Original Article

# Incidence of Root Microcracks Produced by Different Root Canal Preparation Systems: An *in vitro* Study

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## Abstract

**Background:** The aim of the study was to compare the incidence of cracks in root dentin after preparation with various hand and rotary root canal preparation techniques. **Materials and Methods:** Seventy recently extracted human mandibular molar teeth were collected. The roots were randomly assigned to six experimental groups (Group II – Hand ProTaper, Group III – ProTaper Universal, Group IV – ProTaper Next, Group V – Revo-S, Group VI – OneShape, and Group VII – Mtwo) and a control group (Group I) that consisted of ten roots each. Roots of control group were left uninstrumented. Sixty roots were prepared with X Smart using rotary files. **Results:** Incidence of defects was 13%, 50%, 33%, 13%, 47%, and 20% in Group II, Group III, Group IV, Group V, Group VI, and Group VII, respectively. Hand ProTaper (Group II) and Revo- S (Group V) produced the least no. of defects. ProTaper Universal (Group III) produced maximum no. of defects followed by One Shape (Group VI). Mtwo (Group VII) produced lesser no. of defects among rotary systems except Revo-S (Group V). **Conclusion:** Both hand and rotary systems used for root canal preparation produced microdefects. Hand systems produced less number of dentinal defects as compared to rotary systems.

**Keywords:** Crack, File, Rotary, Tooth.

## Introduction

Root fracture is a clinical problem that poses a considerable threat to tooth prognosis often leading to tooth extraction. Studies have suggested that fractures did not occur immediately after canal preparation but craze lines and complete or incomplete cracks in root canal dentin may develop into root fracture due to repeated stress application by occlusal forces.[1,2] Rotary instrumentation results in the formation of dentinal cracks that may eventually develop into complete fracture during and after endodontic procedures due to application of rotational force to root canals.[3] Ashraf *et al*. concluded that dentin removal during root canal instrumentation creates weaker root structure and increases its potential to fracture. The intact roots showed significantly greater fracture resistance as compared to instrumented groups.[4]

ProTaper rotary files were reported to create more dentin damage than other rotary instruments. The large apical taper of finishing files in this system generate increased stress on dentinal walls as compared to other rotary systems, which may increase the incidence of dentinal cracks.[5]

ProTaper Next consists of a set of five instruments which includes X1, X2, X3, X4, and X5 files. The finishing file has a taper of 6%.

Revo-S consists of a set of three instruments which include SC1, SC2, and SU files. The finishing file has a taper of 6%.

OneShape consists of a single instrument system with a taper of 6%.

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Mtwo consists of a set of ten instruments which includes #10, 15, 20, 25, 30, 35, 40, 45, 50, and 60 files. The finishing file #25 has a taper of 6%.

This study is therefore being undertaken to find out the incidence of cracks in mesial roots of mandibular molars prepared with various systems.

## Materials and Methods

Seventy recently extracted human mandibular molar teeth were collected from the Department of Oral Surgery, J.N Kapoor D.A.V (C) Dental College and Hospital, Yamuna Nagar. They were divided into seven groups with 10 mesial roots in each group. Group I served as control group and other groups served as experimental groups which were sectioned in three parts at 3 mm, 6 mm, and 9 mm. Hence, each group had 30 sections (Table 1).

Teeth with severely curved mesial roots and single roots were excluded from the study. The coronal portion and distal roots of all teeth were removed using a diamond bur with water cooling, leaving mesial roots approximately 11 mm in length.

Ten roots were left unprepared as they served as control group. Sixty roots were prepared with X Smart using rotary files. A standard model for PDL simulation using silicon impression material (light body) was used for coating the surface of roots to simulate periodontal ligament.

Seventy mesial roots of mandibular molars divided into seven groups:

**Table 1: Distribution of tooth sections**

| Group | System | Location of sectioning | Number of specimens | Percentage |
|---|---|---|---|---|
| I | CONTROL | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| II | HP | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| III | PTU | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| IV | PTN | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| V | REVO-S | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| VI | ONESHAPE | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |
| VII | MTWO | Apical | 10 | 14.29 |
| | | Middle | 10 | |
| | | Coronal | 10 | |

- Group I: Control (No treatment)
- Group II: BMP with Hand ProTaper
- Group III: BMP with ProTaper Universal
- Group IV: BMP with ProTaper Next
- Group V: BMP with Revo - S
- Group VI: BMP with OneShape
- Group VII: BMP with Mtwo

