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Comparative Evaluation of root micro cracks by different rotary and reciprocating endodontic file systems

Dr. Pratik Mavani[1], Dr. Madhu Pujar[2], Dr. Veerendra uppin[3],
Dr. Hemant Vagarali[4], Dr. Chetan Patil[5], Dr. Viraj Yalagi[6]

Abstract:
Aim: *The aim of this study was to evaluate and compare the incidence of root microcracks observed at apical root surface and within canal wall after canal preparations with different rotary and reciprocating files.*
Materials and methods: *Ninety single rooted teeth were selected and divided into 6 groups of 15 each. Group 1 served as a control in which no treatment was performed. Teeth in Group 2, 3, 4, 5 and 6 were instrumented with ProTaper universal system, Mtwo, K3XF, ProTaper Next system respectively in rotary motion and WaveOne system in reciprocating motion. All roots were sectioned perpendicular to the long axis at 2 and 4mm from the apex and were then observed under a stereomicroscope. The absence/presence of cracks was recorded, and the data were analyzed with Fischer exact test. The significance level was set at p=.05.*
Results: *The ProTaper Next and WaveOne groups showed lesser incidence of cracks as compared to K3XF, Mtwo and ProTaper Universal groups (P < .05).*
Conclusion: *Within the limitations of this in vitro study, all of the instrumentation systems used in this study created microcracks in root dentin.*
Keywords: *root microcracks, rotary files, reciprocating files, ProTaper Next systems and WaveOne reciprocating system.*

I. Introduction

A primary objective of chemomechanical root canal preparations includes preservation of the course of canals and cleaning of the entire root canal system. Over the last 2 decades various NiTi rotary and reciprocating instruments have been introduced, each with new design and instrumentation concepts to perform easier, faster and better root canal therapy. Root canals prepared by NiTi instruments have an edge over the traditional hand files in terms of fewer aberrations such as the ledge & zip formations, canal transportations & perforations. [1] These superior results are attributed to the increased flexibility & superelasticity of the NiTi alloy & specific geometric design feature of each instrument.

However, instrumentation with rotary NiTi instruments having active cutting edges & larger taper produce significant forces on root dentin during instrumentation & leads to root dentinal defects or apical root microcracks which have potential to develop into root fracture, thus deteriorating the root integrity and reducing long term prognosis of endodontically treated teeth.[2-10]

The basic principle of biomechanics indicates that the crack propagation occurs under repeated loads and leads to catastrophic root fracture. It is still unknown whether even minor dentinal defects may lead to root fractures; therefore currently the consensus is that such defects should be prevented. [10] The other factors leading to weakening of root and promoting root fracture include, use of high concentrations of sodium hypochlorite, loss of tissue, dehydration of dentin, tooth anatomy, placement of prosthetic posts and different obturation techniques.[2,3,9]

ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) is a successor of ProTaper universal file system (Dentsply Maillefer, Ballaigues, Switzerland), which is gold standard in endodontics since many years. ProTaper Universal files have been studied extensively, in its tendency to induce dentinal damage in form of root microcracks and were reported to create more dentinal damage because of larger taper and convex triangular cross-section leading to increased dentin removal than other files.[11] ProTaper Next has three unique design features including variable taper, off-centered rectangular cross section and M-Wire NiTi material.[11]

There are no data in the literature on the comparative evaluation of different rotary NiTi Files Mtwo, ProTaper, K3XF, ProTaper Next and reciprocating file WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) on incidence of root microcracks. Thus, the purpose of this present study was to evaluate and compare the incidence of root microcracks observed in the apical root surface and within canal wall after root canal shaping performed with these files.

II. Materials and methods

Ninety single rooted teeth with root canal curvature less than 20^0 that had been extracted for reasons unrelated to this study were selected and kept in purified filtered water until use. The External root surface was inspected under stereomicroscope at 20x to exclude teeth with any external defects or cracks. Radiographs were taken from buccolingual and mesiodistal angles. Width of the canal on both angles was measured at 5 mm from the apex and teeth with comparable widths were selected for further procedures.

Six groups were formed of 15 teeth each. To ensure standardization, the teeth were sectioned under water cooling with low-speed saw at 16 mm from the apex. The roots were covered with a single layer of aluminium foil and embedded in acrylic resin block, followed by removal of root from block and replacement of aluminium foil by light body silicone-based material to simulate the periodontal ligament.

