A Digital microscopic evaluation of the induction of dentinal micro-cracks after canal preparation with rotary and reciprocating NiTi systems in vitro

Abstract

Aim of the study: This study aims to assess the induction of dentinal microcracks by different NiTi systems and to compare rotary and reciprocating systems.

Methodology: Fifty teeth were selected and divided into five groups.. Each group was instrumented according to the manufacturer's specifications and was performed by a single operator. The teeth were then sectioned and viewed under a digital microscope. The study aimed to compare the performance of four different instruments.

Results: No cracks were detected in the control group. The Hyflex EDM produced the highest number of cracks in 4mm (70%), and the highest number of cracks in total (43.3%). ProTaper Universal produced the least number of cracks (16.6%). WaveOne and WaveOne Gold both produced cracks (30%).

Conclusion: Within the limitation of this in vitro study, all the instruments produced microcracks. The Hyflex EDM produced higher cracks in the mid-root section. There was no significant difference in the incidence of microcracks between the four systems or between rotary and reciprocating systems.

Keywords:dentinal microcracks, NiTi systems, reciprocating systems., Hyflex EDM

Introduction

“Preparation of the root canal system is recognized as being one of the most important stages in root canal treatment”.[1] “it includes the removal of vital and necrotic tissues from the root canal system, along with infected root dentine. It aims to prepare the canal space to facilitate disinfection by irrigants and medicaments. Thus, canal preparation is the essential phase that eliminates infection. Prevention of reinfection is then achieved through the provision of a fluid-tight root canal filling and a coronal restoration. Although

mechanical preparation and chemical disinfection cannot be considered separately and are commonly referred to as chemomechanical or biomechanical preparation" .[2]

"Ingle described the first formal root canal preparation technique, which has become known as the 'standardized technique'. In this technique, each instrument was introduced to working length resulting in a canal shape that matched the taper and size of the final instrument. This technique was designed for single-cone filling techniques".[3]

"emphasized the need for thorough cleaning of the root canal system, i.e., removal of all organic contents of the entire root canal space with instruments and abundant irrigation and coined the axiom 'what comes out is as important as what goes in'. He stated that shaping must not only be carried out with respect to the individual and unique anatomy of each root canal but also in relation to the technique of and material for final obturation. When gutta-percha filling techniques were to be used he recommended that the basic shape should be a continuously tapering funnel following the shape of the original canal; this was termed as the 'concept of flow' allowing both removal of tissue and appropriate space for filling".[1]

The purpose of this investigation was to compare the incidence of root canal microcrack formation after preparation with reciprocating files (WaveOne Gold WaveOne) and continuous rotation files (ProTaper Universal and Hyflex EDM), which have not been compared in previous studies. Therefore, an attempt has been made to detect, evaluate and compare the dentinal microcracks caused by rotary and reciprocating instrumentation during root canal preparation using Digital microscopy (HIROX KH 7700) at X700 magnification (lens MXG-2500REZ) this study aims to assess the induction of dentinal microcracks by different NiTi systems and to compare between rotary and reciprocating systems.

Hypothesis

Null hypothesis that will be adopted: there is no significant difference between rotary and reciprocating nickel titanium systems.

Materials and Methods

50 freshly extracted human premolars were taken. Samples were then inspected under a stereo microscope (Meiji Techno EMZ5-BD-LED Zoom Stereo Microscope System) at 2x magnification, to check for any external cracks or craze lines.

Inclusion Criteria:

The following inclusion criteria were applied

Single canal premolars with one root and one apical foramen: Teeth with a single canal and a single root were included in the study to maintain consistency and focus on teeth with a specific anatomical configuration.

Also Straight root: Teeth with a straight root morphology were included to minimize any potential variations in canal curvature that could influence the study outcomes.

Exclusion Criteria:

The following exclusion criteria were applied:

Teeth with multiple roots were excluded from the study to maintain consistency and focus on teeth with a single-root morphology.

Teeth with more than one apical foramen were excluded to eliminate any potential variations in root canal anatomy that could affect the study outcomes.

Teeth with resorption were excluded as the presence of resorption could impact the integrity and properties of the tooth structure, potentially confounding the results.

Teeth with craze lines, which are small cracks in the enamel that do not extend to the dentin, were excluded to minimize the influence of pre-existing enamel defects on the study outcomes.

