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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

# Evaluation of cyclic fatigue resistance of modern Nickel—Titanium rotary instruments with continuous rotation

## *Valutazione della resistenza alla fatica ciclica di strumenti rotanti a rotazione continua prodotti con moderne leghe Nickel-Titanio*

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**KEYWORDS**
Cyclic fatigue;
Nickel-Titanium;
Continuous rotation;
Rotary instruments.

**Abstract**
*Aim:* The aim of present study was to compare cyclic fatigue resistance of three modern Ni—Ti instruments used with continuous rotation.
*Materials and methods:* For this study 3 groups of rotating instruments with continuous rotation (HyFlex EDM, Twisted File Adaptive, Revo S SU) have been used, each group consisted of 20 files. The various groups were subjected to cyclic fatigue testing through an artificial metal device. A statistical analysis with Kruskal—Wallis test and Mann—Whitney test was performed.
*Results:* There were statistically significant differences between the three groups. The HyFlex EDM instruments have a fracture resistance slightly higher than the Twisted file and far higher than Revo S SU.

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**PAROLE CHIAVE**
Fatica ciclica;
Nickel-Titanio;
Rotazione continua;
Strumenti rotanti.

*Conclusions:* Modern Ni—Ti alloys increase resistance of the rotating instruments to cyclic fatigue.


**Riassunto**
*Obiettivo:* Lo scopo di questa ricerca è stato valutare la resistenza alla fatica ciclica di tre differenti Files rotanti prodotti con nuove leghe Ni-Ti con movimento di rotazione continua.
*Materiali e Metodi:* Per la verifica di questo studio sono stati utilizzati 3 gruppi di strumenti rotanti a rotazione continua (HyFlex EDM, Twisted File Adaptive, Revo S SU), ogni gruppo comprendeva 20 files. I vari gruppi sono stati sottoposti a test di fatica ciclica attraverso un dispositivo metallico artificiale. E' stata effettuata una analisi statistica con test di Kruskal-Wallis e test di Mann-Whitney.
*Risultati:* Sono state rilevate differenze statisticamente significative tra i vari gruppi. Gli strumenti HyFlex EDM hanno mostrato una resistenza alla frattura leggermente superiore ai Twisted file e nettamente superiore ai Revo S Su.
*Conclusioni:* Le moderne leghe Ni-Ti determinano una maggiore resistenza dello strumento rotante alla fatica ciclica.


## Introduction

The use of Ni-Ti represented a turning point in the history of Endodontics, in fact it allowed the production of new endodontic instruments both manual and rotating with higher features than stainless steel one, achieving more effective and reproducible results.[1—3]

Ni—Ti alloys used in dentistry have a fair atomic composition of Ni and Ti, corresponding to 55% of Ni and 45% of Ti.[4,5]

In the past the only way to improve performance of Ni—Ti instruments was to change their dimensions, tip, cross-sectional and flutes design.[6,7] With the development of M-wire and Twisted File technology the instruments have been commercialized aiming at improving safety.[8] The movement kinematics is another important factor.[9] Ni—Ti instruments have been traditionally used with a continuous motion, but in the last years a reciprocating movement has been introduced.[10,11]

Some authors demonstrated that the reciprocating motion can extend cyclic fatigue resistance of Ni—Ti instruments when compared to continuous rotation, but these are only preliminary results.[12,13]

Although the use of Ni—Ti alloy involves a series of advantages, the use of these rotating instruments in Endodontics involves a possible and increased risk of fracture compared to steel files use.[14—16]

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.[17] Torsional fatigue is the twisting of a metal about its longitudinal axis at one end, while the other end is in a fixed position.[18,19]

The resistance to cyclic fatigue of Ni—Ti rotary instruments can be increased via improvements in the manufacturing process or by the use of new alloys with superior mechanical properties.[20,21] There have been many studies on the cyclic resistance of different Ni—Ti rotary instruments with different designs or compositions.[22—24]

Therefore, the aim of this study was to compare cyclic fatigue resistance of new rotating files produced with modified Ni—Ti alloys with rotating files produced with common Ni—Ti alloy.

## Materials and methods

Three Ni—Ti rotary instruments — HyFlex EDM (Coltene/Whaledent, Langenau, Germany), Twisted file Adaptive (Kerr, Orange, CA, USA), Revo S SU(Micro-Mega, Besancon Cedex, France) — were selected for the cyclic resistance test. Each group included 20 unused instruments, the size of instruments in Group 1 and 2 was 25/08 and 25/06 for Group 3.

Group 1 was composed by HyFlex EDM Ni—Ti, instruments with complete new properties due to their innovative manufacturing process using electric discharge machining that create unique surface of the new Ni—Ti files and makes the HyFlex EDM files stronger and more fracture resistant.[25] Group 2 was composed by Twisted Files Adaptive, these are formed by twisting a triangular blank in combination with heat treatment and special surface conditioning, which conserves the natural grain structure.[26] Group 3 was composed by Revo S SU, Ni—Ti instruments with asymmetrical cross-section that provides less stress on the instrument and more flexibility.[27]

To evaluate the resistance to cyclic fatigue testing of all instruments, a metal device has been created. The device was composed by a support base to which a rigid locking system for the handpiece was connected. At the head of the handpiece cubes with artificial canals have been set. The entrance of the cubes artificial canal was set in axis with the tools inserted in the handpiece head (Fig. 1).

