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A COMPARATIVE IN VITRO STUDY EVALUATING THE INCIDENCE OF ROOT MICROCRACKS CAUSED BY THREE DIFFERENT SINGLE-FILE SYSTEMS VERSUS THE PROTAPER SYSTEM

Endodontics

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ABSTRACT

Aim: To evaluate and compare the incidence of root microcracks observed in the canal wall after instrumentation with three single file systems (i.e. OneShape, F6 SkyTaper and WaveOne Gold) with the ProTaper system. **Materials and Methods:** Seventy five human mandibular incisor teeth with straight roots and single canal were selected. After decoronation, the specimens were mounted in resin blocks with simulated periodontal ligaments. The coronal part of each specimen was flared with a #2 Gates-Glidden drill, after which the specimens were randomly divided into five groups (n=15). In control group, no further instrumentation was done after coronal flaring with #2 Gates Glidden drill. In Group 1, instrumentation of canals was performed with the ProTaper Universal file system (Dentsply Maillefer) until ProTaper F2. In Group 2, the canals were prepared with OneShape single rotary file #25.06 (Micro-Mega, France). In Group 3, the instrumentation of canals was performed with F6 SkyTaper single file #25.06 (Komet Dental, Lemgo, Germany). In Group 4, the canals were prepared with WaveOne Gold (Dentsply Maillefer) small #20.07 reciprocating single file. Roots of each specimen were sectioned at 3, 6, and 9mm from the apex and were then viewed under a stereomicroscope to evaluate presence or absence of dentinal microcracks. Data were subjected to statistical analysis using a chi square test and the level of significance was set at $P < 0.05$. **Results:** Dentinal defects were found in all experimental groups. Lowest incidence of microcracks was observed in the Gates Glidden group (8.9%) which was also the control group, whereas highest incidence of microcracks was observed in F6 SkyTaper group (33.3%). ProTaper group showed higher incidence of microcracks (28.9%) compared to OneShape group and WaveOne Gold group (20.0%). However, there were no statistically significant differences between any of the experimental groups (p=0.055). **Conclusion:** Root canal instrumentation with F6 SkyTaper single file system caused higher incidence of dentinal defects followed by the ProTaper system. OneShape single file system with an asymmetrical design and WaveOne Gold system with improved metallurgy had lesser potential to induce microcracks in root dentine.

KEYWORDS

Microcracks, Single-file system, ProTaper, OneShape, F6 SkyTaper.

INTRODUCTION

Biomechanical preparation of the root canal system is recognized as being one of the most important stages in root canal therapy and includes the removal of vital and necrotic tissues from the root canal system, along with infected root dentine. Thus, canal preparation is an essential step in eliminating root canal infection as well as preventing the re- infection.

Over the past two decades, rotary nickel - titanium based instrumentation techniques have become the mainstream approach to mechanically enlarge the root canal space, overcoming most of the drawbacks of conventional stainless steel based instrumentation techniques such as canal transportation and perforation.[1]

However, several recent studies have shown that rotary nickel-titanium instrumentation techniques have the potential to cause defects in root dentinal structure. These defects, also termed as "microcracks", occur when the tensile stress on the root canal wall exceeds the tensile strength of dentine. This situation is critical considering the abundance of different designs, tapers, preparation protocols, number of files, and kinematics of various available NiTi systems. In recent times, the use of single file systems in order to shape the entire canal have gained popularity, and a plethora of single file systems with rotary as well as reciprocating kinematics have been developed, with innovative metallurgy and design features.

OneShape files (Micro-Mega, France) are a single file system used in a traditional continuous rotation motion. They have a triangular cutting edge in the apical part, two cutting edges in the coronal part, and a cross-section that progressively changes from three to two cutting edges between the apical and coronal parts. It is the manufacturer's claim that this design offers an optimal cutting action.[2]

F6 SkyTaper (Komet, Germany) is a new single file Ni-Ti system developed for use in continuous clockwise rotation. The files are made of a conventional austenite 55-45 Ni-Ti alloy. The file has a constant taper of 0.06 and is characterized by a modified S-shaped cross sectional design is used for the entire working part of the file.[3]

The WaveOne Gold file System (Dentsply Maillefer) is a single-file system which is based on reciprocating kinematics. It is manufactured by a new supermetal technology termed "Gold-wire". It has an offset parallelogram-shaped cross-section, which is claimed to limit the engagement zone with the dentinal wall. It operates in an unequal bidirectional reciprocation movement with a counter clockwise movement of 150° followed by a 30° clockwise movement, with 3 continuous reciprocating cycles completing one full reverse rotation enabling the instrument to advance apically into the root canal.[4]

