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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Cyclic fatigue of NiTi instruments used in complex curvatures with continuous or reciprocating rotation

Fatica ciclica di strumenti in lega NiTi impiegati con rotazione continua o reciprocante: analisi dei risultati in canali con curvature complesse

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KEYWORDS
Nickel-titanium;
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Cyclic fatigue;
Continuous rotation;
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Abstract
Aim: The aim of present study was to compare cyclic fatigue resistance of Twisted files (TF, Sybron Endo, Glendora, CA) instrument used with continuous rotation and the new Motion (TFAdaptive rotating reciprocation), to evaluate if the new reciprocating motion could affect the lifespan of tested instruments.
Methodology: 30 new TF instruments were submitted to cyclic fatigue tests. Group 1 instruments were tested using a TFA motion (TFA) while group 2 instruments were used in continuous rotation at 500 rpm (CR). The cyclic fatigue testing device used in the present study has been used for studies on cyclic fatigue resistance previously. The artificial canal was manufactured to provide the instrument with a very challenging trajectory 60° curvature, with a 2 mm radius.

All instruments were rotated or reciprocated until fracture occurred. The time to fracture was recorded. All data were subjected to statistical evaluation with analysis of variance test.
Results: TFA reciprocating motion showed a significant increase ($p < 0.05$) in the time to failure when compared to continuous rotation. Mean time to failure was 131 s (SD ±25.2) for group 1 (TFA), and was 68 s (SD ±14.8) for continuous rotation group (CR).

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Conclusions: In accordance with those findings, the results of the present study showed a significant increase of cyclic fatigue resistance of instruments used with the TFA motion. This can be explained by the alternance of engaging/disengaging movements, since the motion can be defined as a non-continuous rotation, while the traditional continuous rotation movement continuously engages and stresses the instruments.

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nichel-titanio;
strumenti endodontici;
fatica ciclica;
rotazione continua;
reciprocazione.

Riassunto
Obiettivi: Lo scopo del presente lavoro è stato quello di valutare la resistenza fatica di strumenti in niche-titanio Twisted files (TF, Sybron Endo, Glendora, Ca) utilizzzati con una metodca tradizionale e con un nuovo movimento reciprocante (TFAdaptive), per valutare se quest'ultimo sia in grado di to evaluate if the new reciprocating motion could affect the lifespan of tested instruments. motions.
Materiali e Metodi: Trenta strumenti nuovi TF sono stati sopposti ad un test di fatica divisi in 2 gruppi identici: nel gruppo 1 il test è stato effettuato con il movimento reciprocante (TFA), mentre quelli del gruppo 2 sono stati testate con rotazione continua (CR) a 500 giri/min. L'appecchiaturà è quella già utlizzata e validati in altri studi, utilizzando però un canale più complesso con raggio di curvature di 2 mm e angolo di 60°. Il tempo necessario per fratturare a fatica gli strumenti è stato misurato, e I dati sottoposti ad analisi statistica con test di varianza
Risultati: Gli strumenti usati con movimento reciprocante hanno mostrato tempi più lunghi per arrivare a frattura, cioè una resistenza significativamente più alta ($p < 0,05$) rispetto agli stessi strumeti utilizzati in rotazione continua. I valori medi sono stati I seguenti: 131 sec (SD +/- 25,2) per il gruppo 1 (TFA)., e 68 sec (SD +/- 14,8) per il grupppo 2 (CR)
Conclusioni: Sulla base dei dati sperimentali rilevati in questo studio, si può evidenziare un significativo aumento della resistenza a fatica derivante dall'uso di un movimento reciprocante. Ciò si speiega con l'alternanza nel movimento di impegno e rllascio delle spire, per cui il movimento reciprocante TFA può anche essere definite come rotazione ''non-continua'', mentre una rotazione continua tradizionale tende sempre più ad impegnare lo strumento ed aumentare gli stress mano mano che procede nel canale.

