Incidence of Deformation and Fracture of Twisted File Adaptive Instruments after Repeated Clinical Use

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ABSTRACT

Objectives: The aim of the present study was to investigate the incidence of deformation and fracture of twisted file adaptive nickel-titanium instruments after repeated clinical use and to identify and check whether the three instruments within the small/medium sequence showed similar or different visible signs of metal fatigue.
Material and Methods: One-hundred twenty twisted file adaptive (TFA) packs were collected after clinically used to prepare three molars and were inspected for deformations and fracture.
Results: The overall incidence of deformation was 22.2%, which was not evenly distributed within the instruments: 15% for small/medium (SM)1 (n = 18), 38.33% for SM2 (n = 46) and 13.33% for the SM3 instruments (n = 16). The defect rate of SM2 instruments was statistically higher than the other two ($P < 0.001$). The fracture rate was 0.83% (n = 3), being two SM2 instruments and one SM3.
Conclusions: It was observed a very low defect rate after clinical use of twisted file adaptive rotary instruments. The untwisting of flutes was significantly more frequent than fracture, which might act as prevention for breakage. The results highlight the fact that clinicians should be aware that instruments within a sequence might be differently subjected to intracanal stress.

Keywords: endodontics; nickel; root canal therapy; titanium.

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INTRODUCTION

The success of endodontic treatment is directly correlated to an efficient biomechanical preparation aiming to clean and disinfect the root canal system. The use of mechanized nickel-titanium (NiTi) files for root canal shaping is associated with well-centered preparations, reduced operator fatigue and less operatory time, but the file separation is still a major concern in clinical practice [1-5].

Reciprocating motions have been recently introduced as an alternative way of shaping root canals with NiTi, aiming at reducing instrumentation stress. The basic concept is that when the two reciprocating angles are different, the resulting motion is a non-continuous rotation. The partial rotation in one direction engages the NiTi instrument inside the canal, allowing cutting, debris removal and apical progression. The partial rotation in the opposite sense (usually with a significantly lower angle) promotes its disengagement and releases the stress. The safety is also increased by using cutting angles smaller than the elastic or fracture limit (deflection angle) of the instrument [1]. Whereas continuous rotation generates the accumulation of metal fatigue, the reciprocating motions promote alternating stress and release, therefore reducing both torsional and flexural stresses. Several studies clearly showed the increase in mechanical resistance of NiTi instruments used in reciprocation when compared to their use in continuous rotation [1-5].

The twisted file adaptive (TFA) system (Kerr Endodontics, Glendora, Orange, CA, USA) consist of a sequence of three NiTi instruments that are meant to be used with a specific reciprocating motion, given by the Elements Motor (Kerr Endodontics, Glendora, Orange, CA, USA). The TFA small/medium (SM) shaping sequence consists of three NiTi instruments with the following tip sizes and tapers: SM1 (20.04), SM2 (25.06) and SM3 (35.04). According to the manufacturer, the TFA motion uses a range of reciprocating angles that automatically vary according to the detected intracanal stress (from 600°/0° up to 370°/50°), aiming at optimizing efficacy and prevention of failures. This kinematic was reported to significantly increase *in vitro* instrument's resistance to fracture compared to the rotary motion, to reduce screwing-in effect [6,7] and to reduce the amount of apically extruded debris [8]. The TFA system also resulted in fewer dentinal cracks and higher cutting efficiency when compared to other reciprocating instruments [9,10]. However, no data are reported about clinical resistance to breakage of TFA instruments.

Previous studies that investigated different brands of rotary NiTi instruments after clinical use suggested that the occurrence of defects is a multifactorial problem and can be affected by the number of uses, the experience of the operator, method of use, instrumentation technique, anatomical complexity of the root canals, design, diameter and taper of the instruments and manufacturing process [11-18]. Since different motions result in different instrumentation stresses, deformation and fracture rate may also be affected. However, to the best of our knowledge there is no information available about the incidence of defects in TFA instruments after repeated clinical use.

Therefore, the aim of the present study was to investigate the incidence of deformation and fracture of twisted file adaptive nickel-titanium instruments after repeated clinical use and to identify and check whether the three instruments within the SM sequence showed similar or different visible signs of metal fatigue.

MATERIAL AND METHODS

A total of 120 TFA SM packs (360 NiTi instruments) were collected after clinical use over 15 months. Prior to use, all instruments were observed under stereomicroscope at original magnification x20 (Karl Kaps Gmbh, Asslar, Germany) to discard those with deformations or defects. Each set of TFA SM was assigned to prepare three molar cases (8 to 10 canals) by three endodontists (GG, GM, DDN). The case selection excluded teeth presenting immature apex, root fractures, previous endodontic treatment, extensive root resorption, C-shaped canals and dilacerated roots.

