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Original Article

Dentistry Section

Dentinal Microcrack Formation by Different Rotary Endodontic File Systems: An In-vitro Study

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ABSTRACT

Introduction: During endodontic treatment, biomechanical preparation of the root canals constitutes one of the prime steps to enable bacterial eradication, irrigant percolation and three dimensional obturation of the canal space. Currently used rotary endodontic instruments generate stresses in the dentinal walls as microcracks and craze lines which can eventually precipitate vertical root fractures. This endangers the prognosis of an endodontically treated tooth or can even lead to tooth extractions.

Aim: To compare dentinal microcrack formation during biomechanical preparation by different Nickel-Titanium rotary endodontic instruments, Reciprocating single file system and Self-Adjusting File (SAF) using a stereomicroscope.

Materials and Methods: The study was a randomised controlled trial conducted for a total duration of two months. A total of 80 extracted human mandibular molars with intact mesial roots were selected. Endodontic access was achieved. Hyflex CM file (Coltene), One Shape file (Micromega), Twisted File (TF; SybronEndo, Orange, CA), One endo file (Nano endo), ProTaper Next file (Dentsply Maillefer), Reciproc file (VDW) and SAFs were used to prepare the samples, leaving ten teeth unprepared which served as control. Sectioning of the prepared samples were carried out perpendicular to their long axes at 9, 6 and 3 mm. Under 40X magnification of a stereomicroscope, digital images of each section were recorded with the aid of a digital camera. Examination of each specimen was carried out by two operators to verify the presence of dentinal defects/microcracks. The statistical analysis was done by Chi-square test.

Results: Except the control group, all the remaining groups recorded the presence of dentinal defects. The incidence of cracks was highest in One Endo (40%) followed by One Shape, Twisted (30%), Protaper Next (23.33%), Reciproc (10%), Hyflex (6.67%), SAF (3.33%) and control (0%). A significant difference was found for the cracks in coronal section between the file systems (p=0.0001).

Conclusion: Usage of nickel titanium rotary instruments leads to the formation of microcracks or craze lines in root dentine. Instruments which have Metallurgical (M) wire or Controlled Memory (CM) wire in their metallurgy result in fewer formations of microcracks. When compared to multiple rotary files system, a reciprocating file led to the induction of lesser number of radicular cracks. SAF creates minimal cracks as compared to other file systems.

Keywords: Nickel-titanium rotary file, Reciprocating file, Root canal preparation, Root microcrack, Self-adjusting file

INTRODUCTION

The success of endodontic treatment relies on the triad of debridement, thorough disinfection and obturation, with all these procedural aspects carrying equal importance [1]. Chemo-mechanical preparation of root canals has a pivotal role in achieving endodontic success as it permits eradication of bacteria, flushing out of debris and facilitates obturation. Perforations, canal transportation, ledge and zip formation, separation of instruments are few endodontic mishaps occurring during root canal preparation and retreatment cases [2]. Preparation procedures can result in fractures or craze lines in the root dentin [3]. It is thus crucial to examine the root surface to determine the development of cracks on dentin at multiple levels [4].

The contact between endodontic shaping instruments and root dentin walls during biomechanical preparation generates transient stress concentrations in dentin which may induce dentinal defects and microcracks or craze lines. There is increased susceptibility of vertical root fracture during endodontic obturation or retreatment [5]. Clinical perspective of these dentinal defects such as craze lines and microcracks is of utmost importance as they might precipitate vertical root fractures leading to tooth extraction [6]. Vertical root fracture is the cause of 10.9-31% of tooth extractions [7].

Kim HC et al., reported a positive correlation between the design of Nickel-Titanium (Ni-Ti) instruments and the incidence of vertical root fracture. They postulated that file design leads to apical stress and strain concentrations during the instrumentation of the root canal [8]. This is a comprehensive study wherein the dentinal microcrack formation using different Ni-Ti rotary files, reciprocating files and SAF have been evaluated and compared. The present study has evaluated the microcrack formation by One Endo file, the data of which is not available in the published literature.

