CASO CLÍNICO

Torsional Failure Characteristics of a NiTi file based on a Case Report

Jorge N. R. Martins*; Joseph DiBernardo**
*DDS, Doctor of Dental Surgery, University of Lisbon, Portugal; Private practice limited to Endondontics, Instituto de Implantologia, Lisboa
** DDS, Doctor of Dental Surgery, Stony Brook University, USA; Private practice limited to Endondontics, Smithtown, NY, USA

(Martins JNR, DiBernardo J. Torsional Failure Characteristics of a NiTi file based on a Case Report. Rev Port Estomatol Med Dent Cir Maxilofac 2010;51:85-89)

Key-words:
Nickel-titanium rotary file; Torsional failure; File separation; Scanning electron microscopy

Abstract: The use of nickel-titanium rotary files has been accepted worldwide. One of the major concerns about its use is the chance of file separation. Two types of failure have already been identified: cyclic fatigue and torsional failure. A scanning electron microscope analysis was performed on a recent case of file separation. The scan was used to show the main characteristics of torsional failure and to compare these characteristics with a known example of cyclic fatigue type failure. The clinical reasons that may lead to such failure are also discussed.

Palavras-Chave:
Limas mecanizadas níquel-titânio; Fractura por torção; Fractura de lima; Microscópio electrónico de varrimento

Resumo: A instrumentação mecanizada com limas de níquel-titânio é usada mundialmente, sendo a separação e fractura destes instrumentos considerada uma grande preocupação. São documentados dois tipos de fracturas: por fadiga cíclica ou por fractura por torção. Uma análise de microscópio electrónico de varredura foi realizada num recente caso de fractura de uma lima. A análise é usada para documentar as características da fractura por torção e compará-la com a fadiga cíclica. As razoes clínicas que podem levar a este tipo de falha são também debatidas.

INTRODUCTION

The introduction of the Nickel-Titanium (NiTi) rotary files has revolutionized the instrumentation of root canals treatment by reducing practitioner fatigue and time required to complete the procedure[1]. There are fewer procedural errors, such as transportation and ledging that are associated mainly with less flexibile stainless steel files used typically with hand instrumentation [2]. Despite the higher flexibility, NiTi file separation may still occur[3,4,5].

The prognosis of an endodontic treatment procedure depends on the correct cleaning, shaping, and disinfection of the canal[6,7]. The separation of an instrument inside the canal may prevent these events from occurring. When it happens it is important to understand that the presence of a separated instrument in the canal in itself does not predispose the case to post treatment disease. Rather, it is the presence of any necrotic, infected pulp tissue that remains in the canal space that determines the prognosis [8]. When separation does happen it is important to rectify the treatment plan based on the correct diagnosis. Depending on the microbiological contamination of the root canal system the separated file may or may not result in a poorer prognosis. The treatment plan options in this situation include by-passing or removal of the instrument, apical surgery, or obturation to the point of the separated instrument depending on the pulp status. Knowing how and why these failures may happen is essential so at the very least, they can be avoided.

The purpose of this paper is to present a case report of a NiTi separation and to review the characteristics of NiTi files torsional failure characteristics and to understand why it may separate based on a case report involving the separation of such a file.

Correspondência para:
Jorge N. R. Martins
E-mail: jnr_martins@yahoo.com.br

CASE REPORT

A 38 year old female was referred to the New York University Post Graduate Endodontics clinic. The patient was sent, by a Prosthodontic clinic resident for re-treatment of tooth 47 (the mandibular lower right second molar) with the objective of improving the result of the previous root canal filling before proceeding with the oral rehabilitation that would include tooth 47 as a terminal abutment of a fixed multi unit bridge (Figure 1). There was no chief complaint and the medical history was non-contributory. The dental history included a previous root canal treatment completed more than ten years previous to the current visit. The patient has not complained of any symptoms. Periapical radiographic analysis showed short fillings on both the mesial and distal roots. No radiographic indication suggesting a periapical lesion was found.

