Original Article

# Comparative evaluation of the effects of different torque settings on dentinal crack formation using single- and multi-file system: An *in vitro* study

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## Abstract

**Context:** To improve efficiency, biomechanical preparation in root canal treatment is shifting from manual SS to nickel–titanium (NiTi) rotary devices. While multi-file NiTi systems entail crack and fracture issues, modern single-file systems address these concerns.

**Aims:** The aim of this study was to evaluate and compare the effects of different torque settings on dentinal crack formation using single-file systems (SFS) (One Curve [OC]) and multi-file systems (ProTaper Next [PTN]) at different levels of the tooth.

**Subjects and Methods:** The study was conducted on 45 freshly extracted human mandibular premolars divided into groups: OC at minimal and maximal torque, PTN at minimal and maximal torque, and a control group. After canal preparation, teeth were horizontally sectioned at 3, 6, and 9 mm from the apex, and then examined for cracks using a stereomicroscope.

**Statistical Analysis Used:** This was analyzed using Chi-square test.

**Results:** PTN group: Highest crack rates at the middle (55.6%) and apical (77.8%) thirds with maximum torque; OC group: Highest rates at the middle (22.2%) with minimal torque and apical (11.1%) with maximum torque.

**Conclusions:** Maximal torque settings had more incidence of cracks compared to minimal torque settings. It can be stated that SFS (OC) produced less cracks compared to multi-file system (PTN) at both minimal and maximal torque settings.

**Keywords:** Canal preparation; dentinal crack; One Curve; ProTaper next; rotary system; torque

## INTRODUCTION

Endodontic success depends on meticulous biomechanical preparation. Preparation of root canals has been carried out with manual SS files over the years. Only in the last two decades have nickel–titanium (NiTi) rotary instruments acquired prominence. Commercially, a rising number of proprietary systems are being introduced to the market at a rapid pace. NiTi rotary instruments have the benefits of enhanced flexibility and decreased working time.[1] To increase the efficacy of NiTi rotary instruments, advanced designs with noncutting tips, radial land, different cross-sectional designs, high torsional fracture strength, and different tapers have been introduced.[2] Over the years, various generations have been introduced which transformed from multi-file systems to single-file systems (SFSs) as described by Ruddle.[3] Recent advances for endodontic canal preparation have focused on the concept "Less is More", i.e., with the use of only one or two files biomechanical preparation of canal can be completed.[4]

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The introduction of the SFS in root canal preparation is a novel and interesting concept. Even in small and curved canals, requires only one file to prepare the canal to the proper size and taper. Furthermore, reduces working time, lowers cross-contamination, and reduces instrument fatigue without compromising cutting efficiency when compared to multiple file systems.[5]

ProTaper Next (PTN) (Dentsply Maillefer) is a series of rotary instruments with changeable tapers and an off-centered rectangular cross-section constructed of M-wire technology. On the other hand, the offset design provides better debris removal from root canals than a file with a centered mass and axis of rotation.[6]

One Curve (OC) (Micro-Mega, Besancon, France) is a heat-treated single-file system that was released in 2018. The heat-treated NiTi alloy is called C. Wire.[7] Although OC files have a single tip size (size 25) and constant taper (6%), different shape designs are available.[8] During root canal instrumentation, there are complications such as perforations, ledge formation, transportation of canal, and formation of cracks in the root dentin.[9] During root canal shaping, the geometry of rotary systems, cutting blade design, taper of files, and their composition all affect root dentin. These factors along with the diameter of the prepared root canal may be responsible for dentinal crack formation.[10] Studies have shown that one of the reasons for the failure is torsional stress whose intensity can be decreased using different torque settings by clinicians. The torque enhancement leads to the lock of the instrument and finally its fractures.[11] According to Marzouk Simonton and Gross (1997), torque is the ability of the handpiece to withstand lateral pressure on the revolving tool without decreasing its speed or reducing its cutting efficiency.[12] Contact between NiTi instruments and canal walls can produce stress, potentially leading to strain accumulation in both the instrument and the canal wall, culminating in the creation of microcracks.[13]

To our knowledge, few studies have examined the impact of single- and multi-file systems on dentinal cracks under minimal and maximal torque. Therefore, this *in vitro* study aims to assess the influence of different torque settings on dentinal crack formation using both types of systems.

## SUBJECTS AND METHODS

### Experimental teeth selection

Forty-five extracted human teeth with single canals, straight roots, and no decay were included. Only permanent teeth meeting the criteria for single canals, without preexisting microcracks, and with mature, straight roots were enrolled. Exclusions comprised teeth with anatomical abnormalities, preexisting microcracks, or multiple canals. Roots were examined under a stereomicroscope (×10 magnification) for preexisting cracks. After cleaning, teeth were stored in 10% formalin at room temperature.

