10.21608/ADJC.2023.193838.1265 Advanced Dental Journal
Volume 6 (2024) | Issue 2| Pages 281-288

Original Article

The Influence of Separated Instruments Metallurgy on the Incidence of Dentinal Cracks following Retrieval (In Vitro Study)

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Submitted: 4/3/2023
Accepted: 28/4/2023

Abstract

Ultrasonic retrieval of separated instruments was proven to be a highly successful procedure. However, its effects on root dentin are of major concern. **Aim:** To assess the influence of separated instruments alloy type on dentinal cracks development following ultrasonic retrieval in the presence of different intracanal lubricants. **Methods:** M-wire ProTaper Next files with tip size #25 and taper 0.6 (n=20), and EDM Neoniti files having the same size and taper (n=20) were fractured at 4mm from their tips in forty double-rooted moderately-curved upper premolars. A modified ultrasonic tip was used for their retrieval in presence of 17% EDTA solution or olive oil. Successfully retrieved samples had their roots horizontally sectioned, at 4mm and 6mm from the apex. Sections was examined under the SEM with different magnifications (60-300x) for cracks detection. **Results:** The majority of samples showed the development of dentinal cracks, with an incidence of 70% and 90% in ProTaper Next and Neoniti groups respectively in presence of EDTA, as opposed to 70% in Protaper Next and 80% in Neoniti in presence of olive oil, and with no statistically significant difference between the different alloys or intracanal. **Conclusion:** Separated instruments of different metallurgy show no effect on the incidence of dentinal cracks following ultrasonic retrieval. Lubricants of different viscosities fail to omit the development of cracks.

Keywords: Separated instruments, ultrasonic tip, ultrasonic retrieval, cracks.

Introduction

Nickel-titanium (NiTi) rotary instruments, ever since their introduction into the endodontic field, have been commonly used for root canal preparations, due to their inherent flexibility and associated minimal shaping procedural errors **(Short, 1997)**. However, the most dreaded disadvantage related to NiTi files is their separation which could take place with no prior warning to the operator **(Ferreira et al., 2017)**. Several techniques have been used for separated instruments retrieval, one of which is the microsonic technique that combines using the dental operating microscope (DOM) together with ultrasonic tips. With the enhanced visibility provided with the DOM, the vibration of ultrasonic tips was proven successful in loosening separated fragments and removing them out of root canals **(Ward et al., 2003)**. However, this technique is accompanied with dentinal loss and changes in root canals diameter, increasing the risk of

cracks propagation and root fractures **(Portela et al., 2021)**.

Several studies have been conducted to assess the influence of separated instruments size or location on radicular dentin following ultrasonic retrieval **(Eid & Seyam, 2016; Gao et al., 2015)**, but none, to our knowledge, assessed the influence of instruments metallurgy on radicular dentin. Therefore, the aim of the study was to assess the influence of alloy type (M-wire and electric discharge machining EDM) on dentinal cracks development following ultrasonic separated instruments retrieval in the presence of different intracanal lubricants.

Materials and Methods

Sample size calculation:

Sample size was calculated using the PS software: Power and Sample Size Calculation Software Version 3.1.2 (Vanderbilt University, Nashville, Tennessee, USA), based on the mean and standard deviation values of a former study **(Shahabinejad et al., 2013)**, using power 80% and α error probability 0.05, and it was found that a total of forty successfully retrieved samples was convenient.