MATERIALS AND METHODS

The randomised controlled trial was conducted at Vasantdada Patil Dental College and Hospital, Sangli, Maharashtra, India, and was approved by the Institution Ethical Committee bearing Approval no. 848/2015-16. It was a randomised controlled trial as randomised control trials are suitable both for preclinical and clinical researches and also the samples were randomly assigned to the groups [9], the duration of which was two months extending from July 2018 to August 2018. A total of 80 extracted human mandibular molars with intact mesial roots were selected.

Sample size calculation: The sample size was determined based on the evaluation of data from previous similar study [4] and was calculated by applying the formula $\{N=(Z\ a/2)^2\ S^2/d^2$, where N is sample size, Z=1.96, S is Standard Deviation and a=0.05} using OpenEpi Version 3.01 software.

Inclusion criteria: Mandibular molars extracted because of carious lesion involving the crown, periodontal recession and loss of bone support, with intact mesial roots with root angulation not more than 20° to 30° and patent root canals and without any cracks or craze lines, root caries and any sign of external or internal root resorption were included.

Exclusion criteria: Teeth with fractured roots, open apex or incomplete root formation and teeth with excessive root curvature were excluded from the study.

Study Procedure

Endodontic access was obtained with round diamond bur (SS White, U.S.A). Size 15 K- file (Mani, Inc., Japan) was introduced into the root canal until its tip was visible at the Apical Foramen (AF). Working lengths were determined by deducting 1 mm from lengths of the file extruding just beyond the apical foramina to obtain a standard working length of 13 mm for all the samples. Decoronation of all the teeth was done at cemento-enamel junction. Distal roots of all samples were removed by using a diamond coated disc under water coolant. All roots were then inspected under stereomicroscopy at 12X magnification to exclude the presence of any pre-existing external defects or cracks. Canal angulation was measured by the Schneider's method [10]. Roots of all the samples were wrapped with a unilayer of aluminium foil before being embedded into a block of acrylic resin. To imitate the clinical structure of periodontal ligament, aluminium foil was replaced by light body elastomeric material.

The teeth were randomly divided into eight groups, with ten samples in each experimental group.

Group 1: Control group

Group 2: ProTaper Next File group (Dentsply Maillefer, Ballaigues, Switzerland)

Group 3: Hyflex File group (Coltene)

Group 4: Twisted File group (SybronEndo, Orange, CA)

Group 5: One shape File group (Micro-Mega, Besancon, France)

Group 6: One endo File group (Nano endo, USA)

Group 7: Reciproc File group (VDW, Munich, Germany)

Group 8: Self-adjusting File (SAF) group

Canal preparation in all the groups was performed using a torque and speed-controlled endomotor (X-Smart; Dentsply) under torque and speed settings recommendations of the manufacturer for each specific system used. In the Reciproc file group, canal preparation was performed with reciprocating file using reciprocating motor (Satelec Acteon) with the manufacturer's configuration setup for Reciproc file.

Each instrument was discarded after preparation of four canals. Apical preparation for all samples was standardised till size 30.

In the SAF group, the apical preparation was done till #20K-file followed by SAF 1.5-mm file with an in-and-out vibrating RDT3 handpiece head (ReDent-Nova, Ra'anana, Israel) The preparation was carried out at a frequency setting of 83.3 Hz (5,000 vibrations per minute), amplitude of 0.4 mm with a torque-control motor (XSMART Dentsply). It was used in a pecking motion to the working length for 4 minutes in each canal according to the manufacturer's instructions. The SAF was connected to a Vatea system irrigator (ReDent-Nova) that supplied a continuous flow of 5% NaOCl at a rate of 4 mL/min. The total volume of NaOCl used for each canal was 16 mL. Each Self-Adjusting File was put to the use of preparing 4 root canals. A final flush of 4 mL, 17 % EDTA for 1 minute followed by 5 mL distilled water was carried out. SAF has a non specific size or taper. Owing to this file design, determining the final diameter or taper of the preparation was not achievable. However, at the completion of the preparation, it was ensured that #30K-file was reaching till the full working length.

