

## EVALUATION OF INCIDENCE OF ROOT MICRO CRACKS AFTER ROOT CANAL PREPARATION WITH DIFFERENT ENDODONTIC FILE SYSTEMS - AN IN VITRO STUDY

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### ABSTRACT

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#### BACKGROUND

Canal preparation is adversely influenced by the highly variable anatomy and relative inability to visualise canal anatomy from radiograph.<sup>1</sup>

The causes of endodontic failure include coronal leakage, radicular fracture, post error due to diameter, length and direction, missed canal, short files, over extension, internal under fillings, ledges perforations, transportation, separated instruments surgical failures.<sup>2</sup>

#### MATERIALS AND METHODS

Ninety freshly extracted human mandibular premolars were collected and stored in Hank's balanced salt solution. Length was standardised at 16mm. The roots were covered by aluminium foil and inserted in acrylic resin. After setting, the root was removed from set acrylic tube and aluminium foil suspended from root surface. A light body silicon-based material was used to fill the space created by the foil to simulate periodontal ligament.

Ninety samples collected were divided into six groups with fifteen teeth in each group. Group 1- Unprepared Root Canal Shaping Group (Control Group). Group 2- prepared by Hand File. Group 3- prepared by Protaper Next. Group 4- prepared by Twisted File. Group 5- prepared by Reciproc. Group 6- prepared by Self Adjusting File.

Statistical analysis was performed with SPSS 20.0 Software by using Kruskal Wallis ANOVA and Mann-Whitney U test. p-value of less than 0.05 was considered statistically significant for all tests.

#### RESULTS

All the file systems showed formation of dentinal microcracks in root canals.

The present study showed that there is significant difference between study groups in number of crack formation at 2 mm ( $p=0.0023$ ) between control group and twisted group  $p=0.029$ , between hand file and twisted file  $p=0.048$  and between twisted file and SAF  $p=0.05$  and 6 mm ( $p=0.0213$ ) between control group and twisted file ( $p=0.05$ ) and between twisted and SAF ( $p=0.05$ ) and there was no significant difference between groups at 4 mm ( $p=0.07$ ) and 8 mm ( $p=0.1367$ ).

#### CONCLUSION

Within the limitations of present study, it was concluded that-

1. All the instruments used, produced cracks with twisted file showing highest number of cracks followed by Reciproc, ProTaper Next, hand files and self adjusting file.
2. There were considerably more cracks produced at apical 2 mm level due to less dentine thickness to counteract the lateral stresses generated by instrumentation.

#### KEYWORDS

Root Micro Cracks, Different File Systems.

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## BACKGROUND

Endodontic therapy involves treating vital and necrotic dental pulp so that patient can retain their natural teeth in function and aesthetics. The endodontic success rates ranges from 53% to 95%. The success rates can be attributed to variety of factors such as number of treated cases, tooth type, operator ability, limited follow up period. One of the most important steps in root canal treatment is canal preparation. Canal preparation is adversely influenced by the highly variable anatomy and relative inability of visualization of canal anatomy from radiograph.<sup>1</sup>

The causes of endodontic failure include coronal leakage, radicular fracture, post error due to diameter, length and direction, missed canal, short files, over extension, internal under fillings, ledges perforations, transportation, separated instruments surgical failures.<sup>2</sup>

Zadik et al found that non-restorable caries 65%, endodontic failures 12.1%, vertical root fractures 8.8%, iatrogenic perforation and stripping 8.8%, periodontal diseases 4.6%, cusp fracture 2.4%, orthodontic factors 1.3%, prosthetic 0.2% and trauma 0.5%.<sup>3</sup> Vertical root fractures is probably not an instant phenomenon but rather a result of gradual propagation of initial dentinal defects such as fracture, craze lines after a long-term functional stresses like chewing.<sup>4</sup>

Traditionally conventional stainless-steel instruments carried out root canal instruments. There are continuous advancement design and material aspects of endodontic instrumentation. Some of them were rotary instruments like ProTaper, ProTaper Next, Twisted. Reciprocating instruments like Reciproc, Wave one and recently self-adjusting file with hollow cylindrical titanium mesh that adapts to root canal anatomy with continuous irrigation.

