ORIGINAL RESEARCH

Comparative Evaluation of ProTaper Gold, TruNatomy, and XP-endo Shaper Instruments on Dentinal Microcrack Formation: Scanning Electron Microscope Study

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Abstract

Aim: The aim of this study was to compare dentinal crack formation in root canal walls after instrumentation with TruNatomy (TN), XP-endo Shaper (XP), and ProTaper Gold (PTG) files under a scanning electron microscope (SEM).

Materials and methods: A total of 24 single-rooted teeth were selected. Teeth with any detectable fractures or cracks, calcifications, or previous root canal procedures were excluded. The teeth were randomly divided into three experimental groups ($n = 8$) as follows: Group A: TN, Group B: PTG, Group C: XP. Following root canal procedures, irrigation with water was used to section the roots at 3, 6, and 9 mm from the apex. To check for cracks, the pieces were examined under an SEM at a magnification of 100× in all directions. The data were analyzed using the Chi-square test.

Results: ProTaper Gold produced a greater number of cracks than TN and XP files. There was a statistically significant difference in microcracks produced by PTG, XP-endo, and TN at coronal and apical levels ($p = 0.001$), while at middle level it was non-significant.

Conclusion: All files produced dentin cracks, however, PTG produced the highest number of cracks, followed by TN and XP.

Keywords: Dentin, Electron scanning microscopy, Endodontics, Nickel–titanium alloy, Root canal.

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Introduction

The removal of unexpurgated debris material, eradication of microorganisms, and a thorough three-dimensional obturation are all essential to the success of endodontic therapy.[1] After undergoing root canal therapy, vertical root fractures are a frequent complication that usually require tooth extraction.[2,3]

The root fracture could have been carried on by a microcrack or craze line that develops as a result of recurrent stress from occlusal challenges.[4] With the exception of S-Apex rotary files, teeth prepared with a number of nickel–titanium (NiTi) rotary tools showed dentinal damage (microcracks).[5] In comparison to hand files, which had no defects, they observed that ProTaper files had the highest defect ratio. It has been demonstrated that restorative methods for root canals may potentially cause cracks. According to Yoldas et al. and Burklein et al., compared with root canals that were produced using manual K files, those that used rotational NiTi instruments showed cracks.[3,6] Shemesh et al. observed that teeth with spreader use had significantly greater dentinal defects (microcracks) than teeth without spreader use.[7] In fact, dentinal injury may occur in varied degrees as a result of retreatment techniques, biomechanical preparation, and obturation methods.[4,8]

Several manufacturers have developed and put out numerous new NiTi rotary instruments over the past few decades. These technologies are favored by the majority of practitioners due to advantages like time savings and increased cutting efficiency. Additionally, there is still debate over some of the features of NiTi rotary systems, including their capacity for cleaning, increased stress, and failure to adequately clean oval canals.[9,10] Regardless of the method or kinematics employed, root canal instrumentation with continuous rotation and reciprocating motion has been documented to resulting in dentinal microcracks. In addition, Kim et al. revealed a possible link between the incidence of vertical root fractures and the design of NiTi instruments.[4] They concluded that apical stress and strain concentrations during root canal instrumentation were influenced by file design.

ProTaper Gold (PTG) files have recently been introduced with improved metallurgical properties like high austenite finish temperatures and 2-stage specific transformation behavior. The PTG systems use the same rotational motion and settings as ProTaper Universal and include five finishing files (F1, F2, F3, F4 and F5) and three shaping files (SX, S1, and S2). All of these files have triangular cross sections and gradual tapers. Due to its superior metallurgy and resulting higher flexibility, PTG files have proven to be more resistant to cyclic fatigue than PTU files.[8]

The XP-endo Shaper (XP), a different recently introduced file system, makes use of a rotatable NiTi snake-shaped instrument.

