comparison of the results of the present study with those reported in the related literature.

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