The present study was undertaken to evaluate and compare the incidence of dentinal microcracks caused by hand and rotary NITI and reciprocating instrumentation and self-adjusting files during root canal preparation.

## MATERIALS AND METHODS

Ninety freshly extracted human mandibular premolars were collected from department of Oral & Maxillofacial surgery. G. Pulla Reddy Dental College and Hospital. All teeth were extracted for various reasons that were not related to present study. Immediately after extraction teeth were rinsed under running water and stored in specimen bottle filled with hank's balanced salt solution. Teeth with cervical abrasion, dental caries, occlusal wear, immature apices, and

anatomic variations in root canal morphology were excluded. All the teeth were cleaned of tissue fragments and visible debris using ultrasonic scaler and were stored in purified filter water until use. To standardize canal instrumentation, teeth were decoronated by using diamond disc, establishing a standardized root length of 16 mm. All roots were inspected with a stereomicroscope (Olympus 5010, Japan) under 12 x magnification to detect any pre-existing craze lines or cracks. Teeth with such findings were excluded and replaced with similar teeth in the study. During the study, specimens were wrapped in 4x4 gauze and kept moist. Canals were negotiated with size #10 K files and after removal of gross pulpal tissue, working length was established by advancing file into canal until just visible at the apical foramen and then subtracting 1 mm from it. Then glide path is established by using 15-k file.

The root was covered by aluminium foil and inserted in acrylic resin. After setting, the root was from set acrylic tube and aluminium foil suspended from root surface. A light body silicon-based material was used to fill the space created by the foil to simulate periodontal ligament figure 1.

Ninety samples collected were divided into six groups with fifteen teeth in each-

- Group 1 - Unprepared root canal shaping group (control group)
- Group 2 - Hand file.
- Group 3 - Protaper next.
- Group 4 - Twisted file
- Group 5 - Reciproc.
- Group 6 - Self adjusting file.

Rotary instruments and reciprocating instruments were set into rotation with a 16:1 reduction hand piece powered by a torque- limited Endo motors (X-smart and X-smart™ plus, Dentsply Tulsa Dental). For each file, the individual torque limit and rotational speed recommended by the manufacturer were used. Reciprocating files were used in a reciprocating motion generated by the motor. Canals were prepared according to the following protocol. Self-adjusting file was used as per manufacturer's instructions.

**Group 1 - Unprepared Root Canal Shaping Group (Control Group)**

**Group 2 - Hand File**

Canals were enlarged to #40 size using step back technique.

**Group 3 - Protaper Next**

Canals were prepared in a crown down fashion with the aid of endodontic motor at 250 rpm at torque 4.0Nm. The ProTaper shaping SX was used in coronal enlargement, and then x1, x2, files were sequentially used to the working length. The file that is used in the apical area corresponds to K file #25 and with a taper of .06.

**Group 4 - Twisted File**

Canals were prepared in a crown down fashion with the aid of endodontic motor at 500 rpm at torque 4Nm. With the file

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rotating as it enters the canal, the file is advanced slowly with a single continuous and controlled motion until the file engages dentin, then the file is withdrawn. The filing is done upto 25 with taper of 0.6%

**Group 5 - Reciproc**

A R25 Reciproc file with size #25 at the tip and taper of .06 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion, no more than three to four times with minimum apical pressure at 300 rpm.

**Group 6 - Self Adjusting File**

X-smart combined with an RDT3NX head (Re-Dent Nova) was used to operate the SAF 1.5 mm diameter with 50 rpm per minute and an amplitude of 0.4 mm, flow rate is 5 ml / min.

**Irrigation Protocol**

After each instrumentation root canal was irrigated with 1% sodium hypochlorite and saline. A total 12 ml, 1% sodium hypochlorite and 12 ml of saline was used.