All instrumentation was done in wet canal using 3% NaOCl. All instruments were liberally coated with glyde during biomechanical preparation. Irrigation was done with 5 mL of 3% NaOCl after each instrument. A 5 mL disposable syringe with a 30 gauge side vented needle was used for irrigation. After completion of canal instrumentation, all canals were irrigated with 1.0 mL of 17% EDTA for 3 min followed by final irrigation with 3.0 mL of NaOCl. Any deformed/broken instrument was immediately replaced. Any breakage of instruments was recorded. Following instrumentation, the roots were removed from the sockets and were washed under running water.

The samples were sectioned horizontally perpendicular to the long axis at 3, 6, and 9 mm from the apex with a slow-speed diamond disc under water cooling. The sections were examined under a dental operating microscope at a magnification of X10 for the following type of dentinal defects.

Dentinal defects were recorded under four categories: [6]

### Not cracked

It is defined as a section without any lines or cracks, in which both the external surface of the root and the internal root canal wall have no defects.

### Cracks

Fracture extending from the root canal space all the way to the outer root surface.

### Internal craze lines

Cracks extending from the canal wall into the dentin without reaching the root surface.

### External craze lines

Cracks extending from the root surface into dentin without reaching the canal lumen.

The statistical analysis was done using Statistical Package for the Social Sciences Version 15.0 Statistical Analysis Software. The values were represented in Number and Percentage (%).

## Results

The present study was conducted to study the incidence of cracks in root dentin after preparation with hand (Hand ProTaper) and various rotary (ProTaper Universal, ProTaper Next, Revo-S, OneShape, and Mtwo) canal preparation techniques. They were divided into seven groups with 10 mesial roots in each group. Group I served as control group and other groups served as experimental Groups. Sections were examined under a dental operating microscope at a

magnification of X10 for the following type of dentinal defects: (i) No Cracks, (ii) Cracks, (iii) Internal Craze lines, and (iv) External Craze lines.

In Group II, out of 30 sections (apical, middle, and coronal), internal craze lines were present in three sections, external craze lines were present in one section while none of the sections showed cracks (Table 2).

In Group III, out of 30 sections (apical, middle, and coronal), internal craze lines were present in one section, external craze lines were present in five sections while nine sections showed cracks (Table 2).

In Group IV, out of 30 sections (apical, middle, and coronal), internal craze lines were absent, external craze lines were present in three sections while seven sections showed cracks (Table 2).

In Group V, out of 30 sections (apical, middle, and coronal), internal craze lines were present in one section and external craze lines were absent while three sections showed cracks (Table 2).

In Group VI, out of 30 sections (apical, middle, and coronal), three sections showed internal craze lines, external craze lines were present in five sections while six sections showed cracks (Table 2).

In Group VII, out of 30 sections (apical, middle, and coronal), two sections showed internal craze lines, external craze lines were present in three sections while one section showed cracks (Table 2).

## Discussion

In the present study, incidence of dentinal defects was studied after root canal preparation with Hand ProTaper, ProTaper Universal, ProTaper Next, OneShape, Revo-S, and Mtwo rotary systems. Recently extracted human mandibular molar teeth were selected. These are the most susceptible roots to fracture with a narrow mesiodistal diameter compared with the buccolingual dimension of maxillary premolars and mandibular incisors.[7,8] Mesial canals of mandibular molars have a constricted anatomic configuration, which could result in more stress on the dentinal surface during mechanical preparation and consequently increase the potential to produce cracks.[9]

In the present study, teeth crowns were removed before the root canal preparation, aiming at sample standardization because the specimens presented crowns in good conditions, restored, and some even absent. Sectioning method using diamond disc in the present study could also result in dentinal defects; however, it had no influence on crack formation because the control teeth did not show any defect.[10] This is in agreement with other studies that used a similar method.[5] Sectioning method allowed to evaluate the effect of root canal cleaning and shaping on the root dentin by inspection of the root sections for dentinal defects such as craze lines, cracks etc. under dental operating microscope.[11]

A standard model for PDL simulation using silicon impression material (light body) was used to simulate periodontal ligament.[7] The use of elastomeric material simulates biological conditions and allows for the removal of the root from the simulated alveolus and consequently the observation of fractures that occur in the cervical, middle, and apical third of the root.[12]