To rule out the presence of any artifact caused by dehydration, the samples were stored in distilled water throughout the entire course of the experiment. Each group consisted of 10 teeth. With the aid of a diamond coated saw (Leica SP1600; Leica Microsystems, Wetzlar, Germany) under water coolant, the teeth samples were subjected to sectioning procedure. It was done perpendicularly to their long axes at 9, 6 and 3 mm using [Table/Fig-1].

[Table/Fig-1]: Hard tissue microtome used for sectioning under water coolant with sawing action.

The sections were examined under stereomicroscope (40X magnification) to record their digital images which were further evaluated by two operators to rule out the presence/absence of dentinal defects (microcracks). "No defect" implied absence of any craze lines/microcracks on the external as well as internal surface of the root. "Defect" suggested microcracks/fractures in radicular dentin [2]. A total of 30 sections were examined in each group. The operators who evaluated the cracks were blind to the specimens. In case of disagreement amongst the operators, specimens were put to re-evaluation.

STATISTICAL ANALYSIS

Frequency of cracks among the groups was compared by Chi-square test. A two-tailed p-value less than 0.05 ($p<0.5$) was considered statistically significant. Data analysis was performed on Statistical Package for Social Sciences (SPSS) software version 17.0.

RESULTS

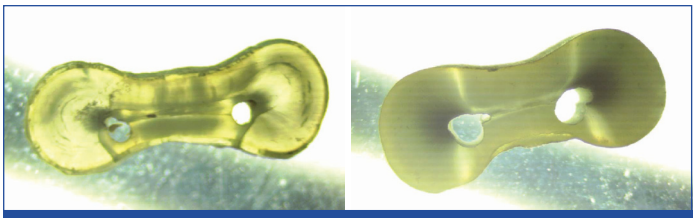
Except the control group, all the remaining groups recorded the presence of dentinal defects. The maximum 12 cracks out of 30 sections (40.00%) examined under stereomicroscope, were found in One Endo followed by 9 (30.00%) in One Shape file and Twisted file, 7 (23.33%) in Protaper Next, 3 (10.00%) in Reciproc, 2 (6.67%) in Hyflex CM, the least in SAF (1 out of 30, 3.33%) and 0 (0.00%) in control [Table/Fig-2].

Files	Defects	%	No. of defects	%	Total
Protaper Next file	7	23.33	23	76.67	30
Twisted file	9	30.00	21	70.00	30
One endo file	12	40.00	18	60.00	30
One shape file	9	30.00	21	70.00	30
Hyflex file	2	6.67	28	93.33	30
Self-adjusting file	1	3.33	29	96.67	30
Reciproc file	3	10.00	27	90.00	30
Control	0	0	30	100	30
Total	43	17.92	197	82.08	240

[Table/Fig-2]: Comparison of eight groups with respect to status of number of sections examined in each group.
Chi-square=21.4651; p-value=0.0020*; *p<0.05

Out of the total 12 cracks in One Endo, the incidence of cracks was highest at coronal section (8 cracks), 3 in middle section and only 1 crack in apical section [Table/Fig-3]. In One shape file, out of total 9 cracks, incidence was highest at coronal section 6, 3 in middle section and 0 in apical section. In Twisted file, there were 4 cracks in coronal section, 5 in middle section and 0 in apical section. In Protaper Next, incidence was highest in middle section (3 cracks out of 7), 2 in coronal and 2 in apical section; which was highest amongst the apical sections of all the file systems. In Reciproc group, 1 crack in all the three sections (1 in coronal, 1 in middle and 1 in apical) were seen. For Hyflex group, there was 1 crack each in

coronal and middle sections and 0 in the apical section. Incidence of cracks was the least in SAF (only 1 crack) in coronal section [Table/Fig-4,5]. However, sections of the control group exhibited a total absence of dentinal cracks. On statistical analysis, significant difference was found for the cracks in coronal section between the file systems (p=0.0001).



