Comparing The Difference in Cyclic Fatigue Resistance of Three different Rotary Ni-Ti instruments in Rotation and Reciprocation motion

Thesis

Submitted to the Faculty of Dentistry

Ain Shams University

For

Partial Fulfillment of the Requirements of the

Master Degree in Endodontics

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BDS-2009

Misr International University

2016

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Acknowledgement

I would like to express my deep gratitude to **Dr. Karim Mostafa El Batouty**, Associate Professor, department of Endodontics, Ain Shams University For his support, kindness and supervision.

My sincere gratitude to **Dr. Shady Ali Hussein**, Lecturer, department of Endodontics, Ain Shams University for his prompt support, cooperation, patience and guidance.

My thanks to **Dr.Waeel ElShater** for his assistance and knowledge throughout his work.

My deep gratitude to all staff members of endodontic department of Ain Shams University for their support, guidance and shared knowledge throughout the years.

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Introduction

Instrument separation is still a major concern when using NiTi endodontic files despite the good mechanical properties of NiTi alloy, [2].

The separation of NiTi endodontic files may occur due to Torsional failure or Flexural failure. It was found that less than one third of fractures of NiTi files can be attributed to torsional failure. This kind of attribution is, however, quite controversial, since NiTi files are often subjected to both torsional and flexural stresses. The manufacturing of NiTi instruments often results in internal residual stresses, work hardening and surface defects that limit the overall strength of the instrument. In unused NiTi instruments, work hardening and surface defects have been reported.

Rotary NiTi instrument can be used in a continues rotation or in reciprocation motion. In the reciprocating motion, the instrument rotates in counterclockwise (CCW) and clockwise (CW) direction. When the instrument rotates in the cutting direction, it will advance in the canal and engage dentin to cut it. When it rotates in the opposite direction (smaller rotation), the instrument will be immediately disengaged. The end result, related to the degree of CW and CCW rotations, is an advancement of the instrument in the canal. This action is thought to reduce the cyclic fatigue and subsequent file fracture.

Based on such evidence, it was thought that the evaluation of cyclic fatigue resistance of different Ni-Ti rotary file systems in both rotation and reciprocation motions is of value.

Review of literature

In this part of the study the following aspects will be discussed; modes of failure of NiTi rotary files and actors affecting cyclic fatigue resistance.

I-Modes of failure of NiTi rotary files:

Separation (fracture) of NiTi rotary files can occur as a result of 1- rotational bending, ie, as a result of fatigue, or 2- shear fracture, usually when the instrument tip is stalled (jammed) but the handpiece continues to rotate [3, 5, 6]. Fatigue has been implicated to be one of the main reasons for the fracture of endodontic rotary files used clinically [5, 7].

Fatigue fracture of endodontic instruments occurs in two different ways: Cyclic fatigue failure or Torsional fatigue failure [1,2,3].

Cyclic fatigue is defined as the accumulated strain that develops from repeated bending of an object at the same location. Rotation of endodontic instruments subjects them to both tensile and compressive forces in the area of canal curvature; with tensile forces on the outside of the curvature and compressive forces on the inside [4].

Rotary files experience cyclic fatigue when they are rotated in curved canals, which cause the instruments to cycle in and out of compression and tension forces at the location of the curve [8]. Fracture caused by fatigue through flexure occurs because of metal fatigue [9,10]. The instrument does not bind in the canal, but it rotates freely in a curvature, generating tension/compression cycles at the point of maximum flexure until the fracture occurs [9,10]. Cyclic fatigue is most likely to occur in a canal with an acute curve and a short radius of curvature, as defined by Pruett et al [11], and is considered to be the leading cause of NiTi instrument separation.

Torsional failure occurs when rotational torque load applied to the instrument exceeds the torque limit of the instrument. An example of torsional failure occurs when an instrument is forced apically under too much pressure and the tip binds under rotational force. The average torque at failure increased with increase in both file tip size and taper[3]. Instruments fractured because of torsional loads often carry a specific signs such as plastic deformation [6,3]. The instrument's torsional strength is directly related to its metal mass [3]. That is why it is influenced by tip size and taper of the instrument [8].

