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CONFOCAL MICROSCOPIC EVALUATION OF DENTINAL CRACKS USING DIFFERENT ROTARY FILE SYSTEMS: PROTAPER NEXT, HYFLEX CM AND HYFLEX EDM.

Dental Science

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ABSTRACT

Aim: The aim of the present study was to investigate the incidence of cracks in root dentin after root canal preparation with ProTaper Next, HyFlex CM and Hyflex EDM rotary file systems.

Methods: 60 single rooted mandibular premolars were selected. All the specimens were divided into four groups of 15 teeth each. Group I- unprepared root canal serve as control. Group II- were prepared with ProTaper Next to size 25/0.06, Group III- were prepared with Hyflex CM to size 25/0.04 and Group IV- were prepared with Hyflex EDM to size 25/-. After root canal preparation, all the roots were horizontally sectioned at 2mm and 4mm from the apex, and the sections were then observed under Confocal Laser Scanning Microscope with 4X magnification. The absence/presence of cracks was recorded, and the data were analyzed with a chi-square test. The significance level was set at P = .05.

Results: No cracks were observed in the control group. Vertical root fractures were not observed in any of the groups. The Hyflex EDM file system caused fewer cracks (10%) than the ProTaper Next (20%) and Hyflex CM (16.7) file systems. However, there were no significant differences in crack formation among different file systems (P > .05).

Conclusions: Within the limitations of this in vitro study, all of the instrumentation systems used in this study created cracks in the root dentin. The Hyflex EDM file system tended to cause fewer dentinal cracks compared with the ProTaper Next and Hyflex CM file systems.

KEYWORDS

ProTaper Next, Hyflex CM, Hyflex EDM, Confocal laser electron microscope, Dentinal cracks.

INTRODUCTION:

Bio mechanical preparation is one of the most important factors for successful root canal treatment and determines the efficacy of all subsequent procedures.[1] It is done to completely remove organic tissue, microorganisms and debris by enlarging the canal diameter and creating a shape that allows a proper seal.[2] The main mechanical objective of cleaning and shaping of root canal is complete and centered incorporation of the original canals into the prepared shape as well as to retain as much cervical and radicular dentin as possible so as not to weaken the root structure, thereby preventing root fractures.[3]

In the last decade **Walia**, **Brantley** and **Gertein** introduced NiTi in endodontics in 1988. The emergence of NiTi rotary instrumentation has transfigured the root canal treatment by reducing the operator fatigue, time required to complete the preparation and minimize the procedural errors as compared with hand instrumentation.[4] However, they produce significant forces on root dentin during instrumentation and leads to root dentinal defects or apical root microcracks which have potential to develop into root fracture, thus deteriorating the root integrity and reducing long term prognosis of endodontically treated teeth.[5]

Over the last decades, technological advancement in rotary NiTi instruments has led to new design concepts and easier, faster and better root canal shaping. Recently, ProTaper Next instruments have been introduced in the family of NiTi rotary instruments that have an off-centered rectangular design and progressive and regressive percentage tapers on a single file, which is made from M-wire technology.[6]

Nitinol rotary instrument HyFlex CM that is machined from a wire (termed CM-wire) previously subjected to a proprietary, novel and thermomechanical processing procedure and has double fluted hedstroem cross section design. Clinical use seems to indicate that these new HyFlex CM rotary instruments have outstanding clinical fatigue resistance.[7]

Recently, patented treatments are involved in the innovative manufacturing of new HyFlex EDM files. The main feature of these files is that they are manufactured via an electro discharge machining (EDM) process. The EDM is a noncontact machining procedure used in engineering for the manufacturing of parts that would be difficult to machine with conventional techniques **Daneshmand et al (2017)**.[8]

Several microscopy techniques are currently used to evaluate the dentinal cracks, including stereomicroscopy. In comparison to conventional stereomicroscope, confocal laser scanning microscope has the advantage of providing detailed information about the presence of thin cracks in the local circumference of the root canal walls at relatively low magnification and need comparatively thick sections.[9]

Recently, advances in rotary nickel-titanium (NiTi) instruments have led to new designs and techniques of root canal preparation. Design features, such as NiTi core diameter, cross sectional shape, rake angle and flute depth may affect the behavior of the file and therefore, may influence the generation of cracks.[10] ProTaper Next, Hyflex CM and Hyflex EDM are files widely used, with each having different design features and manufacturing technology. Hence, they are assumed to cause limited frictional forces within the canal and creating dentinal defects. So, there is a need to study the behavior of different NiTi rotary instruments and systems on root dentin.

