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RESEARCH ARTICLE

COMPARATIVE EVALUATION OF FORCE REQUIRED TO FRACTURE ROOT AFTER ULTRASONIC REMOVAL OF ROTARY NICKEL TITANIUM ENDODONTIC INSTRUMENTS

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ABSTRACT

Rotary nickel-titanium (NiTi) endodontic instruments are commonly used to prepare root canals. Several studies have reported the ability of rotary NiTi instruments to produce well-centered, smooth, minimally transported canals. Although having many advantages, these instruments have one major disadvantage of file breakage during canal preparation, which often occurs without prior warning to the operator. It is difficult to remove a separated instrument from root canal with conventional methods. Ultrasonics prove to be very useful in retrieving a seperated instrument , even though they may result in some complications.

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INTRODUCTION

The introduction of nickel-titanium alloy for the manufacture of root canal instruments has been a major breakthrough in endodontics. New blade design, greater instrument taper and the introduction of full rotary motion for cleaning and shaping root canals have developed because of the favorable mechanical properties of nickel-titanium. Canals prepared by rotary NiTi instruments show increased canal cleanliness and less straightening, apical canal transportation and perforations (Garg *et al*., 2015). Inspite of many advantages, NiTi rotary instruments carry few disadvantages, most important being instrument fracture (Philadelphia: WB Saunders Co., 1991). Problem lies in the fact that fracture of NiTi file can occur without any visible signs of deformation (Tzanetakis *et al*., 2008). The fracture rate of NiTi rotary instruments has been reported between 1.3% and 10.0% (Spili *et al*., 2005). When an instrument separates in root canal, two main concerns need to be addressed to maximize the long-term treatment outcome.

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The first is the existence of a metal fragment inside the tooth and its possibility of corrosion. Other concern is that a separated instrument usually hinders or blocks access to the apical canal terminus, thus compromising the effectiveness of cleaning and shaping procedures, which may affect the treatment outcome (Madarati *et al*., 2009). A case with a broken instrument many times can be managed by an orthograde or a surgical approach. The three orthograde approaches are as follows: attempts to (1) remove the instrument; (2) bypass the instrument; and (3) prepare and obturate till the fractured fragment (Spili *et al*., 2005). When attempting to remove the instrument from canal, the clinician needs to balance between the advantages and disadvantages of retrieval of separated files because this could lead to the excessive removal of root dentin, thus reducing root strength by 30% to 40% and predisposing the teeth to vertical root fracture (Lertchirakarn *et al*., 2003). Most recently, the use of ultrasonic tips has been found to be the most effective method for removing separated instruments from root canals (Ward *et al*., 2003). With ultrasonic systems, the ultrasonic vibration is transmitted to the fractured fragment so that it becomes loose and is easier to remove (Ruddle, 2004). A variety of complications may be associated with removal of separated

instruments with this technique. Ultrasonic tip apart from separation in the root canal can raise the temperature on external root surface and also result in excessive loss of dentin, which further reduces the fracture resistance (Gerek *et al*., 2009). So the aim of our study is to evaluate and compare the required force for root fracture between teeth treated with root canal therapy after instrument retrieval with ultrasonics and teeth treated with routine root canal therapy and to evaluate the success of ultrasonic technique in the removal of separated NiTi instruments at different levels in root canals.

