Effect of heat treatment on the cyclic fatigue resistance of NiTi endodontic openers

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Summary

***Aim*: Aim of the present study is to evaluate if a thermal treatment adopted for endodontic NiTi instruments could increase their cyclic fatigue lifespan.**
***Methods*: 25 thermally treated One Flare (MM, Besancon, France) and 25 non-thermally treated Endo Flare (MM, Besancon, France) were mechanically rotated in a precurved artificial canal until fracture. Differences between Time to Fracture (TTF) and Fragment Length (FL) were statistically analyzed (Student's *t* test, (p<0.05).**
***Results*: One Flare's time to fracture (47.24 seconds; SD±4.24) was significantly longer when compared to Endo Flare's (21.2 seconds; SD±3.08) at the same operating conditions (p<0.005). Differences between the length of fractured segments showed no statistical significance differences (p>0.005).**
***Conclusions*: Heat treated NiTi alloy showed an improved time to fracture when compared to a non-thermally treated one at the same operating conditions. Thermal treatments could enhance the characteristics of NiTi improving the lifespan of rotary endodontic instruments.**

Key words: heat treatment, Endo Flare, One Flare, nickel-titanium, endodontic instruments.

Introduction

The introduction of nickel-titanium (NiTi) alloy for rotary endodontic instruments improved the clinical skills in root canal treatment, making it safer and more predictable (1-3). NiTi alloy allowed the manufacturers to produce instruments with a greater mass and taper than the stainless-steel instruments: this resulted in a more predictable clearness for the root canal system (4, 5). The continuous motion guaranteed a higher cutting ability than the balanced force motion used with the stainless-steel instruments (6-8).
Despite the improved performance of rotary instruments, their relatively higher speed of rotation may lead to an intracanal separation of the endodontic instrument (9-11). Quality of the alloy, manufacturing defects, and cyclic stress accumulation are involved in intracanal leakage of endodontic instruments (12-14). Intraoperational strain affect the integrity of the alloy produces microcracks which grow at every rotating cycle of the instrument. Microcracks may lead to intracanal separation after certain cycles and this is an unavoidable aspect after prolonged use (15-18).
Aim of the present study is to evaluate if a proprietary thermal treatment could increase the resistance to cyclic fatigue of a high tapered endodontic instrument.

Materials and methods

25 Endo Flare (MicroMega, Besancon, France), tip diameter #25, taper 12%, length 15 mm, and 25 One Flare (MicroMega, Besancon, France), tip diameter #25, taper 9%, length 17mm were tested (n=50).
A validated cyclic fatigue testing device was adopted to evaluate time to fracture at known conditions (19-20). The electric handpiece was mounted on a mobile device to allow reproducible placement of each instrument inside the artificial canal to the same depth. The artificial canal had a 60° angle of curvature and 5 mm radius of curvature. All the instruments were inserted at the same length and then rotated at 350 rpm with maximum torque until fracture occurred. For each instrument, the time to fracture was recorded with a 1/100 sec chronometer. All fragments were collected and measured. For each group, mean and standard deviation were calculated. Differences among groups were statistically examined using the Student's *t* test (significance level was set at p<0.05). Data was statistically analyzed using

the SPSS 13.0 software (SPSS Incorporated, Chicago, IL, USA).

Results

Results from the cyclic fatigue tests are shown in Table 1 and Figure 1. Mean values of time to fracture for Endo Flare instruments were 21.2 seconds (SD±3.08) and were 47.24 seconds (SD±4.24) for One Flare. Different time to fracture between groups showed statistical significance ($p<0.005$).
Mean values for fragment length for Endo Flare instruments were 6 mm (SD±0.8) and for One Flare were 7 mm (SD±0.8). No statistically significant differences were found between fragment lengths ($p>0.005$).

Table 1. Time to Fracture (TtF) in seconds (s) and length (mm) of fractured fragments (FL).