Group 1 served as the negative control; wherein no treatment was performed.

All teeth in Group 2,3,4,5 and 6 were accessed coronally with a diamond bur. The working length of teeth was determined by inserting size 10 K-type file (Mani, Tochigi, Japan) into root canal terminus and substracting 0.5 mm from this measurement. A glide path was prepared with a size 15 K-type file. All canals were then enlarged up to size 20 K-type file.

Group 2 was prepared with ProTaper universal rotary instrument at 300 rpm in pecking motions to prepare the canals to full WL with a low speed right torque controlled motor upto master apical file F2, which is comparable with a size 25/.08. One set of instrument were used for the preparation of only 4 canals. After instrumentation of each canal the file was inspected under the operating microscope to exclude any deformations or defects. Each canal was irrigated with 2ml 3% sodium hypochlorite between each instrument by using a syringe and a NaviTip irrigation needle (NaviTip 31ga; Ultradent, South Jordan, UT) placed at 1mm from the WL. A total of 16ml NaOCl was used for each root.

Group 3 was prepared in a similar method and with the same irrigation protocol as group 2; Mtwo rotary instruments were used, in a sequence of 10/.04, 15/.05 and 20/.06 upto master apical file 25/.06.

Group 4 was prepared in a similar method as above group; only K3XF rotary instruments were used in a crown down approach with the sequence of 25/.10 and 25/.08 for coronal shaping followed by 25/.04 upto WL and then master apical file 25/.06 was used.

Group 5 was prepared with ProTaper Next(PTN) rotary File in the sequence of path files P1, P2 and then shaping files X1 17/.04 and X2 25/.06 as master apical file.

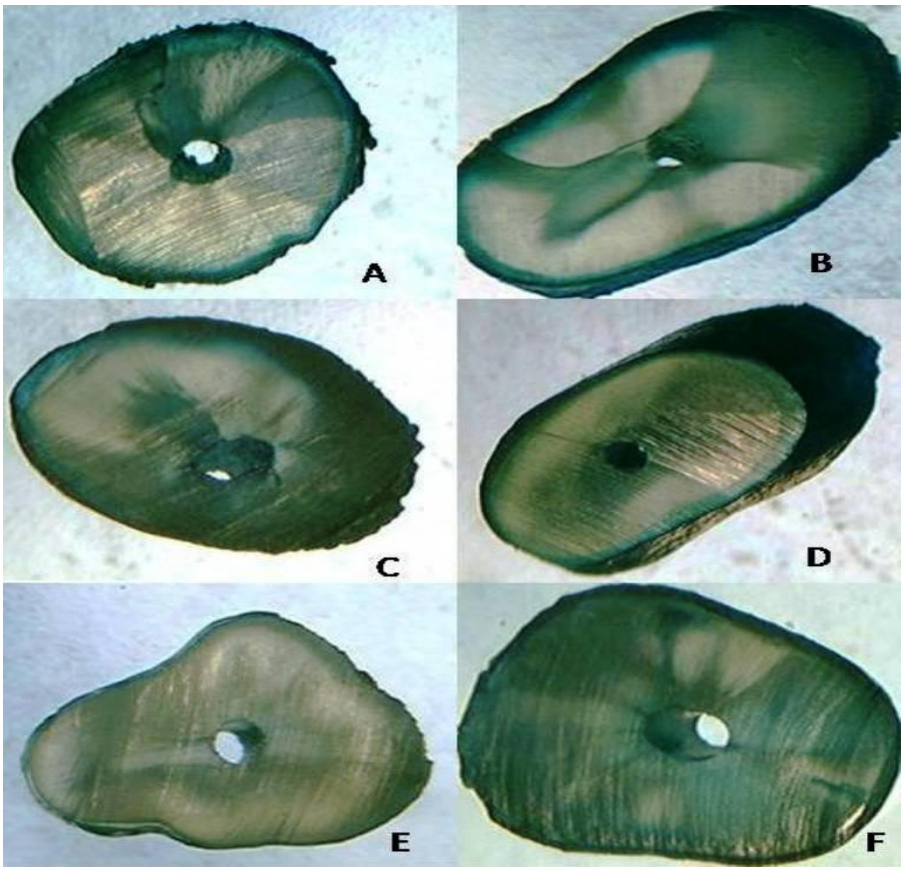
Group 6 was prepared with WaveOne reciprocating instruments in sequence of small file 20/.06 upto WL followed by primary file 25/.08 as master apical file.

