

# Stereomicroscopic Evaluation of Microcrack Formation in Dentin by ProTaper Next, Revo S, and WaveOne Gold File System

## Abstract

**Background:** During the biomechanical preparation of the root canal by rotary file systems, stress is generated within the canal, which leads to dentinal microcrack formation. Such defects are evaluated only under the microscope. **Aim:** The present study aimed to evaluate dentinal microcrack formation after instrumentation with ProTaper Next (M-wire), Revo S (conventional NiTi), and WaveOne Gold (Gold-wire) file systems under the stereomicroscope. **Materials and Methods:** Forty single-rooted teeth free from any defect were selected and divided into four groups (Control, PTN, RS, and WOG). Experimental groups were instrumented with file system used in the study, and the control group were left unprepared. Samples were further decoronated and sectioned at 3 mm, 6 mm, and 9 mm from the apex perpendicular to the long axis and examined under a stereomicroscope at  $\times 25$  for different types of microcracks (no fracture, complete fracture, partial fracture, and other fracture). **Statistical Analysis Used:** Data analysis was done by the Chi-square test using the SPSS version 17.0 software. A two-sided ( $\alpha = 2$ )  $P < 0.05$  ( $P < 0.05$ ) was considered statistically significant. **Results:** The null hypothesis was rejected. There was a statistically significant difference between the groups. All file systems created microcracks in the root dentin. WOG group showed an incidence of 66.7% for no fracture, PTN group had 40% for other fracture, and RS group had 60% for complete fracture. **Conclusion:** Single file system WOG with gold wire technology proves to be the best choice for canal preparation among the tested groups in terms of least dentinal crack formation.

**Keywords:** Microcracks, NiTi instruments, ProTaper Next, Revo S, stereomicroscope, WaveOne Gold

## Introduction

Root canal preparation is a crucial step in the success of endodontic treatment because of the debridement of debris, elimination of bacteria, and facilitating final obturation. During biomechanical preparation, stress is generated within the canal while using rotary instruments, and this could lead to dentinal microcracks and sometimes lead to vertical fracture of the tooth. Dentinal microcracks could be in a horizontal direction or vertical directions at different root levels.<sup>[1,2]</sup> The use of spreaders during obturation could also lead to vertical fracture. Such fractures still have the worst prognosis and lead to loss of a tooth.<sup>[3,4]</sup> Hence, it seems necessary to see which Ni-Ti system causes fewer microcracks at what level of root because these days many newer systems are introduced, and clinicians are unaware of the technical drawbacks of such an instrument.

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The design and composition of NiTi instruments not only provide better flexibility and cutting efficiency but also responsible for stress generation during the instrumentation of tooth.<sup>[5]</sup> Different NiTi systems are available in the market, and they differ in body taper, cutting edge, and tip configuration.

ProTaper Next (PTN) (Dentsply Maillefer) is a fifth-generation NiTi instrument with M-wire technology. These are the set of rotary instruments (X1-X5) with moveable tapers and an off-centred rectangular cross-section.<sup>[6]</sup>

Revo-S (Micro Mega, Besancon, France) NiTi system consists of six files (SC1, SC2, SU, AS30, AS35, and AS40). Due to its asymmetrical cross-section, it acts like snake motion within the canal, that's why it shows resistance against cyclic fatigue.<sup>[7]</sup>

WaveOne Gold (WOG, Dentsply Maillefer) system works on the traditional

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reciprocating motion. WOG has small, primary, medium, and large file series, variable, and reducing tapers, producing a more conservatively shaped canal compared with their WaveOne predecessor. The cross-section of WOG is a parallelogram with an 85° active cutting edge with alternate one and two-point contact. The manufacturer claims that the flexibility of the file is increased due to gold technology design. Heat treatment technology is used in making of WOG files which is an advanced metallurgy process.<sup>[8,9]</sup>

The purpose of this *in vitro* study was to comparatively evaluate the formation of dentinal microcrack after biomechanical preparation by different NiTi system, namely PTN, Revo S (RS), and WOG under the stereomicroscope. The null hypothesis was that there would be no differences among the PTN, RS, and WOG systems in terms of dentinal microcrack formation.