[Table/Fig-3]: Representative microscopic image from one endo file group showing dentinal microcracks. **[Table/Fig-4]:** Representative microscopic image from SAF group not showing any cracks. (Imges from left to right)
SAF: Self-adjusting file

Files	Coronal section		Middle section		Apical section	
	No of defects	%	No of defects	%	No of defects	%
Self-adjusting file	1	10.00	0	0	0	0
Protaper next file	2	20.00	3	30.00	2	20.00
Twisted file	4	40.00	5	50.00	0	0
Reciproc file	1	10.00	1	10.00	1	10.00
One endo file	8	80.00	3	30.00	1	10.00
One shape file	6	60.00	3	30.00	0	0
Hyflex file	1	10.00	1	10.00	0	0
Control	0	0	0	0	0	0
Total	23 Chi-square=27.7651 p-value=**0.0001***		16 Chi-square=13.7500 p-value=0.0560		4 Chi-square=8.4211 p-value=0.2972	

[Table/Fig-5]: Comaprison of eight groups with respect to status of number of roots with defects in coronal, middle and apical section.
*p<0.05; bold p-values denote significance

DISCUSSION

Research has proved that procedural steps as root canal preparation, post space preparation, and obturation lead to bulk removal of dentinal tissue generating high stress concentration in the radicular dentin thereby increasing the dentinal defects and thus incidence of vertical root fracture [11,12].

One Endo is a unique endodontic file introduced by Dr. John McSpadden in 2015. It is S- shaped and is H-type file incorporating two or more dissimilar tapers adjacent to one another within the same file. It has a cut flip tip that can enlarge canals smaller than its tip size more effectively with lesser stress, debris extrusion, blockage and glide path preparation than any other file [13]. Despite these features, in the present study, this file system showed highest number of cracks. It can be attributed to the presence of two or more dissimilar tapers and greater number of sequence of files compared to other file systems. High concentration of stress in root canals walls can be explained owing to the active rotation of the file within the canal [13].

The only groups exhibiting complete cracks traversing from internal to the external canal wall were one endo and one shape. Out of the total 240 sections examined, the only sample showing complete fracture was that of the apical section of one endo file. There is paucity of literature related to the effect of one endo files on root canal wall or in dentinal crack formation.

One shape is a single file system consisting of only one instrument used in traditional continuous rotation motion. The greater number of crack formation by one shape file could be attributed to the asymmetrical cutting edges with active rotating movement which causes stress concentration in root canal walls. Cross-section of the file is triangular thereby rendering the benefit of less space for debris accumulation. This generates stress concentration in root canals walls and dentinal crack formation [14]. These findings were similar to the findings of a study conducted by Liu R et al., where one shape files caused 35% cracks [4].

In the present study, twisted file showed the same amount of cracks as one shape. There was zero crack in the apical section but it showed cracks in coronal and middle sections in spite of having the R phase. High taper might explain for the occurrence of cracks in coronal and middle sections of twisted file. The twisting process increases its cutting efficiency and the triangular cross section could further stress root dentin and results in crack formation [15]. In a study by Yoldas O et al., twisted files caused 44% cracks which are in accordance with the present study [2].

ProTaper Next is a successor of ProTaper Universal file system (Dentsply Maillefer, Ballaigues, Switzerland), which is considered to be the gold standard in endodontics over many years. The reason behind less dentinal damage by Protaper Next could be a different design and manufacturing. The uniqueness of the file is constituted by the triad of offset design of its cross-section, a dual combination of progression and regression of tapers and M-wire Ni-Ti technology [16, 17]. Its rectangular cross-section imparts a snake-like swaggering, smooth, gliding movement of the file within the canal. The file contacts at only two points at a time which decreases the deleterious incidences of screwing effect, taper lock and torque [16,17]. Being manufactured by M-wire alloy, the Protaper Next files shows high degree of flexibility, thereby exerting lesser force and consequently lesser damage on root canal walls during the shaping procedure [17].

