Original Article

Comparative Evaluation of Microcracks Formed During Root Canal Preparation by Five Rotary File Systems in Mandibular Molars under Stereo Microscope – An *Ex Vivo* Study

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Abstract

Aim: This *ex vivo* study compared the dentinal microcracks induced by different nickel-titanium rotary instruments such as ProTaper Gold (Dentsply Tulsa Dental Specialties), HyFlex EDM (Coltene Whaledent AG Switzerland), Neo Endo (Micromega Besancon, Cedex, France), and Edge Taper Encore (Edge Endo) and Silk (Mani) rotary systems under Stereomicroscope. **Methodology:** One hundred periodontaly involved mandibular first molars with intact distal root were selected, were assigned into five groups (*n*: 20 each). All the specimens were with five different rotary file systems and then sectioned at 3 mm, 6 mm, and 9 mm from the apex, and further, the specimens were stores in 2% methylene blue for 72 h. Each specimen was then analyzed by use of stereo microscope for dentinal defects at magnification 40×. **Results:** All the experimental rotary systems created dentinal defects. HyFlex EDM (Group I) showed minimal defects among all the NiTi rotary instruments groups followed by ProTaper Gold (Group V) EdgeEndo (Group III) and NeoEndo (Group IV) maximum defects were shown by Mani Silk (Group II). There was no significant difference between EdgeEndo and NeoEndo file groups. There was a significant difference between HyFlex EDM and the ProTaper gold file group.

Keywords: Biomechanical preparation, Fracture, Microcracks, Radiovisiography, Root canal.

Introduction

Successful endodontic therapy depends on the classical triad of diagnosis, biomechanical preparation, and complete three-dimensional obturation of the root canal space. Adequate biomechanical preparation is one of the prime requirements of successful endodontic treatment,[1] as it is one of the major steps in complete debridement of root canal space by removing microorganisms, debris, and tissues by enlarging the canal diameter and creating a canal form that allows a proper seal.[2]

Dentin is a natural, hydrated, and mineralized hard tissue that forms the major bulk of a tooth. Mature dentin is made up of an organic fraction (30 wt%), which is mainly collagen, and an interpenetrant inorganic fraction (60 wt%) and water (10 wt%). Inorganic fraction (Carbonated apatite) provides stiffness or elastic modulus (Strength) and ultimate compressive strength. Organic fraction (Type I collagen) provides resistance to crack propagation, enhances the ability to absorb strain energy (toughness), and provides ultimate tensile strength. Water (free and bound) provides time-dependent properties (Viscoelasticity), enhances the ability to absorb stress, has a plasticizing and toughening effect, and facilitates uniform distribution of stress/strains along the entire bulk dentin.[3]

During biomechanical preparation, a canal is shaped by the contact between the instrument and dentinal walls. These contacts create many momentary stresses in dentin. These stress concentrations may induce dentinal defects and microcracks or craze lines which may be associated with increased susceptibility to vertical root fracture.[4] A vertical root fracture is a longitudinally oriented fracture of the root, extending throughout the entire thickness of dentin from the root canal to the periodontium. It may be initiated in the crown or at the apex or, in some cases, along the root between these two points.

MANI FILE SYSTEM Mani Silk Simple, Standard, and Complex packs each contain three instruments. All sizes,

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including additional sizes, are available in 21 mm and 25 mm lengths. Mani Silk Files are anatomy based, have a smooth tactile feel (do not "otlil int the canal), and yet provide efficient and safe canal shaping with a minimum number of instruments. Using the Standard Pack as an example, after making straight line access, removing the cervical dentinal triangle (using the 0.08/25 orifice opener-the file on the left side of the pack) and preparing a glide path, Mani Silk Files are used from left to right in the pack (from 0.06/20 to 0.06/25) until the 0.06/25 reaches the true working length. Any motor that provides 500 rpm with an auto reverse torque setting of 300 gf.cm (=3.0N cm) can power Mani Silk Files.[5]

HYFLEX EDM success in endodontic therapy relies on thorough cleaning and shaping of the root canal system followed by its complete obturation. With an increase in the number of cases reporting for endodontic therapy, dental professionals have to deal with more complicated cases such as those with very fine and curved canals. Standard Nickel-Titanium rotary endodontic files, due to their shape, memory properties, and larger tapers, can often not serve well for such difficult cases. The introduction of controlled memory files (Hyflex, Coltene) and the new generation Electrical discharge machine files (EDM, Coltene) has revolutionized endodontics with their extraordinary properties, which have begun a new era in dentistry.[6]