Samples preparation:

Double rooted upper premolars were collected, from the department of Oral surgery, Faculty of Dentistry, Cairo University, and disinfected in 5.25% sodium hypochlorite for 10 minutes. Preoperative digital radiographs were made for all teeth to guarantee having mature, moderately curved roots, with no calcifications or resorptive lesions, and with standardized lengths (19-21mm). Root canal curvature was measured according to the method described by **Pruett et al., 1997**; combining both the angle and radius of curvature. Only root canals having 15-30° angles and 4-8mm radii of curvature were used in this study (Figure 1). Following access cavities preparation under the DOM (SEILER MEDICAL, St. Louis, Missouri), patency was checked in each root canal and a glide path was prepared using K-files of size 10 and 15 (MANI, INC. Industrial Park, Utsunomiya, Tochigi, Japan). ProTaper Universal SX files were activated with an X-smart endodontic motor (Dentsply Maillefer, Ballaigues, Switzerland), at 300 rpm rotational speed and 2 N.cm torque, to coronally flare the canals, after which ProTaper Next X1 files were used to prepare the canals to their working length at 300 rpm and 2.8 N.cm.

The intervention for each group:

Teeth were divided into two groups according to the alloy of instruments to be fractured; Group I, where M-wire ProTaper Next files with tip size #25 and taper 0.6 were fractured in order to reach twenty samples of successful retrieval, and Group II, where EDM Neoniti files having the same size and taper were fractured in order to reach twenty samples of successful retrieval. As per described by **Pruthi et al., 2020**, instruments were notched, with the help of a low-speed 0.3-mm-thick diamond disk, to half their thickness at 4mm from the tip (Figure 1), introduced into the randomly selected root canals until they reached the full working length, and rotated with the X-smart motor, at 250 rpm and 5 N.cm, so that they could easily fracture at the apical 4mm of the root canal when they engaged the canal wall. Teeth with the fractured instruments were subdivided equally according to the lubricant used during ultrasonic retrieval into; Subgroup A, comprising ten samples with loosened instruments in which 17% EDTA solution was used, and Subgroup B, in which olive oil was used.

Assignment to intervention:

Random allocation sequence was generated using random sequence generator internet site (https://www.random.org/sequences) on 4 groups, IA, IB, IIA, IIB. That allocation was concealed by inserting each sample in a numbered opaque sealed envelope until the time of intervention. Random allocation sequence and allocation concealment were performed by the co-supervisor, while the technical procedures were carried out by the investigator.

Separated instruments retrieval:

Aided with the magnification (10x) of the

DOM, and as formerly described by **Terauchi et al., 2021**, instruments retrieval started with preparing a staging platform using modified gates glidden drills (MANI, INC. Industrial Park, Utsunomiya, Tochigi, Japan), followed by ultrasonic activation of an E7 ultrasonic tip (NSK, Tochigi, Japan), that had its thickness decreased with a finishing bur to create a modified katana tip, along the inner wall of dry root canals (Figure 1).

Canals with loosened instruments were then filled with 1 mL of either 17% EDTA solution (Prevest DenPro, USA) or olive oil (RS, Rafael Salgado, Spain) according to the assigned subgroup, and ultrasonic activation continued, while increasing the power settings by 20%, until the separated instruments jumped out of root canals by the acoustic streaming. One ultrasonic tip was modified for each sample.