## Materials and Methods

Forty single-rooted teeth were randomly selected and stored in distilled water. Each tooth root was examined under stereomicroscope under  $\times 15$  for any microcrack or craze lines, and such teeth were discarded and replaced with normal teeth with no defects. All the teeth were decoronated using low-speed saw and coolant to a standard root length of 16 mm. Each root was covered by aluminum foil and was entrenched into acrylic resin fixed in an acrylic tube. After that, the root was removed, and foil was replaced by a hydrophilic vinyl polyvinyl siloxane impression material (Provil Novo; Heraeus Kulzer GmbH, Hanau, Germany) to simulate periodontal ligament, and then immediately repositioned. To prevent drying up of root apical 3 mm was uncovered and dipped in water.

Samples were then divided into four groups of 10 each. Group 1 was left unprepared and was considered as a control group. Groups 2, 3, and 4 were prepared with PTN, RS, and WOG, respectively.

Canal patency was checked with a #15 K-File (Dentsply Maillefer, Ballaigues, Switzerland) and a glide path was prepared up to #25 K-File. As irrigant, 1.5% sodium hypochlorite solution was used during each instrumentation procedure.

In Group 2 (PTN), Group 3 (RS), and Group 4 (WOG), canal preparation was done by X-Smart™ Plus motor (Dentsply Maillefer) at torque and speed recommended by the manufacturer. PTN files X1, X2, and X3 were used at 300 rpm 4 Ncm torque up to working length. RS files SC1, SC2 and SU were used at a speed of 250–400 rpm, torque – 0.8–1.2 Ncm up to working length 1 mm short of the terminus. In WOG group, primary file was used in a reciprocating, slow in-and-out pecking motion at 350 rpm in 170° counter-clockwise direction and 30° clockwise direction to complete 360° in three cycles.

After canal preparation, samples were washed with 2 ml of distilled water. After that samples were sectioned at 3, 6, and 9 mm from apex perpendicular to the long axis using a low-speed diamond-coated saw underwater as coolant. Samples were then examined under a stereomicroscope (LEICA) at  $\times 25$ , and their images were captured in an attached LED monitor. Each specimen was cross-checked by two evaluators for the presence or absence of dentinal defects.

Fractures were divided into four different types [Figure 1] – (i) no fracture groups were no dentinal defect, or craze lines were present, both external and internal wall of the root; (ii) Partial fracture was a craze line propagates from the canal lumen to the outer surface but did not touch it; (iii) Complete fracture group where the fracture line propagates completely from canal lumen to the external surface; and (iv) Other fracture groups where microcrack propagates from the outer surface of the root to canal lumen but did not touch it.

The statistical analyses were done using the Chi-square test. A two-sided ( $\alpha = 2$ ),  $P < 0.05$  was considered statistically significant. Data were analyzed on the SPSS software version 17.0. (IBM, Chicago, IL, USA).

## Results

The main objective of the study was to compare the outcome measures (no fracture, partial fracture, complete fracture, and other fracture) between the groups and also

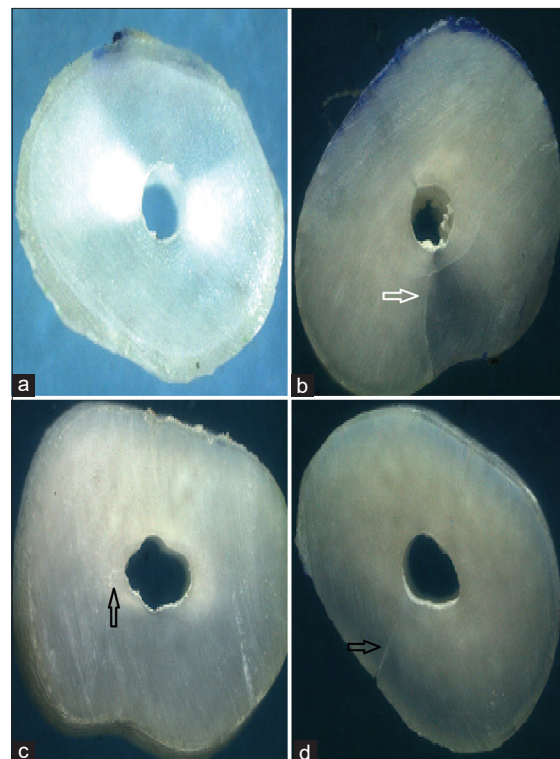


Figure 1: Representative image of (a) no fracture, (b) complete fracture, (c) partial fracture, and (d) other fracture in groups

check the frequency of different fractures among individual groups. The results are summarized in Tables 1, 2 and Figure 2 represents the frequency of different fractures among groups. The tendency of dentinal microcrack followed the following trend among the experimental group: WOG group < PTN < RS.

