



TO COMPARE AND EVALUATE THE CYCLIC FATIGUE RESISTANCE OF THREE NITI ROTARY FILE SYSTEM-AN INVITRO STUDY

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Abstract:

Aim: To compare and evaluate the cyclic fatigue resistance of three NiTi rotary file system

Materials and Methods: Three NiTi rotary system (Hyflex EDM, Protaper Gold and One curve) were used in study. All files were tested in simulated constructed apparatus with angle of curvature 60° and radius of curvature 5mm. The rotary files were used in endomotor X smart (Densply). All the instruments were utilized until fracture occurred, and then the number of cycles to failure (NCF) was calculated. The data were analyzed statistically using Anova test. The statistical significance level was set at $P < 0.05$.

Result: HEDM instruments had the highest cyclic fatigue resistance among all the other instruments ($P < 0.05$). The one curve instruments had a significantly higher fatigue resistance than the Protaper gold instruments ($P < 0.05$).

Conclusion: Within the limitations of this in vitro study, it was found that the cyclic fatigue resistance was higher for the HEDM instruments than for the, Protaper gold and one curve instruments.

Keywords: Cyclic fatigue resistance, heat-treated NiTi instruments, HyFlex EDM, OneCurve

Introduction:

Using nickel–titanium (NiTi) instruments has been the gold standard for preparation and shaping of root canals due to their superelasticity and shape memory since Walia et al.¹ introduced Nitinol in 1988. The superelasticity property enables NiTi instruments to revert to their original shape upon unloading following deformation in a curved root canal due to the austenitic-martensitic crystalline form of the transformations². Unfortunately, instrument fracture continues to be a problem in root canal treatments, in spite of past and current advances.

The unexpected failure of NiTi files during the clinical use arises from two different reasons named cyclic or torsional fatigue³. Torsional fatigue failure occurs when the stress, which emerges when the tip of file is stuck at any point in the canal but the shaft keeps rotating, exceeds beyond the elasticity limits of the instrument⁴. In cyclic fatigue failure, however, the fracture occurs as a result of the accumulation of repetitive tensile and compaction stresses that the file is exposed to in curved canals. The cyclic fatigue was shown to be the main reason for instrument failures during the clinic use³. The kinematics, alloy, and

metallurgical properties of instrument are accepted to be among the factors influencing the cyclic fatigue.

Recently, a number of alterations have been made in the manufacturing process, design, and alloys of traditional NiTi instruments to improve their cyclic fatigue resistance in a curved root canal. Heat treatment (thermomechanical process), one of the most popular approaches, enhances the mechanical properties of NiTi instruments; depending on the phase transition temperatures of the NiTi alloy, this can improve their ability to reduce cyclic fatigue.

One Curve (OC; Micro Mega, Besancon, France) and HyFlex EDM (HEDM; Coltene/Whaledent, Altstatten, Switzerland) are the single file systems working with continuous rotation movement and produced by using different heat treatment procedures. OC is a new generation root canal file, which was recently introduced to the market by manufacturer and is produced with C-Wire heat treatment technology. The manufacturer declares that this technology offers 33% faster root canal preparation in comparison to the reciprocating single-file systems and thus the clinicians would have more time for irrigation.

HEDM, however, works with continuous rotation movement and is made of controlled memory (CM) by using the electronic discharging machining (EDM) technology. This method is based on shaping the file by melting and vaporizing the material through the electrical discharges. EDM technology was reported to give the file a crater-like appearance and an increased resistance to cyclic fatigue.^{5,6}

ProTaper Gold (PG) (Dentsply Tulsa Dental Specialties) rotary systems feature the same exact geometries as ProTaper Universal (PU) rotary systems with advanced metallurgy. PG is made of gold wire that increases its resistance to cyclic fatigue.

It is aimed in the present study to compare the cyclic fatigue resistances of different file systems having different kinematics and heat treatment technologies, which were applied in production process, at the intracanal temperature level.

Materials and methods

10 pcs OC (25/.06), 10 pcs HEDM (25/.08) and 10 pcs Protaper Gold (25/.08) files were involved in the present study.