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Table 1: Microcracks in root canal at coronal, middle, apical region

					95% Confidence interval for mean	
At the coronal level	*N*	*Mean*	*Std. deviation*	*Std. error*	*Lower bound*	*Upper bound*	*p-value*
XP-endo	8	0.3750	0.51755	0.18298	−0.0577	0.8077	0.001*
TruNatomy	8	0.3750	0.51755	0.18298	−0.0577	0.8077	
ProTaper Gold	8	1.3750	0.51755	0.18298	0.9423	1.8077	
Total	24	0.7083	0.69025	0.14090	0.4169	0.9998	
					95% Confidence interval for mean	
At the middle level	*N*	*Mean*	*Std. deviation*	*Std. error*	*Lower bound*	*Upper bound*	*p-value*
XP-endo	8	0.1250	0.35355	0.12500	−0.1706	0.4206	0.800
TruNatomy	8	0.2500	0.46291	0.16366	−0.1370	0.6370	
ProTaper Gold	8	0.2500	0.46291	0.16366	−0.1370	0.6370	
Total	24	0.2083	0.41485	0.08468	0.0332	0.3835	
					95% Confidence interval for mean	
At the apical level	*N*	*Mean*	*Std. deviation*	*Std. error*	*Lower bound*	*Upper bound*	*p-value*
XP-endo	8	0.6250	0.74402	0.26305	0.0030	1.2470	0.022*
TruNatomy	8	1.2500	0.46291	0.16366	0.8630	1.6370	
ProTaper Gold	8	1.5000	0.53452	0.18898	1.0531	1.9469	
Total	24	1.1250	0.67967	0.13874	0.8380	1.4120	

*Statistically significant ($p < 0.05$, Analysis of Variance)

After cooling, the file taper 0.01 originally entered the M phase. According to the structural memory of the A phase, the taper moves to 0.04 when exposed to body temperature (35°C). The XP produces a final minimum canal preparation of 30/0.04 with just one instrument. The possibility of dentin microcracks is supposedly reduced by the manufacturer's claim that XP exerts less strain on the dentin walls. The XP is especially compatible with canal defects and exhibits a great resilience to cyclic fatigue.[9]

There are three sizes of the freshly developed TruNatomy (TN) heat-treated NiTi instruments (TRN): small; size 20, 0.04 taper, prime; size 26, 0.04 taper, and medium; size 36, 0.03 taper. Due to specific heat treatment and design, the TRN instrument exhibits a slide shaping characteristic that allows for a greater debridement area and is more flexible and fatigue resistant.[11]

Numerous nonclinical studies have demonstrated, after sectioning with the aid of microscopy, that various NiTi file systems have distinctive designs, alloys, and kinematics that lead to microcracks during root canal preparation techniques. As far as we know, no studies have been conducted on the frequency with which the XP system produces dentinal microcracks. This study compared the effects of using PTG, XP, and TN files on the risk of developing dentinal defects using SEM.

Materials and Methods

A total of 24 single-rooted, single-canal teeth that had just undergone extraction were collected. The only teeth included in the study had apical foramen that were no larger than size #15 K files. The study did not include teeth with an open apex, root caries, canal calcification, external surface cracks, internal or external root resorption. After cleaning the teeth with an ultrasonic scaler, the teeth were disinfected with 2.5% sodium hypochlorite. They were kept in distilled water storage throughout the duration of the experiment to keep them hydrated. A straight path to the canal was made possible by decorating the crowns of all teeth so that the remaining standardized root length was 17 mm. All samples were randomly divided into three experimental groups ($n = 8$ for each group) as follows:

- Group A: TN file system ($n = 8$)
- Group B: PTG systems ($n = 8$)
- Group C: XP file system ($n = 8$).

The working length (WL) was calculated by inserting a size 10 K file to the root canal terminus and then taking 1 mm away from this measurement. The glide path up to the WL was prepared using size 10 K-files. In order to keep the canal open throughout the entire treatment, a size 10 K-file was also applied after each instrument.

After chemomechanical preparation, all of the samples were divided into horizontal sections at 3, 6, and 9 mm from the apex using a diamond disc and a low-speed handpiece while being cooled by water. Each segment was digitally photographed using SEM at a 100× magnification. Cracked roots were defined as having a crack in at least one segment of the root. This includes fissures that started in the root canal wall and extended all across to the root surface.

Results

Statistical Analysis

The (Statistical Package for the Social Sciences (SPSS), SPSS Inc., v.16) was used to conduct the statistical analysis. The descriptive statistics were produced using calculations of the mean and standard deviation. Tukey's *post-hoc* test for multiple comparisons was used after applying analysis of variance (ANOVA) to compare the microcracks scores in root canals among the study groups. The *p*-value criteria for the current study's level of significance was established at less than 0.05.