Group I (Control group) did not show any defect as the teeth were uninstrumented. It is in agreement with the study conducted by Shemesh *et al*. (2009) who observed that the roots with unprepared canals did not show any defect while canal preparation alone created significantly more defects than unprepared canals.[11]

Roots prepared with hand and rotary systems, both showed dentinal defects. Zandbiglari *et al*. also demonstrated that roots which were prepared with manual technique and rotary files showed lower fracture resistance as compared to intact roots with no significant difference between two instrumented groups.[13]

The number of defects produced with Hand ProTaper (Group II) was significantly more than in the Control (Group I) (Table 3). As quoted by Blum *et al*., the apical pressure used in the root canal preparation might concentrate the force on the external root surface surrounding the apical foramen and

**Table 2: Comparative evaluation of incidence of defects in mesial roots of mandibular molars prepared with different systems at all levels**

| Group | Apical (%) | | | | Middle (%) | | | | Coronal (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NC | C | ICL | ECL | NC | C | ICL | ECL | NC | C | ICL | ECL |
| 1. CONTROL | 10 (100) | 0 (0) | 0 (0) | 0 (0) | 10 (100) | 0 (0) | 0 (0) | 0 (0) | 10 (100) | 0 (0) | 0 (0) | 0 (0) |
| 2. HP | 8 (80) | 0 (0) | 2 (20) | 0 (0) | 9 (90) | 0 (0) | 1 (10) | 0 (0) | 9 (90) | 0 (0) | 0 (0) | 1 (10) |
| 3. PTU | 6 (60) | 1 (10) | 1 (10) | 2 (20) | 4 (40) | 4 (40) | 0 (0) | 2 (20) | 5 (50) | 4 (40) | 0 (0) | 1 (10) |
| 4. PTN | 6 (60) | 1 (10) | 0 (0) | 3 (30) | 7 (70) | 3 (30) | 0 (0) | 0 (0) | 7 (70) | 3 (30) | 0 (0) | 0 (0) |
| 5. REVO-S | 9 (90) | 1 (10) | 0 (0) | 0 (0) | 9 (90) | 0 (0) | 1 (10) | 0 (0) | 8 (80) | 2 (20) | 0 (0) | 0 (0) |
| 6. ONE SHAPE | 6 (60) | 1 (10) | 2 (20) | 1 (10) | 4 (40) | 3 (30) | 1 (10) | 2 (20) | 6 (60) | 2 (20) | 0 (0) | 2 (20) |
| 7. MTWO | 7 (70) | 1 (10) | 0 (0) | 2 (20) | 8 (80) | 0 (0) | 1 (10) | 1 (10) | 9 (90) | 0 (0) | 1 (10) | 0 (0) |

NC: No Cracks, C: Cracks, ICL: Internal craze lines, ECL: External crazelines

**Table 3: Comparative evaluation of incidence of various defects in mesial roots of mandibular molars prepared with different systems at all levels (Apical, Middle, and Coronal)**

| Group | Cracks (%) | Internal craze lines (%) | External craze lines (%) | Total defects (%) |
|---|---|---|---|---|
| I | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| II | 0 (0) | 3 (10) | 1 (3.3) | 4 (13) |
| III | 9 (30) | 1 (3.3) | 5 (16.6) | 15 (50) |
| IV | 7 (23.3) | 0 (0) | 3 (10) | 10 (33) |
| V | 3 (10) | 1 (3.3) | 0 (0) | 4 (13) |
| VI | 5 (16.6) | 3 (10) | 5 (16.6) | 14 (47) |
| VII | 1 (3.3) | 2 (6.6) | 3 (10) | 6 (20) |

**Table 4: Comparative evaluation of incidence of total defects in mesial roots of mandibular molars prepared with different systems at apical, middle, and coronal levels**

| Group | Apical (%) | Middle (%) | Coronal (%) | Total defects (%) |
|---|---|---|---|---|
| I | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| II | 2 (20) | 1 (10) | 1 (10) | 4 (13) |
| III | 4 (40) | 6 (60) | 5 (50) | 15 (50) |
| IV | 4 (40) | 3 (30) | 3 (30) | 10 (33) |
| V | 1 (10) | 1 (10) | 2 (20) | 4 (13) |
| VI | 4 (40) | 6 (60) | 4 (40) | 14 (47) |
| VII | 3 (30) | 2 (20) | 1 (10) | 6 (20 |

can cause a crack.[14] Total defects produced by Hand ProTaper (Group II) were 13% (Table 3), out of which defects produced at apical level were 20% whereas 10% at middle and 10% at coronal level (Table 4). Ashwinkumar *et al*. (2014) observed defects in 34% of samples in mesial roots of mandibular molars. It produced microcracks in 27%, 36%, and 40% at coronal, middle, and apical levels, respectively. It showed more microcracks as compared to the present study. The possible reason could be that the balanced force technique was employed which used both clockwise and counter-clockwise rotation while the technique recommended by the manufacturer was used in the present study.[15]