**Sectioning and Microscopic Examination**

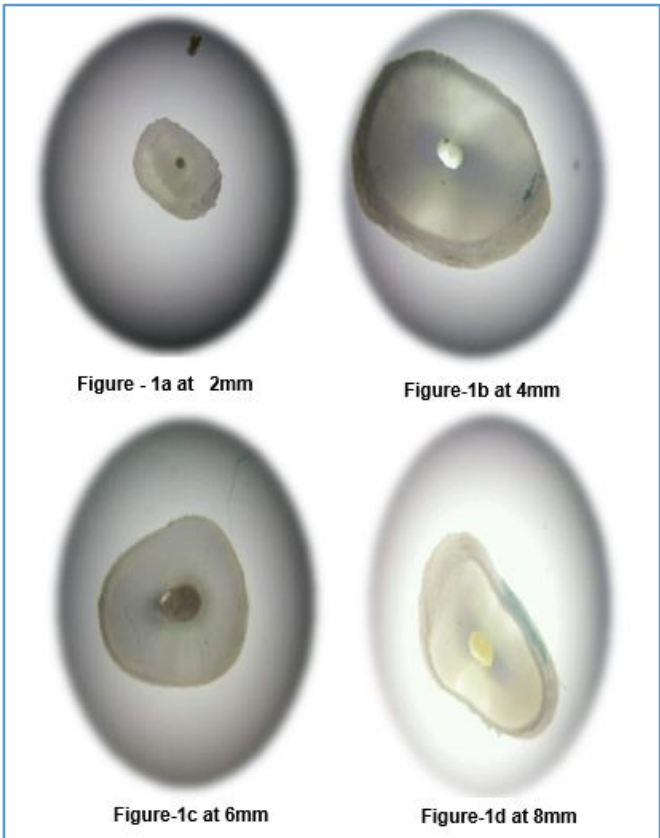
All roots were sectioned perpendicular to the long axis at 2, 4, 6, and 8 mm from the apex using a slow speed water-

cooled saw (Isomet; Buehler Ltd, Lake Bluff, IL). Sections were then viewed under stereomicroscope (Olympus 5010) under 25 x magnifications (Fig. 1, 2, 3). The appearance of dentinal defects was registered by the pictures that were taken digitally using a digital camera (Nikon E 4500, Japan) attached to the stereomicroscope. In order to avoid confusing definitions of root fractures, three distinguished categories were made: "no cracks," "complete cracks" and "incomplete cracks". Showed either a craze line, partial crack, or a fracture.

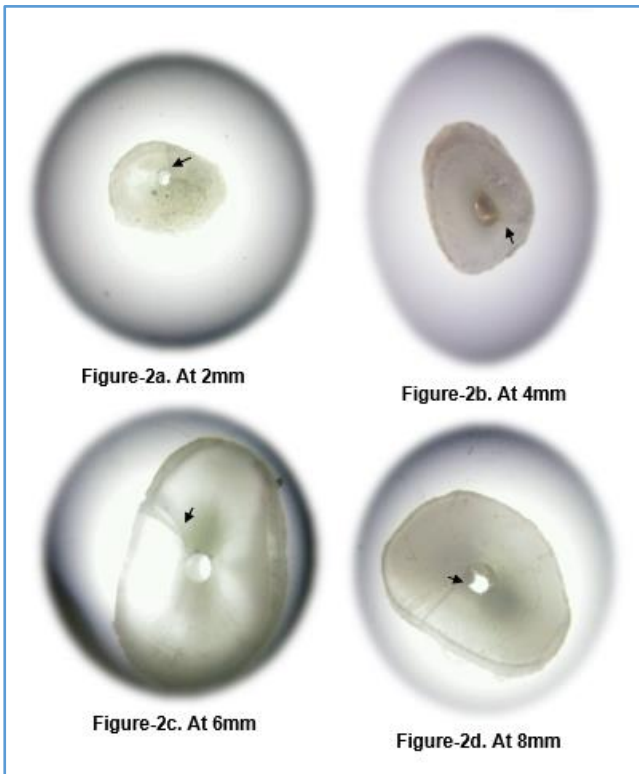
|                |                                                                                                                                         |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| No Crack       | Root dentin without cracks or craze lines either at the internal surface of the root canal wall or at the external surface of the root. |
| Complete Crack | A line extending from the inner root canal space all the way to the outer surface of the root.                                          |
| Partial Crack  | A line extending from the canal walls into the dentin without reaching the outer surface.                                               |

