Comparative Evaluation Of Dentinal Crack Formation After Using Protaper Universal, Protaper Gold, Hyflex EDM, And Neoendo Flex Rotary File Systems: An In Vitro Study

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Abstract

Background: With newer advent of rotary systems being introduced to the market, the effect and comparison of these rotary systems on the radicular dentin always remain a topic of research.This study aims to compare and evaluate the frequency and amount of dentinal cracks after root canal instrumentation using ProTaper Universal, ProTaper Gold, HyFlex EDM, and Neoendo Flex rotary file systems using a digital stereomicroscope.

Material and Methods: A total of 80 extracted single-rooted mandibular premolars were selected with mature apices and straight canals and then randomly divided into four experimental groups (n = 20) according to the different rotary file systems used for preparation; Group 1: ProTaper Universal, Group 2: ProTaper Gold, Group 3: HyFlex EDM, Group 4: Neoendo flex. Sectioning was performed at 3, 6, and 9 mm from the apices. Digital images of the cut sample sections were viewed under a digital stereomicroscope of ×25 and ×80 magnification. Data was analyzed statistically using chi-square test.

Results: A statistically significant difference was found among all the groups ($P < 0.01$). Group A (ProTaper Universal) showed the maximum percentage of dentinal cracks followed by other groups. In the intergroup comparison between the four groups, coronal 9mm sections showed an increased percentage of dentinal cracks which was statistically significant ($P < 0.05$).

Conclusion: All the rotary systems after root canal preparation produced dentinal cracks. There was a significant difference between ProTaper Universal and other groups in terms of dentinal crack formation. The coronal sections had more frequency of cracks than other sections.

Keywords: Dentinal cracks, ProTaper Universal, ProTaper Gold, HyFlex EDM, Neoendo flex files

INTRODUCTION

Utmost goal of endodontics is the elimination of microorganisms, pulp tissue, debris by enlarging the diameter of the original canal anatomy to a more desirable canal shape to obtain a proper seal .We axiomatically damage the root canal by procedural errors in the zest of cleaning and shaping procedure which serves as a pathway to craze line dentinal defects and vertical root fracture (VRF).

Walking from past to present, several instruments and techniques have been developed , rotary nickel-titanium (Ni-Ti) instruments with new design features with tip size, taper, helix angle, cross-section, and pitch are continually manufactured in an attempt to overcome canal preparation errors and have completely changed how routine root canal preparations are performed with the advantages of increased flexibility and shortened working time, while instrument separation and dentinal crack formation are its major disadvantages.[1,2]

Root canal preparation with rotary (Ni-Ti) instruments can significantly weaken the root by generating stresses in root dentin leading to microcracks or craze lines because of bending normal stresses and torsional shear stresses.[3]

This study aimed to evaluate the dentinal microcrack formation by a newer Ni-Ti file system in comparison with other rotary file systems in the field of endodontics using digital microscopic images.

Methods:

The protocol was approved by the Ethis Committee for Biomedical & Health Research reference no. AU/EC_BHR/2K22/154. Statitional sample size estimation was done by using GPower software (version 3.0). Sample size was estimated using χ^2 tests - Goodness-of-fit tests.A minimum total sample size of 76 (19 per group) was found to be sufficient for an alpha of 0.05, power of 80%, 0.38 as effect size. To compensate for the loss of sample during the in vitro study, the sample size increased to 20 per group.

Preparation of the samples

Single rooted mandibular premolars were collected for this study. Teeth with external cracks, severe curves or external defects, incompletely formed apex, and bifurcated canals were removed and replaced.Only straight and single canals (<5º) were included in the study.All the collected teeth specimens were washed and calculus and soft tissue were removed and were then stored in distilled water at room temperature till use.

Preparation of the root canal

All the samples were decoronated using a low-speed saw under water coolant leaving around 16 mm root section for sufficient standardization. All the cut samples were tested using an operating microscope (DFOP-01 Denfort, India). The extracted teeth were decoronated at the cemento-enamel junction with a diamond disc to simplify access to the root canal.The decoronated teeth were then wrapped with aluminium foil (Hindalco Freshwrap) and mounted in acrylic resin (DPI RR Cold Cure). Once the acrylic was set, the teeth were removed, and foil was replaced with light body elastomeric impression material (3M ESPE Empress) to simulate the periodontal ligament.

