Evaluation of Dentin Microcracks after Root Canal Instrumentation using Three Thermally Treated Rotary Nickel Titanium Files

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Abstract

Evaluation of microcrack formation following root canal shaping using three nickel titanium files. One hundred twenty extracted premolars were randomly divided into four equal groups according to instrumentation: Group 1 TruNatomy (TRN; Dentsply Maillefer, Ballaigues, Switzerland); Group 2, XP Endo Shaper (XPES; FKG Dentaire, Switzerland); Group 3 ProTaper Gold (PTG; Dentsply Maillefer, Ballaigues, Switzerland); Group 4, control, no intervention. Roots were then sectioned at 3, 6, and 9 mm from the apex using a diamond disc. Presence/absence of cracks was determined using stereomicroscope at 50X magnification. Statistical analysis was performed using Fisher's exact test.

XPES generated higher overall percentage of cracks 26.7%, followed by the PTG 15.6% while the TRN showed the least percentage of cracks 7.8% with a statistically significant difference.

All tested files have generated microcracks during root canal shaping.

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Introduction

Successful endodontic treatment involves efficient biomechanical preparation by thorough debridement, proper root canal preparation, and well-sealed obturation[1,2]. Contact between rotary files and dentin could induce strain creating cracks and craze lines[3,4]. Under cyclic loading of occlusal stresses, these defects can propagate to form vertical root fracture[5].

There are numerous investigations on the effect of Nickel-Titanium (NiTi) files that weaken dentin which can induce micro-cracks on the dentin walls during cleaning or shaping procedures[6-8]. Nowadays the minimal invasive endodontics concept has led to the manufacture of lower tapered instruments for more dentin conservation which is considered as a key factor that determines prognosis of endodontically treated tooth[9,10].

TruNatomy (TRN) a recently introduced, thermally processed, super-elastic file. These instruments are fabricated from NiTi wire of 0.8 mm. TRN system consists of an Orifice Modifier, a glide path, and three shaper instruments; small, prime, and medium which are used depending on various clinical applications[11,12].

XP-Endo Shaper (XPES) made of MaxWire alloy, is a NiTi alloy that's martensite-austenite-electropolish thermomechanically treated. The manufacturer claims that the preset shape and flexibility enable these files to expand and contract in the root canal system to areas that conventional files are unable to access. International Organization for Standardization (ISO) 30 diameter size and 0.01 taper of this file would aid to minimize physical stresses applied to the dentinal wall[13-15].

ProTaper Gold (PTG) files are thermally processed with high austenite finish temperature. This heating process after machining was proposed to minimize the flaws that developed during machining and altering the structure of the crystalline phase. Similar to ProTaper Universal files, it constitutes three shaping and three

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finishing files with a triangular cross section and progressive taper[16,17].

The aim of this study was to evaluate microcrack formation following root canal shaping using TRN, XPES and PTG. The null hypothesis tested is that there is no difference in microcrack formation amongst the three tested files.

Materials and methods

Sample Selection

Research proposal IRB approval number is IRB/COD/STD/02/Sept-2020. One hundred twenty extracted human mandibular premolars were used in this ex-vivo study. Selected teeth showed single root canal and single apical foramen not larger than file # 15, free from caries, calcification, resorption, and with curvature not more than 5° measured using Schneider method [18]. All roots were examined using the stereomicroscope at 12 x magnification (Zeiss, Jena, Germany) before instrumentation to exclude samples with preexisting microcracks [6].

Sample Preparation

Decoronation was performed using fissure bur under continuous water coolant, adjusting root length to 16 mm to provide a reference plane [6].

The working length of each canal was determined by placing a 21 mm length, size 15 K-type files (Dentsply Maillefer, Ballaigues, Switzerland) until it was visible at its apical terminus and then subtracting one mm from this measurement.

The roots of each extracted specimen were covered by aluminum foil and submerged into an acrylic resin. Once the acrylic resin has completed the setting, the resin and foil present on each extracted tooth were removed. Teeth were placed back into the resin blocks after packing with viscous silicone impression material (tgdent, London, UK) to mimic the periodontal membrane space.