The clinical situation was explained to the patient. The treatment options were given which included no treatment, re-treatment or extraction. The possible complications of the procedure were explained to the patient which included a risk of file separation, perforation, or a less than ideal clinical outcome due to the nature of the preoperative condition of the tooth. An informed consent to treatment was accepted by the patient.

An aseptic technique was used, the access opening was completed and the previous paste-like filling was removed. Three canals were identified and the canals were negotiated to the working length with a stainless steel hand file ISO size .08. This step was accomplished with the continuous intracanal use of a lubricant (RC Prep-Premier Dental, Plymouth PA) and a 5.25% solution of sodium hypochlorite.

Coronal enlargement was first performed with a ProTaper SX file (Tulsa Dental, Tulsa OK) and then a brand new ProTaper S1 (Tulsa Dental, Tulsa OK) rotary file was used to achieve the working length. The instruments were used with a Tulsa Dental Motor (Tulsa OK) at a medium torque setting and a speed of 300 RPM. An instrument separation occurred during this phase of cleaning and shaping (Figure 2). The by-pass option was attempted and was successful. The treatment was concluded in three appointments, with the use of calcium hydroxide as intracanal medication between the appointments. The objective requested by the oral rehabilitation team, the improvement of the quality of the original root therapy procedure, was achieved (Figure 3).

Figure 1 - A diagnostic radiograph. The Prosthodontic clinic requested an improvement of the root canal treatment for a better prognosis.

Figure 2 - Radiographic image of a separated ProTaper S1 file on the mesial bucal canal.

Figure 3 - The final radiograph. The separated file was by-passed and the request of Prostodontic department was achievied.

SEM ANALYSIS OF THE SEPARATED FILE

For research purposes the separated coronal file fragment was taken to the NYU Biomaterials Department laboratory for analysis with the Scanning Electron Microscope.

The longitudinal view showed that the tip of the file

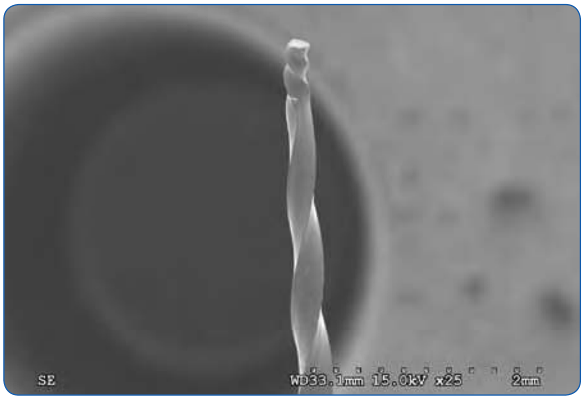

Figure 4 - SEM image of the separated file tip. An 180º unwinding can be seen near to the point of fracture.

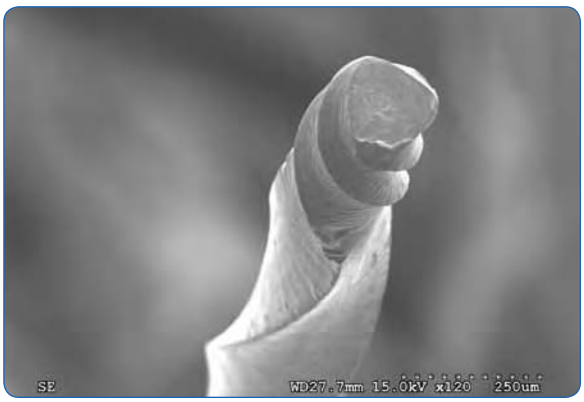

Figure 5 - SEM image of the separated file tip. Another vision of the unwinding area near to the point of fracture.