EDGE ENDO the instrument is made of an Annealed Heat Treated (AHT) nickel-titanium (Ni-Ti) alloy brand named Fire-Wire™. All files are constantly tapered. These files are used in endodontics for the removal of dentin and root canal shaping. They are compatible with the ProTaper® and ProTaper Next® rotary file systems and can be used in the same handpiece at the same speed and torque settings. EdgeEndo produces three different file systems (X3, X5, and X7) which, according to the manufacturer, can be used with the same hand piece, speed, and torque as their specified competitor's recommended settings. X3 files can be used with the same settings as ProTaper and ProTaper Next (Dentsply Tulsa Specialties, Tulsa, OK, USA) rotary file systems.[7] X5 files are compatible with GT and GT Series X (Dentsply) rotary file systems.[8] X7 files are compatible with Vortex, ProFile (Dentsply), K3 (SybronEndo, Orange CA), EndoSequence (Brasseler USA, Savannah GA), TF (SybronEndo), and other similar 04/06 taper rotary file systems. If the competitor's settings are unavailable, then the settings should be 300–500 rpm and 300g/cm for all 3 file systems.

PROTAPER GOLD features the same simplicity, smoothly tapered shapes, and predictable performance you know and trust from ProTaper Universal. Now, the ProTaper legacy continues with ProTaper Gold. Developed with proprietary advanced metallurgy, ProTaper Gold rotary files deliver greater flexibility for predictable ProTaper performance that is more brilliant than ever. The visibly advanced metallurgy of ProTaper Gold creates a difference you can see-and feel. That.r because ProTaper Gold rotary files feature the same exact geometries as ProTaper Universal, but offer an increase in flexibility. This is especially important in the Finishing Files, when navigating challenging curves in the apical region.

NEOENDO Neoendo Neohybrid Rotary Files offer Unique off-centerd rectangular cross section: Asymmetric or swaggering movement (two point contact with the canal wall). Minimal engagement between the file and canal dentin, effectively reducing taper-lock, and screw-in forces as file moves inside the canal. Less cross-sectional area creating higher flexibility for shaping severely curved canals and enhancing loading and augering of debris. CTA Wire-Controlled Thermal Activation Wire: NeoEndo proprietary thermal process. NeoEndo is made through proprietary thermal process which Improves its flexibility while retaining cutting efficiency. Gold, blue, and gray color of the file as progressive heat treatment is applied. Shorter Clinical Sequence. Gold, blue, and gray color of the file as progressive heat treatment is applied. Shorter Clinical Sequence: The merit of efficient endodontics is now understood to be continuous and copious irrigation. Neohybrid, with its unique cross section and CTA wire technology, allows for a shorter clinical sequence – it requires two files for most cases so that you can allocate more time and energy to the pivotal irrigation.

Methodology

One hundred periodontally involved and caries free mandibular first molars will be collected. First, the RVG radiographs were recorded in buccolingual and mesiodistal dimensions before the instrumentation. In an attempt to standardize the length of the root canal, teeth were decorated at Cemento Enamel Junction using High-Speed Alloy Grinder to get approximately 14 mm length of samples to confirm the presence of two distinct and separate root canals. In the mesiodistal dimension, K-File no.10 was inserted into the buccal and lingual canals to assess the degree of root canal curvature according to Schneider's technique. Coronal access was achieved using the High-Speed water cooling Airotor along with Endo-Access Bur to obtain a straight line access. Each tooth was sectioned through the furcation and the mesial portion of the root and crown was used. Distal roots with the respective part of the crown were sectioned at the furcation level and discarded.

Then, the samples were divided into a number of 20 teeth. Each were placed in Group I – Hyflex EDM, Group II – Mani Silk, Group III – Edge Endo, Group IV – Neo Endo, and Group V – Protaper Gold Rotary System. Initial negotiation of root canal space was performed using a size 15 manual K-file used in a watch-winding motion to assure the presence of a glide path as far as the foramen.

In all the groups, canal preparation was performed using a torque and speed- controlled motor (X-Smart; Dentsply Tulsa Dental, Tulsa, OK) at a torque and speed recommended by the manufacturer for each specific system use.

Sectioning of all roots was done perpendicular to the long axis at 3, 6, and 9 mm using a low-speed diamond disk under water

cooling [Figure 1]. The cut sections were stored in 2% Methylene blue for 72 h. Each specimen was then analyzed by use of a stereomicroscope for dentinal defects at magnification 40×.

To define crack formation, two different categories of crack and no cracks were made. No crack was defined as root dentin devoid of any stained craze lines or microcracks originating from the canal lumen. Crack is defined if any stained craze lines, microcracks or fractures are present originating from the root canal lumen.

All the sections of different groups were seen under a stereomicroscope. All the images were analyzed by three observers and defined into categories of a crack or no crack category. The data thus obtained were compiled and subjected to statistical analysis.

