Cyclic Fatigue Resistance Of Three Root Canal Ni-Ti Systems

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List of Abbreviations

Abbreviation	**Meaning**
Ni-Ti	Nickel Titanium
TF	Twisted File
WO	WaveOne
PTU	ProTaper Universal
PTX	ProTaper Next
CF	Cyclic Fatigue
ES	Endosequence
PF	ProFile
TtF	Time to fracture
CW	Clock wise
CCW	Counter clock wise
NCF	Number of cycles to fracture

Fractured rotary Ni-Ti instruments have been classified into those that fail as a result of cyclic flexural fatigue or torsional failure or a combination of both. Clinically, Ni-Ti rotary instruments are subjected to both torsional load and cyclic fatigue. The use of reciprocating movement was claimed to increase the resistance of Ni-Ti file to fatigue in comparison with continuous rotation. Recent improvements in alloys, kinematics, and concepts have been combined to increase the cyclic fatigue resistance of Ni-Ti instruments.

During instrumentation an instrument is inserted and withdrawn from diverse canal configurations, many of which are curved. As a Ni-Ti file bends, it is subjected to compressive stresses on the inside of the curvature. In addition, file motion in this curved posture subjects the file to hundreds of cycles of alternating compression and tension. Memory characteristics and phase transitions of Ni-Ti impart the ability to cycle through the bending demands of a curved canal without fracturing. However, inherent cyclic fatigue resistance is depleted with us, as the additive effects of fatigue stresses accumulate until they eventually exceed the elastic limit. Thus, without warning, file separation may occur as a consequence of cyclic fatigue, torsional fatigue or a combination of both.

Factors influencing cyclic fatigue are often described individually, yet they act collectively. As the radius of curvature decreases, number of cycles to failure also decreases. In addition, a more severe angle of curvature produces greater stress, especially if coincident with a small radius of curvature. File design features such as Ni-Ti core diameter and flute depth may account for different fatigue properties seen among different file brands.

The ProTaper Ni-Ti rotary system was introduced to the dental market in 2001 and is considered one of the most popular rotary systems. It is made of conventional Ni-Ti alloy and had variable taper along its length.

The Twisted File is manufactured using the R-phase technology. The R-phase technology depends on grinding a superelastic wire to form a file blank . The file blank is maintained in the austenite phase of Ni-Ti until it is twisted, when the stress from the plastic deformation of twisting induces martensite formation. A heat treatment step may be performed prior to twisting, during twisting or after twisting of the blank, to further enhance superelastic file properties.

One of the commercially available Ni-Ti rotary systems using M-Wire Ni-Ti material is the WaveOne Systems. It was first introduced to the dental market in 2010. It is a prepackaged, pre-sterilised, single-use system. According to the manufacturer, the M-Wire technology allows the WaveOne instruments more flexibility and resistance to cyclic fatigue. Instead of a rotary motion, the files work in a reverse “balanced force” cutting motion and is driven by a pre-programmed motor that is capable of moving the files in a back and forth “reciprocating” motion.

Compared to reciprocation, continuous rotation utilizing well-designed active Ni-Ti files requires less inward pressure and improves hauling capacity augering debris out of a canal. A reciprocating instrument travels a shorter angular distance than a rotary instrument, which subjects the instrument to lower stress values. Consequently, an instrument should have an extended fatigue life when used in reciprocation as opposed to rotary motion. The development of endodontic instruments used in a reciprocating manner aims to reduce the incidence of breakage .It mimics manual movement and reduces the various risks associated with continuously rotating a file through canal curvatures& decrease screw in the canal.

Based on the previous findings and theories it was thought to be of value to compare three different Ni-Ti systems available in the market concerning their cycling fatigue in two rotation modes and different radii.

Separation of rotary Ni-Ti instruments occurs due to torsional failure or flexural fatigue. Whether the fracture occurs due to the influence of one of them or due to combined effect, Yet cyclic fatigue is proved to be an important reason for instrument separation during clinical use . In this part of the study the history of files under investigation will be discussed, in addition to the effect of mode of motion, effect of methods of file fabrication, and effect of canal geometry and radius of curvature on cyclic fatigue.

I. History of files under investigation:

1. ProTaper Universal:

Ullmann et al.[1] evaluated static fracture loads of ProTaper Ni-Ti instruments that had been subjected to various degrees of cyclic fatigue. Torque and angle at failure of new instruments and instruments that had been stressed to 30, 60, or 90% of their cyclic fatigue rotations in a simulated canal (90° and 5 mm radius) were tested. With unused ProTaper instruments, resistance to cyclic fatigue decreased with diameter increase and ranged from 158 to 450 rotations. Cyclic prestressing significantly reduced torsional resistance in finishing files, while shaping files were largely unaffected. In conclusion, build-up of tension within Ni-Ti rotary instruments depends on instrument diameter. Clinically, larger instruments that have been subjected to some cyclic fatigue should be used with great care or discarded.