Introduction

Even if nickel-titanium (NiTi) rotary endodontic instruments offer greater advantage over stainless steel instrumentation,[1] allowing improved canal shaping and reduced canal transportation,[2] separation via torsional and cyclic fatigue is still a risk with NiTi instruments.[3,4] Cyclic fatigue occurs when a metal is subjected to repeated cycles of tension and compression that causes its structure to break down, ultimately leading to fracture (Parashos and Messer).[13] Torsional fatigue is the twisting of a metal about its longitudinal axis at one end, while the other end is in a fixed position (Sattapan et al.).[19] Cyclic fatigue is most apt to occur in a canal with an acute curve and a short radius of curvature, as defined by Pruett et al.[4] and is the leading cause of NiTi instrument separation. Increasing the resistance to file separation has been a focus in new NiTi rotary instrument manufacture and design.[5]

Since 2008 the only way to improve performance and safety of NiTi instruments was to change their dimensions, tip, cross-sectional and flutes design. With the development of Twisted File technology and m-wire new instruments produced with the new alloys have been commercialized aiming at improving safety, due to the better mechanical properties of the alloy. More recently, a third factor has become important in this search for stronger and better instruments: movement kinematics.

NiTi instruments have been traditionally used with a continuous motion, but in the last years a new approach to the use of NiTi instruments in a reciprocating movement has been introduced.[6] In the proposed technique, only one F2 ProTaper Ni-Ti rotary instrument is used for the canal preparation in a clockwise (CW) and counter-clockwise (CCW) movement. The CW and the CCW rotations originally used by Yared were four-tenth and two-tenth of a circle respectively and the rotational speed was 300 rpm.[6] The concept of using a single NiTi instrument to prepare the entire root canal is interesting, and it is possible due to the fact that reciprocating motion is thought to reduce instrumentation stress. Recent literature data show that the reciprocating motion can extend cyclic fatigue resistance of NiTi instruments when compared to continuous rotation.[7,8] These preliminary positive led to the development of new reciprocating instruments and motions (Reciproc and WaveOne), to take best advantages of the abovementioned concepts.

More recently a new system was developed and commercialized by Sybron Endo (Glendora, USA): TFAdaptive. It is a rotating reciprocation, with one clockwise angle bigger than the counter-clockwise one, but different from the technique proposed by Yared; the angles are not constant, but they can vary according to intra-canal stress. Clockwise angles can vary from 600° to 370°, while the counter-clockwise ones from 0° to 50°. The higher the stress, the motor automatically adjusts the settings by decreasing the cutting CW angle and increasing the releasing CCW one. As a result

the proprietary TFA motion has no predefined speed and has continuously adapting angles for reciprocation, resulting in a unique innovative smooth motion for endodontic NiTi instruments.

The aim of present study was to compare cyclic fatigue resistance of Twisted files (TF, Sybron Endo, Glendora, CA) instrument used with continuous rotation and the new Motion (TFAdaptive rotating reciprocation), to evaluate if the new reciprocating motion could affect the lifespan of tested instruments. The null hypothesis is that there is no difference in fatigue resistance related to the different motions.

Materials and methods

30 TF tip size 25 taper .06 nickel titanium instruments were randomly divided into two groups ($n = 15$ each). All instruments had been previously inspected by using an optical stereomicroscope with $\times 20$ magnification for morphologic analysis and for any signs of visible deformation. If defective instruments were found, they were discarded.

All instruments were submitted to cyclic fatigue tests. Group 1 instruments were tested using a TFA motion (TFA) while group 2 instruments were used in continuous rotation at 500 rpm (CR). The cyclic fatigue testing device used in the present study has been used for studies on cyclic fatigue resistance previously. The device consists of a mainframe to which a mobile plastic support is connected for the electric hand-piece and a stainless steel block containing the artificial canals. The electric hand-piece was mounted on a mobile device to allow precise and reproducible placement of each instrument inside the artificial canal. This ensured three-dimensional alignment and positioning of the instruments to the same depth. The artificial canal was manufactured to provide the instrument with a very challenging trajectory since the 60° curvature was starting in the middle of canal, with a 2 mm radius and a length of the canal after the start of curvature of 10 mm.

