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Comparative Evaluation of Dentinal Crack Formation After Instrumentation With Different Nickel Titanium Rotary Instruments – An *In Vitro* Study.

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Abstract:
Background: *The main objective of chemo-mechanical root canal preparation includes the preservation of the original canal anatomy and cleaning of the entire root canal system. Advancements in the rotary nickel titanium instruments have provided better cleaning and shaping with minimal dentinal defects. With the introduction of rotary instrumentation in endodontics, cleaning and shaping has become more predictable and efficient with less time consuming and decreasing stress to operator. These advancements do come with certain drawbacks or limitations like formation of microcracks in root dentin due to greater taper which creates lateral forces on the root canal walls, these microcracks can further progress to fracture in root dentin when compared to hand instrumentation. The cross-sectional design of rotary instruments does have an impact on the formation of microcracks in root dentin. Since there are no studies comparing the dentinal defects created by TruNatomy, HyFlex CM and NeoEndo Flex file systems, we have selected this study to evaluate the crack formation in coronal, middle and apical third of the root by using these three Rotary Files.*
Materials and Methods: *Sixty freshly extracted human mandibular incisors, were selected for this study. To ensure standardization of the root length, the crown of each tooth was sectioned at the level of cementoenamel junction, leaving the root length of 13 mm. The samples were equally divided into four groups (n = 15 teeth per group). Group 1: Control Group (unprepared), Group 2: TruNatomy files (20/0.08, 17/0.02, 26/0.04), Group 3: Hyflex CM files (25/0.08, 20/0.04, 25/0.04), Group 4: NeoEndo Flex files (30/0.08, 17/0.04, 20/0.04, 25/0.04). To standardize the apical enlargement, the canals were instrumented to an apical preparation size of 25, and taper of the files was 0.04 or as close to 0.04 as possible within each system. All the roots were sectioned perpendicular to long axis at 4, 8 and 12 mm from apex. The sections were then examined for the formation of dentinal cracks using stereomicroscope and the digital images of each section were captured.*
Results: *The results of the present study showed that there was statistically significant difference in the dentinal defects produced in coronal third region among the experimental groups. Independent group t test showed that there was significant difference between TruNatomy and NeoEndo Flex Files group. But there was no significant difference between TruNatomy and HyFlex CM group. In the middle third region, there was no statistically significant difference among all the three experimental groups. In the apical third region, HyFlex CM group produced lesser number of dentinal defects, however the difference between the experimental groups was not statistically significant. Based on the mean values, TruNatomy performed better and produced lesser dentinal defects when compared with HyFlex CM and NeoEndo Flex Files. ($p<0.05$)*
Conclusion: *Within the limitations of the present study, it could be stated that TruNatomy file group caused least dentinal damage in root canals whereas NeoEndo Flex group produced highest dentinal defects at different parts of the instrumented root canals.*
Key Word: *TruNatomy files; HyFlex CM files; NeoEndo Flex files*

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I. Introduction

The irrevocable aim of endodontics is a three-dimensional unblemished seal of the root canal system which is achieved by perfect designing of the canal diameter and canal form. So, the primary goal of endodontic therapy is prevention and treatment of apical periodontitis. It is well established that bacteria are the etiology of pulpal and periradicular pathosis. Therefore, complete debridement of the infected tissues from the root canal complex system to meet biological and mechanical requirements is the main objective of endodontic therapy.

The main objective of chemo-mechanical root canal preparation includes the preservation of the original canal anatomy and cleaning of the entire root canal system. Advancements in the rotary nickel titanium instruments have provided better cleaning and shaping with minimal dentinal defects. A dentinal defect such as microcrack is a major concern regarding the prognosis of root canal treated tooth.[1]

Despite the best possible precautions taken during the root canal preparation there can be certain possible mishaps such as ledge formation, transportation of canal, perforations and formation of cracks in the root dentin. At times, in the zeal of biomechanical preparation we inevitably end up damaging the root canal dentin, which becomes a gateway to dentinal cracks and minute intricate fractures; thereby causing failure of treatment.[2]

With the introduction of rotary instrumentation in endodontics, cleaning and shaping has become more predictable and efficient with less time consuming and decreasing stress to operator. The primary aim of cleaning and shaping the canal is to completely remove the microorganisms, pulp tissue and debris and enlarging the canal diameter to receive an obturating material.[3]