Hyflex CM file showed the least number of cracks amongst all the rotary files used in the present study. Being manufactured by CM wire alloy, these files have high degree of flexibility and hence lesser force is exerted on root canal walls during canal preparation and thus lesser damage to root canal wall [17]. These findings are in accordance with a study conducted by Capar ID et al., in which ProTaper Next and Hyflex instruments caused fewer cracks [16].

Of all the single-file systems, Reciproc, are made of M-Wire Ni-Ti alloy [18]. In the present study, reciprocating Reciproc file were reported to generate lesser incidence of root cracks. This can be explained based on the file motion which is reciprocating in nature and owes similarity to the balanced force technique [19]. It minimises torsion and flexion [19]. There is lesser stress generation as the reciprocating motion involves alternate engagement and disengagement of the file from the canal walls thereby causing less incidence of radicular dentin microcracks compared to other groups in the study. Moreover, M-wire alloy which is used to manufacture Reciproc instrument is a more flexible variant of the Ni-Ti alloy [19]. In a study conducted by Liu R et al., Reciproc files produced cracks in 5% of teeth only which bears resemblance to the findings of the present study [4].

Study performed by Burklein S et al., have contradictory findings such that there were significantly high numbers of incomplete dentinal cracks as compared to full-sequence rotary systems. However, in the study done by Bürklein S et al., the different file system groups were not standardised in terms of taper, and the imitation of periodontal ligament was not carried out too [20].

In the present study, SAF did not create cracks. There was only one crack in coronal section out of the total 30 sections examined under the stereomicroscope. Working in a to-and-fro motion, Self-Adjusting File system abrades away dentin from the canal walls by scraping and does not rotate within the root canal perimeter [21, 22]. This file system comes with a irrigation module attached with it which is supplied through a hollow file. The continuous irrigation helps minimise frictional stresses. The results obtained in the present study bear resemblance to previous studies in which minimum number of cracks were found in teeth prepared with the Self-Adjusting File [2, 4, 21, 22].

Kim HC et al., reported a stress value of 10 MPa with the usage of SAF. They explained it on the basis of minimal or no microcracks generation which further increased the fracture resistance of the teeth instrumented with SAF [23]. Yoldas O et al., and Liu R et al., in their studies found a total absence of dentinal microcracks in the samples in which biomechanical preparation was done with SAF and hand files [2, 4].

In a study performed by Hin ES et al., SAF resulted in some incomplete cracks. Differences in findings of both the studies could be attributed to different study designs. In Hin's study, diameter of SAF used was 2.0 mm as compared to 1.5-mm SAF used in the present study. Larger diameter file exerts greater pressure on root canal walls thereby inducing more damage onto the dentin [24].

In this in-vitro study, with the aid of a stereomicroscope and radiographs, all the teeth were thoroughly examined so that the absence of preinstrumentation cracks or fracture can be confirmed. However presence of dentinal cracks before the commencement of the experiment cannot be completely ruled out as internal cracks if any will be invisible on the exterior of the root surface [25]. Shemesh H et al., [12] and Bier CAS et al., [3] reported probability of occurrence of the dentinal micro cracks during tooth extraction or sawing action. However, in the present study, the control group did not exhibit cracks thereby implying that sectioning procedure did not introduce microcracks. Hence, it may be concluded that biomechanical preparation using the Nickel-Titanium (Ni-Ti) rotary and reciprocating files led to the generation of microcracks in the radicular dentin.

Usage of Ni-Ti rotary instruments forms microcracks in radicular dentin, the extent of which can be explained on the basis of tip design, cross-sectional geometry, taper, pitch and flute form. All these structural features of the file together contribute towards application of fluctuating amount of rotational force on the radicular walls [2]. Studies have shown that all tapered nickel titanium file systems lead to the generation of microcracks ranging from 18-60% of the roots thereby concluding that instrument taper is an important factor for dentinal microcrack formation [2,3,5,26,27]. In present study, although cracks were observed in all the three sections, the number of coronal cracks was five times greater than the middle and apical sections. This may be due to the fact that files have an increasing taper towards their coronal section [28].