### Teeth preparation

To standardize canal instrumentation, all 45 specimens underwent decoronation at a length of 16 mm from apex to crown using a water-cooled diamond disc. Length confirmation was done with a size #10 hand stainless steel K file, followed by glide path preparation with a size 15 K-type file. After rinsing and drying, roots were covered with aluminum foil, embedded in acrylic resin blocks, and simulated periodontal ligament with a silicon-based material. The roots were positioned near the cementoenamel junction in impression material.

### Grouping of the experimental specimens

The specimens were randomly distributed into five groups ($n = 9$) according to the instrumentation files used for cleaning and shaping the root canals:

1. Group 1: Using OC (#25/0.6), 25 mm length with gentle in-and-out rotation movement at working length using endodontic micro-motor (speed: 300 rpm) further divided into
   - 1A: OC minimal torque 1.5 N.cm
   - 1B: OC at maximal torque. 2.5 N.cm.
2. Group 2: Using PTN, used in the sequence ProTaper Universal SX and then PTN X1 (#17/0.04), X2 (#25/0.06), and X3 (#30/0.07) with a brushing motion at a rotational speed of 300 rpm further divided into
   - 2A: At minimal torque 2.5 N.cm
   - 2B: At maximal torque 5 N.cm.
3. Group 3: No instrumentation (Control Group).

All teeth are to be prepared in a crown-down manner.

Prior instrumentation teeth were irrigated with 2 ml of 3% NaOCL, followed by 3 ml of saline. Sodium hypochlorite was used after each instrument change. Teeth were kept moist throughout the procedure. Postoperative photographs were taken after drying each tooth. Following preparation, teeth were soaked in 0.5% basic fuchsine solution for 24 h.

### Sectioning and stereomicroscopic evaluation

Roots were sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex using a water-cooled diamond disc. Sections were examined under a stereomicroscope at ×40 magnification, and digital images were captured. The entire periphery of each section was inspected for fractures, complete cracks, and partial cracks. A crack was identified as a line extending from the inner canal space to the outer surface. "No Crack" indicated root dentin without any cracks or craze lines internally or externally.

## RESULTS

The specimens are examined under the ×40 stereomicroscope (Zeiss, India) [Figure 1].

Comparison of crack formation between five study groups at each level [Table 1].

The control group showed no defects at any level. At all levels, the maximum number of cracks where five study groups were significant. Overall difference in cracks at 6 mm and 9 mm among the five study groups was nonsignificant. Pairwise comparison of cracks at 3 mm showed that difference in cracks between group 1A versus 2B, group 2A versus control group, and between group 2B versus control groups was significant [Table 2].

## DISCUSSION

Dentinal crack is related not only to the design of the instrument but also to its instrument's kinematics. When rotary instruments are employed, they exert a torque force on the canal walls, potentially resulting in the formation of microcracks in the root dentin.[14]

Few studies have addressed the role of torque in dentinal crack formation. Therefore, the present study aims to compare dentinal crack formation following instrumentation with the SFS (OC) and multi-file system (PTN) files at various torque settings. The study included mandibular premolars since Tamse *et al*. observed a significant prevalence of VRF.[15] The roots were encased with an elastomeric impression material and acrylic resin to simulate the PDL, which could influence the distribution of forces during root canal preparation.[16] For irrigation, a 3% solution of NaOCl was selected over a 5% solution since the increased concentration of NaOCl considerably reduces the elastic modulus and flexural the human dentin's strength.[17]

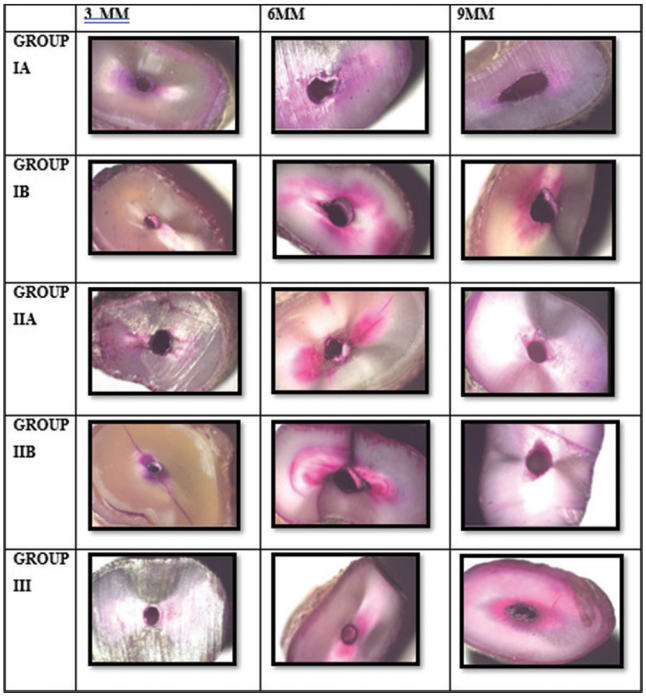


**Figure 1:** Group IA: Dentinal cracks in OC at minimal torque, Group IB: dentinal cracks in OC at maximal torque, Group IIA: dentinal cracks in PTN at minimal torque, Group IIB: dentinal cracks in PTN at maximal torque, Group III: No dentinal cracks seen (control group)

The PTN multi-system was selected for this study because it is one of the commonly used file systems in the field of endodontics. The OC System is a newer SFS introduced in the year 2018.