These advancements do come with certain drawbacks or limitations like formation of microcracks in root dentin due to greater taper which creates lateral forces on the root canal walls, these microcracks can further progress to fracture in root dentin when compared to hand instrumentation. Possible relationship between the design of NiTi rotary instruments and the occurrence of the vertical root fractures was found by Kim *et al.* [4]

The cross-sectional design of rotary instruments does have an impact on the formation of microcracks in root dentin. Studies stated that when instrument have a triangular cross section, a three-point contact with the root canal walls leads to increase in torsional resistance and greater force on root canal walls, further leading to more dentinal crack formation in comparison with the instruments having 'S' shape cross section design of two point contact at the same time leading to fewer cracks. Hence, the design of the file influences the strain concentration and the apical stress during instrumentation of root canal.[5]

To the best of our knowledge there are no studies conducted to compare the dentinal defects created by TruNatomy, HyFlex CM, NeoEndo Flex file systems. Therefore, the aim of this present study was to compare TruNatomy files with commonly used files (HyFlex CM and NeoEndo Flex) for dentinal cracks during canal preparation.

II. Materials and Method

The present study was conducted in the Department of Conservative Dentistry and Endodontics of Geetanjali Dental & Research Institute, Udaipur using 60 human mandibular incisors extracted for Periodontal & Orthodontic reasons obtained from the Department of Oral and Maxillofacial Surgery of Geetanjali Dental & Research Institute, Udaipur.

Inclusion criteria:

- All teeth were radiographed in buccolingual and mesiodistal directions to confirm the existence of fully formed apex, single apical foramen, no signs of internal resorption, no pulp stones, root canal calcification, obstruction or previous endodontic therapy.
- The roots with curvature <5 degree and completely formed apex with patent foramina were selected.

Exclusion criteria:

- The external root surfaces were examined under a DOM at 16X magnification to exclude any visible root caries, external resorption, fractures, or cracks. Teeth which deviate from such findings were excluded from the study and were replaced by new teeth.

Methodology:

Sixty freshly extracted human mandibular incisors, were selected for this study. To ensure standardization of the root length, the crown of each tooth was sectioned at the level of cementoenamel junction using diamond coated bur under water cooling, leaving the root length of 13 mm. Then all roots were observed under a DOM to exclude the presence of any cracks.

Study samples:

Access cavity was prepared with Airotor handpiece and tapered fissure bur for each tooth and patency of canals was checked with ISO No.10 K file. The working length was established by subtracting 1 mm from the length of a size 10 K file inserted into the canal until the tip of the file became visible at the apical foramen.

Each root was wrapped with a single layer of aluminium foil and embedded in acrylic resin set in barrel of 5ml syringe of length 12±1mm coated with petroleum jelly. The roots were then removed and aluminium foil was peeled off. To simulate the periodontal ligament, a hydrophilic vinyl polysiloxane impression material was placed into the space created by the removal of aluminum foil followed by immediate repositioning of the roots into acrylic resin.

Root canal instrumentation:

During mechanical instrumentation, each file was coated with EDTA to act as a lubricant. Prior to rotary instrumentation, a glide path was created till ISO No. 15 K file upto the working length in all the cases. Irrigation was performed using common irrigation protocol for all the specimens using 1% NaOCl solution in a 5 mL disposable plastic syringe with 30-gauge needle. After each instrument change, the root canals were irrigated with 2mL of 1% NaOCl solution for 1 minute. A total 15 ml of 1% sodium hypochlorite was used in each canal. After preparation, the specimens from the prepared groups were rinsed with 2 ml distilled water.

The samples were equally divided into four groups (n = 15 teeth per group).

1. Group 1 : Control Group (unprepared)
2. Group 2 : TruNatomy files (20/0.08, 17/0.02, 26/0.04)
3. Group 3 : Hyflex CM files (25/0.08, 20/0.04, 25/0.04)
4. Group 4 : NeoEndo Flex files (30/0.08, 17/0.04, 20/0.04, 25/0.04)

To standardize the apical enlargement, the canals were instrumented to an apical preparation size of 25, and taper of the files was 0.04 or as close to 0.04 as possible within each system.