Coronal Region

Table 1 shows the comparison of mean microcrack scores in root canal at the coronal region among three file systems. Statistical analysis showed that there was a statistically significant difference in mean microcracks score among the various file systems ($p = 0.001$).

Multiple comparisons (Table 2) showed that:

- There was no statistically significant difference in microcracks between XP-endo and TN ($p = 1.000$).
- There was a statistically significant difference in microcrack score between XP-endo and PTG ($p = 0.002$). The microcracks score in

Table 2: Multiple comparisons

				95% Confidence interval	
At coronal level group	*Group*	*Mean difference*	*p-value*	*Lower bound*	*Upper bound*
XP-endo	TruNatomy	0.00000	1.000	−0.6523	0.6523
XP-endo	ProTaper Gold	−1.00000*	0.002	−1.6523	−0.3477
TruNatomy	ProTaper Gold	−1.00000*	0.002	−1.6523	−0.3477
				95% Confidence interval	
At middle level group	*Group*	*Mean difference*	*p-value*	*Lower bound*	*Upper bound*
XP-endo	TruNatomy	−0.12500	0.831	−0.6664	0.4164
XP-endo	ProTaper Gold	−0.12500	0.831	−0.6664	0.4164
TruNatomy	ProTaper Gold	0.00000	1.000	−0.5414	0.5414
				95% Confidence interval	
At apical level group	*Group*	*Mean difference*	*p-value*	*Lower bound*	*Upper bound*
XP-endo	TruNatomy	−0.62500	0.112	−1.3719	0.1219
XP-endo	ProTaper Gold	−0.87500*	0.020*	−1.6219	−0.1281
TruNatomy	ProTaper Gold	−0.25000	0.681	−0.9969	0.4969

*Statistically significant ($p < 0.05$, Tukey's *post-hoc* test)

root canal was significantly higher in PTG compared with that in XP-endo.

- There was a statistically significant difference in microcrack score between TN and PTG ($p = 0.002$). The root canal microcrack score was significantly higher in PTG compared with that in TN.

Middle Region

Table 1 shows the comparison of mean microcrack scores in root canal in the middle region among three file systems. Statistical analysis showed that there was no statistically significant difference in mean microcrack score among the various file systems ($p = 0.800$).

Apical Region

Table 1 shows the comparison of mean microcrack scores in root canal in the apical region among three file systems. Statistical analysis showed that there was a statistically significant difference in mean microcrack score among the various file systems ($p = 0.022$).

Multiple comparisons (Fig. 1 and Table 2) showed that:

- There was no statistically significant difference in microcrack between XP-endo and TN ($p = 0.112$).
- There was a statistically significant difference in microcrack score between XP-endo and PTG ($p = 0.020$). The microcrack score in root canal was significantly higher in PTG compared with that in XP-endo.
- There was no statistically significant difference in microcrack score between TN and PTG ($p = 0.681$).