The ProTaper Universal system (Dentsply Maillefer) is a versatile sequential rotary file system which is widely used and has been studied extensively in the literature. Each instrument has a changing taper over the length of its cutting blade. Working from the tip to the end of the cutting flutes, taper increases on the shaping files (SX, S1 and S2), and decreases on the finishing files (F1 to F5).[5]

Hence the purpose of this in vitro stereomicroscopic study was to compare the incidence of root microcracks observed on the canal wall after instrumentation with three single file systems namely OneShape, F6 SkyTaper and WaveOne Gold with the ProTaper system.

MATERIALS AND METHODS

Selection of samples:

Seventy five freshly extracted human mandibular incisor teeth with straight roots and single canal extracted for periodontal reasons were used in the study. The teeth were stored in normal saline solution after extraction and throughout the experimental period.

Inclusion criteria:

- Freshly extracted intact human mandibular incisors with single straight root canals confirmed radiographically.
- Teeth with comparable root width.

Exclusion criteria:

- Teeth having more than a single root canal and apical foramen.
- Root canal treated teeth.
- Teeth with internal and external resorption.
- Teeth with immature root apices.
- Teeth with caries/cracks/fractures on the root surface
- Teeth with root curvature more than 10 degrees.

Preparation of Specimens

- Proximal radiographs of teeth were taken to verify the presence of a single canal. Teeth with additional canals and any other prominent aberrations were replaced.
- Root width was measured buccolingually and mesiodistally 5 mm from the apex using a precision caliper and teeth having

comparable root widths were selected for the study.
- The crowns of the teeth were sectioned 2 mm above the proximal cementoenamel junction using a double-sided diamond disc in low speed under water coolant.
- The roots were examined with dental loupes at a magnification of 2.3X to rule out the presence of cracks, fractures, or craze lines on external root surface.
- The distance between the coronal tip and the apical foramen of each root was determined by inserting a size 10 K file into the canal until tip of the file was just visible at the apical foramen and the working length was established by subtracting 1 mm from this length.
- Each root was wrapped with a single layer of aluminum foil and embedded in a stainless steel cube filled with acrylic resin. The specimen was removed from the cube after the resin was set, and the aluminum foil peeled off. A hydrophilic silicone impression material was used to replace the space created by the foil to simulate the periodontal ligament space and the specimen was immediately repositioned.
- The coronal part of each canal was flared with a #2 Gates-Glidden drill, after which the specimens were randomly divided into four groups (n=15) based on the technique used to instrument the root canals. Fifteen specimens, in which no further instrumentation was performed after coronal enlargement with Gates-Glidden drills served as control.

Root canal preparation

The instrumentation of root canals in experimental specimens was performed as follows:

Group 1 (ProTaper group):

The specimens in this group were initially enlarged with K- files upto #25. They were then prepared with ProTaper Universal instruments (Dentsply Maillefer), which were used at the recommended speed of 300 rpm with 2 Ncm torque using an endodontic motor (Endo-Mate DT, NSK, Japan). An SX file was used at one half of the working length, S1 and S2 files were used at two thirds of the working length, and F1 (20/.07) and F2 (25/.08) files were instrumented to the working length. In the canals, the SX, S1, and S2 files were used with a brushing motion. The F1 and F2 files were used with a gentle pecking motion until the instrument had reached the measured working length.

Group 2 (OneShape group):

In this group, the canals were initially prepared with K- files (Mani, Japan) upto #25. Root canal preparation was then performed to the working length with OneShape rotary file #25.06 (Micro Mega) using an endodontic motor (Endo- Mate DT, NSK, Japan) with a constant speed of 400 rpm and 4 Ncm torque in pecking motions as recommended by the manufacturer.

Group 3 (F6 SkyTaper group):

The canals in this group were initially instrumented with K-files (Mani, Japan) upto #25. F6 SkyTaper rotary file #25.06 was then used in full clockwise rotation with a rotational speed of 300 rpm generated by an endodontic motor (Endo-Mate DT, NSK, Japan) with an adjusted torque of 1.8 Ncm. The files were used in a pecking motion according to the manufacturer's instructions.