Statistical analysis

The data obtained were subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS Version 23; Chicago Inc., IL, USA). Data comparison was done by specific statistical tests to find out the statistical significance of the comparisons. Variables were compared using numbers and percentages. The proportion for different readings between the presence and intensity of cracks was compared using the Chi-square test. An ANOVA test was run to compare the severity of cracks between groups at 3 mm, 6 mm, and 9 mm. $P < 0.05$ was considered to be statistically significant.

Results

The average cracks at all levels, or those that are 3 mm, 6 mm, and 9 mm from the apex, are taken into account. Mani Silk file system attained maximum mean value at all levels, while Hyflex EDM attained minimum mean value. With Hyflex EDM, cracks were greatly reduced. At all levels, maximal mean value was achieved for Mani Silk file system, while minimal value was attained for Hyflex EDM. Cracks were significantly less with Hyflex EDM [Tables 1-3].

Table 1: Distribution of cracks at 3 mm between file system

File system	Present *n* (%)	Absent *n* (%)
Hyflex EDM	8 (40.0)	12 (60.0)
Mani Silk	20 (100.0)	0 (0.0)
Edge Endo	18 (90.0)	2 (10.0)
Neo Endo	18 (90.0)	2 (10.0)
Protaper gold	17 (85.0)	3 (15.0)

Table 2: Distribution of cracks at 6 mm between file system

File system	Present *n* (%)	Absent *n* (%)
Hyflex EDM	4 (20.0)	16 (80.0)
Mani Silk	20 (100.0)	0 (0.0)
Edge Endo	18 (90.0)	2 (10.0)
Neo Endo	17 (85.0)	3 (15.0)
Protaper gold	16 (80.0)	4 (20.0)

Table 3: Distribution of cracks at 9 mm between file system

File system	Present *n* (%)	Absent *n* (%)
Hyflex EDM	4 (20.0)	16 (80.0)
Mani Silk	20 (100.0)	0 (0.0)
Edge Endo	19 (95.0)	1 (5.0)
Neo Endo	17 (85.0)	3 (15.0)
Protaper gold	16 (80.0)	4 (20.0)

Discussion

The primary aims of chemomechanical root canal preparation include the preservation of the original course of the canal and creating adequate space for copious irrigation and three-dimensional obturation (Schafer *et al*. 2006). The use of inflexible stainless steel instruments in curved canals can cause iatrogenic damage to the original shape of the root canal.

In this study, Mani silk showed, the maximum number of defects was 100%, followed by EdgeEndo by 80%, then NeoEndo by 70% and Protaper gold by 60% and HyFlex EDM by 40%. As Graph 1 showed, among all the experimental groups, HyFlex EDM File System showed the lowest incidence of dentinal defects due to less taper of the instruments, thereby reducing the damage to root canal walls. This was attributed to less removal of dentine, a consequence of less taper of the instruments.

According to the results of our study, the incidence of cracks was observed in apical, middle, and coronal sections of the apex. In the coronal section, 9 mm from apex, Group I shows 20%, whereas Group II shows 100%, Group III shows 95%, Group IV shows 8, and Group V shows 80% incidence of cracks [Table 1].

In the middle section, 6 mm from apex, Group I shows 20%, Group II shows 100%, Group III shows 90%, Group IV shows 85% of dentinal defects, and Group V shows 80% of dentinal defects [Table 2].

In the apical section, 3 mm from apex Group I shows 40%, Group II shows 100%, Group III shows 90%, Group IV shows 90%, and Group V showed 85% of the dentinal defects [Table 3].

According to a study by Venino *et al*.[6] that showed, ProTaper Next and HyFlex EDM showed a similar shaping ability. Both systems could prepare the root canals while respecting the original anatomy. HyFlex EDM caused less transportation and stayed more centered in the buccolingual direction between the middle and coronal thirds.

Capar *et al*.[7] have examined the dentinal defects on mandibular premolar teeth fewer by HyFlex CM, ProTaper Gold (Dentsply Maillefer), and ProTaper Next NiTi file systems and reported

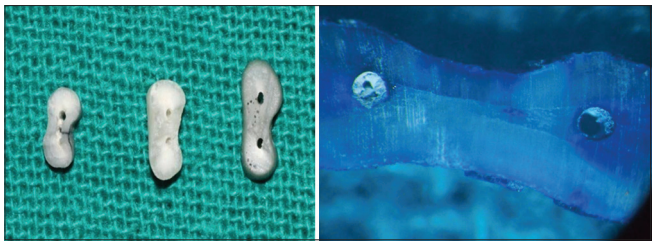
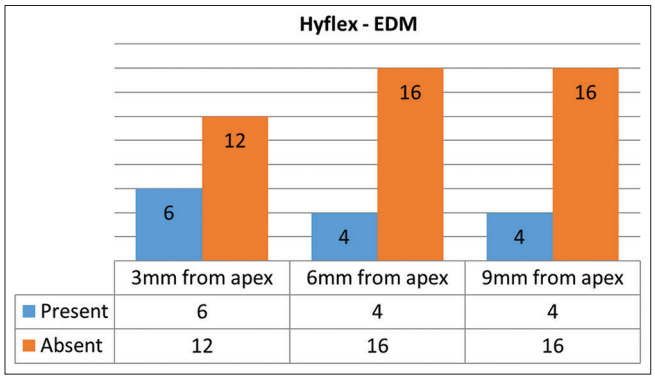


