Orthograde Retrieval of Root Canal Obstructions Using Innovative Techniques

An in Vitro Study

Thesis

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Presented By

Sara Ahmad Abou Ateya

B.D.S, Cairo University
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Faculty of Oral and Dental Medicine
Cairo University
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Supervisors

Dr. Nihal Ezzat Sabet

Associate Professor of Endodontics
Faculty of Oral and Dental Medicine
Cairo University

Dr. Suzan Abdul Wanees Amin

Associate Professor of Endodontics
Faculty of Oral and Dental Medicine
Cairo University

Introduction

Since the introduction of nickel titanium (NiTi) instruments, both NiTi hand files and rotary instruments have been gaining popularity. A major reason for their selection is their much greater flexibility compared to their stainless steel counterparts. Endodontic practice is not risk-free; a variety of technical accidents can complicate root canal treatment, influencing the prognosis and prejudicing the chances of success. Fracture of endodontic instruments within root canal is not uncommon incident and is one of the most problematical incidents in endodontic therapy. There is a potential risk of "unexpected" fracture with NiTi instruments.

Fracture of frequently-used rotary NiTi files has been considered an important factor in the long-term prognosis of endodontic treatment as it usually prevents access to the apex. However, it has been shown that less than 1% of endodontic failure are due to instrument fractures. Among possible choices of whether to maintain the file fragment or remove it from canal space, removal of file fragment has become a favorable decision especially with the technological advancements in instrument retrieval methods and in visibility utilizing the dental operating microscope.

There have been many methods proposed for the removal of separated instruments from root canals using chemical agents as iodine trichloride or mechanical methods such as hand instrumentation, ultrasonic devices, Canal Finder system, Masseran kit, Endo Extractor, and several kinds of pliers. Various surgical methods along with microscope have also been used. Finding a standard procedure with definite success rate is still under investigation.

The maneuvers used in the retrieval of the separated files in this study (the needle-and-wire maneuver and the chloroform-dipped gutta-percha maneuver) were presented only as observational studies (case reports) rather than experimental studies to evaluate the efficiency of these maneuvers in the retrieval of the separated files. Thus, the present study aimed to evaluate the efficiency in retrieval, the amount of removed dentin after the retrieval and the operating time during the retrieval of short and long fragments of nickel titanium (NiTi) instruments.

Review of Literature

In the practice of endodontics, clinician may encounter a variety of unwanted procedural accidents at almost any stage of treatment. One of these procedural problems is intracanal instrument fracture ***(Torabinejad, 2002).*** Nickel titanium (NiTi) files are widely used in endodontics for cleaning and shaping of root canal. Greater instrument taper, new blade design, higher elasticity and resistance to tensional fracture are some favorable properties of these instruments ***(Thompson, 2000; Walia et al., 1988)***. The ability of rotary NiTi files to create well-centered, smooth, and minimally-transported canals with minimal procedure errors has been reported ***(Hubscher et al., 2003 and Versumer et al., 2002).*** Despite these advantages, fracture of rotary NiTi files has become a real concern among endodontists because of the high prevalence of file fracture within the root canals and, also, vague signs of surface alterations in NiTi alloy ***(Di fiore et al., 2006).***

➢ Metallergy of NiTi alloy:

Nickel titanium, is also known as Nitinol which stands for Nickel titanium by Naval Ordinance Laboratory ***(Thompson, 2000).*** NiTi alloys are one of shape memory alloys where nickel and titanium are present in roughly equal atomic percentages. They have the most important practical applications in dentistry because of their biocompatibility, corrosion resistance and super elasticity. The properties of the alloy occur as a result of the austenite to martensite transition, which in turn is because of the alloy having an inherent ability to alter its type of atomic bonding. The martenistic transformation requires a reversible atomic process termed twinning that allows reduction of strain during transformation ***(Otuska and Wayman, 1998).***

NiTi can exist in more than one crystalline form either austenitic (parent phase) or martensitic (daughter phase).The transformation from one phase to another is thermo-mechanical where, at high temperature, nitinol assumes the austenite phase, which is an interpenetrating primitive cubic crystal structure and, at low temperature, nitinol transforms to the martensite phase which has a more complicated monoclinic crystal structure. The temperature at which austenite transforms to martensite is referred to as the "Transformation Temperature". A temperature difference between martenistic and austenistic is" temperature transition range" (TTR) ***(Thompson, 2000).***

The austenitic phase is a low-stress, high-temperature form while the martensitic phase is a high-stress, low-temperature form. In endodontics, we are more concerned about stress induced martenistic transformation due to complex stresses to which files are subjected during shaping curved canal ***(Thompson, 2000).***