Access was gained and a number 10 K-file (Dentsply Maillefer, Switzerland) was used to check the patency of the canal.The canal's working lengths were determined by inserting a size 10 K-file into the root canal terminus and subtracting 1 mm from this measurement.

Instrumentation procedure

Eighty teeth were then randomly divided into four

experimental groups with 20 samples in each group according to the different rotary file systems used.

In group 1, samples were instrumented with ProTaper Universal in crown-down manner using 3-4 light brushing strokes at speed of 250rpm and torque 3Ncm for the shaping file SX (19/0.04) and S1(17/0.04), and speed 250rpm and torque 2.0 Ncm for shaping files S2(20/0.04), while for finishing file F1(20/0.07) and F2(25/0.08) the speed was 250rpm and torque 1.5Ncm.

In group 2, samples were instrumented using the ProTaper Gold system following the same sequence as ProTaper universal (group 1) was used, SX file (19/0.04), S1(18/0.02) and S2 (20/0.04)files, F1(20/0.07),F2 (25/0.08)file till full working length.

In group 3, samples were instrumented using HyFlex EDM file at speed 500rpm and 2.5Ncm, with slightly apical pressure and pecking motion. The sequence was 25/0.12 at coronal two-thirds of the working length, followed by 10/0.05 (glide path) and 25/~ (Onefile) till the working length.

In group 4, samples were instrumented using a set of Neoendo flex files at speed of 350rpm and 1.5 Ncm torque. The sequence followed was 30/0.08 for coronal flaring, followed by 17/0.04, 20/0.04, 25/0.04, 20/0.06 and 25/0.06 till working length.

All the samples in the four experimental groups were prepared with rotational motion using X-Smart motor (Dentsply-Maillefer,Switzerland) and instrumented with uniform tip diameter #25 and with the use of proper lubricant, EDTA gel (De smear, Anabond Stedman Pharma, India.). Canal irrigation was done using 3% NaOCl (Nova Dental Products Pvt. Ltd, Mumbai, India) (5 mL), employing a 30-gauge side-vented needle (Dispovan).

Sectioning and microscopic analysis:

Sectioning was performed in horizontal plane perpendicular to the long axis at 3, 6, and 9 mm from cementoenamel junction using a diamond disc (DFOP-01 Denfort, India) under water coolant. A digital caliper (AR instrumented,Germany) was used to measure the slices to ensure uniform thickness of all slices. The cross sections were photographed under ×25 and ×80 magnification using a stereomicroscope (Olympus, Tokyo, Japan) attached to a digital camera. A total of 240 digital images (60 per group) were obtained.A single examiner observed each sample to check the presence or absence of dentinal cracks.

The Scoring criteria was categorized into two groups.No cracks was defined as root dentin free of craze lines, cracks, or defects on the root surface (inner and outer).Cracks was defined as all lines and cracks observed, which were extended or not extended to the external root surface, for example, a craze line or a partial crack, and complete crack.

RESULTS

A chi-square test was performed to compare the incidence of dentinal cracks between the four groups. All statistical analyses were performed by using Statistical Package for Social Sciences, (SPSS) version 25.0. (SPSS Inc., Chicago, IL, USA). The level of significance was set at $P = 0.05$.

Figure 1 depicts the presence of cracks in the cross-sections of the experimental groups.

Table 1 represents the comparison of dentinal cracks between all four groups. Group A (ProTaper Universal) showed the maximum percentage of dentinal cracks ($P < 0.05$) followed by Group D (Neoendo Flex), Group B (ProTaper Gold), and Group C (HyFlex EDM) showed the lowest percentage of cracks.

Table 2 represents the intergroup comparison of cracks at different levels of the root. In the intergroup comparison between the four groups, coronal 9mm sections showed an increased percentage of dentinal cracks ($P = 0.007$) followed by 6mm and 3mm which was statistically significant. ProTaper Universal had an overall appearance of cracks in all the three sections in comparison to other groups.