Figure 1: Sections at 3 mm, 6 mm, and 9 mm dentinal microcracks under ×40 maginification (stereomicroscopic image)



Graph 1: Distribution of cracks in Hyflex EDM

that ProTaper Next and HyFlex CM files created less dentinal defects than ProTaper Universal files.

Ashraf *et al*.[9] have investigated the dentinal defects of ProTaper Universal, ProTaper Next, and HyFlex CM NiTi file systems on mandibular premolar teeth using a sectioning method. Researchers have reported that HyFlex CM files caused fewer cracks than ProTaper Universal and ProTaper Next files.

The variable taper and controlled memory of this file system contributes to a lower number of defects. Due to its controlled properties, HyFlex EDM files follow the anatomy of the canal, which can significantly reduce the risk of ledging, transportation and perforation.[7]

On the other hand, microcracks formation with silk files may be attributed to a few of its design characteristics. They are selective heat treatment, teardrop shape, and off-center cross-sectional design. Although, both Silk and Protaper Next have an off-centered cross-section, such difference may be due to their metallurgy. The different design features of Protaper Next include offset cross-sectional design and M-wire technology.[10] Whereas, EdgeEndo the instrument is made of an AHT Ni-Ti alloy brand named Fire-Wire™. All files are constantly tapered. These files are used in endodontics for the removal of dentin and root canal shaping. They are compatible with the ProTaper® and ProTaper Next® rotary file systems.[10]

The NeoEndo Neohybrid Rotary Files offer unique off-centered rectangular cross section: Asymmetric or swaggering movement (two point contact with the canal wall). The off-center rectangular cross section of the NeoEndo Neohybrid Rotary Files is particularly distinctive: Movement that is asymmetric or swaggering (two points of contact with the canal wall). There is very little contact between the file and the canal dentin, which significantly lessens the pressures that cause the file to taper and screw in. a smaller cross-sectional area increases flexibility.

For this reason, it is very difficult to specify which one of these design characteristics influences the study results. Moreover, these design properties of files also affect the level of stress on root dentin during the preparation procedure.[3] Furthermore, in a finite elements analysis, it has been shown that increasing taper of files increased the stress on root canals during the preparation procedure.[10]

Dane *et al*.[8] studied that increased rotational speed was associated with increased cutting efficiency. According to them, higher cutting efficiency might be related to lower crack formation. Moreover, in our study, HyFlex EDM group used a single file (size 25/0.06 taper), Mani Silk 2 files were used from left to right in the pack (from 0.06/20 to 0.06/25), whereas Neoendo used four files (size 20/0.02, 25/0.02, 30/0.02 and 25/0.06). Edge Endo files used by PTG systems consist of three shaping files (SX, S1, and S2) and five finishing files (F1, F2, F3, F4, and F5).

Even though this *ex vivo* study did not reflect clinical settings, we can conclude that NiTi instruments tend to induce various degrees of dentinal damage during root canal preparation. HyFlex EDM (Group I) showed minimum defects among all the NiTi rotary instruments groups followed by ProTaper Gold (Group V) Neoendo (Group IV) and EdgeEndo (Group III). Maximum defects were shown by Mani Silk (Group II). There was no significant difference between EdgeEndo and NeoEndo groups.

There was a significant difference between HyFlex EDM and Mani silk file groups. There was a significant difference between HyFlex EDM and Edge Endo file groups. There was significant difference between HyFlex EDM and NedoEndo file groups and a difference between HyflxEDM and Protaper Gold file group. There was significant difference between ProTaper Next and Mani silk groups and between ProTaper Next and Edge endo Files file groups and Protaper Gold and NeoEndo files. However, more *ex vivo* studies need to be conducted to correlate the results of this study.

Conclusion

Within the limitation of this *ex vivo* study, rotary endodontic preparation methods might induce the dentinal defects. The following conclusions were drawn:

1. All the experimental rotary systems created dentinal defects.
2. HyFlex EDM (Group I) showed minimum defects among all the NiTi rotary instruments groups followed by ProTaper Gold (Group V) EdgeEndo (Group III) and

NeoEndo (Group 1V) Maximum defects were shown by Mani Silk (Group II).

3. There was no significant difference between EdgeEndo and NeoEndo file groups.
4. There was significant difference between HyFlex EDM and ProTaper gold file group

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