THE ABILITY OF TWO NICKEL-TITANIUM ROTARY SYSTEMS MADE OF DIFFERENT ALLOYS TO INDUCE DENTINAL RADICULAR MICROCRACKS

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SUMMARY

Purpose: The objective of the present study was to evaluate the ability of two nickel-titanium rotary systems made of different alloys to induce dentinal radicular microcracks

Materials and methods: Thirty – six extracted lower incisors were included in the current *in vitro* experiment. The samples were randomly assigned into three equal groups (n=12): negative control, ProTaper Universal and HyFlex CM. Roots in the control group were left unprepared, and the other two were shaped by using ProTaper Universal and HyFlex CM files. After mechanical instrumentation of the root canals all specimens were horizontally sectioned at 3, 6, 9 mm from the apex and the occurrence of dentinal microcracks was registered. Statistical analysis of the results was performed by Fisher's exact and chi-square tests ($p < 0.05$).

Results: The samples from the control group remained intact. Both tested NiTi file systems induces dentinal defects. There was no statistically significant differences between ProTaper Universal and HyFlex CM. Defects in the apical region in both experimental groups were significantly more than those in the coronal and midportion of the roots.

Conclusions: ProTaper Universal and HyFlex CM systems performed equally and resulted in dentinal defect formation regardless of their alloy type. More damages were registered in the root apical portion for both tested systems.

Keywords: NiTi instruments, ProTaper Universal, HyFlex, microcracks, instrumentation

INTRODUCTION

Thorough debridement of the root canal space is essential for the outcome of the initial endodontic therapy. Recently, various nickel-titanium instruments have been advocated and preferred by dentists over stainless-steel hand ones due to their improved cutting ability, minimized procedural errors and shortening of the clinical time[1, 2]. Nevertheless, during the cleaning and shaping procedures, these files are reported to induce

microcrack initiation into the root canal wall [3, 4]. Their deleterious effect depends on the alloy they are manufactured from, taper, tip design, cross-section and type of rotation [5]. In time, minor dentinal defects can further propagate into vertical root fracture, which is assumed as one of the most common reasons for tooth loss [3, 4, 6].

ProTaper Universal (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) files are made of conventional nickel-titanium alloy, have a convex triangular cross-section design and several percentage tapers, enabling a dynamic cutting motion and removing greater amount of dentin coronally [7]. Earlier *in vitro* investigations have linked shaping with that system with a higher incidence of dentinal microcracks [7, 8, 9]. In an attempt to overcome the deficiencies of the latter, a new system made of heat-treated Controlled Memory alloy – HyFlex CM (*Coltene-Whaledent, Allstetten, Switzerland*) has been introduced into the market. The files from the system have asymmetrical cross-section design with three to four cutting edges. The Controlled Memory wire has improved cyclic fatigue resistance and shaping ability [2, 10].

Despite the accumulated body of knowledge, further investigations are necessary to find the minimally-invasive and safest shaping instruments. The objective of this study was to evaluate and compare the incidence of dentinal defects following root canal shaping with two rotary nickel-titanium systems made of different alloys. The null hypothesis is that neither of the tested files induces dentinal damages on the root canal wall.

MATERIALS AND METHODS

All samples in the experiment were recruited from a pool of freshly extracted teeth from the Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Medical University – Sofia, Bulgaria. Overall fifty intact mandibular incisors were extracted due to periodontal lesions and stored in purified, filtered water until further use. The external surface of all samples was cleaned from calculus and plaque using an ultrasonic tip under water cooling. Afterwards, the teeth were examined under a stereomicroscope for detection of external root damage.

Teeth with multiple canals, apical curvature, fractured and/or immature root apices, any root or coronal defects, were excluded from the investigation. Thirty-six, non-endodontically treated lower incisors were finally included in the study. To ensure standardization all teeth were horizontally sectioned using a diamond bur under copious water cooling at the cemento-enamel junction, leaving roots at 16 mm length.

The process of periodontal ligament simulation was done in the following way: all roots were wrapped with a single layer of aluminum foil and inserted in putty impression material set in an acrylic tube. Afterwards a light body silicon based material (*Oranwash; ZhermackSpA, Rovigo, Italy*) was used to fill the space created by the foil, in order to simulate the periodontal ligament. Then, the roots were placed into the acrylic mould (Figure 1).