In the present study, the OC group showed the least crack formation compared to PTN.

The PTN files system's distinctive architecture, with an offset mass of rotation causing oscillating motion comparable to a sinusoidal wave, resulted in a larger cutting envelope than similarly sized files with symmetrical mass and rotation axes. This design features a unique cross-section and utilizes the M-Wire NiTi alloy. The cross-section of an instrument has a significant impact on its torsional behavior. Because of the asymmetric contact between the instrument and the dentin, the off-centered cross-section may create various patterns of forces and torques.[18]

PTN showed maximum cracks in the apical third and minimum in the middle third. Compared to the minimal torque group, with 55.6% apical and 44.4% middle-third crack development, the maximum torque group showed 77.8% apical and 55.6% middle-third fracture formation. PTN files, with torque values of 4–5.2 Ncm, exceed those of other file systems (2–3 Ncm). The increased crack formation

**Table 1: Comparison of crack formation between five study groups at each level Chi-square test**

| Groups | 3 mm | | 6 mm | | 9 mm | |
|---|---|---|---|---|---|---|
| | Crack | No crack | Crack | No crack | Crack | No crack |
| 1A | 1 (11.1) | 8 (99.9) | 2 (22.2) | 7 (77.8) | 0 | 9 (100) |
| 1B | 2 (22.2) | 7 (77.8) | 4 (44.4) | 5 (55.6) | 2 (22.2) | 7 (77.8) |
| 2A | 5 (55.6) | 4 (44.4) | 4 (44.4) | 5 (55.6) | 2 (22.2) | 7 (77.8) |
| 2B | 7 (77.8) | 2 (22.2) | 5 (55.6) | 4 (44.4) | 4 (44.4) | 5 (55.6) |
| Control | 0 | 9 (100) | 0 | 9 (100) | 0 | 9 (100) |
| *P* | 0.002* | | 0.092 (NS) | | 0.074 (NS) | |

*Significant difference at $P \leq 0.05$. NS: Not significant

**Table 2: Pairwise comparison of crack formation within each group**

| Group | 3 mm versus 6 mm | 3 mm versus 9 mm | 6 mm versus 9 mm |
|---|---|---|---|
| 1A | 1.000 | 1.000 | 0.471 |
| 1B | 0.620 | 1.000 | 0.620 |
| 2A | 1.000 | 0.335 | 0.620 |
| 2B | 0.620 | 0.335 | 1.000 |

in the high torque group may stem from greater stress on the dentinal surface.

OC files are crafted from a NiTi alloy with a patented heat treatment (C. Wire), granting them a shape memory effect. Maintaining the same tip size (size 25) and constant taper (0.06) as their predecessors, they boast a unique design featuring variable cross-sections—a triangular shape at the tip and an S-shape near the shaft are claimed to allow effective cutting and centered trajectory. The file design could be the reason for more cracks in the middle third.[5]

OC showed maximum cracks in the middle third and minimum in the apical third.

Compared to the minimal torque group, with 11.1% apical and 22.2% middle-third fracture formation, the maximum torque group showed 22.2% apical and 44.4% middle-third fracture formation. No cracks were observed in the control group.

There are also studies reporting that single-file systems can cause less dentinal damage than multi-file systems and it can be due to more manipulations in the canal that lead to more stress concentration as reported by Liu *et al*.[19] and Shemesh *et al*.[20] These findings align with Dane *et al*.'s study, which explored the impact of torque on root canal walls, revealing that shaping at high torque induced more dentinal cracks compared to low-torque settings. Elevated stress and torque strain the root canal walls, resulting in dentinal defects.[21] Similar results were observed in another study, Choudhary *et al*. examined the effects of One Shape (SF) rotary systems and Hero Shaper (MF) rotary systems on the incidence of dentinal defects. Statistical analysis results represented that the number of dentinal defects was greater in the Hero Shaper system (MF) than One Shape system (SF).[22]

Torque generation correlates with instrument stiffness, which is determined by elasticity. This elasticity, influenced by alloy properties and geometries, differs among alloys. M-wire and R-phase alloys may exhibit lower martensitic phase and higher stiffness, leading to greater stress generation compared to C-wire and CM-wire. However, results can also be based on the geometric characteristics, especially the taper and sizes, which seemed to have a higher effect on stress generation.[23]

While *in vitro* studies commonly compare dentinal cracks among different rotary systems, our study sets itself apart by examining both single- and multi-file systems across minimal and maximal torque settings.

## CONCLUSIONS

Maximal torque settings had more incidence of cracks compared to minimal torque settings. It can be stated that the SFS (OC) produced less cracks compared to the multi-file system (PTN) at both minimal and maximal torque settings. However, further studies should be performed to extrapolate the results of this study to clinical situations.

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Nil.

### Conflicts of interest
There are no conflicts of interest.

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