Sectioning and imaging with stereomicroscope:

All the roots were sectioned perpendicular to long axis at 4, 8 and 12 mm from apex using isomet saw with water cooling. The sections were then examined for the formation of dentinal cracks using stereomicroscope and the digital images of each section was captured.

Scoring system used according to the type of defects present:

No Defect (Score 0): Root dentin devoid of any lines or cracks where both external surface of root and internal root canal wall does not present any evident defects.

Craze line (Score 1): Line extending from outer surface into dentin but does not reach the canal lumen.

Partial crack (Score 2): Line extending from canal walls into dentin without reaching outer surface.

Fracture (Score 3): Line extending from root canal space all the way to outer surface of root.

Statistical analysis:

Data obtained were statistically analysed by chi-square test and independent group t test. All statistical testing was performed at significance level P-value less than 0.05. The statistical analysis was carried out with SPSS version 16.0 software for windows (SPSS Inc., Chicago, IL, USA).

III. Results

In the present study each specimen was checked for the presence of dentinal defects (microcracks) using stereomicroscope after canal preparation using various Rotary files.

"NO DEFECT" was defined as root dentin devoid of any craze lines or microcracks either at the external surface of the root or at the internal surface of the root canal wall.

"DEFECT" was defined if any lines, microcracks, or fractures were present in root dentin.

A total of 45 sections were examined in each group.

Table 1: The dentinal defects seen in coronal third after using TruNatomy, HyFlex CM and NeoEndo Flex files.

			Coronal Scoring system				Total	Pearson Chi-Square
			0	1	2	3		p value
Group	No Preparation	Count	15	0	0	0	15	23.961
		%	100.0 %	0.0%	0.0%	0.0%	100.0%	0.005
	TruNatomy	Count	10	5	0	0	15	
		%	66.7%	33.3%	0.0%	0.0%	100.0%	
	HyFlex	Count	6	7	0	2	15	
		%	40.0%	46.7%	0.0%	13.3%	100.0%	
	NeoEndo	Count	7	3	2	3	15	
		%	46.7%	20.0%	13.3%	20.0%	100.0%	
Total		**Count**	**38**	**15**	**2**	**5**	**60**	
		%	**63.3%**	**25.0%**	**3.3%**	**8.3%**	**100.0%**	

Significant at 0.01 level

Table 1 shows that NeoEndo Flex file group showed maximum dentinal defects among all the groups.

Table 2: The dentinal defects seen in middle third after using TruNatomy, HyFlex CM and NeoEndo Flex files.

			Middle Scoring system				**Total**	**Pearson Chi-Square**
			0	**1**	**2**	**3**		**p value**
Group	No Preparation	Count	15	0	0	0	15	20.376
		%	100.0%	0.0%	0.0%	0.0%	100.0%	0.016
	TruNatomy	Count	8	4	2	1	15	
		%	53.3%	26.7%	13.3%	6.7%	100.0%	
	HyFlex	Count	6	7	0	2	15	
		%	40.0%	46.7%	0.0%	13.3%	100.0%	
	NeoEndo	Count	5	7	1	2	15	
		%	33.3%	46.7%	6.7%	13.3%	100.0%	
Total		**Count**	**34**	**18**	**3**	**5**	**60**	
		%	**56.7%**	**30.0%**	**5.0%**	**8.3%**	**100.0%**	