**Discussion**

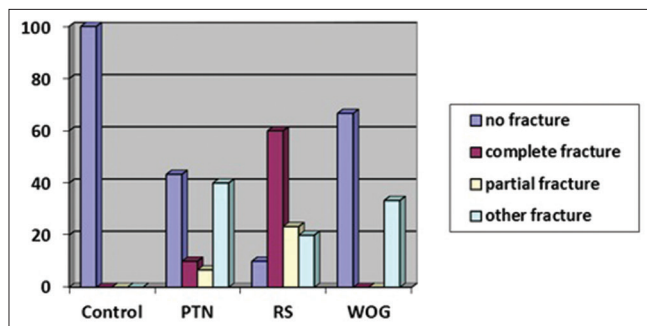
The present study used PTN, RS and WaveOne Gold NiTi instrument for dentinal microcrack evaluation as ProTaper Universal and its successors are commonly used by the clinician as an instrument of choice for rotary endodontics, WOG is newer single file system introduced, and no such study reported till date which compared these three NiTi systems. RS was used as this is representative of conventional rotary multifile NiTi system and based on cyclic rotation movement, PTN is also a multifile system made up of M-wire technology and followed alternate or continuous rotation in the canal while WOG is unifile system, made up of advanced Gold metal technology and based on reciprocating movement. Hence, the comparison between three groups compared different metal technology of NiTi instrument.

Rotary instrument exerts torsional stress in root dentine while rotating, and this stress is transferred externally, which could loosen its bond to the surrounding structure.<sup>[3]</sup> These stress can propagate vertically to root apex. When the tensile strength of dentin surpasses the tensile stress in the canal wall, then fracture occurs.<sup>[10]</sup> Eventually, the deleterious effect is the loss of the tooth. The reason for such a defect is correlated to design and cross-section of NiTi instrument, variability in taper, and flute form.<sup>[11]</sup>

**Table 1: Number of samples undergone different types of fractures (n=30)**

Outcome measures	Control	PTN	RS	WOG
No fracture	30	13	3	20
Complete fracture	0	3	18	0
Partial fracture	0	2	7	0
Other fractures	0	12	6	10

PTN: ProTaper Next; RS: Revo S; WOG: WaveOne Gold



**Figure 2: The frequency (%) of samples representing the types of fracture after canal preparations with different NiTi instruments**

Apical preparation was done 1 mm short of apical terminus because different apical preparation length could lead to more incidence of apical crack formation.<sup>[12]</sup> In the present study, samples were surrounded by polyvinyl siloxane impression material and then mounted in resin block to simulate periodontal ligament and bony socket. However, clinical conditions are more complex because of the presence of external forces which could alter the distribution of forces within the tooth.<sup>[4]</sup>

In RS system SC1 has a 6% taper, SC2 has a 4% taper, and SC2 has a 6% taper, asymmetrical design, and three-point contact with the wall, which is responsible for its better cutting efficiency. Hence, removal of more amount of dentin and its rotation movement is responsible for more crack formation. Greater taper used till working length in the samples could be responsible for more crack formation.<sup>[13]</sup>

The PTN system has M-Wire technology, consists of five instruments: X1 (tip 0.17 mm with 4% taper), X2 (tip 0.25 mm with 6% taper), X3 (tip 0.30 mm with 7% taper), X4 (tip 0.40 mm with 6% taper), and X5 (tip 0.50 mm with 6% taper). PTN X1 and X2 have variable tapered design over the active portion of the instruments while X3 to X5 has a decreasing percentage taper from the tip to the shank.<sup>[6]</sup> According to the manufacturer, most canals can be prepared using only the first two files. PTN has an off-centred rectangular cross-sectional design that allows for the removal of debris in a coronal direction, allowing for more space around the flutes of the instrument and leading to improved cutting efficiency through continuous contact of the blades with the surrounding dentin walls. This design characteristic allows the instrument to experience a rotational phenomenon known as precession or swagger. The swaggering motion of the instrument initiate activation of the irrigation solution during canal preparation, improving debris removal and reduced risk of instrument fracture because there is less stress on the file.<sup>[6]</sup>