MATERIALS AND METHOD:

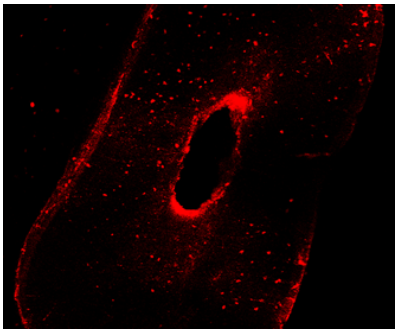
Sixty extracted single rooted mandibular premolars teeth, with single canal and mature apices were selected and stored in saline throughout the study. The teeth were inspected for the evidence of root caries or fracture, open apices, calcified canals, multiple canals, anatomical variations or resorption and discarded if any of these characteristics were found. The coronal portion of all teeth were decoronated 12mm in length from the apex under water-cooling with diamond disk for standalization.[11] Silicon impression material was used to simulate periodontal ligament and specimens was mounted in gypsum stone for stabilisation.[2] Root canals of all teeth were enlarged to size 20 by hand K-file and copious irrigation alternating with sodium hypochlorite and saline was done between the instrumentation.[12] Finally, all the specimens were divided into four groups of 15 teeth each. Group I were unprepared root canals serve as a control, Group II were prepared with ProTaper Next to size 25/0.06, Group III were prepared with Hyflex CM to size 25/0.04 and Group IV were prepared with Hyflex EDM to size 25/- (variable taper).

Prepared specimens were horizontally sectioned at 2mm and 4mm from the apex with diamond disk under water cooling.[12]

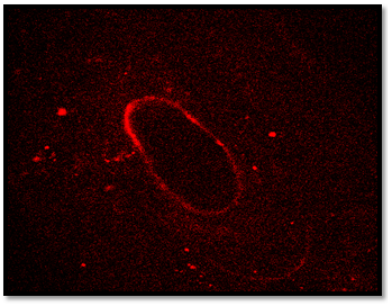
Imaging of prepared sections was performed in 3-D Confocal Laser Scanning Microscope with a 4X magnification. 3D reconstruction and display of cubic imaging were built up by NIS – Element D (Advance Research Microscope Imaging Software) BR Ver4.13.05 32 bit edition.

The defects were classified depending on the following criteria and scored accordingly.[13]

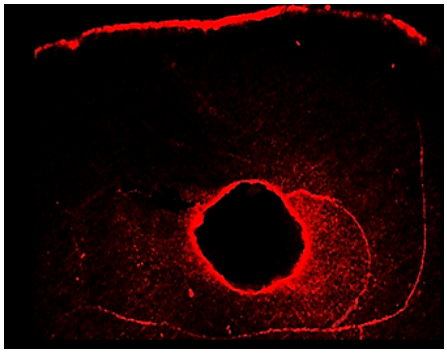
1. Score 1 : No defect in root dentin without any lines or cracks on the external or internal surface.
2. Score 2 : An incomplete crack that is a line extending from the canal wall into the dentin without reaching the outer surface.
3. Score 3 : A complete crack that is a line extending from the canal wall to the outer surface of the root.



SCORE 1: No defect in root dentin without any lines or cracks on the external or internal surface.



SCORE 2: An incomplete crack that is a line extending from the canal wall into the dentin without reaching the outer surface.



SCORE 3: A complete crack that is a line extending from the canal wall to the outer surface of the root.