DISCUSSION

Momentary stress concentrations during canal enlargement using different techniques and the subsequent profound contact of instruments with dentin walls result in the initiation of dentinal defects. The higher frequency of defects in a material exponentially increases the risk of stress concentration during mechanical loading and potentially impairs the mechanical performance of the restorative assembly leading to catastrophic fracture under lower loads than the conventional nominal resistance, and that microcracks induced by different root canal preparation techniques could

compromise tooth mechanical performance during masticatory.[4]

Peter et al in their study concluded that the rotary and reciprocating files create microcracks in the radicular dentin ranging from 15% to 60% and the clinical prevalence of VRFs leading to tooth extraction of root filled teeth ranged from 8.8% to 13.4% according to various data.[5,6] In the present in vitro study, out of 240 samples evaluated for cracks,12% of the samples showed dentinal cracks. There were no cracks in some samples of each group as in agreement with other studies depicting sectioning method had no effect on crack formation and also sectioning was carried out with water coolant which might have lead to this.[6] Sodium hypochlorite in a concentration of three percentage was used in this study as an attempt to preserve dentin mechanical properties.[7] For standardization of the canal anatomy, mandibular premolars with single roots were chosen.

Digital stereomicroscope aids in high-resolution digital photos, imaging qualities displayed in a larger format on a high-resolution provides for better accuracy, diagnostic precision, and qualitative evaluation than the conventional approaches. The time required for analysis with SEM was almost double that of a digital stereomicroscope which is an alternative in less demanding tasks.[8]

Numerous improvements and evolution of different generations of engine-driven nickel-titanium instruments in the past 20 years were observed in the geometric design, manufacturing surface treatment such as electropolishing, thermal treatment, and metallurgy.

ProTaper Universal (Dentsply –Maillefer, Ballaigues, Switzerland) represented a revolutionary progression in root canal preparation procedures. It was the first system to offer active cutting edges, a progressively tapered design on a single file, and both Shaping and Finishing files, made of the conventional Ni-Ti and ProTaper Gold (Dentsply –Maillefer), the next in the series of the ProTaper file system with the exact geometries as the former but fortuitously has been metallurgically enhanced through heat treatment technology leading to increased flexibility and cyclic fatigue. HyFlex EDM (Coltene, USA) is a 5th-generation rotary system that adapts the advantages of the second and third generations. The most recent Neoendo Flex files (Orikam Health India Private Limited), is a third-generation rotary file with two file-shaping systems. According to the manufacturers, this system underwent proprietary heat treatment (Gold Thermal Treatment) that increases cutting efficiency and flexibility.

In the present study,ProTaper Universal rotary files demonstrated 20% dentinal defects as compared to ProTaper Gold (8.3%) Hyflex EDM (5%) and Neoendo (16.6%) .

The increased percentage of cracks found in the ProTaper Universal group maybe attributed to progressive taper design along with increased relative stiffness as these were manufactured using the conventional Ni-Ti wire which might have lead to more stress generation and concentration of stress especially in the apical root end comparing to Protaper Gold and Hyflex in accordance with Bergmans et al. [9]

Pirani et al in their study quoted HyFlex EDM with a variable cross-section design (from triangular to trapezoidal and quadratic) and EDM technology being used in their manufacturing which makes it extremely flexible and built-in memory which prevents stress during canal preparation by the change in their spiral shape and following the anatomy of the canal, thus creating fewer cracks.[10] Consequently, the overall lesser percentage of cracks in the HyFlex compared with other groups in this study might be related to these confounding factors.

There were more cracks in the coronal (9mm) of the root in all the groups which might have been produced by the orifice opener presenting with larger taper instruments generating forces on walls of oval canals of mandibular premolars and sacrificing more of normal dentine. These forces lead to the creation of stress and crack propagation on the weakened dentinal walls in the coronal sections.[11,12] The SX file of Protaper instruments exhibits nine increasingly larger tapers ranging from 3.5% to 19% between D1 and D9, and a fixed 2% taper between D10 and D14.[13]

Despite the 12% taper of HyFlex orifice opener files, the lesser percentage of cracks can be attributed to the increased rotational speed as recommended by the manufacturers. According to Peters et al the

increase in the rotational speed was associated with increased cutting efficiency and might be related to less crack formation.[1] An extended fatigue resistance and recommended speed of 500 rpm which is higher than the other instruments tested in the present study could be reason for overall decrease in cracks by Hyflex.

