Dissolution of Nickel-Titanium Endodontic Files via an Electrochemical Process: A New Concept for Future Retrieval of Fractured Files in Root Canals

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Abstract

Introduction: The retrieval of fractured instruments from root canals has been largely reported in the literature. However, a less complex retrieval method that causes minimum damage to the dental structures is needed. The aim of this article is to introduce a new concept of retrieval of fractured instruments from root canals based on an electrochemical process. **Methods:** Current register tests were used to evaluate the dissolution process of 25.04 nickel-titanium (NiTi) K3 rotary files. A constant anodic potential was applied to the NiTi files, whereas the Potentiostat registered the anodic current. After the tests, all files were observed by using an optical microscope. **Results:** The current attained initial values of approximately 55 mA that declined during the entire test. A good reproducibility of results was observed. The optical microscopy analysis evidenced a progressive consumption of the files with increasing polarization time. **Conclusions:** The results presented here show that the concept of fractured file retrieval by an electrochemical process is feasible. This concept resulted in a consistent basis for the development of a method to remove fractured instruments from root canals. *(J Endod 2010;36:717–720)*

Key Words

Endodontic instrument, fracture, micro-electrodes, nickel-titanium, retrieval of fractured instrument

The presence of a fractured instrument in the root canal represents an obstacle to routine endodontic therapy (1). The retrieval of fractured instruments from root canals has been largely reported in the literature, and many devices and methods have been proposed to accomplish that (2–14). However, those mechanical methods present some limitations related to canal morphology, reduction of root strength, and operator ability. According to Alomairy (15), less curved canals and longer radius of curvature are favorable factors for removal of fractured nickel-titanium (NiTi) fragments. In many cases a straight-line access to the fractured instrument is not obtained (16, 17), thus making its visualization and access to the adjacent dentin with straight instruments impossible. Consequently, it is not recommended to attempt to remove a fragment situated beyond the curve of the canal (18–21). Such attempts might lead to ledge formation and perforation, and they might also promote a reduction of the root strength (18–21). Madarati et al (22) observed that removal of fractured files located deeper in the root canal resulted in significant tooth structure loss. However, excessive removal of dentin tissue and significant loss of mechanical resistance of the root were observed even in cases of removal of fractured instruments situated in straight canals or in the medium third of curved canals (21, 23). Another point to be considered is that mechanical methods to remove fractured instruments are strongly dependent on professional ability (23), and most of the time the use of an operating microscope is necessary (10, 13, 17).

In this context, a less complex retrieval method that causes minimum damage to the dental structures is necessary. Dissolution of a fractured instrument might represent an actual possibility to solve this problem. This dissolution would enable the recovery of the original canal path without damaging the root structure. The concept of retrieval of fractured instruments presented here is based on the electrochemical-induced dissolution of the fragment. The method requires the existence of 2 electrodes immersed in the solution, one acting as a cathode and the other as an anode. The contact between the fractured file and the electrode used as an anode is necessary, because the dissolution of the fractured file is the objective of the process (Fig. 1). An adequate electrochemical potential difference is imposed between the 2 electrodes, resulting in the migration of the electrons from the anode to the cathode and, consequently, the release of metallic ions to the solution. This process corresponds to the progressive dissolution of the fragment inside the root canal.

Incidentally, NiTi alloys present high resistance to corrosion in most environments. This resistance is a consequence of the formation of an oxide layer at the interface between the metal and the solution, which protects the immersed material. However, the formation of this oxide protective layer does not occur at the surface of NiTi in some environments such as fluoride-containing solutions, resulting in the dissolution of the alloy (24–30). The purpose of this study was to test the ability to dissolve K3 NiTi endodontic instruments by using electrochemical process in a sodium fluoride medium. This dissolution might result in a consistent basis for the development of a method to remove fractured instruments from root canals without damage to the adjacent dental structures.

Materials and Methods

Current register tests were used to evaluate de dissolution process of 25.04 NiTi K3 rotary files (SDS Kerr, Glendora, CA). A 3-electrode electrochemical cell was used that

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0099-2399/$0 - see front matter

doi:10.1016/j.joen.2009.11.024

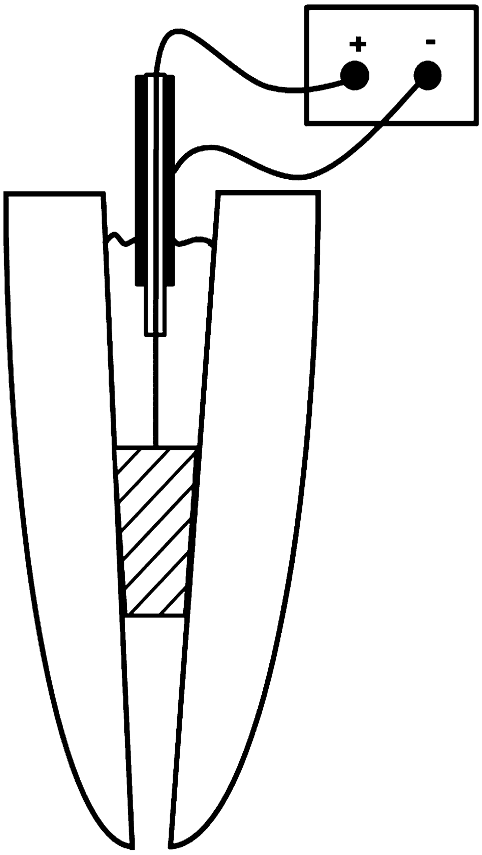

Figure 1. A possible configuration of the electrochemical-induced dissolution of a fractured file. The microelectrode combines anode and cathode, both immersed in the solution. The contact between the fractured file and the anode is promoted.