Statistical analysis: The data was analysed using 3D reconstruction and display of cubic imaging were built up by NIS – Element D (Advance Research Microscope Imaging Software) BR Ver4.13.05 32 bit edition. Chi square test was used to determine statistically significant difference in the appearance of defected roots between the experimental groups.

RESULTS :

Table 1 shows the number and percentage of cracks in each sections and the total number of defective samples. Figure 1 is a bar chart representing the percentage of defects in each group. Hyflex EDM produced least percentage of dentinal microcracks at 2mm and 4mm level from the apex. Hyflex CM produced slightly lesser cracks than ProTaper Next at 2mm level from the apex but relatively same percentage of cracks at 4mm level from the apex.

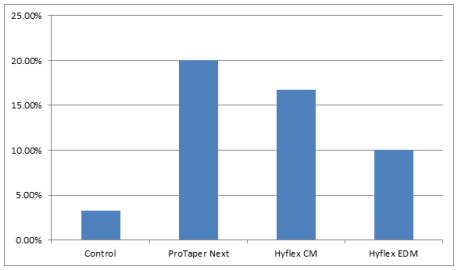
All instrument tested created dentinal microcracks, mainly in the apical sections (2mm). Hyflex EDM showed fewer microcracks than other experimental groups. However, no statistically significant difference was found between them in dentinal microcracks formation. At 2mm level from the apex least cracks were present in control group followed by Hyflex EDM. Hyflex CM showed slightly greater cracks than ProTaper Next.

At 4mm level from the apex no cracks were there in control group. ProTaper Next, Hyflex CM and Hyflex EDM showed same percentage of cracks.

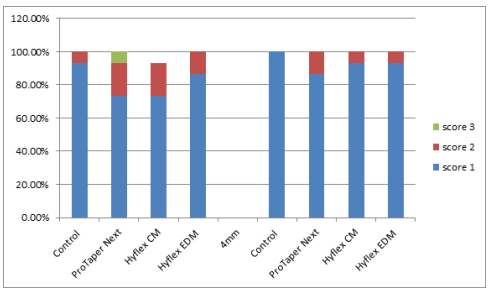
Total Percentage Of Cracks Including 2MM And 4MM Sections.

			Group				Total
			Cntrl Gp	ProTaper Next	Hyflex CM	Hyflex EDM	
Microcracks	1	Count	29	24	25	27	105
		% within Microcracks	27.6%	22.9%	23.8%	25.7%	100.0%
		% within group	96.7%	80.0%	83.3%	90.0%	87.5%
	2	Count	1	5	5	3	14
		% within Microcracks	7.1%	35.7%	35.7%	21.4%	100.0%
		% within group	3.3%	16.7%	16.7%	10.0%	11.7%
	3	Count	0	1	0	0	1
		% within Microcracks	.0%	100.0%	.0%	.0%	100.0%
		% within group	.0%	3.3%	.0%	.0%	.8%
Total		Count	30	30	30	30	120
		% within Microcracks	25.0%	25.0%	25.0%	25.0%	100.0%
		% within group	100.0%	100.0%	100.0%	100.0%	100.0%

Graphical Presentation Of Total Percentage Of Microcracks Induced By Different Rotary File System: Protaper Next, Hyflex Cm And Hyflex Edm.



Graphical Presentation Of Percentage Of Microcracks At 2mm And 4mm Level From The Apex With Respect To Scoring Criteria.



DISCUSSION :

In this study, mandible premolars were selected to be assessed as they are probably more prone to be influenced by forces during instrumentation as a result of their small dimensions and thin dentinal walls. If tapered files cannot induce cracks in mandible premolar, it is unlikely that rotary files induce cracks in other teeth.[14] The teeth were then sectioned at different levels and looked for microcracks using a Confocal Laser Scanning Microscope (CLSM). The sectioning method has a significant disadvantage related to its destructive nature and possible microcracks induced by the sectioning as reported by **Priya et al**.[15] In contrast, the study conducted by **Milani et al** and **Capar et al** reported that sawing action could not result in dentinal defects, because no microcrack defects were found in the control group.[16,17] Similar findings were also present in our study, with no influence of sectioning on crack formation. These variations might be caused by some methodological differences used in this study, such as the exclusion of teeth that presented with microcracks before canal shaping and the use of precision low speed saw that counterbalance downward force applied to the samples during sectioning.[2,10]