ProTaper Gold has a convex triangular cross-section geometry which decreases rotational friction between the blade of the file and dentin and its two-stage specific transformation behavior and high austenitic finishing temperatures similar to CM wire technology imparts more flexibility. [14] These findings are per the findings of Pedulla et al who concluded M wire and CM wire exhibit more flexibility than conventional Ni-Ti rotary instruments. [1,15]

The Protaper S1 file exhibits twelve increasingly larger tapers ranging from 2% to 11% between D1 and D14 and S2 file exhibits nine increasingly larger tapers ranging from 4% to 11.5% between D1 and D14. They are designed to prepare the coronal one-third of a canal and middle one-third respectively .[13] The increasingly larger tapers over the length of their cutting blades of shaping files might have lead to more cracks in Protaper universal and Protaper gold in the middle sections comparing to the other groups.[11]

The finishing file of Protaper instruments (F1) have fixed taper of 7% between D0 and D3 and from D4-D14 each instrument has increasing cross-sectional dimensions but over this same length, each instrument has a decreasing percentage taper. Decreasing the percentage taper over a portion of a files' cutting blades serves to improve flexibility, and reduces the potential for dangerous taper-lock. [11,13] This might have lead to comparatively lesser cracks in Protaper instruments in relation to the constant 6% taper along the whole length of the Neoendo flex files in the apical sections of samples. The cracks found in the sample prepared with Neoendo can be attributed to its triangular cross-section along with the constant taper, and lack of shape memory feature can lead to increased torsional load and fatigue to file and also imparts more dentinal cracks. [16] The study done by Ananya et al analysed that because of the triangular cross-section, the file comes in contact with the dentin at 3 points which creates more tensile stress on the dentin wall leading to dentinal microcracks comparing to the convex triangular cross-sections of Protaper instruments where the contact stresses are less.[17] The increase in the mass and the contact points between the instrument surface and the dentin walls influence the flexibility of the Ni-Ti endodontic rotary files leading to excessive root canal dentine removal, apical transportation , root perforations, and fractures.[18]

Various speed and torque of the instruments were a limitation in this study as it could not be standardized. The forces during instrumentation could be considered for possible bias .More advanced technologies and simulation of similar oral and clinical conditions should be carried out for the assessment of dentinal cracks to conclude choosing a dentin-friendly file system.

CONCLUSION

Within the limitations of this study, it can be concluded that all Ni-Ti files tested in this study may cause dentinal cracks on the root surface. The Contact stress levels created in the root dentin are determined by their cross-sectional, longitudinal design and the heat treatment undergone by the various file systems which play a integral role in crack formation and propagation. The overall frequency of cracks was more in Protaper universal files compared to Neoendo flex files followed by ProTaper Gold and Hyflex EDM files.

Clinical significance

All the rotary systems tested in this invitro study produced dentinal cracks. These cracks create stresses in the dentinal walls which can propagate to vertical root fracture and ultimately lead to poor endodontic prognosis and failure.