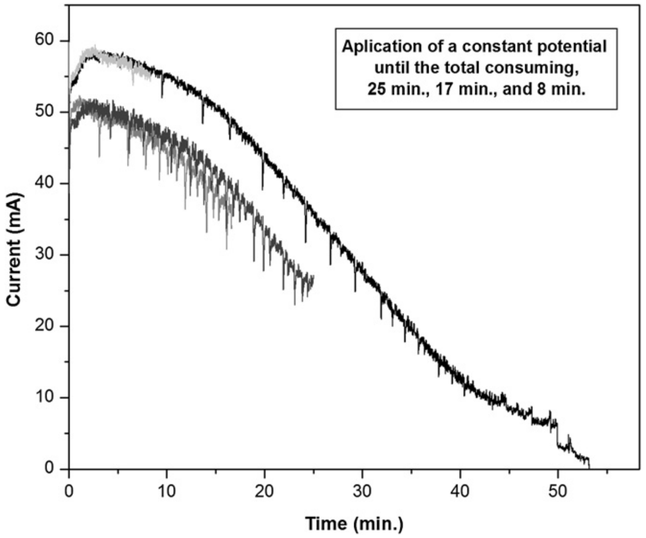

Figure 2. Current registered during the application of a constant anodic potential to 25.04 NiTi K3 rotary files in the [NaF 5 g/L + NaCl 1 g/L] solution during different periods.

contained a saturated calomel electrode as reference; platinum as counter-electrode, and a NiTi file as the working electrode. The solution was composed by [NaF 5 g/L + NaCl 1 g/L] and presented pH 5.0. The tested files were isolated with a polymeric coating, and only 6 mL from the tip were exposed to the solution. The electrodes were immersed in the solution and connected to an AutoLab Potentiostat (Metrohm Autolab B.V., Utrecht, The Netherlands) controlled by a computer. A constant anodic potential was applied to the NiTi files, while the Potentiostat registered the anodic current. Twenty files were divided into 4 groups of 5 files each and were tested in different periods of time: until the total consumption of the immersed portion of the file, for 25 minutes, 17 minutes, and 8 minutes. Weight loss measurements were applied to quantify the degree of file degradation by the process. The electrical charge generated during the dissolution of each file was obtained from the respective Current × Time curve. Analysis of variance ($P < .05$) was used to compare the different groups in relation to weight loss and electrical charge generated. After the tests, 1 file of each group was aligned from the handle and observed with magnification of 6.5× by using an optical microscope.

Results

The anodic current records obtained during the tests are shown in Fig. 2. The current attained initial values of approximately 55 mA and declined during the entire test. A good reproducibility of results was observed. The weight loss values and the electrical charge generated during the tests are summarized in Table 1. The results evidence that there is a statistical difference among the 4 groups considering either the weight loss or the electrical charge generated (analysis of variance, $P < .05$). The longer the polarization time, the higher the weight loss and the higher the electrical charge. Fig. 3 shows an optical microscopy analysis of 5 different files: a file as received, a file submitted to constant potential until total consumption of its immersed portion, and files submitted to constant potential for 8, 17, and 25 minutes. The optical microscopy analysis evidenced a progressive consumption of the files with increasing polarization time.

Discussion

The concept of retrieval of fractured instruments by an electrochemical process is based on the dissolution of a metal alloy in aqueous environments, and it requires the existence of 2 electrodes and an electrolyte. The electrolyte might have a composition that varies according to the metal to be dissolved; it is essential that the metal has susceptibility for dissolution in this electrolyte. Therefore, once the cathode is composed by an inert metal, the transfer of electrons from the metal to be dissolved to the cathode tends to occur even without the imposition of a difference of potential between the 2 electrodes. However, this process would be too slow to be used during the endodontic treatment. Consequently, a difference of potential must be applied to accelerate the transfer of electrons and the release of metallic ions to the solution. This could be dangerous if the electrical current is conducted by human

TABLE 1. Weight Loss and Electrical Charge Generated during the Dissolution Process

	Weight loss (mg)		Electrical charge (C)	
Time	Mean	SD	Mean	SD
8 minutes	0.82	0.13	27.61	2.30
17 minutes	1.68	0.29	52.41	4.80
25 minutes	2.52	0.46	68.63	5.63
Total consumption	3.64	0.72	96.99	8.92

SD, standard deviation.