Two unique properties of great importance to endodontics, which are shape memory or superelasticity (up to 8% of strain is fully recoverable), are derived from the phase transformation property of nitinol ***(Muhonen, 2008).***

Shape memory refers to the ability of nitinol to undergo deformation at one temperature, then recover its original, undeformed shape upon heating above its transformation temperature, while superelasticity occurs at a narrow temperature range, just above its transformation temperature, where no heating is necessary for recovery of undeformed shape and the material exhibits enormous elasticity, some 10-30 times that of ordinary metal ***(Muhonen, 2008).***

➢ Fracture of NiTi instruments:

A disadvantage of NiTi alloy is its low ultimate tensile and yield strength compared with stainless steel, making it more susceptible to fracture at lower loads. This property may play a role in the influence of the operator on fracture prevalence regarding operator's proficiency with the instruments and the decision on the number of uses of the instruments ***(Parashos et al, 2004).***

In general, fracture of metals can be classified as either brittle or ductile. Features of both brittle and ductile fractures have been identified in fractured rotary NiTi endodontic instruments. Ductility refers to the ability of a material to undergo plastic deformation before it breaks, whereas brittle fractures are associated with little or no plastic deformation. Hence, brittle fractures usually occur in metal with poor ductility. Typically, there is an initiation of cracks at the surface of the metal, and stress concentration at the base of the cracks results in its propagation either along grain boundaries (intergranular) or between specific crystallographic planes (cleavage fracture). The crack, thus, behaves as a stress- raiser, because an applied load will be concentrated at one point or area, instead of being spread over a smooth surface. Examination of a fracture surface (fractography) using scanning electron microscope (SEM) reveals certain features that help identify the type of fracture mechanism involved. In brittle fracture crack fronts create ridges that spread along different planes within the alloy and generally radiate away from the origin of the crack producing chevron pattern. In ductile fractures, microvoids are produced within the metal and nucleation, growth, and microvoids coalescence ultimately weaken the metal and result in fracture ***(Askeland et al., 2003).***

Fractured rotary NiTi instruments have been classified into those that fail as a result of cyclic flexural fatigue or torsional failure or combination of both. This is based on low-power microscopic examination of the lateral surfaces of instruments subsequent to laboratory fracture experiments ***(Serene et al., 1995).***

Borgula (2005) found that accurate SEM examination of fracture surfaces of clinically used instruments was infrequently possible because of the severe distortion of the surface, presumably because of rubbing of the fragments immediately upon fracture. However, in laboratory follow-up ensuring no or minimal rubbing of fractured surfaces, ***Borgula*** **(2005)** confirmed that the lateral inspection classification was validated under SEM examination of the fracture surfaces. Clearly, these findings highlight the great difficulty in accurate assessment of clinically used instruments because of the distortion they often suffer in complex root canal anatomy.

Cyclically-fatigued instruments show no microscopic evidence of plastic deformation, but instruments that fracture as a result of torsional overload demonstrate variable deformation such as instrument unwinding, straightening, reverse winding and twisting. NiTi instruments rotating around a curvature for a prolonged period of time are subjected to repeated tensile and compressive stresses such that during each rotation the inner surface of the instrument is compressed and the outer surface is under tension. This results in work hardening within the metal and initiation of cracks leading to eventual cyclic flexural fatigue ***(Parasho et al., 2004).***

Cyclic fatigue is defined as the accumulated strain that develops from repeated bending of an object at the same location. Rotation of endodontic instruments subjects them to both tensile and compressive forces in the area of curvature of the canal, with tensile forces on the outside of the curvature and compressive forces on the inside ***(Haikel et al., 1999)***. Rotary files experience cyclic fatigue when they are rotated in a curved canal, which causes the instrument to cycle in and out of compression and tension forces at the location of the curve ***(Pruett et al., 1997)***. The main factors affecting cyclic fatigue in the rotary endodontic instruments are: speed and torque parameters, instrument diameter (size), and radius and angle of curvature ***(Parashos and Messer, 2006).***

Torsional fracture occurs when the tip or some part of the instrument is "locked" or jammed in the canal, but the shank of the file (driven by the hand piece) continues to rotate. This is the reason why the torsional fracture can occur in straight canal ***(Parashos and Messer, 2006)***.

➢ Factors predisposing to fracture of NiTi endodontic files:

The reasons for fracture of rotary NiTi instruments are complex and multifactorial grouped as follows: influence of rotational speed and torque parameter upon the cyclic fatigue of rotary NiTi instruments, influence of diameter and taper of NiTi instruments on cyclic fatigue, canal configuration, manufacturing process, preparation/instrumentation techniques, number of uses, cleaning and sterilization procedure, surface treatment and role of operator.