The root canal treatments were conducted under anaesthesia and rubber dam isolation. After coronal access, a mechanical glide path was created, by using the 0.02 stainless steel (SS) manual K-files (which are included in the SM package) attached to an M4 reciprocating 30° - 30° hand-piece (M4 program available in the Elements Motor). The SS files ISO sizes 8, 10 and 15 were used with the M4, until the 15 K-file could be inserted into the canal without pre-bending or pressure. After the establishment of glide path, the sequence of three NiTi TFA instruments were used according to manufacturer's instruction, running with the non-editable TFA program available in the Elements Motor. All the instruments reached working length, progressing in a series of steps of 1 - 2 mm. After each step, the instrument was retrieved from canal and cleaned to limit packing of debris inside flutes. Following manufacturer's instructions,

if any sign of distortion or fracture was detected, the instrument was identified, discarded and replaced for a new one; being that the substitute instruments were not included in the data. Irrigation with 5% sodium hypochlorite [19] was performed during all the shaping procedures. After completing the preparation of each molar case, the set of instruments was sterilized by autoclave and also identified to be used up to a maximum of 10 canals.

The length of each collected instrument was measured by using a digital caliper to a precision of 0.01 mm, this aimed to determine if occurred any fracture that was not previously clinically detected. In the same way, they were visually inspected for plastic deformation under a stereomicroscope at original magnification x20 (Karl Kaps Gmbh, Asslar, Germany). The surfaces of fractured instruments were also viewed under a Scanning Electron Microscope (SEM) to evaluate the fracture mode. Data was statistically analysed using the SPSS 17.0 software (SPSS Incorporated, Chicago, IL, USA).

Statistical analysis

Data were described in terms of absolute and relative (percentage) frequencies. Chi-squared test was used to assess differences in frequency of defects among SM2 instruments and operators and to compare frequencies of fractures and unwinding. The significance level was set at $P < 0.05$.

RESULTS

A total of 352 molars were prepared (188 maxillary and 164 mandibular). Deformation of files after the use in the first molar was observed in 4 kits (8 instruments), and these files were no longer used to prepare more cases. The remaining 116 kits of TFA SM instruments were used to prepare a minimum of 8 canals, up to a maximum of 10 for each set of instruments. The incidence of instrument deformation (Figure 1) was 22.2%, which was not evenly distributed within the three instruments of the sequence (Table 1). The defect rate of SM2 instruments was statistically higher than the other two ($P < 0.001$). Of the 80 deformed instruments, 71 (88.75%) were elongated and 9 (11.25%) presented shortening of the flutes. There was no difference among the three operators regarding the percentage of incidence of defects (Chi-square test $P > 0.05$). Regarding the number of uses, in 53.75% of the cases the distortion was noted in the preparation of the third molar but with no statistically significant difference (Table 2).

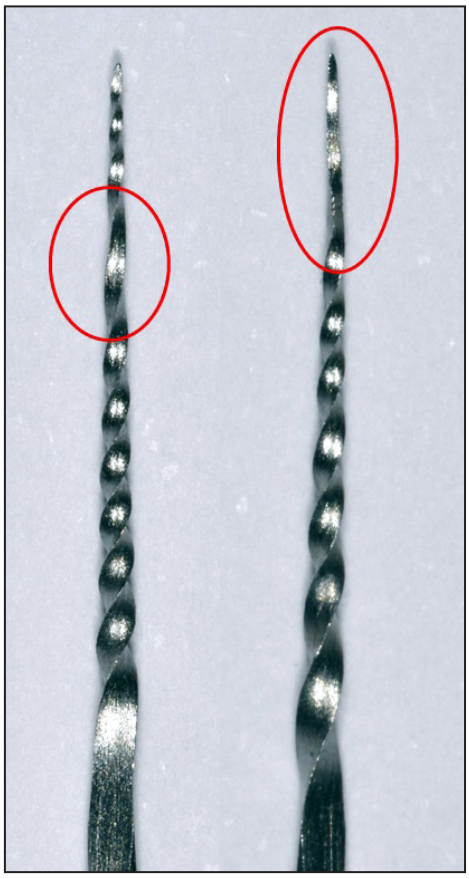

Figure 1. Example of plastic deformation (unwinding of flutes) of twisted file adaptive SM2 and SM3.

Table 1. Number and percentage of defects on twisted file adaptive (TFA) instruments

Instrument	N	Deformation		Fracture	
		n	%	n	%
SM1	120	18	15[a]	0	0[a]
SM2	120	46	38.33[b]	2	1.66[a]
SM3	120	16	13.33[a]	1	0.8[a]

Different superscript letters indicate statistically significant difference within column.
N = number of TFA instruments used; n = number of deformations or fractures observed; SM = small/medium.