Teeth with previous restorative or endodontic therapy were excluded to ensure a homogeneous sample and avoid any potential effects of prior treatments on the properties being evaluated.

Teeth that were not freshly extracted or were stored in a different solution than the study storing solution were excluded to maintain standardized conditions and avoid any impact of storage methods on the properties being measured.

Cracked or fractured teeth were excluded to prevent potential interference with the study measurements and to focus on structurally intact teeth.

By implementing these exclusion criteria, the study aimed to enhance the internal validity of the research findings by minimizing confounding factors and ensuring the selection of suitable teeth for the investigation.

Dentsply X-smart plus motor and Digital Microscope (HIROX KH 7700) at X700 magnification (lens MXG2500REZ) also Slow speed cutting saw with water cooling (BUEHLER Isomet 2000 Precision Saw) was used along withThe Memmert Universal Oven , Meiji Techno EMZ5-BD-LED Zoom Stereo Microscope System Alcohol solution (Avalon Pharma) and Pure Glycerin (Sun Care Pharma)

Samples Preparation

50 freshly extracted human maxillary and mandibular premolar teeth were used in this study,and were visualized under a stereomicroscope (Meiji Techno EMZ5-BD-LED Zoom Stereo Microscope System) to exclude any roots with visible external cracks.

Each of the samples were decoronated at the cemento-enamel junction using an Isomet low speed saw (BUEHLER Isomet 2000 Precision Saw) with a 0.50 mm thick diamond blade while irrigating with water. Lengths of the canals were determined using size 15 K-files. The file was inserted into the canal until it was visualized at the apical foramen. One mm was then subtracted from the length of the file at the apical foramen to determine the final working length.

Sample Distribution

The samples were randomly divided into 5 groups: ▪
Group 1 / (n=10): Contr of Group. ▪
Group 2 / (n=10): Instrumented by Protaper Universal (PTU)(Dentsply Maillefer, Ballaigues, Switzerland) (Rotary system).
▪ Group 3 / (n=10): Instrumented by WaveOne (WO) (Dentsply Maillefer, Ballaigues, Switzerland) (Reciprocating system).
▪ Group 4 / (n=10): Instrumented by WaveOne gold (WOG)(Dentsply Maillefer, Ballaigues, Switzerland) (Reciprocating system).
▪ Group 5 / (n=10): Instrumented by Hyflex EDM (Coltene/Whaledent AG, Altstatten, Switzerland) (Rotary system)

Specimen Preparation

Root canals were instrumented by a single operator according to manufacturer's instructions for each system.

Results

All specimens 10 (100%) in control group, 8 (80%) waveOne, 8 (80%) waveOne gold, 9 (90%) Hyflex EDM, and 9 (90%) Protaper universal groups showed no cracks at point 2 mm away from root apex. However, waveOne and protaper universal systems produced 2(20%) and 1 (10%) cracks extending from outside and reaching the canal wall. Waveone gold and Hyflex EDM each produced 1 (10%) cracks from the outer surface not reaching the canal wall as shown in fig 1.

Fig 1 A photograph of micro crack mag 700x

Additionally, waveOne gold 1 (10%) produced cracks from the canal walls not reaching the outer surface. However, none of the rotary instrument systems used in this study produced two types of cracks at point 2 mm away from the root apex, as shown in Table 1.

Table 1: Descriptive analysis on the incidence of dentinal cracks by different rotary instrument systems at 2mm away from the root apex

	At point 2mm away from root apex									
	Control		Waveone		Waveone gold		Hyflex EDM		Protaper universal	
	n	%	n	%	N	%	n	%	n	%
Type A	10	100	8	80	8	80	9	90	9	90
Type B	0	0	2	20	0	0	0	0	1	10
Type C	0	0	0	0	1	10	1	10	0	0
Type D	0	0	0	0	1	10	0	0	0	0
Two types of cracks	0	0	0	0	0	0	0	0	0	0

Waveone 2 (33.3%) and Waveone gold 2 (33.3%) produced a similar amount of root dentin defect whereas Hyflex EDM 1 (16.7%) and Protaper universal system 1 (16.7%) produced defects at 2 mm away from the root apex. This difference was not significant ($\chi 2 = 7.84$, $p=1.00$) among studied experimental groups as shown in table 2.