Fig. 1. Simulation of periodontal ligament: A) Root B) Root wrapped in aluminum foil C) Placement into an acrylic mould filled with putty impression material D) Space formed from the root E) Placement of light body silicon.

Negotiation and apical patency of the root canal was achieved by inserting a stainless-steel K-file size 10 (ISO) (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) and the working length (WL) was set 1.0 mm shorter of the apical foramen. A glide path up to the full WL was established with K-file ISO 15 (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*). The instrumentation was carried out with speed and torque-controlled endo motor X-Smart Plus (*Dentsply Sirona Endodontics, Ballaigues, Switzerland*) following the manufacturer's instructions for each of the rotary NiTi file systems. A single set of instruments was used per three root canals.

The specimens were evenly distributed into 3 groups (n=12) as follows:

1. *Group I* (negative control): unprepared roots.
2. *Group II* (positive control): roots instrumented with ProTaper Universal (speed 250 rpm) in the following order: SX, S1, S2 with brushing motion, F1 (20/.07), F2 (25/.08) with in-and-out movement
3. *Group III*: roots instrumented with HyFlex (speed 500 rpm, torque 2,5 Ncm) in the following order: 25/.08, 20/.04, 25/.04, 20/.06 using the single-length technique

During the shaping procedure, the root canals were irrigated with saline using 27G endodontic irrigation needle. Flutes of the files were cleaned regularly and checked for signs of wear and distortion. All samples were kept moist in sterile, distilled water at 37 °C and 100% relative humidity to prevent dehydration.

Sectioning and Microscopic Examination

The horizontal sectioning of the roots was executed by a low-speed saw (*Leica SP1600, Leica Microsystems, Wetzlar, Germany*) under copious irrigation with water.

Each specimen was cut at three different levels: apical – 3mm, middle – 6 mm and coronal – 9mm. Each of the acquired 108 slices was observed stereomicroscopically applying a cold light source at x 40 magnification (*Leica S6, Leica Microsystems, Wetzlar, Germany*) and digitally captured.

All images were inspected by a single observer three times. The dentinal defects were then categorized into three groups using the following definitions:

No defect - intact root dentin free of any lines, microcracks and/or fractures.

Other defects – root dentin with incomplete cracks such as: lines, extending from the outer surface into the dentin, without reaching the canal lumen (craze lines); defects originating from the canal walls without reaching the outer surface of the root (partial cracks).

Fracture - a line crossing the entire root canal space all the way to the outer surface of the root.

STATISTICAL ANALYSIS

The results were expressed as the number and percentage of the defects in each group at 3, 6, 9 mm levels. Fisher's exact and chi-square tests were used for statistical analysis of differences between groups at 95% confidence level ($p < 0.05$) (*SPSS v.25.0.0.0.*)

RESULTS

No cracks were observed in the control group. Dentinal defects were registered in both shaping systems, and the distribution of microcracks per group and section level is shown in Table 1. Only one complete fracture was present in the HyFlex group at 3 mm level. Comparison between ProTaper Universal and HyFlex CM instrumented

group revealed insignificant difference concerning the number of defects registered at the three examined levels. Coronally, one craze line was observed in the HyFlex CM group, whereas ProTaper Universal samples were free of dentinal defects. The two experimental systems per-

formed equally in the middle part of the root inducing five slices with dentinal microcracks in each group. In both tested groups, defects at the apical portion of the root canal were significantly more than those observed at the coronal portion ($p < 0.05$). Table 1, Figure 2.

Table 1. Number and percentage of slices with dentinal defects at the three tested levels in the two experimental groups. Different letters in each group display a statistically significant difference.

NiTi System	Number of slices with dentinal defects	Level			Total	<i>p</i>
		3 mm	6 mm	9 mm		
ProTaper Universal	N	9a	5a	0b	14	0,001
	%	75,0%	41,7%	0,0%	38,9%	
HyFlex	N	8a	5a, b	1b	14	0,046
	%	66,6%	41,7%	8,3%	38,9%	

Fig. 2. Stereomicroscopic images at X40 magnification. Red arrow – fracture; Blue arrows – partial cracks. A) Negative control-3 mm level B) HyFlex – 3 mm level C) ProTaper Universal – 6 mm.