Following preparation the root apices of all samples were stained with 1% methylene blue dye to simplify the crack detection.

III. Sectioning and microscopic examination

All roots were sectioned perpendicular to the long axis at 2 and 4 mm from the apex using low-speed saw under water cooling. Individual sections were examined under stereomicroscope at 20x magnification. Digital images of each section were captured at 20x magnification using digital camera attached to stereomicroscope.

To define crack formation, 2 different scoring criteria were made. ‘‘No defect’’ was defined as root dentin devoid of any craze lines or micro cracks either at the external surface of the root or at the internal surface of the root canal wall. ‘‘Defect’’ was defined if any craze lines, micro cracks, or fractures were present in root dentin or extending to outer root surface.



Images A & B shows microcracks at 2mm & 4mm section in ProTaper group, images C &D shows microcracks at 2mm & 4mm sections in Mtwo group, image E shows microcrack in K3XF group and image F shows microcrack in ProTaper Next group

IV. Statistical analysis

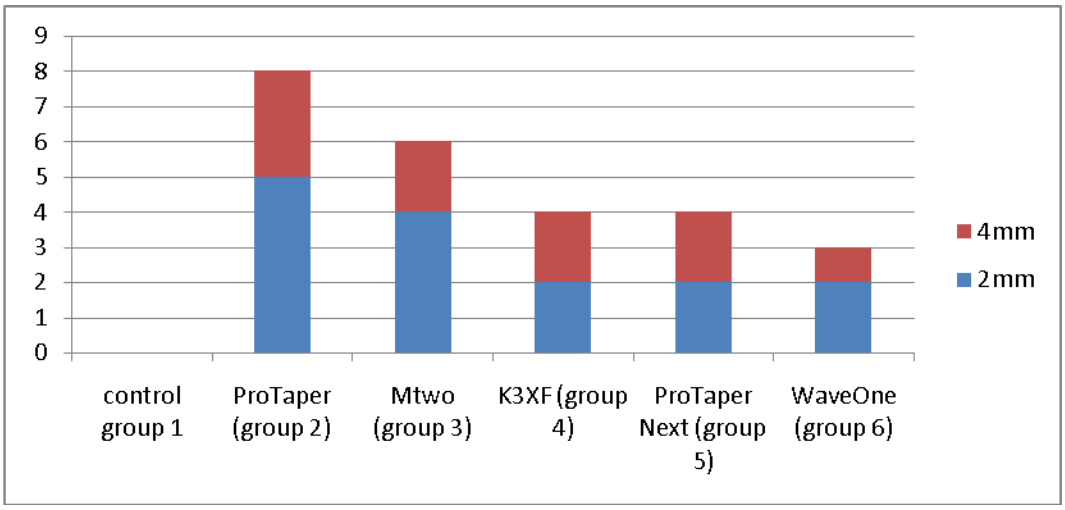
The results were expressed as the number and percentage of cracked roots in each group. The data was analyzed with a fisher exact test. The testing was performed at the 95% confidence level (p=.05).

V. Results

The unprepared canals (the control group) presented no defects. Defects were found in all NiTi rotary and wave one reciprocating files Groups. No statistical difference ($p<0.05$) between PTN and WaveOne groups was observed when compared with control group. Statistically significant difference ($p>0.05$) was observed when Mtwo, ProTaper and K3XF groups were compared to control group.

Group	N	Microcracks at different levels		Total (%)
		2mm	4mm	
Control group	15	0	0	0
ProTaper (group 2)	15	5	3	8 (53%)
Mtwo (group 3)	15	4	2	6 (40%)
K3XF (group 4)	15	3	2	5 (34%)
ProTaper Next (group 5)	15	3	1	4 (26%)
WaveOne (group 6)	15	2	1	3 (20%)

Table 1 Depicts Microcracks at 2mm and 4mm level in all groups along with total percentage of cracks in individual groups



Graph: Total number of cracked teeth at different levels with different instrumentation techniques

VI. Discussion

In this in vitro study, all teeth were inspected with a microscope and periapical radiographs for the presence of pre-instrumentation cracks or fracture. But, ruling out the presence of dentinal cracks before start of the experiment is impossible because some of these cracks could be internal and may not visible on the external root surface. The control group however showed no cracks which implied that sectioning method did not induced microcracks. It may be concluded that the microcracks seen were as a result of the preparation procedures with nickel titanium rotary and reciprocating files.