Table 2: Dentinal defects produced among experimental rotary instrument systems at 2mm away from the root apex

	No defect		Defect		DF	Chi-square	sig
	N	%	n	%			
Waveone	8	23.5	2	33.3	3	7.84	1.0
Waveone gold	8	23.5	2	33.3			
Hyflex EDM	9	26.5	1	16.7			
Protaper universal	9	26.5	1	16.7			

All specimens 10 (100%) in control group, 7 (70%) waveOne, 8 (80%) waveOne gold, 3 (30%) Hyflex EDM, and 9 (90%) Protaper universal groups showed no cracks at point 4 mm away from root apex. However, waveOne and Hyflex EDM groups produced 2(20%) similar cracks extending from outside and reaching the canal wall. However, waveOne 1 (10%), waveOne gold 1(10%), Hyflex EDM 3 (30%) and protaper gold 1(10%) groups produced cracks from the outer surface not reaching the canal wall. Hyflex EDM produced 2 (20%) cracks from the canal walls not reaching the outer surface. WaveOne gold is the only group which produced 1 (10%) of two types of cracks at a point 4 mm away from the root apex, as shown in table 3.

Table 3: Descriptive analysis on the incidence of dentinal cracks by different rotary instrument systems at 4mm away from the root apex

	At point 4mm away from root apex									
	Control		Waveone		Waveone gold		Hyflex EDM		Protaper universal	
	n	%	n	%	n	%	n	%	n	%
Type A	10	100	7	70	8	80	3	30	9	90
Type B	0	0	2	20	0	0	2	20	0	0
Type C	0	0	1	10	1	10	3	30	1	10
Type D	0	0	0	0	0	0	2	20	0	0
Two types of cracks	0	0	0	0	1	10	0	0	0	0

At 4mm away from the root apex, 3 (23.1%) waveOne, 2 (15.4%) waveOne gold, 7(53.8%) Hyflex EDM and 1 (7.7%) protaper universal experimental groups produced

root dentin defect. This difference in defects was statistically significant ($\chi 2 = 9.46$, $p=0.043$), as shown in table 4.

Table 4: Dentinal defects produced among experimental rotary instrument systems at 4 mm away from the root apex

	No defect		Defect		DF	Chi-square	sig
	n	%	n	%			
Waveone	7	25.9	3	23.1	3	9.46	**0.043**
Waveone gold	8	29.6	2	15.4			
Hyflex EDM	3	11.1	7	53.8			
Protaper universal	9	33.3	1	7.7			

Statistical Analysis

Descriptive statistical analysis was expressed as the number and percentage of cracks produced at sections of 2mm, 4mm, and 6 mm away from the apex. Roots were then classified as defective if any one section at 2mm, 4mm or 6mm demonstrated a crack. Chi-square fisher's exact tests were performed to compare the root defects between experimental groups. For all statistical purposes IBM SPSS Statistics software for Windows Version 21.0 (Armonk, NY: IBM Corp) was used. The level of significance was set at 0.05. 107 After using the chi square test with $p> 0.05$ there was no statistical difference between all group, But in C2 HEDM had a higher incidence rate then the other groups with statistical difference.

Discussion

One of the most important stages of root canal treatment is root canal preparation But in the zeal of biomechanical root canal preparation, we unwillingly end up damaging the root dentin making a gateway of dentinal cracks and minute intricate fractures or even vertical root fractures, which leads to treatment failure. The quantity of dentinal defects can be affected by numerous factors in the physical properties of teeth. Instrumentation with rotary and reciprocating nickel-titanium instruments could potentially cause dentinal cracks, which may have the potential to develop into cracks and vertical root fractures

Previous studies suggested that strain accumulation in dentin during root canal preparation may cause dentinal cracks from which VRF(variable refrigerant flow) can develop. "A finite element analysis simulation of shaping procedures with different

preparation systems indicated that the file design may affect apical stress and strain concentrations during instrumentation. Although mechanical preparation with NiTi instruments has been mostly associated with high forces near the file tip and apical cracking, the highest root stresses were located at the most curved mid-root canal wall area". [4,5]
"hypothesized that the large number of microcracks observed on root dentin after instrumentation with NiTi instruments could be attributed to their rotary kinematics". [4,5]

A lot of stress will be concentrated on test samples if they were mounted in acrylic resin only, but a periodontal simulation will aid in distributing the forces and help mimic a more realistic scenario[6] in this study periodontal simulation was achieved during the mounting stage.