Cyclic fatigue testing was performed in a stainless steel artificial canal manufactured by reproducing the instrument's size and taper. All files were tested in simulated constructed apparatus with angle of curvature 60° and radius of curvature 5mm. The rotary files were used in endomotor X smart (Densply).

Each file was placed in endomotor X SMART handpiece with file tip between two adjustable metal frame on simulated constructed apparatus. A static fatigue testing device was fabricated which consist of 2 adjustable metal frames made of steel to which an artificial canal system and a support for handpiece were being attached. It was constructed with curvature started at 5mm from tip to canal.

All the instruments were rotated with endomotor X SMART (DENSPLY) according to the manufacturers' recommendations for speed and torque settings. The instruments were rotated until they were broken, and the time to fracture was recorded in seconds. The number of cycles to failure (NCF) was further calculated using the following formula: $(NFC = \text{revolutions per minute (rpm)} \times \text{time to fracture (s)}/60)$. The fractured fragment length (FL) was determined by a digital micro caliper.

Statistical analysis

The observations were statistically analysed using ANNOVA TEST

Table 1: The Means and Standard Deviations of the Number of Cycles to Failure (NCF)

FILE SYSTEM	NCF	F VALUE	P VALUE	SIGNIFICANCE
Hyflex EDM	116.23 ±4.41			
One Curve	64.85±3.34	1963.7	< 0.05	Significant
Protaper Gold	35.28±2.32			

Result

The intergroup comparison for time to fracture was done by using one way ANNOVA, the difference was found to be statistically significant at $p < 0.05$.

Hyflex EDM is having high mean and standard deviation of 116.23 ±4.41 followed by one curve (64.85±3.34) and protaper gold (35.28±2.32)

Discussion

Cyclic fatigue is the major reason for the instrument fracture that occurs unexpectedly at the instrument's maximum flexure point while it is rotating freely inside curved root canals⁷. Therefore, it is very important to conduct cyclic fatigue tests on novel NiTi instrument systems; doing so provides clinicians with information about their resistance to fracture. Standardization of natural teeth cannot be achieved due to their different morphological properties; therefore, they are not suitable for a cyclic fatigue test. We used a nontooth model as have many other studies in the literature. An artificial stainless-steel simulated root canal with a 60° angle of curvature and a 5 mm radius of curvature was used to test the instruments in the cyclic fatigue model.

This study compared the fatigue resistance of newly developed HEDM, PG and OC instruments manufactured using different heat treatments, in an artificial root canal. All of these instruments has common features, such as flexibility and superelasticity. Superelasticity is an isothermal phenomenon in which the material can recover from a high degree of strain triggered by mechanical stress⁸. The instruments in this study can change their shape against very low mechanical stress and do not tend to return to their previous shape upon removal of the stress, unlike traditional NiTi instruments. Therefore, they can be easily utilized even in the most anatomically complex root canal. Each manufacturer uses a different word to describe the alloys in the instruments it produces, such as CM wire, Gold

wire or C. Wire According to the manufacturer of HEDM, its instrument has a shape memory effect; thus, after autoclave sterilization, the shape of a used instrument can be recovered. In this study, the NCF was significantly higher in the HEDM instruments than the OC and PG instruments ($P < 0.05$).

This can be because the processing of the CM wire using electrical-discharge machining technology increases the phase transformation temperatures and hardness. Kaval *et al.*⁹ evaluated the cyclic fatigue resistance of HEDM, PG, and PU instruments.

According to the results of this study, the OC instruments showed the higher resistance to cyclic fatigue than PG instruments. The OC instrument is a new product of the company that produces the One Shape instrument. Although there are similarities between the two products, such as cross-sectional designs, cross-sectional area at 5 mm of OC is smaller than OS instruments. Not only for this reason, OC instrument, unlike the OS instrument, has a higher fracture resistance due to the fact that it is produced from an alloy with a martensitic transformation called C.Wire.

Conclusion

Within the limitations of the present *in vitro* study, the HEDM instruments were found to more effectively resist cyclic fatigue than the OC and PG instruments. Moreover, the OC instruments were found to be more resistant to cyclic fatigue than the PG instruments

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