Total defects produced by ProTaper Universal (Group III) were 50%, out of which cracks produced at apical level were 40% whereas 60% at middle and 50% at coronal level (Table 4). Ashwinkumar *et al*. observed defects in 80% of samples in mesial roots of mandibular molars prepared by ProTaper Universal system. More dentinal defects were produced as compared to the present study probably because S1 was carried to the full working length while in our study S1 was first carried to the coronal two-third of the canal.[15]

Total defects produced by ProTaper Next (Group IV) were 33%, out of which cracks produced at apical level were 40% whereas 30% at middle and 30% at coronal level (Table 4). The results are similar to the studies by Capar *et al*.[16] and Priya *et al*.[17] who observed that ProTaper Next produced cracks in 28% and 36% of the teeth, respectively.

Total defects produced by Revo-S (Group V) were 13%, out of which cracks produced at apical level were 10% whereas 10% at middle and 20% at coronal level (Table 4). Zaka *et al*. (2012) reported defects in 25% of teeth probably because Revo-S rotary files were used to prepare canals up to apical size #30 while in the present study, it was prepared till size #25.[7]

Total defects produced by OneShape (Group VI) were 47%, out of which cracks produced at apical level were 40% whereas 60% at middle and 40% at coronal level (Table 4). Liu *et al*. observed defects in 35% probably because mandibular incisors were used.[18]

Total defects produced by Mtwo (Group VII) were 20%, out of which cracks produced at apical level were 30% whereas 20% at middle and 10% at coronal level (Table 4). Hin *et al*. observed defects in 25% of the teeth probably because mandibular premolars were used.[19]

Defects produced in mesial roots of mandibular molars prepared with Hand ProTaper (Group II) were less (13%) (Table 3) as compared to those prepared with rotary systems (group III, IV, V, VI, and VII showed defects in 50%, 33%, 13%, 47%, and 20% of samples, respectively) (Table 3). Rotary instrumentation requires less time to prepare canals as compared with hand instrumentation but results in significantly more rotations of the instruments inside the canal as compared with the hand ones.

Group II (Hand ProTaper) produced lesser number of dentinal defects than the Group III (ProTaper Universal) (Table 4). Topcuoglu *et al*. also concluded that hand files caused neither crack initiation nor propagation.[20]

ProTaper Universal (Group III) led to higher no. of defects than ProTaper Next (Group IV) (Table 3). This might be because of the difference in the nature of the manufacturing material or instrument design of both the instruments. As quoted by El Nasr and El Kader stiffer file designs generate higher stress concentration, which raises the risk of dentinal defects that may lead to root cracks.[21]

Revo-S produced least number of dentinal defects amongst the rotary systems and were same as Hand ProTaper (Table 4). Yoldas *et al*. (2012) showed that roots prepared with Revo-S and PTU showed defects in 25% and 30% of teeth, respectively. Revo-S instruments have a constant taper with an asymmetrical cross-section and extended cutting part in the coronal region, which increases instrument flexibility.[7]

ProTaper Next (Group IV) led to higher no. of defects than Revo-S (Group V) (Table 3). This is in agreement with Cicek *et al*. (2015) who observed more number of defects in teeth prepared with PTN as compared to Revo-S.[22]

OneShape (Group VI) produced higher number of dentinal defects than other rotary systems except ProTaper Universal

AQ5 system (Group III) (Table 3). Burklein *et al*. (2013)[25] reported more dentinal defects with single file system than the full sequence rotary systems.[23]

## Conclusion

From the present study, it can be concluded that:

1. Both hand and rotary systems used for root canal preparation produced microdefects.
2. Hand systems produced less number of dentinal defects as compared to rotary systems.
3. Single file system (OneShape) produced more number of defects than the full sequence rotary systems.

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