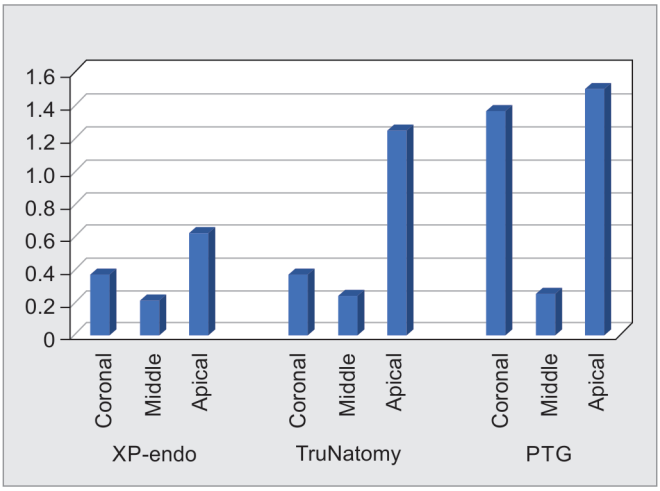


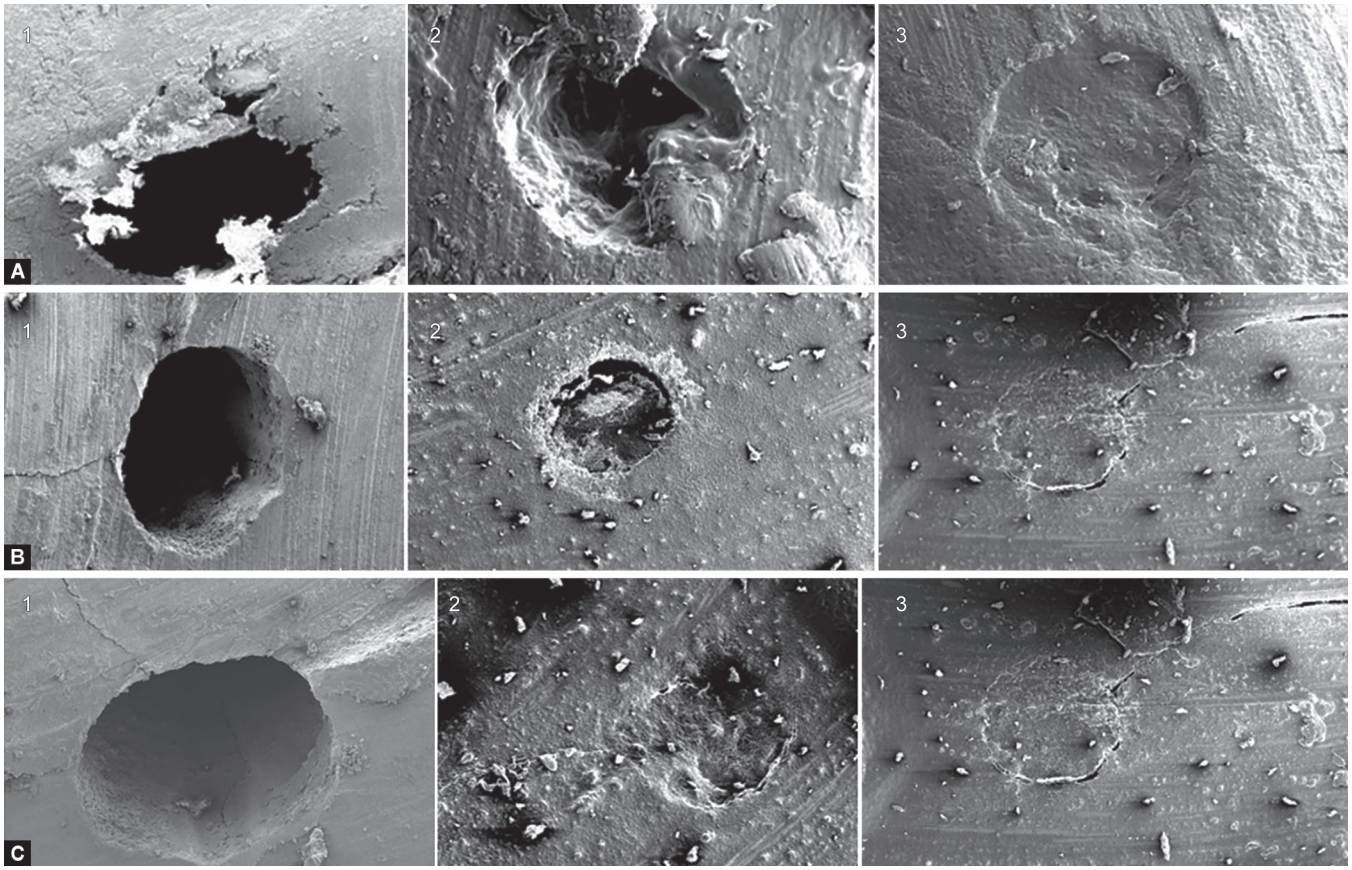
Fig. 1: Comparison of microcracks in root canal

Discussion

During preparation, the contact of the instrument with the canal walls causes instantaneous stress concentrations in the root dentin, which may result in dentinal defects from which microcracks, which may eventually induce vertical root fracture, may develop. Biomechanical preparation is a crucial step to achieve success in endodontic treatment. According to Shemesh et al., severe dentin abnormalities including fractures, craze lines, and partial cracks were caused by canal preparation.[7] According to Bier et al., the considerably higher number of rotations of the rotary systems may have caused the significantly higher number of dentinal defects that occurred during canal preparation utilizing rotary NiTi files as opposed to manual files.[5] Dentinal crack formation may be influenced by instrument characteristics such tip design, cross-sectional geometry, taper, pitch design, and flute form.