DISCUSSION

There is a lack of consensus in the literature regarding the choice of the experimental teeth in *in vitro* studies on dentinal microcrack initiation and propagation [1]. The finite element analysis of Lertchirakrnet al. showed higher stress accumulation in oval roots exhibiting greater buccal-lingual diameter and thinner proximal dentin [11]. Mesiodistal forces applied from the inside out are capable of inducing a higher number of dentinal defects in flat canals compared to round ones [12]. This might be explained with the sharpened notch at the end of their oval extension. The utilization of mandibular incisors in the current study represents an attempt to select teeth, which are more prone to fracture, thus ensuring a reproducible experimental design. Moreover, stress distribution throughout the shaping procedures was assured by simulated PDL, as suggested previously by Liu et al. [4], though in the present investigation we filled in the acrylic mould with putty impression material instead of an acrylic resin [13]. Saline was used as an interim irrigant with the

intention to eliminate the adverse impact of the commonly used endodontic irrigation solutions such as sodium hypochlorite (NaOCl) and EDTA [13].

In an attempt to find the safest way an endodontic treatment should be conducted, various evaluation methods are used nowadays for detection and investigation of dentinal defects appearing in the course of initial root canal shaping [1, 14]. The most prevailing method enabling direct visualization of the exposed dentin surface is sectioning of the specimens at the apical, middle and coronal level in combination with a stereomicroscopic observation under different magnifications [1]. By using this destructive approach, part of the sample is inevitably lost, and the risk of appearance of new or propagation of pre-existing cracks might increase as well [14, 15]. In order to avoid false interpretation of the received results, we utilized a negative control group with uninstrumented root canals. No cracks were observed in the negative control group, confirming that the incidence of any dentinal damages registered in the course of the root canal shaping has occurred due to the instrumentation procedures, rather than the sectioning technique. This is in accordance with the findings obtained in previous investigations [3, 13, 16].

The choice of the two full-sequence rotary NiTi systems in the present study is based on the assumption that each preceding file enables shaping with successive ones thus reducing the contact surface with the dentin wall and lowering the incidence of defects [12, 17]. The cross-section design of the tested files in our study differs: for all ProTaper Universal files it is a triangular convex, whereas HyFlex files exhibit either triangular or square shape. The number of contacts of file blades with the dentinal surface may exert high pressure, causing an instant microcrack formation [18]. Nearly the same number of contacts (3 to 4) of the blades of the tested instruments with the dentinal wall resulted in a lack of statistically significant difference between them.

File taper might be another contributing factor to

the occurrence of dentinal defects, especially in narrow, oval roots. The larger the taper is, the greater amount of dentin is removed, thus, increasing fracture susceptibility of the root [12]. The two NiTi systems used in the current *in vitro* study had equal apical diameters (ISO 25). Despite the higher apical tapers of the ProTaper Universal files compared with those of the HyFlex sequence, both systems induced a relatively equal number of microcracks at the apical root canal portions ($p>0.05$).

CM wire is a novel NiTi alloy with flexible properties that was introduced in 2010. Control memory (CM) NiTi files have been manufactured using a special thermomechanical process that controls the memory of the material, making the files extremely flexible and with controlled memory effect. In contrast with the conventional NiTi instruments, the file doesn't attempt to retrieve its original form while working within the canal. In our experiment we used HyFlex CM because of its increased flexibility, resistance to cyclic and torsional fatigue and reduced root canal transportation when compared with the conventional NiTi ProTaper Universal [2, 10, 19]. It might be speculated that shaping with the novel, heat-treated instruments would result in a lesser number of dentinal microcracks. Surprisingly, the only evident fracture was in-

duced at the apical level after shaping with HyFlex. Nevertheless, our results indicated that the type of alloy did not significantly influence the defect formation as dentinal cracks in the three portions of the root canals instrumented with ProTaper Universal and HyFlex CM did not differ statistically. Therefore, the null hypothesis was rejected. Our findings are in contrast with the results obtained from previous studies which reported a lower incidence of dentinal defects after using CM wire instruments [7, 20].

CONCLUSION

Within the limitations of the present study, it could be concluded that ProTaper Universal and HyFlex NiTi rotary systems performed equally and resulted in dentinal defect formation regardless of their alloy type. Significantly higher incidence of microcracks was observed in the apical section of the root canal in the two experimental groups compared to its coronal aspect.

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