**Table 1. Diagnostic Classification of Cracks**

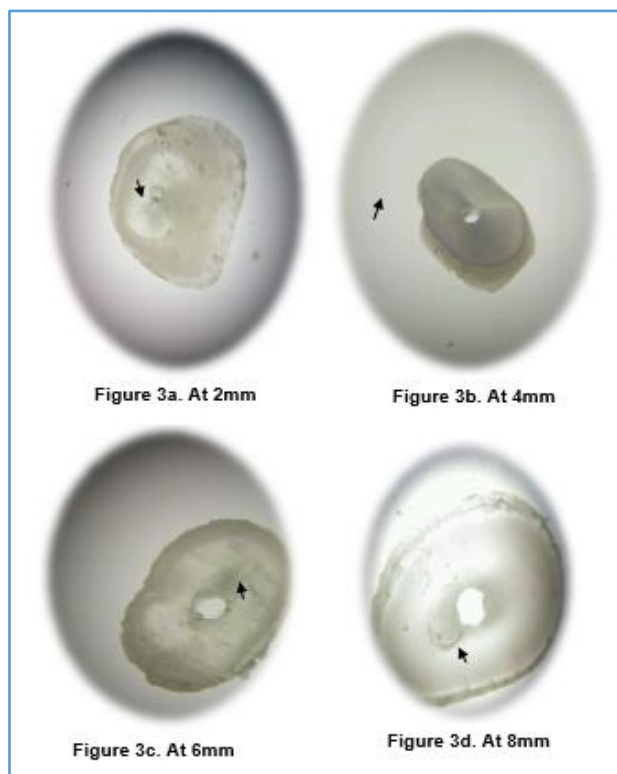
**Stereomicroscopic Photographs of Root Sections**



**Figure 1. No Cracks Control Group**



**Figure 2. Complete Cracks**



**Figure 3. Partial Cracks**

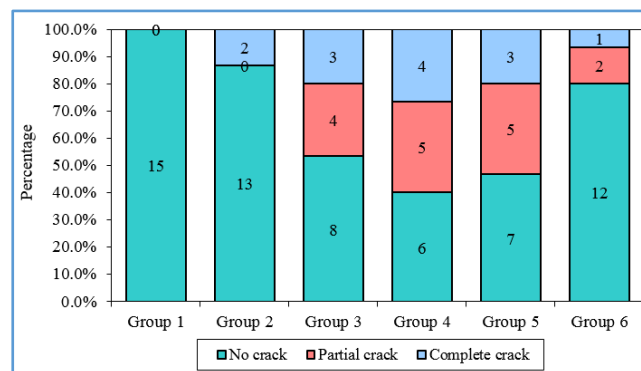
### Statistical Analysis

Statistical analysis was performed with SPSS 20.0 Software. Comparison of six groups with respect to status of cracks at 2 mm, 4 mm, 6 mm and 8 mm from apex by Kruskal Wallis ANOVA. Pair wise comparison of six groups with respect to status of cracks at 2 mm, 4 mm, 6 mm and 8 mm from apex by Mann-Whitney U test. p-value of less than 0.05 was considered statistically significant for all tests.

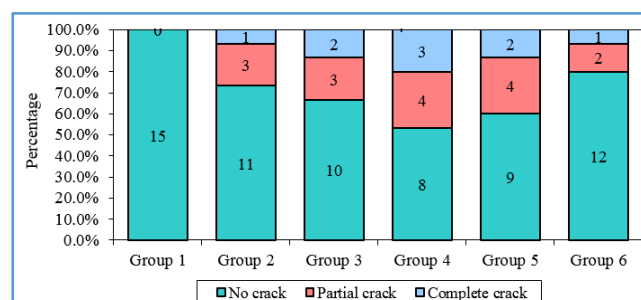
### RESULTS

The obtained data were statistically analysed using One-way ANOVA with by Mann-Whitney U test for inter group comparison.