	Endo Flare		**One Flare**	
Group	Mean	SD	Mean	SD
TtF (s)	21.2	3.08	47.24	4.24
FL (mm)	6	0.8	7	0.8

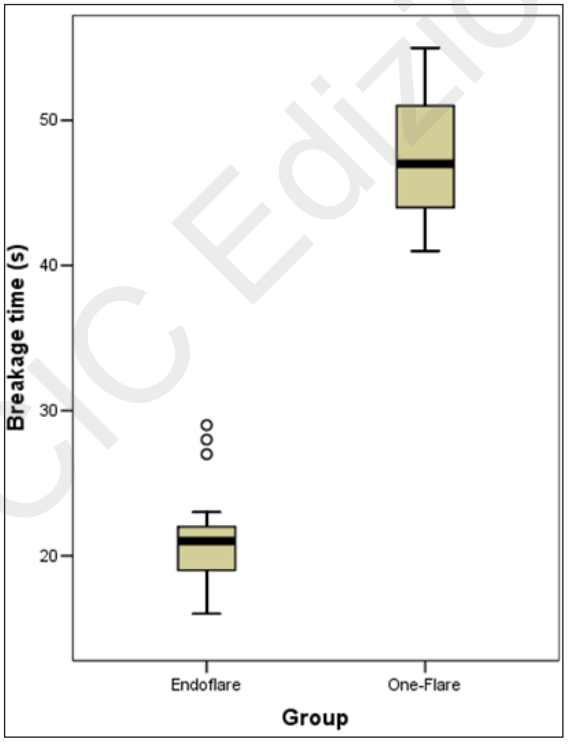

Figure 1. One Flare *vs* Endo Flare time to fracture box plot.

Discussion

The thermal treatment applied to the NiTi rotary instruments allowed changes in the metallurgical phase at environmental temperature. At higher temperature the NiTi alloy is in austenitic phase, at lower temperature it is in martensitic phase and at average temperature the alloy is in R phase. Thermal treatments allow the achievement of improved qualities for the rotary instruments, such as superelasticity and shape memory (21). The vacuum casting of an ingot, hot molding, rolling and cold drawing followed by heat treatment are typical applied processes for the NiTi wires. The thermal treatment applied to the rotary instrument is usually under patent. Usually, instruments are brought to high temperature, between 450° and 550° degrees, in furnaces that can work in controlled atmosphere or air. This kind of thermal treatment allows an increase in the instrument performances, reaching the superelastic or the shape memory characteristics (22). Thermal treatments dramatically affect the *in vitro* instruments' performance, resulting in an increased cyclic fatigue resistance.
Geometrical design, rotary motion and thermal treatment of the alloy could improve the characteristics of the endodontic instrument (19-24). Superelastic and shape memory characteristics could be reached treating the alloy at certain temperatures at controlled atmosphere (15).
The orifice opener is a high tapered instrument used for the enlargement of the coronal third of the endodontic canal (flaring) due to facilitate irrigation and the penetration of the subsequent instrument (25).
Flexibility of One Flare is higher therefore, it may also allow a safer and more predictable clinical usage. The One Flare seems to be mostly indicated for obtaining straight access to constricted orifice and\or bad positioned orifice. Due to its flexibility and ductility, One Flare presents a lower risk of canal perforation and/or stripping. Endo Flare presents a 12% taper, this makes the instrument harder and less flexible when compared to One Flare. In addition, no thermal treatments were applied to its alloy and this could represent a detriment for its cyclic fatigue lifespan (26).
High tapered instruments should be thermally treated to improve their resistance to fracture, contrasting the minor flexibility and ductility given by the increased mass of alloy. Data obtained in this study are in accordance with previous studies which enlightened the importance of heat treatments in improving NTRIs' resistance to breakage (12, 15, 18, 24, 26).

Conclusions

MM proprietary thermal treatment applied at One Flare improves the resistance to cyclic fatigue, allowing a safer use by the clinician compared to the non-thermally treated Endo Flare. Apply a thermal treat-

ment in manufacturing NiTi endodontic rotary instruments may improve mechanical properties and lifespan rather than conventionally processed NiTi instruments.

Declaration of conflicting interests

The Authors deny any conflict of interest.

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