MATERIALS AND METHODS

The present study was undertaken in the Department of Conservative Dentistry and Endodontics, Genesis Institute of Dental Sciences and Research, Ferozepur (Punjab). A sample size of seventy freshly extracted single rooted non carious human maxillary premolars indicated for extraction due to orthodontic reason were selected for this study. The criteria for teeth selection was teeth free of restoration, no prior root canal therapy, and teeth with root length 12-16 mm without any root resorption. Root surfaces were assessed under a dental operating microscope (Global Surgical Corporation, USA) at 25 x magnification to exclude any teeth with preexisting root fractures, cracks, or root caries. All the teeth were radiographed preoperatively by using a prefabricated jig, which was designed to provide the same exposure angles and distances for all the specimens. The crowns were sectioned at the cementoenamel junction, and the roots were mounted in a standard mold made of putty impression material (Zetaplus, Zhermack Italy). Access cavity was prepared for each tooth and pulp debris was removed from the canal space using K-files. During the instrumentation, the canals were irrigated with 3% sodium hypochlorite solution (Parcan, Septodont, Saint Maur des Fosses, France). The specimens were randomly assigned to 2 groups: Group A (experimental group) and Group B (control group) of 35 teeth each.

For Group A, pre operative radiograph of each tooth was taken. To achieve file fracture at predictable levels within the canal for each sample of the experimental group, a #30/.04 taper K3 file (SybronEndo, Orange, CA) was used, which was notched to a depth of half the instrument thickness at a point 3 mm from the file tip. Control of the level of file fracture within the root canal was obtained by varying the amount of apical pressure, speed of rotation, and angle of insertion. A radiograph was taken to trace the exact location of the fractured file. Categorization of file location was carried out according to the level of canal i.e. coronal, middle, and apical third. Before removal of the fractured file, operator tried to bypass the lodged file for 10 minutes by using #8 and #10 K-files (Mani Inc, Japan). 10 minute time period for bypassing the separated instrument was fixed keeping the Indian clinical setup in mind. If operator failed to bypass the instrument in stipulated time, removal of the lodged instrument was commenced as follows. According to the method described by Ruddle *et al*. and modified by Ward *et al*, a staging platform was shaped to a level at the most coronal part of the fractured segment by using Gates Glidden Drills (Mani Inc, Japan) which had their tips sectioned off. When properly performed, straight-line coronal and radicular access, was achieved magnification and lightening, enabled the clinician to fully visualize the coronal-most aspect of a broken instrument (Figure I).

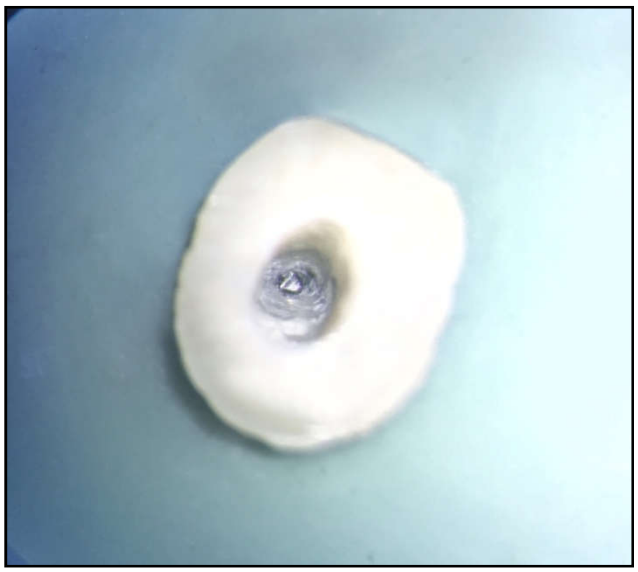

Figure 1. Magnified view of the tooth sample showing separated instrument and completion of staging platform

In the specimens in which the coronal end of the broken file could not be visualized with the dental microscope, removal attempts were abandoned, and they were considered unsuccessful. Fine ultrasonic tips were used to apply vibration to the fractured file. In the present study, ET25, ET25S, ET25L and ET20 (Satelec, Merignac, France) tips were used. An appropriately sized ultrasonic tip was selected, such that its length would reach the broken obstruction and its diameter would passively fit into the previously shaped canal. The tip of this ultrasonically selected instrument was placed in intimate contact against the obstruction and typically activated within the lower power settings of the Ultrasonic scaler (P5-Newtron; Satelec). Removal of dentin surrounding the fractured file and application of vibration was performed until the files got loose. Counterclockwise movements of ultrasonic tips dislodged and removed the fractured file. 45 minutes was considered the maximum time for the removal process, because clinicians believe that approximately 45 minutes is the time available for file removal during a 60-minute appointment (Ward *et al*., 2003). Specimens of the experimental group were designated as successful (in which fractured files were successfully removed or bypassed) or unsuccessful (in which fractured files could not removed in the stipulated time period of 45 minutes). All the successful and unsuccessful cases were radiographed to record transportation errors and inspected under an operating microscope for root perforations