The M-wire, a metallurgically improved version of NiTi introduced more flexibility to NiTi instrument.<sup>[14,15]</sup> The reciprocating movement, preset speed, different rotating angles decrease the hazard of cyclic fatigue due to compression and tension during movement, which in turn relieves stress on the instrument. Researchers claimed that this technology reduces cyclic fatigue by 400% when compared with the symmetrical file of the same taper.<sup>[16,17]</sup>

The Gold-Wire, a new supermetal was introduced by the desired phase transition between martensite and austenite. This thermal and postmachining procedure has produced more clinically optimal metal than NiTi itself as claimed by the manufacturer. The WOG system is based on a single-file/single-use concept. It has reverse helix; semi-active and modified guiding tip. WOG files are 80% more flexible, 50% more resistant to cyclic fatigue, and 23% more efficient as compared to the WaveOne M-wire file.<sup>[18]</sup>



**Table 2: Frequency (%) of all type of fractures among all the groups**

Type of fracture	Occurrence	Control (n=30) (%)	PTN (n=30) (%)	RS (n=30) (%)	WOG (n=30) (%)	$\chi^2$ (DF=3)	P
No fracture	Yes	30 (100.0)	13 (43.3)	3 (10.0)	20 (66.7)	27.64	<0.001
No fracture	No	0 (0.0)	17 (56.7)	27 (90.0)	10 (33.3)		
Complete fracture	Yes	0 (0.0)	3 (10.0)	18 (60.0)	0 (0.0)	51.43	<0.001
Complete fracture	No	30 (100)	27 (90.0)	12 (40.0)	30 (100.0)		
Partial fracture	Yes	0 (0.0)	2 (6.7)	7 (23.3)	0 (0.0)	15.74	0.001
Partial fracture	No	30 (100.0)	28 (93.3)	23 (76.7)	30 (100.0)		
Other fracture	Yes	0 (0.0)	12 (40.0)	6 (20.0)	10 (33.3)	2.93	0.402
Other fracture	No	30 (100.0)	18 (60.0)	24 (80.0)	20 (66.7)		

$P < 0.05$  was considered statistically significant. DF: Degree of freedom; PTN: ProTaper Next; RS: Revo S; WOG: WaveOne Gold

According to the results of the present study, null hypothesis was rejected because there was a statistically significant difference between PTN, RS, and WOG groups. Group 4 (WOG) showed the least number of dentinal microcrack, and RS showed maximum crack formation. WOG showed a maximum incidence of 66.7% for no fracture and only 33.3% for another type of fracture. Therefore, it can be concluded that minimal internal stresses were generated within the canal when WOG files were used. RS showed a 60% complete fracture while PTN showed 40% other fractures. The reason for better results of PTN than RS may be due to its M-wire technology, more flexibility, and lesser stress generation within the canal.

One of the reasons for less crack formation by WOG could be its reciprocating movement in the canal rather than continuous rotation.<sup>[19,20]</sup> The offset parallelogram-shaped cross-section of this file system and off-centred rectangular cross-section of PTN allows restricted contact of instrument and root surface which results in minimal stress and less crack formation into the dentine.<sup>[5,21,22]</sup> van der Vyver *et al.* stated that PTN removed more dentine and produced more canal transportation than WOG. Thus, it exerts more stress in the canal than WOG.<sup>[23]</sup>

Some of the researchers found that reciprocating uni-file systems generated less dentinal crack than a multi-sequence rotary file instrument.<sup>[24,25]</sup> Others found that there was no statistically significant difference between them.<sup>[20,26,27]</sup> However, some authors reported that a multifile rotary system induces fewer dentinal crack because more stress is exerted on the root canal wall when only one file is used for chemomechanical preparation as more dentinal mass is removed.<sup>[28-30]</sup> However, *in vitro* studies simulate *in vivo* conditions, but clinically other factors also contribute to stress generation within the canal during instrumentation. Therefore, newer technologies like micro-CT could be used in the future for *in vivo* studies to compare microcrack formation before and after instrumentation with different NiTi systems.

## Conclusion

Based on the results of this *in vitro* study, it can be concluded that single file system WOG with

gold-wire technology proves to be the best choice for canal preparation among the tested groups in terms of least dentinal crack formation.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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