According to Kim HC et al., during the preparation procedure rotary files produce stress values of 311-368 MPa on the exterior of dentin. This stress value is three times the tensile strength of radicular dentin which is 106 MPa, thereby precipitating microcracks [8]. In the previously conducted studies, single-rooted teeth were included to assess the dentinal damages. In the present study, multirooted teeth especially the mesial root of manibular first molar was studied taking into consideration the anatomical challenges associated with the tooth such as strip perforation. It has been suggested that mandibular and maxillary first molars are more prone to fracture development [29].

Periodontal ligament is viscoelastic in nature, which plays a crucial role in dissipating stress created by load application by absorbing a major amount of stress [28]. Literature review depicting the incidence of dentinal microcrack formation by different rotary endodontic file systems has been done in [Table/Fig-6] [3,4,8,17,25,28-33].

S. No.	Author's name and year	Place of study	Sample size	Files compared	Parameters assessed	Conclusion
1.	Bier CAS et al., (2009) [3]	Araraquara, Brazil.	260	Flexofiles, ProTaper, ProFile, SystemGT S-ApeX	Compared the incidence of dentinal defects (fractures and craze lines) after canal preparation.	No defects were found in the uninstrumented roots. Preparation with hand files and S-ApeX, ProTaper, ProFile, and GT led to dentinal defects in 16%, 8%, and 4% of teeth, respectively.
2.	Kim HC et al., (2010) [8]	Gyeongnam, Korea	Three different file systems were used.	ProFile ProTaper Universal Lightspeed LSX	Compared the stress conditions during rotary instrumentation in a curved root for three Ni-Ti file designs.	ProTaper Universal induced the highest stress, tensile and compressive principal strain values at the exterior of the root surface. Light- Speed generated the lowest stresses.
3.	Liu R et al., (2013) [4]	Beijing, China	240	K3 ProTaper Flex K	Compared the incidence of apical root cracks and dentinal detachments after canal preparation with hand and rotary files at different instrumentation lengths (till major Apical Foramen (AF), short of AF, or beyond AF)	Rotary instruments caused more dentinal defects as compared to hand instruments. When instrumentation is done short of AF incidence of dentinal defects decreases.
4.	Priya NT et al., (2014) [28]	Telangana, India	100	ProTaper ProTaper Next One shape Reciproc	Compared the incidence of dentinal micro cracks after instrumentation with various types of Ni-Ti files in rotary and reciprocating motion.	Least cracks were seen in canals instrumented with Pro Taper Next files both in rotary and reciprocating motion. Full sequence rotary systems showed less cracks than single file systems and full sequence rotary systems showed less cracks in reciprocating motion than in rotary motion.
5.	Ustun Y et al., (2015) [29]	Kayseri, Turkiye	120	ProTaper retreatment files Reciproc files	Compared the incidence of dentinal defects caused by reciprocating and rotary techniques during retreatment procedures.	Both nickel–titanium systems were associated with dentinal defects during retreatment procedures.
6.	Ashraf F et al., (2016) [17]	Kanpur, India	65	Gates Glidden, ProTaper Universal, ProTaperNext, HyFlex CM	Evaluated the dentinal cracks after root canal preparation with rotary files at different instrumentation lengths: till the major AF, short of AF, and beyond AF.	Pro Taper Universal rotary files caused more dentinal cracks than ProTaper Next and HyFlex CM. Instrumentation short of AF reduced the risk of dentinal defects.
7.	Oliveira BP et al., (2017) [30]	Pernambuco, Brazil	60	ProTaper Universal for hand use, Hyflex CM, Reciproc	Compared apical microcrack formation after root canal shaping by hand, rotary, and reciprocating files at different working lengths (at the AF and 1 mm short of the AF (AF-1 mm) using micro-computed tomographic analysis.	Root canal shaping with ProTaper Universal for Hand Use, HyFlex CM, and Reciproc systems, regardless of the working length, did not create microcracks in the apical section.
8.	Langaliya AK et al., (2018) [25]	Gujarat, India	84	Hand Ni-Ti, ProTaper Universal, ProTaper Next, Silk, WaveOne, Self-adjusting files	Evaluate and compared dentinal microcracks formation during root canal preparation by different commercially available Nickel-Titanium (Ni-Ti) file systems.	All rotary files created microcracks in the root dentin, whereas the SAF and hand files produced acceptable results with no dentinal microcracks.