Closed environment system i.e dental stone moulds and silicone impression material were used to simulate bone and periodontal ligament respectively, to mimic clinical conditions as closely as possible, as previously reported in other studies.[18,19,20] In the oral cavity, the periodontal ligament acts as a buffer against the stress generated during mastication and dissipates the masticatory forces to the tissues supporting the teeth, thus causing changes in the mastication pattern and providing high resistance to restoration fractures.[10] Silicone impression material was used to hold the specimen during instrumentation to maintain hydration of the specimens and simulate the resilience of the periodontal ligament.[16] This choice was made on the basis of the assumption that not using a resilient material to create this experimental closed system would result in an even less accurate simulation of the clinical reality.

3% sodium hypochlorite was used for irrigation in the present study. NaOCl being an alkaline material reacts with organic tissue and can change the chemical structure and the mechanical properties (elastic modulus and flexural strength) of dentine.[21] It was observed that there was marked decrease in microhardness of dentin when irrigation was done with NaOCl.[22] **Goldberg et al** conducted a study on the effect of NaOCl on root dentin microhardness for various irrigation periods and found that there is no significant difference in groups irrigated for 10 and 20 minutes. So, concordant to this finding, this present study also limits the irrigation period between 10 to 20 minutes for control and prepared groups with ProTaper Next, Hyflex CM and Hyflex EDM for standardization.[23]

The screw- in effect of a rotary file, deviation of canal from the original anatomy and cutting efficiency of a file influence dentinal micro crack formation during root canal preparation by rotary files.[21] The cross-section of the rotary files influences the screw-in effect, maintenance of the centrality of the canal and the cutting efficiency. Thus, the cross section of the file has a major role on the crack formation in dentin. In the cross section of the file, core diameter, flutes depth and land play major role when a rotary file works inside a canal.[22]

Burklein et al found that preparation technique and the cross-sectional geometry of instruments are more important in crack occurrence than the working type.[24] **Nasr et al** concluded that the alloy from which an instrument is manufactured is a more important factor in the occurrence of dentinal defects.[25] **Shori et al** stated that file design affects the force applied to root dentin, which is relevant to fracture risk.[26] These studies reported that manufacturing type and the cross-sectional geometry of instruments affect the force applied to root dentin, and subsequently crack occurrence.

Hence, the present study was aimed to compare dentinal crack formation caused by the following rotary instruments: Protaper Next, with an off-centered rectangular cross-section design and manufactured with M-wire technology; Hyflex CM , with double fluted hedstroem design , 2 cutting blades and CM-wire technology and Hyflex EDM, with three different cross sections: quadratic in the apical third, trapezoidal in the middle third, and almost triangular in the coronal third and manufactured using the technique of electrical discharge machining (EDM) with CM-wire features.

In the present study, unprepared control group and prepared root canals with ProTaper Next, Hyflex CM and HyFlex EDM rotary files, showed the incidence of dentinal microcracks as 3.3%, 20.0%, 16.7% and 10.0% of the specimens respectively. ProTaper Next was the only group where complete crack running from internal wall to external wall was noted. Results of the present study indicated that instrumentation techniques and rotary systems used for all the canals created dentinal defects without a significant difference between them.