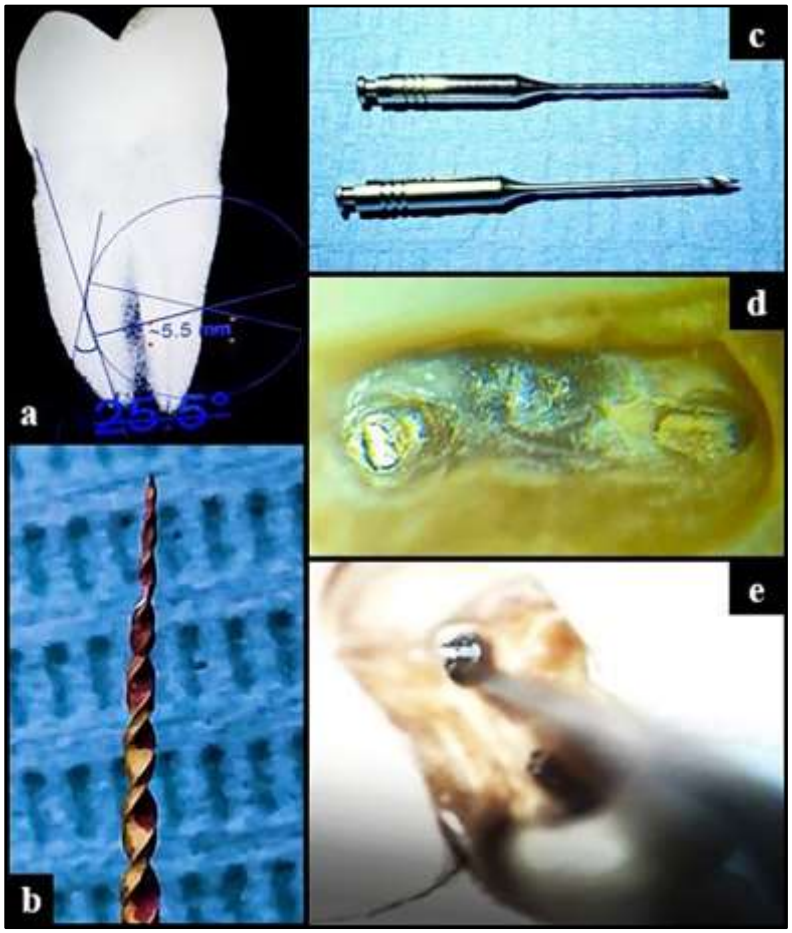

Figure 1: a) Digital periapical radiograph representing the angle and radius of curvature measured according to Pruett et al., (1997). **b)** An instrument notched to half its thickness. **c)** Gates-Glidden drills modification. **d)** Staging platform creation under the dental operating microscope (x10 magnification). **e)** Katana tip application along the inner curve of the root canal.

Power settings were kept at 10-20% of the maximum device settings until the instruments were observed to loosen from the dentinal walls.

Teeth sectioning and detection of dentinal cracks

Successfully retrieved samples had their roots horizontally sectioned (Figure 2), using an IsoMet saw (IsoMet 4000, BUEHLER, USA) equipped with a 0.3mm diamond disc and continuous water cooling, at 4mm and 6mm from the apex **(Abou Almakarem et al., 2020)**. Sections was examined under the SEM (S360, Oxford Co., Cambridge, UK), with different magnifications (60-300x) for cracks detection. Starting with low magnification (60-100x), every section was examined for the development of cracks, which if not detected, the magnification was increased (150-300x) to confirm their incidence **(Campello et al., 2021)**. Once cracks were observed, a micrograph of the section was taken (Figure 3). Cracks development was set as a binary outcome in the present study. Samples were confirmed to have developed dentinal cracks when the latter were observed at any horizontal section under any magnification of the SEM.

Data were collected and tabulated to be tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests where they showed non-parametric distribution. Wilcoxon test was used to compare between two groups in related samples. Mann Whitney test was used to compare between two groups in non-related samples. The significance level was set at $P \leq 0.05$ and statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Outcome measuring:

Cracks development was measured, after horizontal root sectioning of successfully retrieved samples at two levels being; 4mm and 6mm from each root apex, using the SEM as the measuring device. It was set as a binary outcome (Yes in samples with cracks development at any horizontal section, or No in samples with no cracks development at any horizontal section).