For Group B, teeth were instrumented with K3 files (SybronEndo, Orange, CA), by using crown-down technique up to file #25/.06 taper till working length. Subsequently, they were be obturated by using gutta-percha .04 as the master cone, AH Plus sealer (Dentsply Maillefer, Ballaigues, Switzerland), using lateral condensation technique. In the successful subgroup of the experimental group A, the root canals of specimens were prepared and obturated in a way

similar to that in the control group B. The control teeth and successful specimens of the experimental group were incubated at 37 C and 100% relative humidity for 7 days to allow setting of the sealer. To measure the fracture resistance of these specimens, teeth were mounted parallel to the root trunk using Ney's surveyor (Confident Dental Equipments Ltd, India). The apical 3 mm of each root was embedded in steel rings with self cure resin (Rapid Repair, Pyrax Polymars, India) and allowed to polymerize for 1 hour, leaving the rest of the root uncovered. Prepared blocks were placed in the universal testing machine (Instron India Pvt. Ltd.) for mechanical testing .To determine the force required to fracture a tooth root, a narrow tapered probe with 1-mm diameter round contact surface was directed parallel to the root trunk and perpendicular to the cut surface. The probe was advanced at a rate of 1 mm/min until root fracture occurred. In the present study the point at which a sharp and instantaneous drop greater than 25% of the applied load occurred was defined as fracture, which was usually accompanied by an audible crack. For each specimen, the load at fracture (measured in newtons) and location of root fracture was recorded. The results were analyzed statistically. One-way ANOVA was used to determine the difference among the groups. Tuskey HSD test was used to detect the group that caused the difference. T-test was done to measure group statistics for fracture resistance. The level of significance was set at $P < 0.05$

RESULTS

In the present study, the required force for root fracture between teeth treated with root canal therapy after instrument retrieval with ultrasonics and teeth treated with routine root canal therapy was compared. In the present study, out of 35 samples, separated instrument in 9 samples was bypassed and attempt to bypass was unsuccessful in 26 samples. The average time required for removing file fragments was 25.26 ± 12.08 minutes, with a minimum of 8 minutes and a maximum of 40 minutes. There was a marginally insignificant statistical difference between the time needed for removing file fragments from the mid-root and the time required for removing file fragments from the apical third (P = .05). There was a significant difference between the time needed for removing file fragments from the coronal and the time needed for removing file fragments from middle third, and highly significant between coronal and apical third of the root canal. The highest rate of instrument fracture (60%) was observed in the middle portion of the root canal and least in the coronal portion (17.1%) (Table-1).

The comparison of the average force required for root fracture in the control group with that required in the experimental group showed that the required force in the control group was more than that in the experimental group, the difference was significant (P = < 0.001) (Table- 2).