Table 2. Incidence of defects on twisted file adaptive instruments according to the number of uses

Instrument	N	1st case		2nd case		3rd case		Unknown	
		n	%	n	%	n	%	n	%
Deformation	80	8	10[a]	26	32.5[a]	43	53.75[a]	3	3.75[a]
Fracture	3	0	0[a]	0	0[a]	3	100[b]	0	0[a]

Different superscript letters indicate statistically significant difference within row.
N = total number of deformations and fractures observed; n = number of deformations and fractures observed after each case.

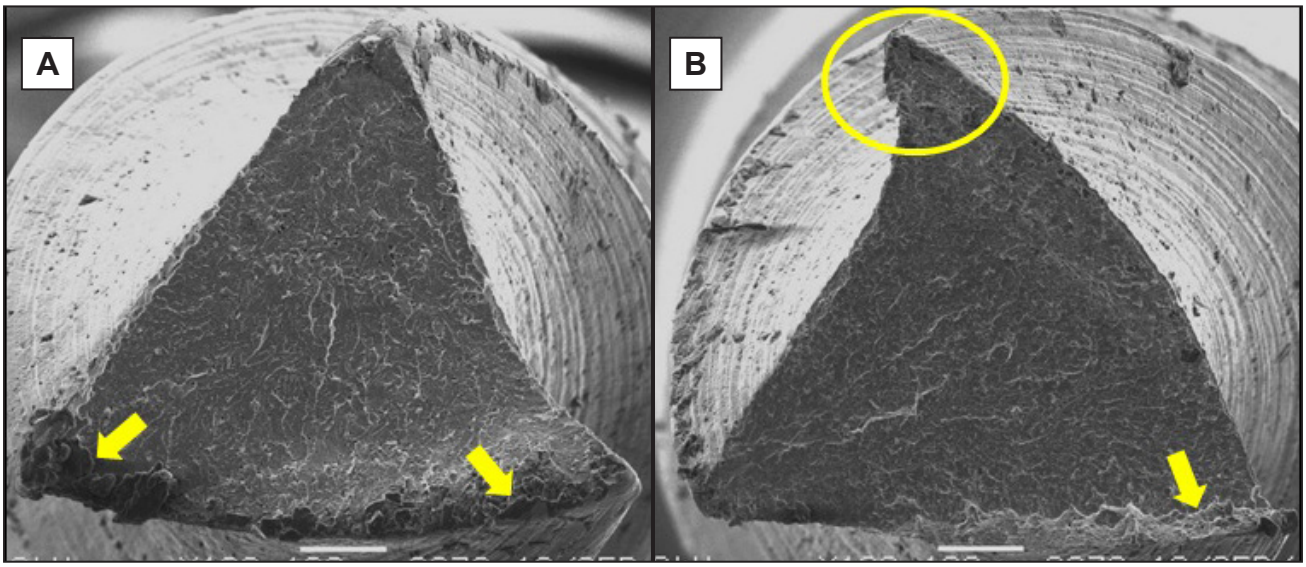

Figure 2. Fractographic analysis of twisted file adaptive broken instruments showed signs of flexural fatigue (indicated by the arrows) and in some specimens also torsional fatigue (indicated by the circle).
A = SM3 instrument; B = SM2 instrument.

There was a difference in the site of deformation among instruments: while most of SM2 deformed at middle part, the SM1 and SM3 deformed close to the tip.

During the clinical procedures, three instruments fractured (two SM2 and one SM3). The fracture was confirmed by the later inspection and measurement of the files. The overall fracture rate was 0.8%, significantly lower than the incidence of unwiding ($P < 0.0001$). All the fractures occurred after the third clinical case. SEM fractographic analysis of the broken instruments showed signs of both torsional and flexural fatigue (Figure 2).

DISCUSSION

Previous studies have shown that the clinical fracture incidence of NiTi instruments varied from 0.3% to 23% among different clinics worldwide [11-16,18,20,21]. The overall fracture incidence of TFA recorded in the present study (0.8%) is close to the lowest values of the reported range. This low fracture rate could be related to different factors, including the motion, the design of the instruments and its manufacturing process [1-3,7]. Gambarini et al. [22] showed that the twisting process of TF instruments resulted in an increased resistance to breakage compared to instruments produced by grinding.