Group 4 (WaveOne Gold group):

After initial canal enlargement with K-files upto #20 (Mani, Japan), the specimens in this group were prepared with a single WaveOne Gold small reciprocating file #20.07. The instrument was activated using a 6:1 reduction handpiece powered by a torque-controlled motor (X-Smart Plus, Dentsply) using the pre- set 'WAVEONE GOLD' programme. The preparation was made with gentle pecking movements until the measured working length was reached. All canals were instrumented on the buccolingual extensions with brushing movements.

Specimens of all the groups were copiously irrigated with 2 mL of 3% Sodium hypochlorite solution after each change of instrument. The irrigant was delivered using a 30 gauge single-side vented endodontic irrigation needle (Neo Endo, Orikam) by advancing it as deeply as possible inside the canal without binding to the root canal walls.

Sectioning and Microscopic observation

All specimens were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex using a low speed precision saw (Minitom, Struers, Denmark) at 300 rpm under water coolant. The root sections thus obtained were observed under a stereomicroscope (Carl Zeiss Discovery V 20) with a 30X magnification under a cold light source and digital images were then examined for the appearance of dentinal cracks.

Evaluation of Dentinal Defects

To evaluate crack formation, two different scoring criteria were made.[6]

No crack: -

was defined as root dentin devoid of any craze lines or micro cracks either at the external surface of the root or at the internal surface of the root canal wall.

Crack: -

was defined if any craze lines, micro cracks, or fractures were present in root dentin or extending to outer root surface.

The results were expressed as the number and percentage of defects in each group. The data collected were subjected to statistical analysis to compare the incidence of cracked roots between experimental groups.

Statistical analysis

The data were analyzed using statistical software SPSS version 20 (SPSS Inc., Chicago) and Microsoft Excel version 2010. A Chi-square test was performed to determine statistically significant difference in the appearance of dentinal microcracks between the experimental groups. Chi-square test was also performed to determine the microcracks at different horizontal sections in each group. The level of significance was set at $P<0.05$.

RESULTS

According to the results of the present study, dentinal defects were found in all experimental groups. Lowest incidence of microcracks was observed in the Gates Glidden group (8.9%) which was also the control group, whereas highest incidence of microcracks was observed in F6 SkyTaper group (33.3%).

ProTaper group showed higher incidence of microcracks (28.9%) compared to OneShape group and WaveOne Gold group (20.0%). However, there were no statistically significant differences between any of the experimental groups (p=0.055).

Analysis of results in the coronal third revealed a similar incidence of dentinal cracks between the control group and OneShape group (13.3%). F6 SkyTaper group showed the highest incidence of microcracks in coronal sections (33.3%) followed by the ProTaper group and WaveOne Gold group (20.0%), both showing similar incidence of microcrack formation at this level.

In middle third, control group showed the least number of microcracks (6.7%) while ProTaper group and F6 SkyTaper group (40.0%) showed the highest incidence of microcracks. It was found that WaveOne Gold group caused lower incidence of microcracks (13.3%) when compared to OneShape group (26.7%) at this level.

In apical third, control group showed the least incidence of microcracks (6.7%), followed by One Shape group (20.0%). ProTaper, F6 SkyTaper and WaveOne Gold group (26.7%) showed no difference in the incidence of root microcracks at this level.