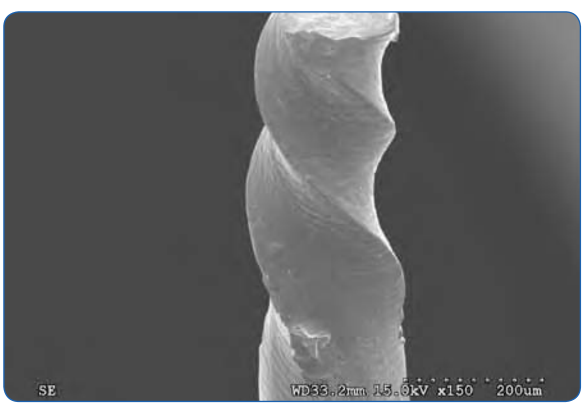

Figure 6 - SEM image of the separated file tip. The area where the file started to twist presents severe deformation areas.

twisted 180º in the opposite direction proximal to the point of fracture (Figures 4 and 5). At the base of this unwinding can be seen a severe deformation of the metal alloy (Figure 6). A higher magnification view is able to show several microfractures on the alloy around the severe deformation (Figure 7).

The cross sectional view of the separation area shows dimpling on each of the three cutting edges and a central

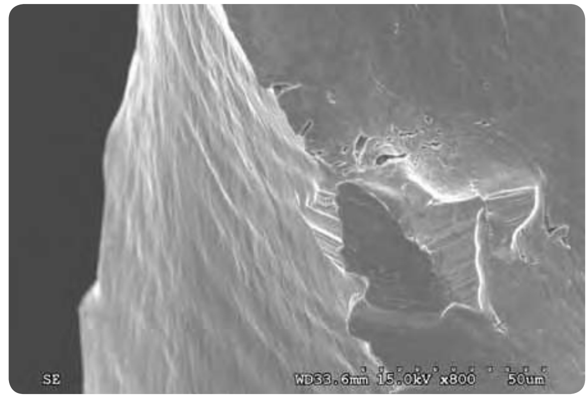

Figure 7 - SEM image of the separated file tip. Closer view of the deformation area. Several microcracks and microvoids can be seen.

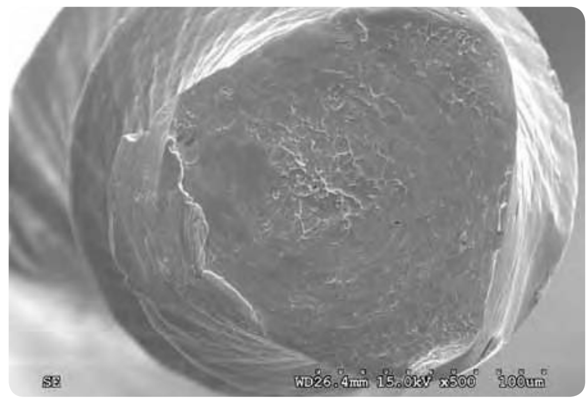

Figure 8 - SEM image of the separated file tip. Cross section view of the separated area. A smooth surface with a dimpling zone on the center of the file and several microvoids can be seen on this image.

dimpling with the presence of several microvoids. One of the cutting edges has a deformation compatible with plastic deformation (Figure 8).

DISCUSSION

One of the major concerns about the use of rotary NiTi files is having an unexpected separation. The incidence of this type of failure rages from 1,33%[4] to 2,4%[5] of the times. Fracture mechanisms may be of clinical interest. This type of incident may have an influence on the treatment prognosis but also because the situation management may be very difficult and time consuming. The fracture mechanism has not yet been completely understood but the two main types of NiTi file failure have already been identified: torsional failure and cyclic fatigue[9].

The NiTi alloy can exist in three distinct crystalline phases. A more stable phase with a body centered cubic geometry (austenitic phase), a more unstable phase with a hexagonal geometry (martensitic phase) and an intermediate series of phases that transform one on the other by the movement of the Ni and Ti atoms (transformation phase)[8,10,11]. This transformation may be induced by stress. This characteristic of transforming a more stable austenitic phase to a more unstable martensitic phase by passing an intermediate phase of transformation gives this alloy the shape memory and the super-elasticity[11]. The super-elasticity of the NiTi allows a strain of 8% before any permanent deformation, eight times more than stainless steel files[10]. It is believed that the austenite phase when loaded tends to transform on the martensitic phase and reverts back to austenite when unloaded, recovering the original shape [12].