Significant at 0.05 level

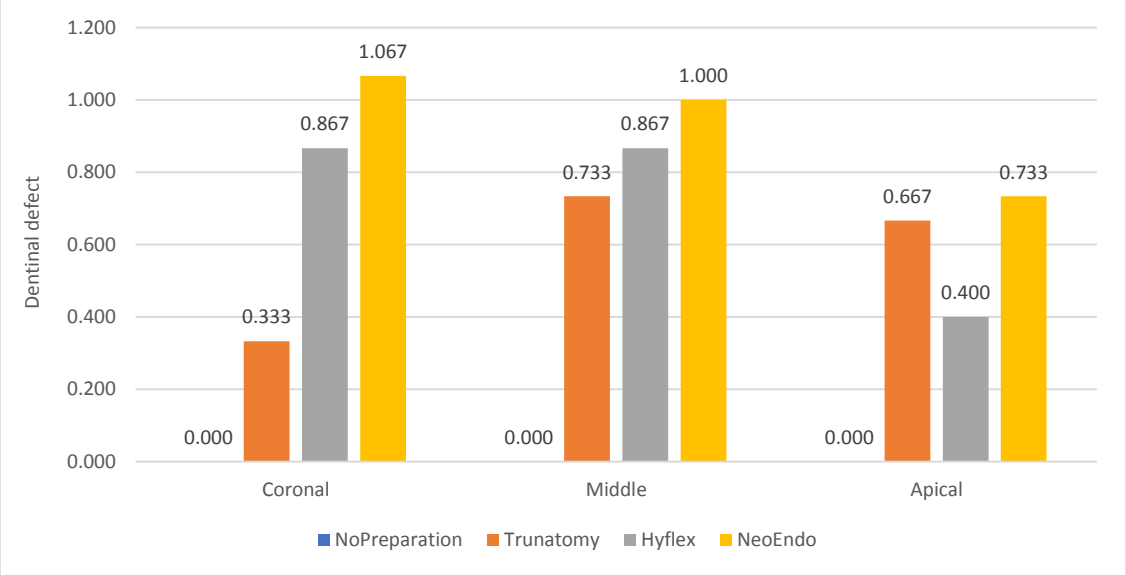
Table 2 shows more dentinal defects in HyFlex and NeoEndo group as compared to TruNatomy group.

Table 3: The dentinal defects seen in apical third after using TruNatomy, HyFlex CM and NeoEndo Flex files.

			Apical Scoring system				**Total**	**Pearson Chi-Square**
			0	**1**	**2**	**3**		**p value**
Group	No Preparation	Count	15	0	0	0	15	15.385
		%	100.0%	0.0%	0.0%	0.0%	100.0%	0.081
	TruNatomy	Count	7	6	2	0	15	
		%	46.7%	40.0%	13.3%	0.0%	100.0%	
	HyFlex	Count	10	4	1	0	15	
		%	66.7%	26.7%	6.7%	0.0%	100.0%	
	NeoEndo	Count	7	6	1	1	15	
		%	46.7%	40.0%	6.7%	6.7%	100.0%	
Total		**Count**	**39**	**16**	**4**	**1**	**60**	
		%	**65.0%**	**26.7%**	**6.7%**	**1.7%**	**100.0%**	

Table 3 shows lesser dentinal defects in apical third in HyFlex group as compared to TruNatomy and NeoEndo group but the difference is statistically insignificant.

Graph 1: Comparison between the dentinal defects formed in TruNatomy, HyFlex CM and NeoEndo Flex file groups.



Graph 1 indicates highest dentinal defects in NeoEndo group followed by HyFlex CM group and least in TruNatomy files group at coronal, middle and apical region.

Table 4: Mean value table shows comparison between unprepared group, TruNatomy group, HyFlex CM group and NeoEndo Flex group.

	Coronal	**Middle**	**Apical**
No Preparation	0.000	0.000	0.000
TruNatomy	0.333	0.733	0.667
HyFlex	0.867	0.867	0.400
NeoEndo	1.067	1.000	0.733

Table 4 Indicates that TruNatomy group showed least dentinal defects in coronal and middle thirds and HyFlex group showed least dentinal defects in apical third. NeoEndo group showed highest dentinal defects in coronal, middle and apical thirds of the root.

The results of the present study showed that there was statistically significant difference in the dentinal defects produced in coronal third region among the experimental groups. Independent group t test showed that there was significant difference between TruNatomy and NeoEndo Flex Files group. But there was no significant difference between TruNatomy and HyFlex CM group.

In the middle third region, there was no statistically significant difference among all the three experimental groups.

In the apical third region, HyFlex CM group produced lesser number of dentinal defects, however the difference between the experimental groups was not statistically significant.

Based on the mean values, TruNatomy performed better and produced lesser dentinal defects when compared with HyFlex CM and NeoEndo Flex Files.