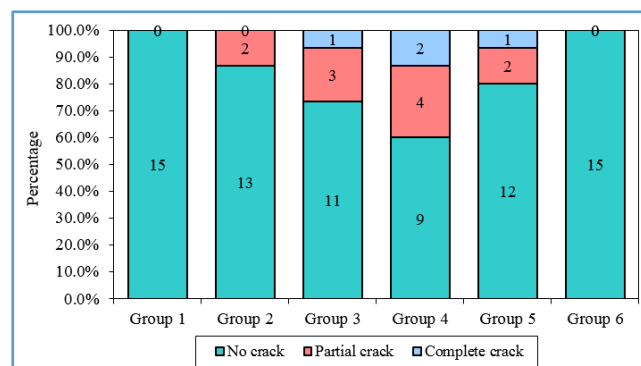
In present study five different files hand k files, ProTaper Next, Twisted files, Reciproc files and Self Adjusting Files were used for preparing root canals. The teeth were sectioned and observed under stereomicroscope for presence of root microcracks.



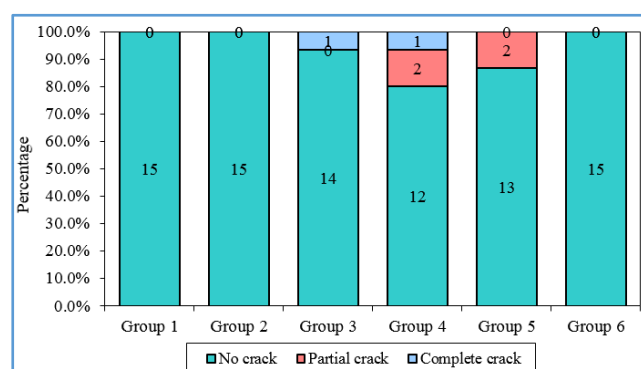
**Graph 1. Comparison of Six Groups with Respect to Status of Cracks at 2mm from Apex**



**Graph 2. Comparison of Six Groups with Respect to Status of Cracks at 4mm from Apex**



**Graph 3. Comparison of Six Groups with Respect to Status of Cracks at 6mm from Apex**



**Graph 4. Comparison of Six Groups with Respect to Status of Cracks at 8mm from Apex**

**Table 2- Comparison of 2mm, 4mm, 6mm and 8mm from apex with status of cracks in six groups.**

| Groups  | Status         | 2mm | %      | 4mm | %      | 6mm | %      | 8mm | %      |
|---------|----------------|-----|--------|-----|--------|-----|--------|-----|--------|
| Group 1 | No crack       | 15  | 100.00 | 15  | 100.00 | 15  | 100.00 | 15  | 100.00 |
|         | Partial crack  | 0   | 0.00   | 0   | 0.00   | 0   | 0.00   | 0   | 0.00   |
|         | Complete crack | 0   | 0.00   | 0   | 0.00   | 0   | 0.00   | 0   | 0.00   |
|         | Total          | 15  | 100.00 | 15  | 100.00 | 15  | 100.00 | 15  | 100.00 |
| Group 2 | No crack       | 13  | 86.67  | 11  | 73.33  | 13  | 86.67  | 15  | 100.00 |
|         | Partial crack  | 0   | 0.00   | 3   | 20.00  | 2   | 13.33  | 0   | 0.00   |
|         | Complete crack | 2   | 13.33  | 1   | 6.66   | 0   | 0.00   | 0   | 0.00   |
|         | Total          | 15  | 100.00 | 0   | 100.00 | 15  | 100.00 | 15  | 100.00 |
| Group 3 | No crack       | 8   | 53.33  | 10  | 66.67  | 11  | 73.33  | 14  | 93.33  |
|         | Partial crack  | 4   | 26.67  | 3   | 20.00  | 3   | 20.00  | 0   | 0.00   |
|         | Complete crack | 3   | 20.00  | 2   | 13.33  | 1   | 6.67   | 1   | 6.67   |
|         | Total          | 15  | 100.00 | 15  | 100    | 15  | 100.00 | 15  | 100.00 |
| Group 4 | No crack       | 6   | 40.00  | 8   | 53.33  | 9   | 60.00  | 12  | 80.00  |
|         | Partial crack  | 5   | 33.33  | 4   | 26.67  | 4   | 26.67  | 2   | 13.33  |
|         | Complete crack | 4   | 26.67  | 3   | 20.00  | 2   | 13.33  | 1   | 6.67   |
|         | Total          | 15  | 100.00 | 0   | 0.00   | 15  | 100.00 | 15  | 100.00 |
| Group 5 | No crack       | 7   | 46.67  | 9   | 60.00  | 12  | 80.00  | 13  | 86.67  |
|         | Partial crack  | 5   | 33.33  | 4   | 26.66  | 2   | 13.33  | 2   | 13.33  |
|         | Complete crack | 3   | 20.00  | 2   | 13.33  | 1   | 6.67   | 0   | 0.00   |
|         | Total          | 15  | 100.00 | 0   | 0.00   | 15  | 100.00 | 15  | 100.00 |
| Group 6 | No crack       | 12  | 80.00  | 12  | 80.00  | 15  | 100.00 | 15  | 100.00 |
|         | Partial crack  | 2   | 13.33  | 2   | 13.33  | 0   | 0.00   | 0   | 0.00   |
|         | Complete crack | 1   | 6.67   | 1   | 6.67   | 0   | 0.00   | 0   | 0.00   |
|         | Total          | 15  | 100.00 | 0   | 0.00   | 15  | 100.00 | 15  | 100.00 |