The torsional failure usually is the result of a strong and intense tensional force that has been applied to the file for a short period of time. This means the files suffer a high stress tension that may be superior to the 8% allowed by the alloy that initially causes a plastic deformation and later leads to fracture[13].

A closer look at the files that suffer this kind of failure may show an unwinding of the cutting edge spirals usually the final result of the plastic deformation previous to the fracture moment[9] (similar to Fig. 4). On the SEM cross sectional view, the torsional failure usually presents a smooth surface and a central dimpling area with microvoids [14] (similar to Fig. 8) and may or not be present also dimpling areas on the cutting edges. The central dimpling area may be the result of the rotation of the last area to dissemble at the moment of the separation and the dimpling areas on the file cutting edges may be compatible with a higher stress applied on those areas during the dentin wall cutting process.

Causes for torsional failure may be a larger surface contact of the instrument with the dentin wall (taper-lock) [9,13,15] due to deficient coronal enlargement or presence of cut dentin debris blocking the flutes of the file. To avoid this, the flutes should be regularly cleaned to allow not only better cutting efficiency but also to reduce the probability of fracture. To reduce the taper-lock effect a crown down technique should be used with instruments of larger taper[16]. The idea is to use the rotary instruments in sequence from the largest to the smallest. Each time allowing a reduction in size so that the next smallest instrument in sequence does not have to prepare a larger area than that by which the previous instrument has[16]. A good coronal enlargement with orifice shapers or Gates-Glidden drill also allows a free passage of the rotary instruments to the last third of the canal avoiding the lock on the two coronal thirds[9,13]. Excessive apical pressure should also be avoided since is one of the most common errors that may end in file failures[9,13,17]. One last situation that may develop torsional fractures is when an instrument tip is locked in a smaller diameter canal while the shank continues rotating[8,13,18]. Berutti's studies[19] have shown that a manual preflaring with a #20 file is able to reduce by six times the chance of fracture of a ProTaper S1 file on endo-training blocks. The objective is to create a manual glide path that avoids over stressing the file tip. Stress reduction is also achieved by using the rotary instruments with an abundant lubricant and always in canals flooded with irrigants.

The cyclic fatigue failure occurs when the file is subjected to repetitive cycles of compression and tension, as it happen in canals with abrupt curvatures or anatomic ledges. It is also a result of a low intensity of stress tension that are applied for a long period of time, this situation is associated to the overuse. The cycling stress significantly reduces the torsional resistance of the file [18]. After some loading, and then SEM analysis, the files begin to show irreversible microcrack formation on the alloy structure. These microcracks contribute to the failure by the crack propagation process[12,20]. The files undergoing cyclic fatigue are not able to withstand the same 8% of strain and will fracture much earlier. The files that show this kind of failure usually have sharp fractures without any kind of unwinding or plastic deformation[9].

Cyclic fatigue typically presents on the SEM cross sectional view as a dimpling area that involves the whole fracture surface with the presence of microvoids and microcracks[14].

The failures may also be a combination of both cyclic fatigue and torsional failure [18] (Table 1).

The SEM images collected on this separated file show characteristics of torsional failure. The twisted image present near the point of fracture is compatible with a binding situation, the file's tip may have engaged the dentine and blocked while the rest of the file kept rotating and provoked the unwinding until the time of separation. This may have been due to the small patency size of the canal prior to the rotary instrumentation. Separation of this kind can be avoided by enlarging the canal with the appropriate hand filing technique to prevent binding of the file.