IV. Discussion

Endodontic practice aims to restore and preserve remaining natural dentition using safe instruments and techniques. Adequate cleaning and shaping of the root canal system is one of important steps in root canal treatment. Biomechanical preparation is an important step to achieve success in endodontic treatment.[6]

When NiTi rotary instruments are used, a rotational force is applied to the root canal walls which can create microcracks or craze lines in the root dentin. The extent of such a defect formation may be related to the tip design, cross-section geometry, constant or progressive taper type, constant or variable pitch and flute form.[5]

In the present study, all root canal shaping files, produced microcracks in root dentin. These findings are in accordance with Yoldas *et al.*[5] and Bürklein *et al.*[1], who found cracks in the root canals prepared by rotary NiTi

instruments but not in the root canals instrumented with hand K file. According to Kesim *et al.*[7], examination with any kind of magnification is not fully sufficient for detecting the pre-existing craze lines or cracks that may be present on the inner surface of the root.

The tip size of the files also creates a large amount of difference in dentinal defects.[8] As the tip size of orifice openers are 20.08, 25.08 and 30.08 in TruNatomy, HyFlex CM and NeoEndo Flex files respectively. According to the results of our study NeoEndo Flex files produced higher dentinal defects compared to other two file systems which has higher tip size.

According to Krishna Kanth Jaju *et al.*[9], TruNatomy Files has an off-centered parallelogram cross-sectional design, so each time the file rotates in the canal during biomechanical preparation; there is at least a one or two point contact between the instrument and the root canal wall. It has been argued that TruNatomy instruments are less destructive for root canal system due to the regressive tapers and the heat treatment of the NiTi alloy. The slenderized pattern might have caused relatively fewer apical cracks in the TruNatomy system.

HyFlex CM (control memory) files show a martensite active crystal structure which when heated transforms temporarily into austenitic phase, this enables the file to regain its original shape before cooling down. During autoclaving, shape and strength of the files with straightened spirals can be restored. The files are capable of regaining their shape after sterilization and reuse. This property of CM wire technology helps in more flexibility and easy movement of files through the root canal especially in the curved roots. The less taper (4 %) and core diameter with increased flexibility of HyFlex CM would have led to lesser number of cracks than NeoEndo Flex files. The triangular cross-sectional geometry of HyFlex instrument produces only a single point contact with the root canal walls during instrumentation. The better cutting efficiency and decreased rate of transmission of torsional forces onto the dentin might have contributed to lesser number of cracks in HyFlex.[10]

In this study, NeoEndo flex files produced a greater number of dentinal cracks than TruNatomy and HyFlex CM files. NeoEndo Flex files are heat-treated rotary NiTi files available in tapers of 4% and 6% with a safety noncutting tip. NeoEndo Flex[11] has a triangular cross-sectional design, so each time the file rotates in the canal during biomechanical preparation; there is at least a three-point contact between the instrument and the root canal wall which transmits more tensile stresses to the root canal dentinal wall, leading to more dentinal microcracks than that of TruNatomy and HyFlex CM files.

In the present study, TruNatomy has faired better than HyFlex CM and NeoEndo Flex files as it produced least dentinal defects because of its lesser tip and taper size in orifice opener and other shaping files.[12] Also, TruNatomy has off-centered parallelogram cross-sectional design whereas other two file systems have triangular cross-section design which leads to higher dentinal defects.[13]

This is an *in vitro* study, but in a clinical scenario completely different outcome can be expected due to various variables. As the strengths of this study, the tested systems were used according to the manufacturer's instructions, which makes the study clinically relevant.

V. Conclusions

Within the limitations of the present study, the following conclusions can be drawn;

- Root canal preparation with rotary systems influence dentinal crack formation inside the root canal.
- NeoEndo Flex files group produced maximum dentinal defects and TruNatomy files group produced minimum dentinal defects in coronal and middle thirds. This could be attributed to the difference in tip diameter and taper of their orifice openers.
- There was statistically significant difference in the dentinal defects of coronal thirds produced by TruNatomy files group and NeoEndo Flex files group.
- In apical third HyFlex CM files group produced minimum dentinal defects and NeoEndo Flex files group produced maximum dentinal defects. However, the difference was not statistically significant.

Hence, it could be stated that TruNatomy file group caused least dentinal damage in root canals whereas NeoEndo Flex group produced highest dentinal defects at different parts of the instrumented root canals.

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