ProTaper universal files (53%) and Mtwo (40%) caused significantly more cracks than ProTaper Next (26%) and WaveOne files (20%). The lowest defect number was seen in the reciprocating and ProTaper Next group. ProTaper (53%), K3XF (34%) and Mtwo (40%) group showed comparatively higher incidence of micro cracks (depicted in table 1). Moreover, ProTaper (image A and B) and Mtwo(image D) were the only groups where complete cracks running from internal canal wall to external wall were noted. The results obtained in this study were similar to obtained by Capar et al. [11] who concluded that ProTaper Next and Hyflex instruments caused less microcracks than ProTaper universal system. More incidence of root microcracks (graph 1) were observed in apical 2mm section suggesting maximal stress concentration in apical third of root canals by rotary instrumentation during canal preparation.

The different design features of ProTaper Next include Offset cross-sectional design and M-wire NiTi technology as compared to ProTaper Universal files. The offset cross sectional design provides rectangular cross-section which in turn generates swaggering motion with two point contact at a time and thus decreasing the screwing effect and dangerous taper lock. Previous studies reported that endodontic instruments manufactured with M-wire alloy and controlled memory NiTi wire have more flexibility than those made from conventional NiTi wire.[11,12] The increased flexibility of PTN files manufactured by M-wire alloy exerts lesser force on root canal walls during shaping and thus causes lesser damage to root canal wall.

The ProTaper universal files and Mtwo files have active rotating movement resulting in high levels of stress concentration in root canal walls.[17] Furthermore progressively greater taper of ProTaper files resulted in more coronal dentin removal and resulted in significantly more cracks than K3XF files. K3XF files are manufactured in R-Phase heat treatment which provides it increased flexibility hence, it was proposed that less pressure might be required in advancing the file apically, resulting in lesser stress concentration on dentinal walls and less defects [16] but, results depicted no statistical differences among ProTaper Universal, Mtwo and K3XF groups. Liu et al. [18] reported cracks in 25% of roots instrumented with ProTaper. Hin et al. [9] reported that ProTaper and Mtwo files caused cracks in 35% and 25% of roots instrumented with respective instruments.

In the present study, reciprocating WaveOne file created lesser incidence of root cracks as compared to multiple rotary files system. Reciprocating motion is similar to balanced force technique which minimizes torsional and flexural stresses [15]. Alternating engaging and disengaging of canal walls in reciprocating motion might have lead to lesser stress concentration on canal walls and caused least incidence of root microcracks compared to other groups in the study. Moreover, WaveOne instrument is manufactured with M-wire, which is a more flexible variant of the NiTi alloy. Kansal et al. [12] conducted a similar study and found that when ProTaper F2 and WaveOne files were used in reciprocating motion induced lesser dentinal damage as compared to

ProTaper F2 file used in rotary motion. Liu et al. [8] found that when Reciproc was used in reciprocating motion less cracks (5%) were found as compared to ProTaper universal files (50%) used in full sequence rotary motion.

Bürklein et al. [13] Stated that reciprocating single file created more defects than protaper and Mtwo files used in full rotary sequence. The reason stated by author was that as single file was in reciprocating system used till working length there would be more stress on canal walls. Furthermore, Bürklein et al. [13] did the apical enlargement directly with Reciproc R40 files (40/0.08) and did not use methods to simulate periodontal ligament which could have attributed to more defects. The instruments used in the present study as master apical files were of smaller sizes (Primary WaveOne file, ProTaper F2) as compared to Bürklein et al. [13]

Files used in this study were used at varying recommended speed and torque which cannot be standardized for all files. The use of different speed and torque settings for each files system could be a limitation of the present study. Also it was difficult to standardize the downward force used during each instrumentation. Furthermore, teeth with only straight root canals were selected without anatomic complexities which did not reproduce true clinical presentation. In some teeth microcracks might have been present pre-operatively which cannot be completely eliminated. However, further studies using other methods like optical coherence tomography or infrared thermography will eliminate the sectioning procedure and thus would be less destructive. De-Deus et al. [14] reported that micro-CT image technology was accurate and is a nondestructive method that allows the assessment of specimens before instrumentation.

VII. Conclusion

Instrumentation of root canals with ProTaper, Mtwo, K3XF, WaveOne and ProTaper Next could cause damage to root canal dentin. WaveOne and ProTaper Next have tendency to cause less microcracks compared to other files.

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