DISCUSSION

Rotary endodontics was developed with the aim of reducing the treatment time, increasing efficiency and accuracy of root canal preparation (Monga *et al*., 2015). It is believed that NiTi endodontic instruments have the ability to produce well-centered, smooth, minimally transported canals while minimizing procedural errors as NiTi rotary instruments only follow an existed path and do not create one (Versumer *et al*., 2002). One reported disadvantage with their use is file breakage, which often occurs without prior warning to the operator. There are two modes of failure that cause rotary instrument separation, namely, torsional and cyclic flexural fractures (Sattapan *et al*., 2000). Various factors, such as rotational speed, canal curvature, instrument design and preparation technique, torque, absence of glide path, and operator experience, have been associated with the fracture of NiTi rotary instrument (Daugherty *et al*., 2001). When an instrument fracture occurs during root canal preparation procedure, the clinician has to evaluate the treatment options with consideration of the pulpal status, the root canal infection, the root canal anatomy, the position and type of fractured instrument and the amount of damage that would be caused to the remaining tooth structure. Removal of the fractured segment, bypassing or sealing the fragment within the root canal space are approaches available with the clinician (Ruddle, 2004). An attempt to bypass a fractured instrument

Table 1. Success rate of the ultrasonic technique in relation to file location and bypass

	Successful	Not Successful	Total	p value
Location				
Coronal	6 (100%)	0	6 (100%)	0.003*
Middle	19 (90.5%)	2 (9.5%)	21 (100%)	
Apical	3 (37.5%)	5 (62.5%)	8 (100%)	
Bypass				
No	19 (73.1%)	7 (26.9%)	26 (100%)	0.082^{NS}
Yes	9 (100%)	0	9 (100%)	

NS: p > 0.05; Not Significant; *p < 0.05; Significant

Table 2. Required force for root fracture in control and experimental specimens

	Study Group	Control Group	't' value	p value
Number of specimens	28	35	19.126	<0.001
Force (Mean ± SD)	138.07 ± 13.68	228.23 ± 21.72		Highly
Std. Error of Mean	2.584	3.671		Significant
95% Confidence Interval	132.77 - 143.37	220.77 - 235.69		

should always be initially considered because it can often be successful (Al-Fouzan, 2003). Also, some authors suggest that it is more conservative to bypass the fractured instrument, particularly in cases where access to the fragment is restricted (apical one-third of canal or beyond the canal curvature) and also attempt to remove a separated instrument in these areas may lead to excessive removal of dentine with associated complications (Souter and Messer, 2005). It has been reported that if the file is bypassed, the retained fragment does not compromise obturation quality (Saunders *et al*., 2000). However, the incorporation of the operating microscope has considerably increased the chances of removal of separated instruments, as have fine ultrasonic tips and other innovations such as staging platforms (Ward *et al*., 2003). To date, no standardized procedure for the safe, successful removal of fractured instruments exists, although various techniques and devices have been used. These techniques have shown only limited success while also often causing considerable damage to the remaining structure of root (Hulsmann, 1993). The combination of ultrasonic techniques and the dental operating microscope is consistently reported to be successful and safe for the removal of broken files from root canals (Fu *et al*., 2011). The success rate of the ultrasonic technique has been evaluated by many studies. Success rates for fragment removal by using ultrasonics in clinical trials have ranged from 67% by Nagai *et al*. (1986) to 88% and 95% reported recently by Cuje *et al*. (2010) and Fu *et al*. (2011), respectively. Ward *et al*. (2003) conducted an in vitro study on artificial resin canals and extracted teeth and reported a success rate of 76.6% and a success rate of 66.6% in an in vivo study on 24 cases. Nevares *et al*. (2012) reported 70.5% success rate in removing or bypassing fractured instruments in 112 clinical cases. The results of the present study are in congruence with the results of above studies. Working dry during the removal of separated instruments by ultrasonic tips is needed to improve visibility under the operating microscope (Ruddle, 2004). However, the high-frequency vibration and the friction between the ultrasonic tip and both the dentin and the broken instrument generate heat that could be transmitted to the external root surface and subsequently to the periodontium. Thinner and small cross-sectional diameter ultrasonic tips vibrating at a lower power setting together with the use of irrigating regimen will minimize the risk of high temperature generation during ultrasonic activity. In the present study maxillary second premolar teeth having a single root canal were taken. Therefore, to avoid the effect of coronal factors, all the crowns were removed. In this way, optimal conditions for the removal of fractured instruments were ensured, and the groups were standardized. Short fragments (3 mm), K3 file#30/.04 instruments were chosen because this is a common length and size of fractured instrument seen in endodontic practice. Previous studies have shown that large fragments are easier to remove than small fragments and that removal rates are low for fragments that are located apical to the curvature (Hulsmann, 1993). In our study, 3 mm fragments were fractured and lodged at three levels relative to the root canal length. This allowed a comparison of success rates, procedure time, and assessment of the canal after file removal at these three levels. K3 rotary instruments were chosen in the present study as there is no study considering the removal of fractured K3 instruments in the literature.