Material fatigue appears to be an important reason for the Separation of rotary instruments during clinical use. Peng et al classified most of the fractured instrument analyzed as flexural failure, implying fatigue being the predominant mechanism for material failure [6,12]. In a related study, Cheung et al, reported that the great majority (93%) of instruments appeared to have failed because of flexural fatigue [6,12]. This might be explained as follows [9] : first; fatigue-crack growth rates in NiTi alloys have been reported to be significantly greater than in other metals of similar strength [13].Thus, once a microcrack is initiated, it can quickly propagate to cause catastrophic failure [6].

In comparison, Sattapan et al [3] reported that torsional fracture occurred in 55.7% of all fractured files, whereas flexural fatigue occurred in 44.3%. These results indicated that torsional failure, which may be caused by using too much apical force during instrumentation or by other contributing factors such as the preexisting size of the canal, occurred more frequently than flexural fatigue, which may result from use in curved canals [6].

It has been shown that nickel titanium endodontic instruments fail in a complex manner consisting of both brittle and ductile aspects. The presence of surface cracks created during machining of the instruments from the starting Nickel titanium wire stock seems to be a major drawback, as dentin chips and other debris created during clinical instrumentation of the root canal can become lodged in these cracks, which can then propagate under the localized stress conditions and result in instrument fracture**.** [4].

II- Factors affecting cyclic fatigue resistance:

A) Modification in metallurgy of NiTi:

1-The mechanical performance of NiTi alloys is sensitive to their microstructure and associated thermomechanical treatment history. Heat treatment or thermal processing is one of the most fundamental approaches toward adjusting the transition temperature in NiTi alloy, which affects the fatigue resistance of NiTi endodontic files [14,15,16].

As a result of its unique crystalline structure, a NiTi file has superelasticity (ie, the ability to return to its original shape after being deformed). Simply stated, NiTi alloys currently are the only readily available and affordable materials with the flexibility and toughness for routine use as effective rotary endodontic files in curved canals. Superelasticity occurs in association with a reversible phase transformation between austenite and martensite. Therefore, the transformation temperatures have a critical influence on the mechanical properties and the behavior of NiTi, which can be altered by small changes in composition, impurities, and heat treatments during the manufacturing process [17]. This distinct property of NiTi alloys has created a revolution in the manufacture of endodontic instruments. From the point of view of practical applications, NiTi can have 3 different forms: martensite, stress-induced martensite (SE), and austenite. When the material is in its martensite form, it is soft and ductile and can easily be deformed. SE NiTi is highly elastic, whereas austenitic NiTi is quite strong and hard [18]. The equiatomic NiTi alloy has all these properties, with the specific expression being dependent on the temperature at which it is used.

Brantley et al [19] were the first ones in the endodontic literature to show that the structure of the NiTi rotary instruments can be conveniently investigated by differential scanning calorimetry (DSC). They indicated that the $A_f$temperature of conventional NiTi rotary instruments (Lightspeed and ProFile) was near 25°C at room temperature. Therefore, these instruments would show SE behavior during clinical use.

At the beginning of 2000, a series of studies [20- 23] found that changes in the transformation behavior via heat treatment were effective in increasing the flexibility of NiTi endodontic instruments. Since then, heat-induced or heat-altering manipulations were used to influence or alter the properties of NiTi endodontic instruments, which were once cited as the main reasons for pursuing the use of NiTi instruments in endodontics. Proprietary thermomechanical processing is a complicated process that integrates hardening and heat treatment into a single process. Alapati et al [24] found that heat treatments at 400°C, 500°C, and 600°C raised the A_f temperature of ProFile to 45°C–50°C, and heat treatment at 850°C caused a loss of SE behavior and recrystallization of the wrought microstructure. DSC curves were very complex with irregular peaks. These results were also confirmed by other studies [21, 25]. Therefore, the manufacturer must perform an appropriate heat treatment, which will be