It is known that intracanal file breakage is more likely to occur in severe, abrupt curvatures or S-shaped canals [12,23,24]. The fact that file separation occurs mainly in molars, when compared to other tooth types, have been correlated not only to the anatomical complexity but also to its clinical accessibility [12]. However, clinically it is not possible to standardize the anatomy of the teeth or the difficulty of the cases (e.g. the canal diameter, the curvature angles, dentin hardness). Most of previous clinical studies that reported low fracture rates of different brands of instruments, have included all dental groups [12,15,18,21]. Nevertheless, in the present study it was set a level of difficulty by including only molar cases. These tooth type was selected because TFA SM sequence is recommended for small and/or curved canals, which are more likely found in molars. Even tough, the incidence of fracture in the present study was similar to that reported in studies that included also anterior teeth and premolars [12,15,18,21].

The deformations rate of NiTi files reported in the literature vary from 0.3 to 28%, which commonly is slightly lower or similar to the fracture rate [11-14,16-21]. In the present investigation, the incidence of defects was significantly higher (22.2%) than the fractures rate (0.8%). It has been suggested that the design of the instrument play a major role in determining resistance to intracanal stress [12,14]. However, for the TFA instruments, the manufacturing process might also explain the greater occurrence of deformations. The combination of heat treatment and twisting process leads the TFA instruments to present a clinical behaviour different from the majority of grounded NiTi rotary instruments. Likewise stainless steel files, when subjected to excessive intracanal stress, they tend to show a greater amount of plastic deformation (unwinding of flutes) before breakage (Figure 1). This propensity for unwinding flutes can be considered as a safety feature [12,13,23]

that allows clinicians to visualize metal fatigue and avoid overuse. The plastic deformation of the files in the present investigation could be detected clinically in the majority of cases (96.25%). In four cases, it was observed plastic deformation during the first use of the TFA set, probably related to the complex anatomy of the teeth. By showing clinical evidence of metal fatigue, these instruments allow the clinician to discard the deformed instruments on a rationale base [17]. The majority of grounded NiTi rotary instruments usually undergo to unexpected fracture without any previous signs of metal fatigue or unwinding of flutes [12,13,17,23].

The present study also confirmed previous ones showing that instruments within a sequence are subjected to different intracanal stresses, due to different dimensions and different blade engagement [12,25,26]. Among the three TFA instruments, the first and third one (SM1 and SM3) presented lesser deformation/fracture rates. Although unwinding was observed in 15% of SM1, none of the 120 instruments fractured. This finding is probably related not only to the instrument smaller size, but also to the previous establishment of an adequate glide path, up to a number 15 K-file [27,28]. Similarly, the SM3 is subjected to stress only in the last 4 mm, which explains their low deformation rate and only one fractured file.

The SM2 presented the highest deformation rate (38.33%) and two fractures. This is correlated to the dimensions, because this file increased both taper and size preparation, being more subjected to intracanal stress. These results showed SM2 to be the most critical instruments inside this sequence, thus requiring a more delicate and cautious approach, to minimize blade engagement and tip lock. Clinical studies showed that among the ProTaper sequence, the S1 instrument corresponded to 62% of all separated files [12] while for K3 instruments, the defect rates were significantly higher for the tapers 0.06 and 0.04 [15]. Accordingly, the present findings highlight that to provide useful information, studies about fracture and deformation rates of NiTi instruments should be more detailed and analyse their behaviour inside a sequence.

The separation of rotary NiTi instruments has been mainly associated to flexural stress [12,13,15,26]. Fractographic analysis of TFA SM2 and SM3 broken instruments showed signs of both torsional and flexural fatigue (Figure 2). This fact might be also related the influence of the kinematics (reciprocation) on the response to mechanical stresses [29,30]. This assumption is corroborated by a recent study that evaluated the incidence of defects after clinical use of WaveOne and found that these reciprocating instruments fractured by shear stress [18].

The evaluation of the other two commercially available reciprocating instruments also showed a very low incidence of fracture and deformation after clinical use, respectively 0.47% and 0.35% for Reciproc [20], and 0.5% and 9.6% for Waveone [18]. However, it is important to notice this low fracture rate of Reciproc and WaveOne are also related to the fact that, according to manufaturers' instructions, both are single-use system while TFA is intended for multiple uses. The repeated use of NiTi files (more than 8 times), have been reported to increase significantly the separation rate [12,28]. In the present study despite the repeated clinical use, only 3 instruments fractured (0.8%) which are probably correlated to the combination of TFA instruments with the adaptive motion [7,30].

CONCLUSIONS

Therefore, it was concluded that twisted file adaptive instruments presented a very low fracture rate and a high incidence of plastic deformation after repeated clinical use. Since the small/medium 2 instruments presented significantly more deformation, the clinical relevance of the present study lies in demonstrating that instruments within a sequence might be differently subjected to intracanal stress and clinicians must understand the different behaviour and perform instrumentation accordingly.

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The authors declare that there are no financial or other conflicts of interest related to this publication.

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