**Table 2. Shows Total Number and Percentage of Cracks Produced**

Group 1- Unprepared group did not showed presence of any cracks.

Group 2- Hand files showed 13.3% of complete cracks at 2mm level and 13.3% partial cracks at 6 mm level and 20% partial cracks and 6.66% complete cracks were produced at 4mm and no cracks 8mm level.

Group 3- Pro Taper Next files 20 % complete cracks, 26.67% partial cracks at 2mm level, 20% partial cracks and 13.33% complete cracks at 4mm level, 20% partial cracks and 6.6% complete cracks at 6mm level. 6.66% complete cracks at 8mm level.

Group 4- Twisted files 26.67 % complete cracks, 33.3% partial cracks at 2mm level, 26.6% partial cracks 20% at 4mm level, 26.67% partial cracks and 13.3% complete cracks at 6mm level. 13.33% partial cracks and 6.66% complete cracks at 8mm level.

Group 5- Reciproc files 20 % complete cracks, 33.3% partial cracks at 2mm level, 26.6% partial cracks 13.33% and complete cracks at 4mm level, 26.66% partial cracks and 6.66% complete cracks at 6mm level. 13.33% partial cracks at 8mm level.

Group 6- SAF 6.67 % complete cracks, 13.3% partial cracks at 2mm level, 13.3% partial cracks and 6.67% complete cracks at 4mm level, no cracks at 6mm and 8mm levels.

## RESULTS

All the file systems showed formation of dentinal microcracks in root canals.

The present study showed that there is significant difference between study groups in number of crack formation at 2mm ( $p=0.0023$ ) and 6mm ( $p=0.0213$ ) and there was no significant difference between groups at 4mm ( $p=0.07$ ) and 8mm ( $p=0.1367$ ).

At 2mm level there is significant difference in crack formation between control group and twisted group  $p=0.029$ , between hand file and twisted file  $p=0.048$  and between twisted file and SAF  $p=0.05$ . There is no significant difference among other groups.

At 6mm level there is significant difference in crack formation between control group and twisted file ( $p=0.05$ ) and between twisted and SAF ( $p=0.05$ ). There was no significant difference between other groups.

## DISCUSSION

Vertical root fracture was defined by Walton et al, As a devastating episode that has poor long term prognosis eventually requires tooth extraction.<sup>5</sup> There is high prevalence of Vertical root fracture in endodontically treated teeth due to presence of dehydrated and less elastic dentin.

Many factors are responsible for microcrack formation in root canal walls<sup>6</sup>. Some of them were different designs, number of files, kinematics of available NiTi systems these instrumentation-induced dentinal defects act as trigger points for vertical root fractures. Hence this issue requires in depth scientific investigation and reflection.

In last decade many rotary instruments were developed and introduced by various manufacturers. Some recently introduced file systems are twisted, Reciproc, self-adjusting files and protaper next files. The effect of instrumentation on roots by these file systems were compared to that of hand files and unprepared roots in the present study.