BIBLIOGRAPHY

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004; 30:559-67.
2. Jacob J, Paul M, Sara B, Steaphen P, Philip N, Mathew J. Comparative Analysis of Dentinal Crack Formation Following Root Canal Instrumentation with Hand K-Flex Files, ProTaper Next, and Self-adjusting Files. J Contemp Dent Pract 2019; 20:935-939.
3. Devi TP, Kaur A, Priyadarshini S, Deepak BS, Banerjee S, Sanjeeta N. Microscopic Assessment of Dentinal Defects Induced by ProTaper Universal, ProTaper Gold, and Hyflex Electric Discharge Machining Rotary File Systems - An in vitro Study. Contemp Clin Dent 2021; 12:230-234.
4. Valle AD, Dotto L, Morgental RD, Pereira-Cenci T, Pereira GKDR, Sarkis-Onofre R. Influence of Root Canal Preparation on Formation of Dentinal Microcracks: A Systematic Review. Braz Dent J 2020; 31:201-220.
5. Peters OA, de Azevedo Bahia MG, Pereira ES. Contemporary Root Canal Preparation: Innovations in Biomechanics. Dent Clin North Am 2017; 61:37-58.
6. Versiani MA, Cavalcante DM, Belladonna FG, Silva EJNL, Souza EM, De-Deus G. A critical analysis of research methods and experimental models to study dentinal microcracks. Int Endod J 2022; 55:178-226.
7. Moorer WR, Wesselink PR. Factors promoting the tissue dissolving capability of sodium hypochlorite. Int Endod J 1982; 15:187–96.
8. Daher R, Krejci I, di Bella E, Marger L. Evaluation of the Validity of Digital Optical Microscopy in the Assessment of Marginal Adaptation of Dental Adhesive Interfaces. Polymers (Basel) 2021; 14-83.
9. Bergmans L, Cleynenbreugel JV, Beullens M, Wevers M, Meerbeek BV, Lambrechts P. Smooth flexible versus active tapered shaft design using NiTi rotary instruments. Int Endod J 2002; 35:820-8.
10. Pirani C, Iacono F, Generali L, Sassatelli P, Nucci C, Lusvarghi L, et al. HyFlex EDM: superficial features, metallurgical analysis and fatigue resistance of innovative electro discharge machined NiTi rotary instruments. Int Endod J 2016;49:483-93.
11. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod 2009; 35:236-8.
12. Sindi F, Zahid A, Alghamdi F, Albassam A. The Incidence of Dentinal Microcracks in Single-Rooted Teeth Using Reciproc, One Curve, and Vortex Blue Endodontic File Systems: An In Vitro Study. Journal of Research in Medical and Dental Science 2021; 9:50-8.
13. Ruddle CJ. The ProTaper advantage: Shaping the future of endodontics.Dentistry Today 2001; 10:1-9.
14. Zan R, Tunç T, Hubbezoğlu İ, Sümer Z. Apical extrusion of intracanal biofilm using ProTaper Gold, WaveOne Gold,Twisted File Adaptive, OneShape New Generation and K3XF. Eur Endod J 2016; 1:1-6.
15. Pedullà E, Genovesi F, Rapisarda S, La Rosa GR, Grande NM, Plotino G, et al. Effects of 6 Single-File Systems on Dentinal Crack Formation. J Endod 2017; 43:456-461.
16. Chhabra A, Ramya KP, Prathap BS, Yadav P. Life span of Neoendo Flex and ProTaper Next rotary files with reciprocating motion in single-rooted teeth. J Conserv Dent Endod 2023; 26:420-423.
17. Guha A, Pandharikar R, Shivangi S, Rao RD, Verma M, Jain AK. Comparative evaluation of dentinal crack formation after root canal preparation with Neoendo Flex and Mani Silk files: An in vitro study. J Conserv Dent 2020; 23:468-472.
18. Faus-Llácer V, Hamoud-Kharrat N, Marhuenda Ramos MT, Faus-Matoses I, Zubizarreta-Macho Á, Ruiz Sánchez C, Faus-Matoses V. Influence of the Geometrical Cross-Section Design on the Dynamic Cyclic Fatigue Resistance of NiTi Endodontic Rotary Files-An In Vitro Study. J Clin Med 2021; 10:4713.

Table 1: Overall cracks comparison among the study groups

Group	No.of cracks present	No.of cracks absent	Chi-Square	p-value
	n(%)	n(%)		
Group A (Universal)	12(20)	48(80)	24.56	<0.01*
Group B (Gold)	5(8.33)	55(91.67)		
Group C (Hyflex)	3(5)	57(95)		
Group D (Neoendo)	10(16.67)	50(83.33)		

*: statistically significant

Table 2: Intergroup comparison of cracks at apical (3mm), middle (6mm) and coronal (9mm) among the study group.

Levels	Groups	Present	Absent	Chi-square	p-value
		n (%)	n (%)		
Apical level (3mm)	Group A (Universal)	1(5)	19(95)	8.14	0.039 *
	Group B (Gold)	0(0)	20(100)		
	Group C (Hyflex)	0(0)	20(100)		
	Group D (Neoendo)	3(15)	17(85)		
Middle level (6mm)	Group A (Universal)	3(15)	17(85)	8.14	0.039 *
	Group B (Gold)	1(5)	19(95)		
	Group C (Hyflex)	0(0)	20(100)		
	Group D (Neoendo)	0(0)	20(100)		
Coronal level (9mm)	Group A (Universal)	8(40)	12(60)	11.23	0.007 *
	Group B (Gold)	4(20)	16(80)		
	Group C (Hyflex)	3(15)	17(85)		
	Group D (Neoendo)	7(35)	13(65)		