Voreadi et al.[2] evaluated the failure mechanism of ProTaper Ni-Ti rotary instruments fractured under clinical conditions. A total of 46 ProTaper instruments that failed (fractured and/or plastically deformed) during the clinical use were collected from various dental clinics, wherease a new set of ProTaper instruments served as control. After inspection under stereomicroscopy the instruments were classified into three categories: (a) plastically deformed but not fractured, (b) fractured with plastic deformation and (c) fractured without plastic deformation. Three instruments from each group were analyzed with computerized X-ray microtomography (micro-XCT) to detect surface and internal defects, whilst all the fractured surfaces were investigated under SEM. Steriomicroscopic inspection showed that 17.4% of the discarded instruments were only plastically deformed, 8.7% were fractured with plastic deformation and 73.9% were fractured without plastic deformation. Micro-XCT revealed instruments without any surface or bulk defects along with a few files with crack development below the fractured surface. No defects were identified in the unused instruments. SEM examination of the fractured surfaces demonstrated the presence of dimples and cones, a typical pattern of dimple rupture developed because of ductile failure. The results suggest that a single overloading event causing ductile fracture of ProTaper instruments is the most common fracture mechanism encountered under the clinical conditions.

Wei et al.[3] investigated the mode of fracture of ProTaper rotary instruments after clinical use and compared stereomicroscopy with scanning electron microscope (SEM) to determine which is better for confirming the mode of material failure. In all, 100 fractured ProTaper instruments were examined under stereomicroscope for the presence of plastic deformation along the cutting edge near the fracture site. Fractographic and longitudinal examinations were carried out at high power magnification with SEM. Steriomicroscopy revealed 88 flexural cases and 12 torsional cases. Fractomicrographs verified 91 flexural cases with fatigue striations and three torsional cases with circular abrasion marks. Six instruments showed characteristics of both flexural and torsional failure. Cracks, microcracks and pittings were common findings on longitudinal micrographs. This study demonstrated that inspecting the fractured surface at high magnification by SEM is a better method to reveal the mode of Ni-Ti rotary instrument separation.

Ounsi et al.[4] studied the effect of clinical use on the cyclic fatigue resistance of ProTaper nickel-titanium rotary instruments. The resistance of ProTaper nickel-titanium rotary instruments to cyclic fatigue was examined after their initial use in straight or curved canals in vivo. These instruments were rotated freely inside a steel phantom until separation. The number of rotations before failure and the lengths of the separated fragments were compared with data derived from new instruments under the same experimental setup. With the exception of F1 and F3, instruments previously used in curved canals were more susceptible to cyclic fatigue than those previously used in straight canals . Separation occurred predominantly at the D10 to D12 level. For the F series, a negative correlation was observed between the number of rotations before failure and the file diameters at their separation levels. ProTaper F3 instruments are highly susceptible to cyclic fatigue failure and should be reused with caution irrespective of whether they are initially used for shaping straight or curved canals.

Whipple et al.[5] compared cyclic fatigue resistance of ProTaper Universal and V-Taper (Guidance Endo, Albuquerque, NM). Files was measured while rotating around a 5-mm radius curve with 90° of maximum flexure at 250 rpm with a continuous axial oscillation of 4 mm at 1 Hz. The number of cycles to failure was calculated and analyzed. For the instruments tested, the ProTaper files appeared to resist fracture better than the V-Taper files.

Lopes et al.[6] evaluated the effects of rotational speed on the number of cycles to fracture of ProTaper Universal instruments F3 and F4. They were used in an artificial curved canal under rotational speeds of 300 rpm or 600 rpm. The number of cycles required to fracture was recorded. Fractured surfaces and the helical shafts of the fractured instruments were analyzed by scanning electron microscopy. The results showed approximately a 30% reduction in the observed number of cycles to fracture as rotational speed was increased from 300 to 600 RPM . The morphology of the fractured surface was always of ductile type, and no plastic deformation was observed on the helical shaft of fractured instruments.

Shen et al.[7] investigated the mode of failure of ProTaper, ProTaper for Hand Use and K3 that separated during clinical use. A total of 79 fractured instruments were collected from three endodontic clinics over 16 months . The fracture surface of each fragment was examined by scanning electron microscope. Most of the rotary instruments (78% of K3 and 66% of ProTaper) failed