The potential damage produced by the interplay among three sources of stresses on root dentin.

1. Mechanical preparation.
2. Chemical attack with sodium hypochlorite.
3. Sectioning procedures.

High concentrations of sodium hypochlorite (NaOCl) can significantly decrease the elastic modulus, and flexural strength of dentine when used as an endodontic irrigant. Sim et al. reported decreased micro hardness of radicular dentine after exposure to NaOCl in concentrations 5.25%, but not when NaOCl was used in lower concentrations. In the present study, 1% NaOCl was used to minimize alterations of the mechanical properties of dentine during the experimental procedures.

The sectioning method used in the present study allowed the evaluation of the effect of root canal preparation procedures on root dentine by direct inspection of the roots and is similar to the methodology described in recent studies.<sup>7</sup>

Most sectioning studies on dentinal defects relies on direct observation by some type of reflected light microscopes as an observational tool mainly stereomicroscope.

The silicon layer that simulated a periodontal ligament allowed limited freedom whilst avoiding external reinforcement. The periodontal ligament has viscoelastic property and plays a major role in dissipating stresses generated by load applied to teeth. Elastomeric impression materials were used to simulate periodontal ligament as described by Bortoluzzi. It has viscoelastic properties similar to periodontal ligament.

The present study showed that there is significant difference between study groups in number of crack formation at 2mm ( $p=0.0023$ ) and 6mm ( $p=0.0213$ ) and there was no significant difference between groups at 4mm ( $p=0.07$ ) and 8mm ( $p=0.1367$ ).

Regardless of level of significance twisted files showed highest percent of dentinal microcracks. This may be due to its taper of 0.08, triangular cross section. Continuous rotary motion also causes high tension over the root canal walls.

Followed by twisted file, Reciproc system showed more cracks. This might be due to larger taper 0.08, number of cracks were less than twisted files as reciprocating motion relieves stresses on root canal wall by clockwise and counter-clockwise motion.

Followed by R 25, Pro Taper Next system showed less cracks due to less taper of tip diameters X1. Off centered design of file, multiple files use and two point contacts. Swaggering motion of offset design relieves stresses on dentinal wall

Hand files and self-adjusting file showed less number of cracks this might be due to less number of rpm, no torque. Hence it exerts less pressure on root canal and they have a constant Taper -0.02.

In present study stainless steel hand file produced 13.3% of dentinal micro cracks. These were in accordance with study conducted by Adorno, Yoshikoa, H. Suda. Yoldas et al. Hin et al. and this could be attributed to the less aggressive movements of the hand files in the canal compared with engine-operated files in which there is more aggressive rotation of Ni-Ti instruments.<sup>8</sup>

In his study he proposed that smaller files conserved dentinal structure as much as possible. Larger files remove more tooth structure causing cracks. 27.5% of tooth showed dentinal microcracks after use of size 25 hand files whereas after use of 15 size hand files 10% of teeth showed microcracks. He also said that the propagation of cracks generated during root canal preparation could be caused by the release of internal stresses accumulated during root canal treatment or from occlusal forces after tooth restoration which might lead to vertical root fracture.

The number of rotations required for complete root canal preparation is more with NiTi instruments than with the hand files. Additionally, it has been suggested that the total volume of dentin removed from the root canals was significantly greater with NiTi rotary systems in comparison with hand files, which implicates more problems that might affect prognostic stability of the teeth, but HFs' cleaning ability and inefficiency in preparing canals are still controversial.

Milani showed that technique of hand instrumentation may influence the crack formation. Balanced force produced significantly less cracks than step back technique.<sup>9</sup>

ProTaper Next produced 28.7% of dentinal microcracks. These results were in accordance with study done by Tulasi priya et al., done a study to compare the dentinal defects produced by hand instruments, ProTaper universal files, ProTaperNext files, Wave one and Reciproc both in rotary and reciprocation. From that study ProTaperNext files Produced less number of dentinal microcracks in both motions compared to Reciproc.<sup>10</sup>

Capar ID et al. concluded Protaper Next produced less dentinal microcracks due to off centered rectangular cross-section, which relieves stresses and produces less number of microcracks.<sup>11</sup>