All instruments were rotated or reciprocated until fracture occurred. The time to fracture was recorded visually with a 1/100 s chronometer. Mean and standard deviation were calculated. All data were recorded and subjected to statistical evaluation with analysis of variance test. Statistical significance was set at $p < 0.05$.

Results

TFA reciprocating motion showed a significant increase ($p < 0.05$) in the time to failure when compared to continuous rotation. Mean time to failure was 131 s (SD $\pm$25.2) for group 1 (TFA). Mean time to failure of continuous rotation group (CR) was 68 s (SD $\pm$14.8).

Discussion

It has been clearly shown that multiple factors contribute to file separation, and cyclic fatigue has been shown as one of the leading causes.[9] Fatigue failure usually occurs by the formation of micro crack at the surface of the file that starts from surface irregularities. During each loading cycle micro cracks develop, getting deeper in material, until complete separation of the file.[10] All endodontic file shows some irregularities on the surface, and inner defect, as a consequence of the manufacturing process, and distribution of these defects influence fracture strength of the endodontic instruments.[11,12]

Cyclic fatigue is adversely affected by increasing the angle of curvature and the length of canal after the curvature, or by decreasing the radius of curvature and the canal dimensions.[13–18] The experimental canal used in the present study (small radius) can be defined as complex, since it challenges a lot of resistance to fatigue. It was used because the advancement in TF technology and manufacturing process has allowed to produce a new generation of nickel titanium instruments, with better flexibility and more resistance to cyclic fatigue. This has been clearly showed for continuous rotation, but on the contrary, little is known about the effect of the new TFA reciprocating motion on the lifespan of endodontic instruments.

Recent literature show that reciprocating motion can extend cyclic fatigue life when compared to continuous rotation. However, the term reciprocating motion includes several possible movements and angles, each of which may influence performance and strength of the nickel titanium instruments. Reciproc (VDW, Munich, Germany) and Wave One (Dentsply Maillefer, Ballaigues, Switzerland) instruments have been commercialized with motors allowing a rotating reciprocation, but angles are not clearly disclosed by manufacturers; however, all studies showed increased lifespan of the instruments, mainly related to the reduction of instrumentation stress by using a reciprocating motion.

This reduction of instrumentation stress (both torsional and bending stress) is the main advantage of reciprocating movements, even if it has been shown that a lot of different reciprocating movements can be used, each one affecting performance and safety of the NiTi instruments. Therefore, when discussing about advantages and disadvantages of reciprocation, the exact motion should be mentioned, since it has a great influence on both clinical and experimental behaviour of NiTi instruments. Design of instruments is also critical, since some instruments could theoretically benefit more or less from the reciprocating motion.

In the present study, however, attention was paid only in the different motions, so the same instrument design was selected, actually TF instruments which are currently used in TFA technique. In accordance with those previously mentioned findings, the results of the present study showed a significant increase of cyclic fatigue resistance of instruments used with the TFA motion. This can be explained by the alternance of engaging/disengaging movements, since the motion can be defined as a non-continuous rotation, while the traditional continuous rotation movement continuously engages and stresses the instruments.

Conclusions

The kinematic is among the factors which could affect lifespan of NiTi instruments. The extent depends on many factors, including type of motion, manufacturing process and instrument design. This study compared cyclic fatigue

resistance of TF instruments used with the new TFA reciprocating motion and in continuous rotation on a static metal block, and clearly showed that the TFA reciprocating motion can significantly extend cyclic fatigue life of TF when compared with continuous rotation.

Conflict of interest

The authors have no conflict of interest to declare.

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