Teeth were randomly assigned into four groups as follows:

Group 1 (n=30), root canals were prepared with TRN instruments using the following sequence orifice modifier (20/.08); TRN glider (17/.02); prime (size 26/.04), medium (size 36/.03) in two to three gentle in-and-out apical movements. The preparation was considered done when the last file reached to the full WL.

Group 2 (n=30), root canals were prepared using XPES single file with 3 vertical strokes till reaching the working length.

Group 3 (n=30), canals were prepared using PTG files in the following sequence: SX (19/0.04) as an orifice opener followed by S1: (0.18/0.02), S2: (0.20/.04) in a brushing motion till reaching the WL then F1: (0.20/.07), F2: (0.25/.08), F3: (0.30/.09) were used to the WL.

Group 4 (n=30), left unprepared, negative control.

All roots were marked at 3, 6, and 9 mm from the apex using a marker and were sectioned off at the perpendicular plane along the long axial surface of tooth using a low-speed straight handpiece with a double-sided diamond disc (Kerr, Michigan, USA) under continuous water cooling, the roots were stored in distilled water to avoid dehydration before examination under the stereomicroscope.

Dentin microcrack evaluation

Slices were examined under 50X magnification using stereomicroscope (Zeiss, Jena, Germany) to detect the presence of dentin microcracks. Photographs were taken using a digital camera (Canon, Tokoyo, Japan) to be evaluated by two operators to avoid observer bias.

Defects extending from the inner canal lumen were considered as microcracks. All the other deformities that do not extend as craze lines from the canal wall were not counted as microcracks. The number of slices with 'microcracks' in each group was allotted as one category and with 'no microcracks' as the other category.

Statistical analysis: Statistical analysis was performed using Fisher's exact test followed by pairwise comparisons utilizing multiple z-tests with Bonferroni correction. While intragroup comparisons were analyzed using Cochran's Q test followed by pairwise comparisons utilizing multiple McNemar's tests with Bonferroni correction. R statistical analysis software was used and significance level was set at $p<0.05$.

Results

Intergroup comparisons presented in table (1) showed that all control group slices did not show any detection of microcracks. Comparison between experimental groups at 3 mm showed that XPES showed statistically significant higher number of cracks. There was no statistically significant difference between

TRN and PTG. At 6 mm distance from the apex, there was a significant difference between different groups, with XPES showing the higher number of cracks followed by PTG and the least was TRN (p=0.001). At 9 mm from the apex, there was no significant difference between different groups (p=0.060).

Distance from the apex	Crack presence		TRN	XPES	PTG	Control	p-value
3 mm	No	n	27^{AB}	23^{B}	26^{AB}	30^{A}	0.044*
		%	90.0%	76.7%	86.7%	100.0%	
	Yes	n	3	7	4	0	
		%	10.0%	23.3%	13.3%	0.0%	
6 mm	No	n	28^{A}	19^{B}	24^{AB}	30^{A}	0.001*
		%	93.3%	63.3%	80.0%	100.0%	
	Yes	n	2	11	6	0	
		%	6.7%	36.7%	20.0%	0.0%	
9 mm	No	n	28^{A}	24^{A}	26^{A}	30^{A}	0.060
		%	93.3%	80.0%	86.7%	100.0%	
	Yes	n	2	6	4	0	
		%	6.7%	20.0%	13.3%	0.0%	
Overall	No	n	83^{B}	66^{C}	76^{BC}	90^{A}	<0.001*
		%	92.2%	73.3%	84.4%	100.0%	
	Yes	n	7	24	14	0	
		%	7.8%	26.7%	15.6%	0.0%	

Table 1. Number and percentage of microcracks in all groups at different root levels.
Different superscript letters indicate a statistically significant difference within the same horizontal row; *significant (p<0.05)

Figure 1. Representative stereomicroscopic 50X image of dentinal slice showing presence of microcrack.