*: statistically significan

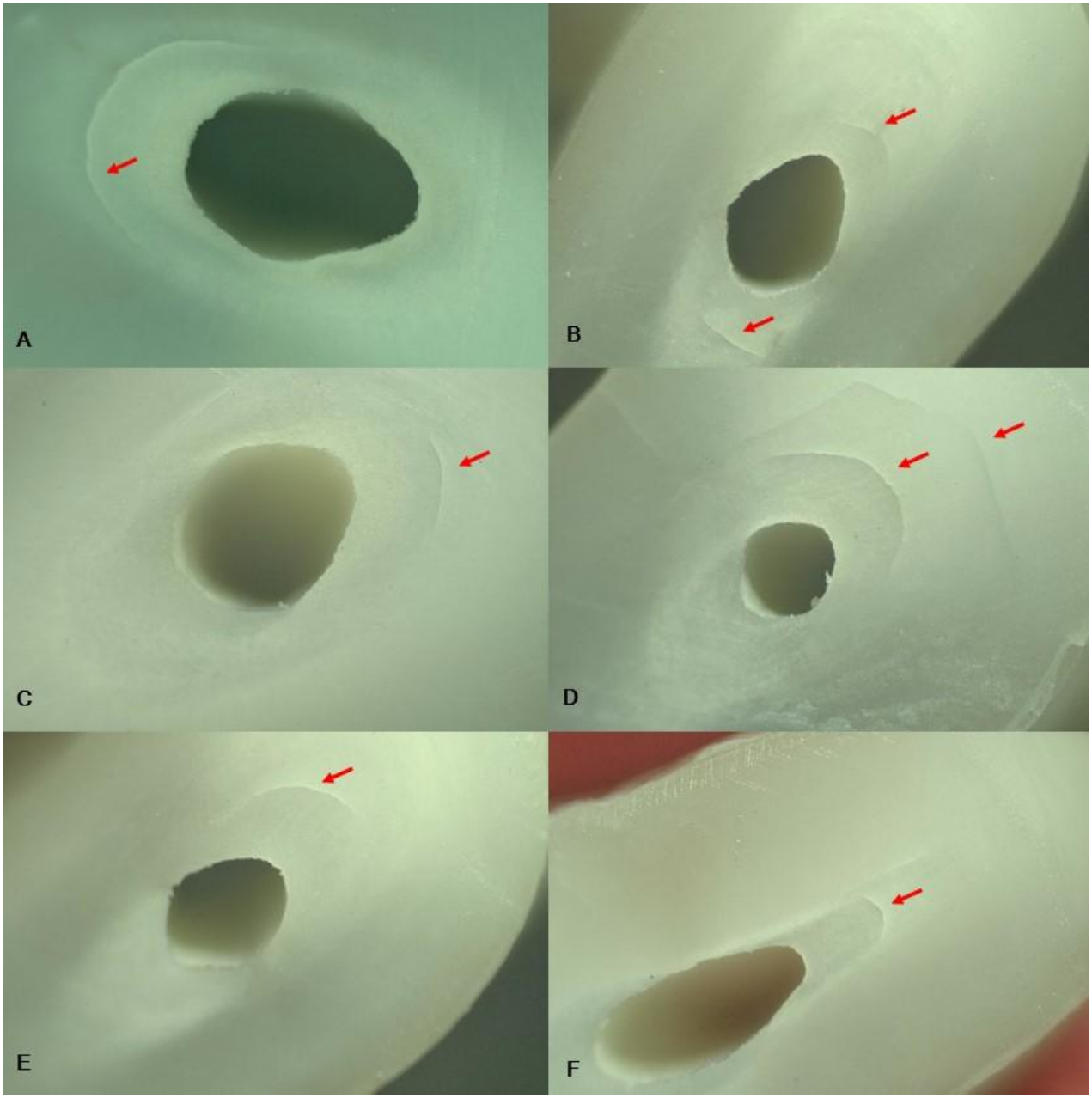

FIGURE LEGENDS

Figure 1: Cross section at 9-mm level (A and B), at 6mm (C and D), at 3mm(E and F) viewed under ×80 magnification. Visible cracks after Ni-Ti instrumentation(marked by red arrows)