Some points of this technique to remove fractured instruments from root canals should be noted. First, the use of the dental operating microscope is essential when working deep within a canal. Without the direct visualization and increased illumination that the microscope provides, it is probably impossible to remain centered within the canal, and perforation is likely. This can occur during the creation of the staging platform with Gates Glidden instruments or with the ultrasonic tips. Direct vision also is essential to maximize success, because the ultrasonic tips are most effective when used alongside the fractured instrument. Without the microscope, it is common to contact the top of the instrument segment and push it further into the canal. Careful washing and drying of the operating field is also essential to maintain visibility at all times to prevent procedural accidents. Second, the creation of a staging platform was found to be essential for working circumferentially alongside the coronal end of the instrument fragment. In most cases a Gates Glidden size 3 or 4 was needed. Without a staging platform it is very difficult to work alongside the instrument fragment and it can be easily pushed further into the canal. In our study, when the success rate of broken instrument removal was investigated regarding the location of the broken instrument in the canal, 100% success rate was obtained in coronal third of the all canals. These findings collaborated the results of Ward *et al*. (2003). The success rate was found the lowest in the apical third. Collaborating to the findings in our study, Souter *et al*. (2005) also reported lower success rate in removing instrument from apical third of the root canal. Vertical root fracture (VRF) is essentially untreatable, and usually results in tooth loss. The loss of dentine during retrieval of instrument using ultrasonic technique increases the susceptibility of teeth to fracture. More recently, asymmetrical canal shape and the formation of irregularities have been proposed as crucial factors in the generation of VRF (Lertchirakarn *et al*., 2003). In this regard, when an attempt is made to remove a fractured instrument, the potential loss of dentine must be minimized. File removal typically results in ledge formation, and therefore, a possible stress concentration point. The force that is required to fracture roots vertically after the removal of broken instruments using ultrasonic tips has been investigated in many studies (Souter and Messer, 2005). Madarati *et al*. (2009) reported that there was no significant difference in relation to the changes in either canal volume or mass between a group in which the canals were only instrumented and a group in which a broken instrument was removed from the coronal part of the canal. Souter and Messer (2005) stated that the removal of fractured instruments from the middle or apical one-third significantly affected the force required to fracture the roots vertically. In the present study, a significant difference was observed between the force required for root fracture in the control and experimental groups.

Ward *et al*. (2003) reported in their in vitro study that although in extracted teeth ultrasonic success rate was not affected by canal curvature, in artificial resin canals the ultrasonic success rate was significantly higher in specimens with coronally positioned files. In the present study, the majority of file fractures (60%) occurred in the middle third of the canals; 22.8% of fractures were in the apical region and 17.1% files fractured in the coronal third. The force required to fracture a

tooth root did not significantly differ in various locations of lodged file, whether in the apical or mid-root region and whether before or beyond the curve. Therefore, on the basis of the results of the present study, it can be inferred that in clinical attempts to remove fractured files it does not matter at which location the file has been separated. It should be taken into consideration that the condition of the present study was different from the usual clinical situation. In the present study all the crowns were removed, whereas in most clinical situations clinicians do not remove that much tooth structure. Therefore, success rate of the ultrasonic technique, time required for file removal, force required for root fracture, fracture patterns, and procedural errors in clinical situations may differ from what was observed in the present study.

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