Concerning the ProTaper Files, several studies compared it to different file systems. the effect of the file design on stress during dentin preparation, using a finite element analysis test. They found that ProTaper Universal induced the highest von Mises stress concentration in the root dentin and had the highest tensile and compressive principal strain components at the external root surface(13). The calculated stress values from ProTaper Universal, which had the biggest taper shaft, approached the strength properties of dentin. Light-Speed generated the lowest stresses. In the present study, 111 pro-taper produced microcracks in 16.6% of the total sections (n=30). A study by [7]reported that pro-taper produced microcracks in only 8.75% of the samples. (12,8) reported that there was no significant difference found between ProTaper files and other files tested in their studies, which comes in agreement with our study.

WaveOne has several studies evaluating its effect on the presence of dentinal microcracks especially because it's one of the main reciprocating files out in the market. In the present study, WaveOne created microcracks in 30% of the specimen sections. (8) have reported varying results concerning the incidence of microcracks related to WaveOne file, numbers as high as 91% were reported (9), and as low as 15% were reported .[10]

There are not a lot of studies on WaveOne Gold and Hyflex EDM. In the present study, the Hyflex EDM system produced the highest number of cracks: 70% of the mid root section (4mm) and a total of 43.3% of all sections were cracked making it the highest file system to produce cracks in this study. The WaveOne Gold produced microcracks in 30% of the tested samples. The statistical analysis concluded that Hyflex EDM produced significantly more microcracks in the mid-root section, but when comparing the sum of the sections with 112 in the rest of the tested groups it was found that there

were no significant differences among file systems. Pedulla, E did compare between the WaveOne Gold, Hyflex EDM, and the WaveOne system and two single file systems. In his study Hyflex EDM

produced the lowest percentage of roots with microcracks at 33.3%, the WaveOne Gold produced 58.3% and the WaveOne produced 91% microcracked roots.

“The sectioning method used in this study is more commonly used because it does not require sophisticated sample preparation, and has low cost. not labor-intensive, not time-consuming, and dedicated software may not be required, but on the other hand, this technique is criticized in that it is a destructive method, part of the sample is lost during the cutting procedure, which causes loss of information, allows the evaluation of only a few slices per root, the pre-operative condition of the dentin tissue is unknown, unable to assess cracks developing on the longitudinal axis of the root and measured by milli meter, submits the specimens to additional mechanical stress and inability to assess the severity of cracks, particularly subsurface dentinal cracks” [11].

The high variance in the data obtained by these studies may be related to factors like tooth age, storing media, operator skill, different procedural approaches, use of different methodologies to assess the number of microcracks, and different tooth morphology. Based on the findings of our study the null hypothesis was proven, as there was no significant difference between rotary and reciprocating nickel titanium file systems.

Conclusion

After comparing the results it was found that :

There is no significant difference between rotary and reciprocating systems.

Although when compared at individual sectioning levels, Hyflex EDM was found to produce the highest number of microcracks at the 4mm level .

There was no significant difference when comparing all systems together thus proving the null hypothesis.

Ethical Approval and Consent:

This research study, titled "A Digital microscopic evaluation of the induction of dentinal micro-cracks after canal preparation with rotary and reciprocating NiTi systems in vitro," has obtained ethical approval from the relevant institutional review board or ethics committee. The study protocol and all associated procedures involving human teeth or specimens comply with the ethical principles outlined in the Declaration of Helsinki and other applicable guidelines.

The ethical approval process involved a comprehensive review of the research proposal, including the study objectives, methodology, potential risks, and benefits. The committee assessed the protection of human subjects, the informed consent process (if applicable), and the adherence to ethical standards for conducting research.
Informed consent was obtained for the use of human teeth or specimens, ensuring that the study participants were fully informed about the nature of the research, its purpose, potential risks, and any alternative options. Confidentiality and privacy of any identifiable information were strictly maintained throughout the study.
The ethical approval obtained for this research study demonstrates the commitment to conduct the research in an ethically responsible manner, safeguarding the rights, well-being, and confidentiality of all individuals involved.

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