- **Influence of rotational speed and torque parameter on cyclic fatigue of Nickel- Titanium rotary instruments:**

The speed at which instruments operate seems to have no effect on the number of cycles to fracture, but higher speeds reduce the period of time required to reach the maximum number of cycles before fracture ***(Martin et al., 2003).*** Rotary NiTi instruments worked better at high torque, speculating that the auto-reverse function at low torque may result in unnecessarily stored stress thus reducing the instrument's useful life ***(Berutti et al., 2004)***. Accumulation of internal stresses did not produce unfavorable changes in the superelastic properties of NiTi but could eventually, lead to fatigue failure of the instruments ***(Bahi et al., 2005).***

Kitchen et al. (2007) compared the number of rotations to fracture of nickel titanium files operated at different speeds and different angles. They used sixty ProFile nickel titanium rotary files, size 25 (30 of each of 0.04 and 0.06 taper) operated at speeds of 350 or 600 rpm at angles of 25, 28, and 33.5 degrees. The time and number of rotations to fracture were recorded and calculated. A significant difference in the number of rotations to fracture according to taper and angle was observed and the files of taper 0.06 fractured more readily than files of 0.04 taper. It was concluded that increasing the angle at which the file was rotated decreased the number of rotations to fracture for both tapers. 0.04-taper files were more affected by an increase in the angle than 0.06-taper files. However, regarding the speed at which the files were operated, the number of rotations to fracture was not related.

Yong et al. (2010) compared the cyclic fatigue resistance of ProFile Vortex rotary instruments made of two different raw materials: M-Wire and regular super-elastic wire (SE-wire) at two different rational speeds (300 and 500 rpm) in an artificially-constructed stainless steel canal with a 5mm radius and a 90-degrees angle of curvature.. The used instruments were 25 mm in length, #30 in size with tapers 0.04 or 0.06. The time to failure was recorded, and the total number of cycles to failure was calculated and compared for a total of 160 samples. However, for rotary instruments made from the same material (either M-wire or SE-wire), there was no significant difference of cyclic fatigue life under different rotational speeds (300 and 500 rpm). Profile Vortex files made of M-wire exhibited superior cyclic fatigue resistance compared with those made of regular SE-wire at two test frequencies.

Bardsley et al. (2011) studied the effect of three rotational speed settings (200, 400 and 600rpm) on torque (N mm) and apical force (N) with Vortex rotary instruments *in vitro*. S- Shaped canals in plastic blocks (n= 12/group) were instrumented with Vortex rotaries size #15 to 30 with a 0.04 taper. Rotaries were used in a manufacturer–recommended sequence: #30, # 25, and # 20 in a crown-down approach progressively deeper in to the canal, #15 to the working length, and apical enlargement with sizes 20 and 25 to WL. Torque and apical force were continuously recorded and peak values statistically contrasted using analysis of variances. No file fractures were observed in any of the three experimental groups. The number of discernable peaks for torque (threshold: 0.3 N mm) and force (threshold: 0.2 N) significantly decreased from 200 rpm to 400 rpm and did not decrease further with 600 rpm. Rotational speed had a significant impact on preparation with Vortex rotaries.

- **Influence of diameter and taper of rotary instruments on cyclic fatigue:**

Wu et al. (2011) studied the influential factors responsible for clinical instrument separation of re-used ProTaper Universal rotary instruments. Six-thousand-one-hundred-fifty-four root canals in 2,654 teeth were prepared using ProTaper Universal files in endodontic clinics. Separation incidence was determined based on the number of treated teeth or canals. Data were collected including the size of fractured instrument, the length, the location of a broken segment within root canal, and the curvature of the canal. Result showed that, the overall instrument separation incidence was 2.6% according to the number of teeth and 1.1% according to the canal number, respectively. Separation incidences according to number of teeth or canals were significantly higher in molars than those in premolars or anterior teeth. Because of its largest diameter, F3 file presented the highest separation incidence according to the number of teeth (1.0%) or canals (0.4%). The tooth type, rotary file size, canal location, and anatomy were correlated with the instrument separation of re-used ProTaper Universal files.