9.	Pawar AM et al., (2019) [31]	Maharashtra, India	140	Hand files RevoS ProTaper Next WaveOne Reciproc SAF	Compared the formation of dentinal defects using stainless-steel hand K-files (HFs), rotary files, reciprocating files, and Self-Adjusting File (SAF), when used for oval root canals.	The control, Hand Files, and SAF did not exhibit any dentinal defects. Roots instrumented by RevoS, ProTaper Next, WaveOne, and Reciproc files exhibited microcracks (incomplete or complete) in 40%, 30%, 55%, and 50%, respectively.
10.	Saberi EA et al., (2020) [32]	Zahedan, Iran	50	Neoniti, Reciproc, ProTaper	Evaluated and compared the dentinal micro cracks following root canal preparation with Neoniti, Reciproc, and ProTaper rotary systems.	Micro cracks in the root dentin were created with all the file systems More cracks were observed in the Reciproc system.
11.	Haridas K et al., (2020) [33]	Kerala, India	60	ProTaper Next WaveOne Gold	Compared root microcrack formation after root canal preparation using ProTaper Next in rotation or forward reciprocation and Waveone gold in reverse reciprocating motion.	Nickle titanium rotary instruments tend to induce varied degrees of root dentinal damage during canal instrumentation. ProTaper Next files in rotation as well as forward reciprocation presented with minimal microcrack defects when compared with Waveone gold.
12.	Present study	Maharashtra, India	80	ProTaper Next Hyflex Twisted File One shape One Endo Reciproc SAF	Compared dentinal microcrack formation during biomechanical preparation by different Nickel-Titanium rotary endodontic instruments, Reciprocating single file system and SAF using a stereomicroscope.	Ni-Ti instruments tend to induce various degrees of dentinal microcracks or craze lines. Reciprocating file results in fewer cracks as compared to rotary Ni-Ti files. SAF represents satisfactory results with only a single microcrack defect.

[Table/Fig-6]: Literature review depicting the incidence of dentinal microcrack formation by different rotary endodontic file systems [3,4,8,17,25,28-33].
GT: Greater taper; S Apex: S shaped apex; Ni-Ti: Nickel-Titaniun; SAF: Self-adjusting file; CM: Controlled memory

Limitation(s)

This study could not match the roots for root dentine thickness. Although, the authors have used only mandibular molars in all groups, there would still be differences in dentine thickness. The authors could not standardise the different speed and torque settings for each file and downward force used. In some teeth microcracks might have been present preoperatively which cannot be completely eliminated.

CONCLUSION(S)

The Ni-Ti instruments tend to induce various degrees of dentinal microcracks or craze lines during root canal preparation which is related to the tip design, cross-sectional geometry, taper, pitch, flute form, metallurgy and manufacturing technique of the instrument. Reciprocating file results in fewer cracks as compared to rotary and SAF represents satisfactory results with only a single microcrack defect in this study.

However, future studies can be carried out using less invasive techniques like optical coherence tomography or infrared thermography which will eliminate the sectioning procedure. Also, further studies are required which will evaluate the effects of other endodontic procedures as obturation or retreatment using rotary systems on the root canal wall or formation of dentinal defects in the form of cracks and fracture.

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