Shu- Li et al. compared the incidence of dentinal microcracks produced during root canal instrumentation in severely curved teeth at most curved plane and 2mm above the curved plane. ProTaper Next files have produced less number of Dentinal microcracks at both highest curved plane and 2 mm above curved plane.<sup>12</sup>

In this study Twisted files produced 41.6% dentinal microcracks. These results were in accordance with studies done by Oguz Yoldas et al. which concluded that twisted files produced more number of dentinal microcracks. Twisted files has less resistance to torsional forces and continuous rotary motion with 10% taper produced more number of cracks.

In this Reciproc produced 34.5% dentinal microcracks. These results were In accordance with study conducted by Ayidin U et al.<sup>13</sup> In study done by Tulasi Priya, when used in both continuous and reciprocating motions reciproc files produced less number of microcracks in reciprocation than in continuous motion.<sup>10</sup>

Sebastian Burklein compared the incidence of dentinal defects after root canal preparation using reciprocation and rotary instrumentation.<sup>7</sup> In this study Reciproc system produced more number of complete cracks and partial cracks than remaining groups. In contrast to these studies, Rui-LI et al. and De deus observed less dentinal microcracks with Reciproc file system.<sup>14</sup>

In this study SAF file of diameter was used which led to 10% microcrack formation in dentin. Ellemiekes has performed a study and showed that SAF produced more number of incomplete cracks and no complete crack was formed. It creates less stress on canal wall and continuous irrigation through SAF may minimize friction and facilitates removal of dentin.<sup>15</sup> Rui Li et al. said that SAF has neither cutting edge, nor flutes and operates like sand paper removing the dentin producing no cracks.<sup>16</sup>

In present study, more cracks developed in apical 2mm of tooth when compared to other three levels in all the five groups. This might be because Root stresses generated from inside the root canal are higher in apical region because the apical pressure used in filing might concentrate on external surface that surrounds the apical foramen and initiate a crack if the tooth structure is not sufficiently strong enough.

The pattern of stresses distribution in apical area might influence crack development and propagation.

Two types of toughening mechanisms operating in dentin has been suggested, 1. Intrinsic toughening mechanism operates ahead of crack tip and act to enhance the dentin's inherent resistance to micro structural damage and cracking. 2. Extrinsic toughening mechanisms to operate that operate behind the crack tip by promoting the crack tip shielding which reduces the localized stresses.

The amount of dentine behind the file tip was apparently insufficient for toughening mechanism to resist the propagation of crack on apical surface. In addition, deviation of major apical foramen from the root canal axis might have provoked a slight bending of file during preparation and consequently lateral forces increases the stresses at point which forces applied.<sup>17</sup>

### Limitations

The sectioning method has some limitations. Besides the inability to detect pre-existing defects, it is possible that some defects extended to different levels of the root and are counted as defects. Sectioning methods are unable to assess

micro cracks and craze lines developing along the longitudinal surfaces.

Stereomicroscopic observations give about 39% to 58% accuracy. However light reflection and irregularities on root surface make identification of dentinal cracks difficult and may have resulted in greater observer inaccuracy.

The current knowledge indicates that VRF starts from micro cracks in the radicular dentin, and laboratory studies have linked the crack formation to some routine endodontic procedures such as root canal preparation, obturation, retreatment, and post preparation. However, a close critical appraisal of the methods used in these studies yields an interesting thought for consideration; it is rather unlikely that, in the clinical setting, some ordinary canal procedure could cause micro cracks in a range of 40%–80%, as reported by most of the studies. If this phenomenon would actually be accurate, it would also be fair to consider endodontics prone to generate more risks than benefits to patients, which is clearly not the case. Thus, currently, there is an evident lack of correlation between the results obtained in this type of study and the clinical reality.

### CONCLUSION

Within the limitations of present study, it was concluded that-

1. All instruments produced cracks with twisted file showing highest number of cracks followed by Reciproc, ProTaper Next, hand files and self adjusting file.
2. There were considerably more cracks produced at apical 2mm level due to less dentine thickness to counteract the lateral stresses generated by instrumentation.

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