DIAGRAMS

Figure 1. Mandibular incisors used in the study

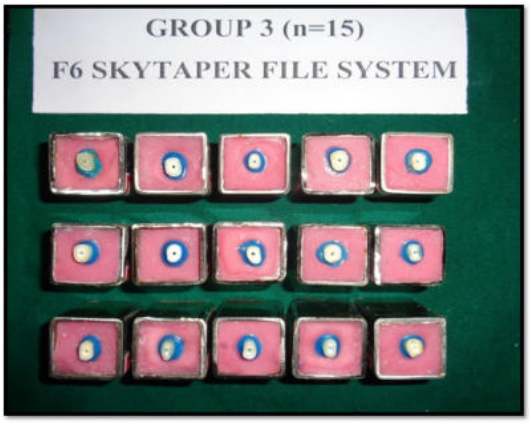


Figure 2. Decoronated experimental specimens with periodontal simulation

Figure 3. Biomechanical preparation of specimens

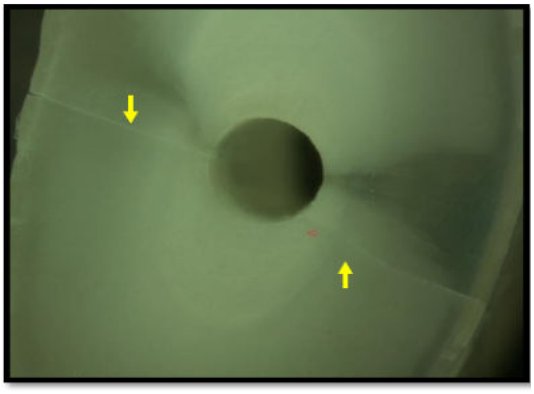
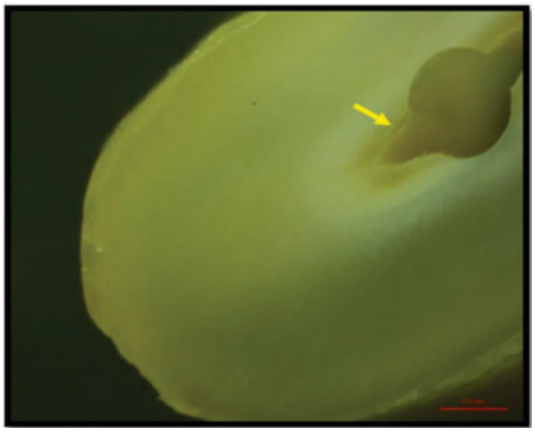
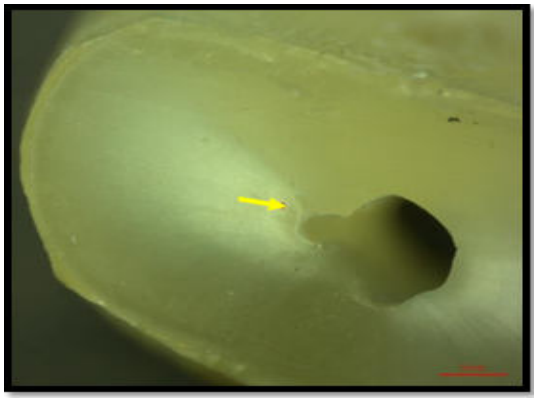


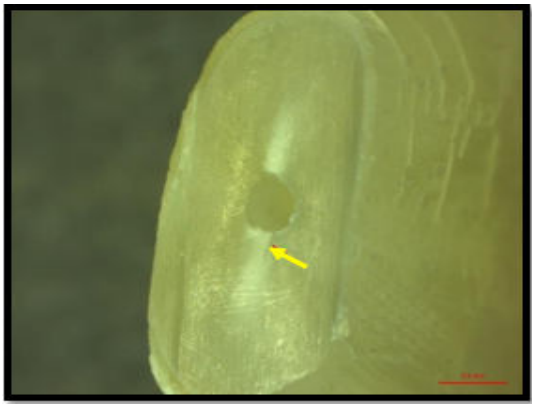
Figure 4. Stereomicroscopic images of dentinal microcrack formation after sectioning of teeth ProTaper group (Coronal third)



F6 SkyTaper group (Coronal third)



WaveOne Group (Middle Third)



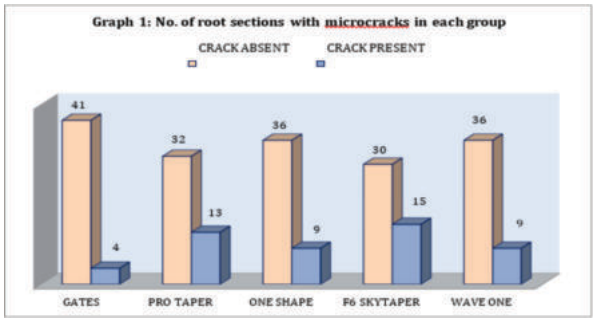
OneShape group (Apical third)

Table 1. The number and percentage of cracked sections for each group: Chi-Square test.

Chi-Square Tests								
TOTAL		GROUP					Total	p
		GATES GLIDDEN	PRO TAPER	ONE SHAPE	F6 SKYTAPER	WAVE ONE		
CRACK ABSENT	Count	41	32	36	30	36	175	0.055
	%	91.1%	71.1 %	80.0%	66.7%	80.0%	77.8%	
CRACK PRESENT	Count	4	13	9	15	9	50	
	%	8.9%	28.9 %	20.0%	33.3%	20.0%	22.2%	
Total	Count	45	45	45	45	45	225	
	%	100%	100%	100%	100%	100%	100%	

The incidence of dentinal microcracks among various groups was as follows:

F6 SkyTaper > ProTaper > OneShape = WaveOne Gold > Gates Glidden (control)



The incidence of dentinal microcracks among various groups was as follows:

F6 SkyTaper > ProTaper > OneShape = WaveOne Gold > Gates Glidden (control)

DISCUSSION

Since decades, various causative factors for the occurrence of dentinal defects have been elucidated. Among them, stress on the root canal walls due to rotary NiTi instrumentation, taper of the instrumentation files, root canal obturation procedures, retreatment, placement of intra-radicular posts, high concentration of sodium hypochlorite, age changes and parafunctional habits are the most prominent factors mentioned in literature.[7]

In the present study, highest incidence of dentinal microcracks was seen in F6 SkyTaper group (33.3%). It was also revealed that higher number of coronal and middle third samples instrumented with this file system showed the presence of microcracks compared to other groups. According to Lam et al. (2005), file design affects the force applied to root dentin, which is relevant to fracture risk.[8] The same concept was reiterated by Kim et al. (2010), who proposed that there is a relationship between dentinal micro crack formation and instrument design.[9] The design features of F6 SkyTaper account for effective shaping of the canal by virtue of its cutting efficiency. However, root canal preparation using only a single, large-tapered instrument, which cuts substantial amounts of dentin in a short period of time may tend to create or aggravate the dentinal defects when compared with the conventional preparation that allows for a more progressive and slower mechanical enlargement.[10] This may explain the higher incidence of dentinal cracks caused by this single file system (33.3%) in the present study, compared to the ProTaper system (28.9%), which is a sequential multiple file system.

Results of the present study revealed a similar incidence of dentinal microcracks (20%) in teeth instrumented with two single file systems with different working motions. i.e. OneShape, which works in continuous rotation and WaveOne Gold, which uses reciprocating kinematics. These results are consistent with the findings of Ustun Y et al. (2015), who found that instrumentation kinematics had no significant effect on crack formation[47] and Pop I et al. (2015), who concluded that there was no significant difference between rotary and reciprocating instrumentation in the formation of root dentinal defects.[11]

In the present study, the overall incidence of dentinal microcracks in the ProTaper group was found to be 28.9%. The incidence of microcracks induced by the ProTaper system in coronal, middle and apical thirds was 20%, 40% and 26.7% respectively. According to previous studies, the incidence of dentinal defects created by ProTaper Universal instruments ranged from 16%–56% (Karatas E et al. 2015 ; Bier CA et al. 2009 ; Capar ID et al. 2014).[12, 13, 14] Studies conducted by Liu R et al. (2013) and Kansal R et al. (2014) have shown a higher incidence of about 50% with this instrumentation technique, whereas other studies have reported lower incidence of microcracks in the ProTaper system with the range of 10% to 30% (Bürklein S et al. 2013; Yoldas O et al. 2012; Karataş E et al. 2015; Monga P et al. 2015).[2, 13, 15, 16,17]

Burklein S et al. (2012) postulated that convex triangular design of ProTaper cross section decreases the cutting efficiency and provides less space for dentinal chips, thus generating stresses on root canal walls.[18] Yoldas et al. (2012) and Milani et al. (2012) reported that the incidence of microcracks with the ProTaper rotary files could be attributed to their larger cross- sections, greater stiffness, and higher levels of torque and bending force.[19, 20] The higher incidence of cracks caused by the ProTaper system in the middle third can thus be explained under the light of these findings.

In the present study, samples of the control group in which the canals were coronally flared with Gates Glidden Drill #2 with no further instrumentation showed the presence of dentinal microcracks; albeit lowest among all experimental groups (8.9%). The presence of cracks in this group can be explained by the fact that coronal flaring procedure requires instrument contact with the root canal wall, which results in momentary stress concentration in the dentin.[21] Kim HC et al. (2010) stated that as the volumes of coronal flaring instruments are greater than those of other instruments, the procedure of coronal flaring may create defects in the root dentin.[9]

CONCLUSION

Within the limitations of this in-vitro study, it was concluded that root canal instrumentation with F6 SkyTaper single file system caused higher incidence of dentinal defects followed by the ProTaper system. OneShape single file system with an asymmetrical design and WaveOne Gold system with improved metallurgy had lesser potential to induce microcracks in root dentine.

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Conflict of interest: None

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21. Arslan H, Karatas E, Capar ID, Ozsu D, Doganay E. Effect of ProTaper Universal, Endoflare, Revo-S, HyFlex coronal flaring instruments, and Gates Glidden drills on crack formation. J Endod. 2014;40(10):1681–3. experimental groups. Chi-square test was also performed to determine the microcracks at different horizontal sections in each group. The level of significance was set at $P < 0.05$.