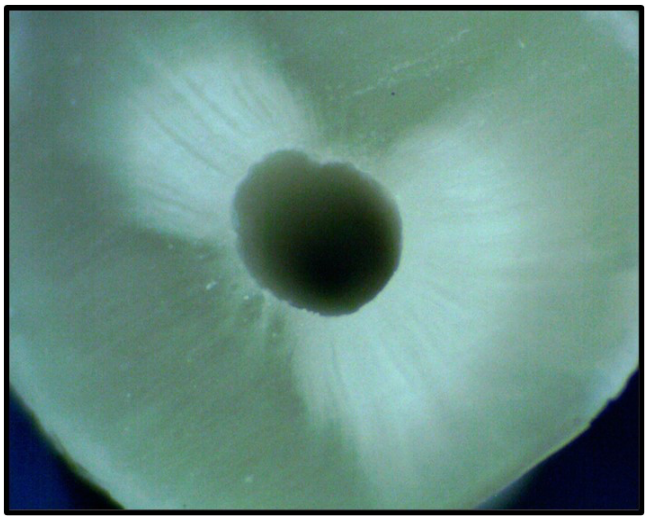

Figure 2. Representative stereomicroscopic 50X image of dentinal slice showing absence of microcrack.

Discussion

A direct correlation exists between the amount of dentin removed and the formation of micro-cracks [19]. Therefore, it is important to evaluate the ability of any novel file to create microcracks during preparation.

In this study determination of the microcracks was investigated by stereomicroscope after teeth sectioning which can be a cause for dentinal defects. However, no cracks have been seen in the control group which means that the microcracks developed due to preparation and not tooth sectioning process.

All tested files have proven to produce microcracks at all levels. The overall results have shown a statistically significant difference between the incidence of microcracks between the tested files. The highest incidence of the microcracks were present in the XPES group followed by the PTG and the least was TRN. Therefore, the null hypothesis was rejected.

The high percentage of microcracks was seen in the XPES group. Although it has a slim design and low taper, the higher incidence of microcracks might be caused by the relatively high rotational speed and more contact with the dentinal walls because of the dimensional change upon exposure to body temperature. These results come in agreement with Alkahtany and Al-Madi [20] who reported great number of cracks following root canal shaping using XPES. In disagreement with our result, Bayram et al [21], Aydin et al [7] and Aksoy et al [22] showed no crack

formation following root canal shaping using XPES. The difference could be attributed to different methodology of microcracks assessment.

PTG files showed overall percentage of microcracks was 15.6%. These results come close to those of Hussein et al (11.1%) [23], Soujanya et al (12.5%) [24], Karatas et al (9%) [25]. Whereas, in disagreement with our result, Bayram et al [21] and Vila et al [26] reported no new dentinal microcrack formation after using PTG. The difference could be related to different instrument sizes used during instrumentation.

Regarding the effect of different anatomical levels, our study revealed that the middle third slices showed significantly higher percentages of microcracks (15%) followed by the apical third (11.7%) while the coronal third showed the least percentage (10%) of microcracks. This comes in accordance with Versluis *et al* [27] who reported that in oval shaped canals greater stress is concentrated at the middle and coronal third during instrumentation leading to microcracks.

In the current study, TRN was tested to determine whether the novel design and thermal treatment influences microcrack formation. TRN is manufactured from 0.8 mm NiTi wire, offset parallelogram cross section which have made the file flexible and more resistant to cyclic fatigue [11,12]. Results of TRN revealed the least number of microcracks (7.8%). This can be referred to the instrument's geometry, i.e., off centered parallelogram cross section, regressive tapers, and slim design. These results comes in agreement with Yoldas et al [5] who concluded that the number of microcracks formed following instrumentation is dependent on the file design features.

In the current study the three selected files have different designs and different movement in the root canal which may have an impact on generation of microcracks. One limitation of this study is the use of stereomicroscope not the microcomputed tomography which has a better resolution and ability to detect microcracks precisely.

Conclusions

Under the condition of this ex vivo study, it can be concluded that all tested NiTi rotary files initiated microcracks. TRN can maintain the integrity of the dentin and generate the least number of microcracks.

Declaration of Interest

The authors report no conflict of interest.

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