In Hyflex EDM group; two files were used for canal preparation, while in ProTaper Next group and Hyflex CM group; three files were used. Finishing the root canal preparation with more files and using an initial instrument with greater taper might explain why ProTaper Next and Hyflex CM caused more cracks than the Hyflex EDM rotary file system.[27]

The rotary file systems tend to generate greater stress on the root canal walls. Higher stress induction on the walls is due to greater number of rpm, resulting in faster and more aggressive cutting. At the same time, due to positive rake angle and lower contact area as compared to hand files, the stress concentration is higher.[22]

Hyflex EDM produced fewer, but not significantly different cracks compared with other rotary file systems used in the study. Among rotary file systems, Hyflex EDM which is a single file system induced least number of defects when compared to multiple file system. This result is probably caused by the high flexibility of Hyflex EDM caused by the synergistic effect of the Controlled Memory wire and the electrical discharge machining (EDM) manufacturing process which is in agreement with previous reports.[20,28,29] Previous studies reported higher flexibility of Controlled Memory files than those made from conventional NiTi wire or M-Wire.[20,28,29] In addition, in Hyflex EDM group, two files were used for canal preparation, hence finishing the root canal preparation with less files might explain why Hyflex EDM caused less cracks as compared to other rotary file groups.[27]

According to **Zandbiglari et al** greater taper instruments significantly weaken the root.[22] **Kesim et al** also confirmed that when taper of the instrument is increased, it tends to remove more root dentin, compromising the root which is more likely to get dentinal defects.[30] **Bier et al** found that when NiTi rotary instruments with a taper of 0.06 or more are used, dentinal defects result.[2]

Contrary to these findings, in our study, Hyflex EDM although possessing greater taper at the tip (.08) than the other rotary file systems used in the study did not result in higher number of dentinal defects. The probable reason for this result could be because the number of cutting edges reduced from three to two in apical and coronal region respectively.[27]

In coherence to our study, **Pedulla et al** compared the formation of microcracks after canal preparation performed with different single-file systems and concluded that HyFlex EDM showed fewer microcracks than other experimental groups; however, no significant difference was found between them in crack formation.[29] These results are probably because of the easy canal configurations (mandibular premolars) of the tested teeth as well as the use of only single-file techniques (no sequences of files) to shape root canals. This result is also probably caused by the high flexibility of Hyflex EDM caused by the synergistic effect of the Controlled Memory wire and the electrical discharge machining manufacturing process.

Results of our study showed that microcracks caused by ProTaper Next (20.0%) are more as compared to Hyflex CM (16.7%). Similarly, **Ashraf et al** also found that ProTaper Next (47.1) caused more microcracks as compared to Hyflex CM (2.9%).[14] But the percentage of cracks observed in both the groups are different in their study compared to our study, which is probably due to the use of less quantity and lower concentration of sodium hypochlorite i.e 2mL of 1% sodium hypochlorite after each instrument and different stabilizing method i.e acrylic moulds.

The major number of microcracks was observed in the apical section (2mm from the apex) for all the tested instruments as compared to middle sections (4mm from the apex), which is in agreement with previous studies.[12,13,14,29] It suggested that the maximal stress concentration occur in apical third of root canals by rotary instrumentation during canal preparation. This is the result of an accumulation of mechanical stress over the successive instrumentation

sessions or of lower capability of thinner and therefore more fragile apical dentin to with stand the mechanical stress produced by direct contact with the instruments.[12] These results are probably influenced from the different cross sections of the rotary file systems used such as variable taper which can explain the reduced number of microcracks at 4mm of the teeth sections.[13,29] Although the difference is not significant. Using an initial instrument with greater taper and size may explain why more cracks occurred at 2mm level. Likewise, preparing root canals without performing an open and wide pathway with the smaller size of the instruments may also result in more cracks at 2mm level.[22]

Overall, the discrepancy in results can be explained by the differences in size between sample teeth, methodological design, different sectioning levels, periodontal ligament simulation, and different types and sizes of instruments, which precludes a direct comparison of the results of the present study with those reported in the related literature. Because the combination of instruments used in the present study are not used in any other study, the experimental data available in the literature are scant; therefore, more studies are required to understand the influence of these instruments on the incidence of dentinal defects formed on the root canal wall.

CONCLUSION:

With in the limitations of this in vitro study, the instrumentation of root canals with ProTaper Next, Hyflex CM and Hyflex EDM instruments can cause crack formation in root canal dentin. The Hyflex EDM instruments have a tendency to cause fewer dentinal cracks compared with the ProTaper Next and Hyflex CM.

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