	Torsional Failure	Cyclic Fatigue
Stress applied	- Short but intense	- Low intensity but for a long period of time - repetitive cycles of compression and tension
Fracture lateral view	- File deformation - Unwinding	- Sharp cut fracture
Cross sectional view (SEM)	- Central dimpling area surround by a smooth area - Microvoids and microcracks	- Dimpling areas covering all the facture surface - Microvoids and microcracks
Clinical causes of fracture	- Taper Lock - Insufficient coronal enlargement - Dentin debris on the flutes - Apical pressure - Tip locked	- Abrupt curvatures - Overuse

Table 1 - Summary of the basic characteristics of both kinds of fractures[8,9,10,13].

REFERENCES

1 – Glickman GN. Nickel titanium rotary instruments for root canal preparation: are we there yet? Alpha Omegan 1997;90:29-38.

2 – Peters AO. Current challenges and concepts in the preparation of root canal systems: a review. J Endodon 2004;30:559-567.

3 – Iqbal MK, Kohli MR, Kim JS. A retrospective clinical study of incidence of root canal instruments separation in an endodontics graduate program: a PennEndo Database study. J Endodon 2006;32:1048-1052.

4 – Tzanetakis GN, Kontakiotis EG, Maurikou DV, Marzelou MP. Prevalence and management of instrument fracture in the postgraduate endodontic program at the Dental School of Athens: a five-year retrospective clinical study. J Endodon 2008;34:675-678.

5 – Wolcott S, Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S, Meyers J. Separation incidence of protaper rotary instruments: a large cohort clinical evaluation. J Endodon 2006;32:1139-1141.

6 – Klevant FH, Eggink CO. The effect of the canal preparation on periapical disease. Int Endod J 1983;16:68-75.

7 – Donnelly JC. Resolution of a periapical radiolucency without root canal filling. J Endodon 1990;16:394-395.

8 – Peters OA, Peters CI. Cleaning and shaping the root canal system. In: Cohen S, Hargreaves KM. Pathways of the pulp. 9th edi. St.Louis: Mosby, 2006:290-357.

9 – Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endodon 2000;26:161-165.

10 – Thompson SA. An overview of nickel-titanium alloys used in dentistry. Int Endodon J 2000;33:297-310.

11 – Anusavice KJ. Dental casting alloys. In: Anusavice KJ. Phillips' Science of dental materials. 10th edi. Philadelphia: WB Saunders Company, 1996:491-524.

12 – Kuhn G, Jordan L. Fatigue and mechanical properties of nickel-titanium endodontic instruments. J Endodon 2002;28:716-720.

13 – Berutti E, Cantatore G. Rotary instruments in nickel-titanium. In: Castellucci A. Endodontics Vol.II.1st edi. Florence: Il Tridente, 2005:518-547.

14 – Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. J Endodon 2006;32:1031-1043.

15 – Blum JY, Cohen A, Machtou P, Micallef JP. Analysis of forces developed during mechanical preparation of extracted teeth using ProFile NiTi rotary instruments. Int Endodon J 1999;32:24-30.

16 – Morgan LF, Montgomery S. An evaluation of the crown-down pressureles technique. J Endodon 1984;10:491-499.

17 – Thompson SA, Dummer PH. Shaping ability of Quantec Series 2000 rotary nickel-titanium instruments in simulated root canals. Part 1. Int Endodon J 1997;31:259-262.

18 – Wei X, Ling J, Jiang J, Huang X, Liu L. Modes of failure of ProTaper nickel-titanium rotary instruments after clinical use. J Endodon 2007;33:276-279.

19 – Berutti E, Negro AR, Lendini M, Pasqualini D. Influence of manual preflaring and torque on the failure rate of ProTaper rotary instruments. J Endodon 2004;30:228-230.

20 – Herold KS, Johnson BR, Wenckus CS. A scanning electron microscopy evaluation of microfractures, deformation and separation in EndoSequence and Profile nickel-titanium rotary files using an extracted molar tooth model. J Endodon 2007;33:712-714.