In the present study, 24 single-rooted teeth were selected. The teeth were divided into three experimental groups randomly ($n = 8$) as follows: Group A: TN file system, Group B: PTG, and Group C: XP file system. Following root canal treatments, the roots were divided into sections at 3, 6, and 9 mm from the apex using irrigation with water. To check for cracks, the fragments were examined under a SEM at a magnification of ×100 in all directions. When we observed all the samples under SEM, cracks were found in all the samples. When researchers Yoldas et al. and Burklein et al. observed cracks in the root canals produced by rotary NiTi instruments but not in the root canals instrumented with manual K files, they came to the conclusion that all rotary root canal shaping files established microcracks in root dentin.[3,6] According to Kesim et al. observed that any pre-existing craze lines or fractures that could be present on the inner surface of the root could not be seen under any magnification.[10]

Studies have been done to determine whether single file systems or multiple file systems fracture more frequently. According



Figs 2A to C: Image of each section at ×100 magnification using SEM (A) XP-endo Shaper file system; (B) TruNatomy file system; (C) ProTaper Gold file system.); 1 at coronal third (9 mm), 2 at middle third (6 mm); 3 at apical third (3 mm); respectively

to Priya et al., instrumentation using single-file systems led to more dentinal errors than full-sequence systems.[11]

Additionally, a micro-CT research conducted by De-Deus et al. revealed that the ProTaper Universal system did not result in any new dentinal flaws.[12] Full sequence rotary ProTaper systems produced considerably less-micro fractures than reciprocating files, according to Burklein et al.[6] ProTaper full sequence rotational technology created cracks in 50% of the teeth in another investigation by Liu et al., whereas reciprocating movement caused micro-cracks in only 5% of the samples.[13]

In our study, we compared multiple file system PTG with single file systems TRN and XP, we found that cracks in the coronal region were less than the cracks in the apical region for all three groups but according to Adorno et al. and Liu et al. who conducted a similar study, reported abundant cracks in the coronal region as compared with the apical region and this was because of Taper of files which cause increased stresses on canal walls leading to cracks.[13,14] Therefore, the taper of the files could have a contributing factor in the formation of dentinal cracks. A steeper taper also results in less dentine thickness remaining. According to Wilcox et al., the amount of tooth structure eliminated increases the risk of root fracture.[15] The use of larger root canal devices is linked to the emergence of new cracks and the spreading of old ones.

In this study at the coronal and apical portion, PTG files showed more cracks than XP and TN files whereas in the middle portion, XP produced less cracks than TRN and PTG. XP is snake-shaped with a triangular cross-section. It has a 0.27 mm apical diameter and a 0.01 fixed taper (Fig. 2).

Convex triangular cross-sectional and flute designs, along with a gradual taper sequence throughout the shaft, are features of PTG. ProTaper Gold file rotates in the canal while making three points of contact with the root canal dentinal wall during biomechanical preparation, transmits more tensile stresses than TN and XP files, resulting in more dentinal microcracks. In contrast, an attempt reduces cracks during biomechanical preparation, TN files have an off-centered parallelogram cross-sectional design with a uniform taper. This design ensures that there is at least one or two points of contact between the instrument and the root canal wall.

Since this is an *in vitro* study, it's possible that the clinical situation and result might vary significantly. Versiani et al. claim that routine root canal treatments are extremely unlikely to result in microcracks in the range of 40–80%, as shown by the majority of research, in a clinical situation.[16] The sectioning approach and difficulties in recognizing internal pre-existing cracks are potential drawbacks of our *in vitro* study.

The latest advances in imaging technology and its application to the study of dentinal microcracks will undoubtedly lead to a greater understanding of the formation and development of microcracks. Therefore, we may be confident that subsequent developments in the approaches discussed here will significantly increase our understanding of the process underlying crack formation and its relation to endodontic procedures.

The variability in dentin thickness among teeth and the inability of our methods (sectioning and stereomicroscopy observation) to identify pre-existing abnormalities were two limitations of the present research.

Conclusion

In this study at coronal region, we concluded that among three file systems all are producing microcracks but PTG files showed more cracks compared with other system.

There was no statistically significant difference in microcracks between XP-endo and TN at coronal region.

At middle regions XP-endo files system showed less cracks than PTG files and TN showed equal amount.

At apical region, PTG files showed more cracks than XP and TN.

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