**Figure 1** Device created for the cyclic fatigue resistance tests of the rotary instruments.

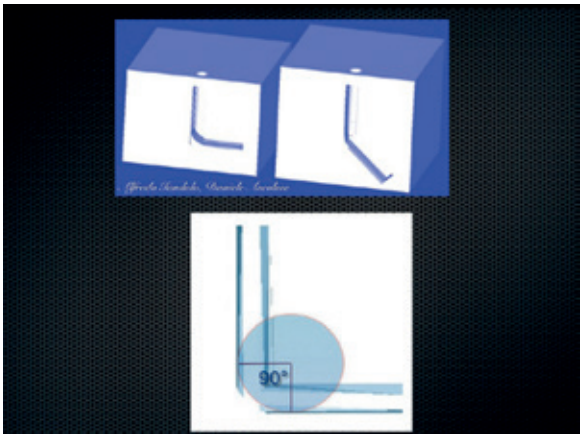


**Figure 2** The artificial canal had an angle of 90° and an arch of 5 mm.

The cubes were created through 3D printing (precision 0.1 mm) with a material similar to dentin, to simulate conditions similar to a true root canal during the test. The artificial canal had an angle of 90° and an arch of 5 mm (Fig. 2).

To avoid variables, for each instrument a new artificial canal has been used. Each instrument was rotated within the artificial canal for a length of 13 mm.

The endodontic motor used was the Elements Motor (Sybron Endo) with Sybron Endo 8:1 contra-angle. Continuous rotation at 300 rpm has been used and the maximum torque delivered by the device.

Each instrument was rotated until fracture occurrence, easily detectable because the device allowed the complete visibility of the working part of the instrument during the test. The times from start of the rotation to the point of fracture, were recorded using a digital stopwatch 1/1000 s.

Mean and standard deviation were calculated (Table 1). All data were recorded and subjected to statistical evaluation with Kruskal—Wallis and Mann—Whitney tests. Statistical significance was set at $p < 0.05$.

**Table 1** Mean and standard deviation of tested Ni—Ti instruments expressed in milliseconds.

| | Mean ± standard deviation |
|---|---|
| HyFlex EDM | 93385,00 ± 2088,635 |
| Twisted file | 80020,00 ± 3095,770 |
| Revo S Su | 31935,00 ± 2077,011 |

## Results

Kruskall—Wallis test indicated significant differences among the tested instruments with $p = <0.001$. Mann—Whitney significance test was set at $p < 0.05$, it showed that HyFlex EDM had a very similar fracture resistance but slightly above to the Twisted File and higher than Revo S Su.

## Discussion

In the literature, there is still a debate regarding the impact of torsional stress and metal fatigue on the fracturing of Ni—Ti rotary instruments.[28] A number of studies have stated that fatigue is the predominant mechanism in material failure.[29,30] Different types of rotary files exhibit differences in resistance to fatigue failure due to differences in various determinants such as their manufacturing process, structural characteristics and geometric designs, surface texture.[31—33]

It has been clearly shown that multiple factors contribute to file separation, and cyclic fatigue is one of the leading causes. Fatigue failure usually occurs by the formation of micro crack at the surface of the file that starts from surface irregularities.[34,35] During each loading cycle micro cracks develop, getting deeper in material, until complete separation of the file.[36]

Gambarini et al.[37] also concluded that instruments made of M-wire alloy did not show higher resistance to fatigue when compared to instruments produced by the traditional Ni—Ti. Further research is required regarding the different factors involved in this matter.

All tested instruments fractured at the point of the maximum flexure within the curved part of the artificial canal where the stress concentrates.

Recent literature show that reciprocating motion can extend cyclic fatigue life when compared to continuous rotation.[12,13,38] However, the term reciprocating motion includes several possible movements and angles, each of which may influence performance and strength of the nickel titanium instruments. All the reciprocating 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.[39,40] This reduction of instrumentation 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 Ni—Ti instruments.[41,42]

In this study HyFlex EDM showed the best characteristics in terms of cyclic fatigue resistance than Twisted Files and Revo S Su.

Finally it should be noted that in clinical conditions, rotary files are used in a dynamic mode, endure torsional stresses and cyclic fatigue at the same time and are bind to the root canal walls; therefore, their fatigue resistance may be different from the results of this study. Further research is required.

## Conclusions

This study showed how modern Ni—Ti alloys increase resistance of the rotating instruments to cyclic fatigue. HyFlex EDM and Twisted Files showed the best characteristics. However, further studies investigating the different factors which can affect the instruments cyclic fatigue resistance are necessary.

## Conflict of interest

The authors have no conflict of interest to declare.

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