- **Canal configuration:**

Instruments are subjected to experimental cyclic stress fracture at the point of maximum flexure, which corresponds to the point of greatest curvature within the tube ***(Haikel et al., 1999).*** Instrumentation of teeth with complex root canal anatomy may lead to torsional failure. The effect of double curvatures has not been reported but the consequences of stresses on the instrument intuitively would be the same as for single curvatures although occurring at more than one site ***(Peters et al., 2003).***

Pirani et al. (2011) compared cyclic fatigue resistance of four nickel-titanium rotary system files (Easy-Shape, ProTaper, NRT, and Alpha-Kite) in artificial canals with angle of curvature of 45°and 60° and a radius of curvature of 5 mm until fracture occurred. They evaluated their surface, fractographic, and matrix morphology. Analysis of testing revealed significant differences among the groups. NRT files had the highest fatigue resistance followed by Alpha-Kite, Easy-Shape, then ProTaper. All the new files presented surface imperfection. The angle of curvature was confirmed to influence the fatigue life of nickel-titanium instruments.

Font et al. (2012) evaluated the effect of number of uses, angle of curvature and radius of curvature on the fracture of ProTaper rotary instruments when used by undergraduate students on three hundred and seventy-six extracted molars, with a total of 1114 root canals. A decrease the radius of curvature of the canal significantly increased the likelihood of fracture. Instrument fracture significantly increased as the number of uses increased. A reduction in the angle of curvature did not produce a significant decrease in the incidence of instrument separation.

- **Manufacturing process:**

Very importantly, during the manufacture and processing of NiTi alloy, a variety of inclusions, such as oxide particles, may become incorporated into the metal resulting in weakness at grain boundaries. Cracks may then propagate along these boundaries ***(Parashos and Messer, 2006).*** Furthermore, the manufacture and machining of rotary NiTi instruments often results in an instrument having an irregular surface characterized by milling grooves, multiple cracks, pits, and regions of metal rollover. These irregularities have been recently confirmed in a topographic study of rotary NiTi instruments using atomic force microscopy that also found more surface irregularities with instruments of greater taper. These sites may act as areas of stress concentration (stress raisers) and crack initiation during clinical use ***(Alapati et al., 2004).***

Alapati et al. (2004) observed the apparent widening of original machining grooves and cracks by embedded dentinal debris after clinical use of rotary nickel-titanium instruments causing a wedging action leading to further crack propagation. However, only ultrasonication in ethanol was used to clean the instruments to remove debris before SEM examination, which, on its own, is unreliable means of cleaning endodontic instruments. Reliable cleaning of endodontic instruments requires a protocol involving chemical and mechanical steps.

- **Preparation/instrumentation technique:**

During canal preparation, taper lock and the familiar clicking sound may be produced by the repeated binding and release of the rotary instruments during canal preparation, which together with the repeated locking of instrument during dentin removal could subject these instruments to higher torsional stress ***(Peters et al., 2003).***

Roland et al. (2002) compared the rates of separation of twenty sets of 0.04 taper profile series 29 nickel-titanium rotary instruments using two different instrumentation techniques in the mesial (mandibular) or buccal (maxillary) canals of extracted human molars. The rotary instruments were used up to 20 times either with crown-down technique or with a combination of pre-flaring with hand files in a passive step-back technique followed by rotary instrumentation. Pre-flaring significantly declined the frequency of instrument separation due to the decrease in instrument binding or taper-lock with subsequent decrease in complex stresses to which the files were subjected.

Schrader and Peters (2005) studied the torque, force developed and number of rotations to working length using two sequences of nickel-titanium rotary instruments. In group A, canals were prepared using Profile 0.04 taper alone, while, in group B, the canals were prepared using Profile 0.06 and 0.04 taper alternatively. Multiple tapers were recommended to use during canal preparation to decrease procedural errors. However, it utilizes a larger number of instruments with subsequent increase in preparation time.

Tzantetakis et al. (2008) recorded a significant decline in instrument separation rate among postgraduate students. They attributed that to the technique of instrumentation which included proper access cavity preparation, coronal preflaring using gates glidden drills and establishing a manual glide path using hand K-files prior to any rotary instrumentation.

- **Number of uses:**

Prolonged clinical use of rotary NiTi instruments significantly reduces their cyclic flexural fatigue resistance ***(Gambarini, 2001).***

Svec and Powers (2002) found signs of deterioration of all instruments in their study after only one use. However***, Yared et al. (1999), Yared et al. (2000), Peters and Barbakow (2002)*** have reported that rotary NiTi instruments may be used up to ten times, or to prepare four molar teeth, with no increase in the incidence of fracture. No correlation has been found between number of uses and frequency of file fracture. Therefore, it can be concluded that the number of uses of rotary NiTi instruments will depend on a number of variables including instrument properties, canal morphology, and operator skill ***(Parashos et al., 2004).***