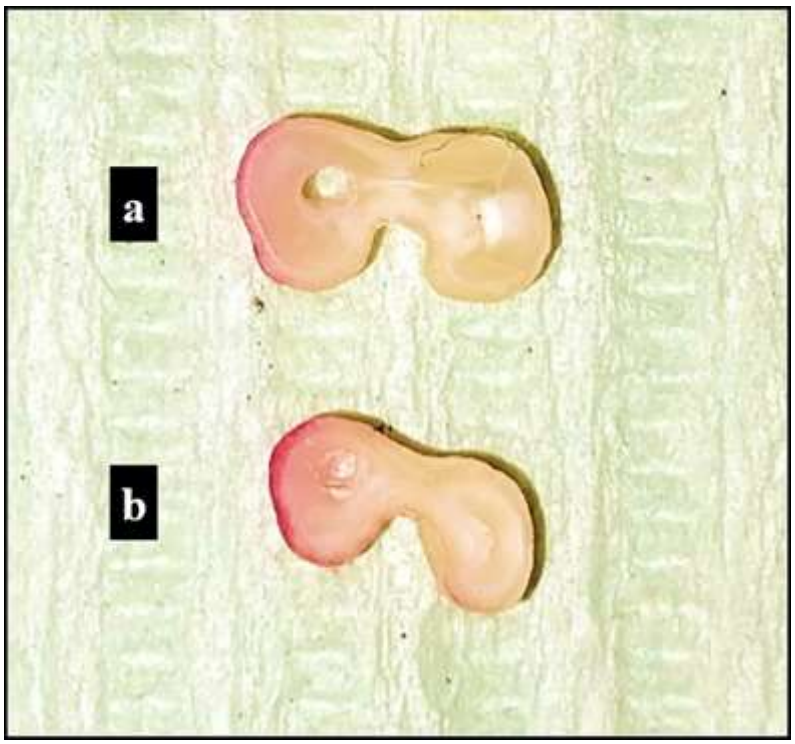

Figure 2: Sectioning samples under x4 magnification; a) at 6mm from the apex, b) at 4mm from the apex.

Statistical analysis:

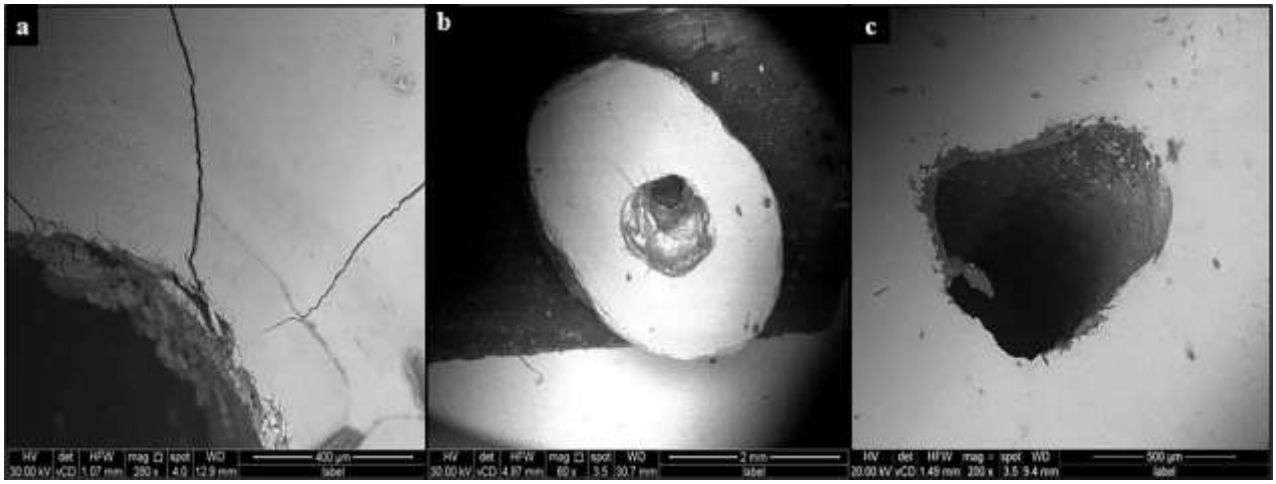

Figure 3: Scanning electron micrograph showing; a) a sample with cracks under high magnification, b) a sample with cracks under low magnification, and c) a sample with no cracks under high magnification.

Results

The majority of samples showed the development of dentinal cracks at both 4mm and 6mm from the apex.

There was no statistically significant difference between the different alloys or intracanal lubricants used regarding the incidence of cracks development (Table 1, Figure 3).

Table 1: The percentage of cracks development

	Development of cracks								
	Group I (Pro-taper next)				**Group II (Neoniti)**				**p-value**
	Yes		**No**		**Yes**		**No**		
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Subgroup A (EDTA)	7	70%	3	30%	9	90%	1	10%	**0.276**
Subgroup B (Olive oil)	7	70%	3	30%	8	80%	2	20%	**0.615**
p-value	**1**				**0.542**				

Discussion

Separated instruments retrieval is one of the most difficult and time-consuming procedures in endodontic treatment. It does not only require high clinical skills, but also special techniques and equipment are needed. The use of ultrasonic tips for separated instruments retrieval, in spite of its highly reported success rate, has been accompanied with some risks including root canal transportations, perforations, secondary fractures of the separated fragments and excessive removal of root dentin which subsequently leads to weakening of the tooth structure and increasing the liability for root fracture **(Shen et al., 2004)**.

In order to assess the influence of separated instruments metallurgy on dentinal cracks development, X2 ProTaper Next instruments made of M-wire alloy, and A1 Neoniti instruments, made of EDM alloy, were selected in the present study due to the fact that they share the same rectangular cross section, the same tip size and taper (25, 0.6) at the apical four millimeters of the instruments, making the alloy type the only variable that could possibly affect the results **(Pruthi et al., 2020)**.

Micro computed tomography has been reported to successfully detect dentinal cracks development following ultrasonic retrieval of separated instruments **(Fu et al., 2018)**. However, its unattainability called for using another method of cracks detection. Scanning electron microscopy was therefore used due to its superiority in cracks detection in comparison to cone beam computed tomography and stereomicroscopy **(Campello et al., 2021; Çapar et al., 2019)**.

According to the results reported by previous studies **(Madarati et al., 2009, 2010)**, the greatest changes in root dentin following ultrasonic retrieval of apically-located separated instruments was found to take place in the apical third of root canals. Accordingly, for cracks development assessment, two levels along the root canal length were chosen; the first being at the coronal end of the separated instrument, which was 4 mm from the apex, and the second was 2 mm coronal to the separated instrument; at 6 mm from the apex.

Teeth were horizontally sectioned using an IsoMet saw under copious water coolant to keep the samples moist and limit the chances of cracks development during sectioning **(Abou Almakarem et al., 2020; Çapar et al., 2019)**.

Low magnification (60-100x), where the whole horizontal section could be viewed, was first used to examine the samples for cracks, which if not detected, the magnification was increased up to 300x, until cracks were observed or confirmed to not have developed **(Campello et al., 2021)**.

The majority of the samples in the current study showed the presence of dentinal cracks, at both horizontal levels, with no statistically significant difference between neither the type of NiTi alloy nor the intracanal lubricant used. This was supported by the findings of **Fu et al., 2018** who stated that the vibratory motion of ultrasonic tips inside the root canals during separated instruments removal had the potentiality to induce dentinal microcracks, that could be multiple in number and short in length. However, they might propagate with time into vertical root fractures, worsening the prognosis and compromising the overall survival of the endodontically-treated teeth.

According to the results of the current study, it could be deduced that separated instruments retrieval using ultrasonic tips is unavoidably accompanied with dentinal cracks developments, irrespective of the instruments alloy type or lubricant used during retrieval.

One of the limitations of the current study is lack of operator's blinding. Additionally, teeth sectioning, despite having been performed under copious water coolant, could potentially induce cracks development. Dentinal cracks, when developed, were observed at both 4mm and 6mm from the apex. However, their number, depth and extension in dentin were not assessed at different levels.

Further studies using micro computed tomography, once available, are recommended

for better investigation of cracks incidence, location and depth, and for accurate measurement of the remaining dentin thickness following ultrasonic separated instruments retrieval.

Conclusion

Metallurgy of separated endodontic instruments shows no effect on the incidence of dentinal cracks following ultrasonic retrieval. Lubricants of different viscosities fail to omit the development of cracks.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics

This study protocol was approved by the ethical committee of the faculty of dentistry- Cairo university on: 29/9/2020, approval number:32920.

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