In Vitro Comparison of Cyclic Fatigue Resistance of ProTaper Next, HyFlex CM, OneShape, and ProTaper Universal Instruments in a Canal with a Double Curvature

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Abstract

Introduction: The aim of this study was to compare the resistance to cyclic fatigue of ProTaper Next X2 (PTN X2; size 25, 0.06 taper), Hyflex CM (HCM; size 25, 0.06 taper), OneShape (OS; size 25, 0.06 taper), and ProTaper Universal F2 (PTU F2; size 25, 0.08 taper) nickel-titanium files in an artificial root canal with a double (S-shaped) curvature. **Methods:** A total of 160 new PTN X2, OS, HCM, and PTU F2 files were tested in an artificial stainless steel canal with a double curvature. Forty files from each system were rotated until fracture to calculate the number of cycles to failure. The length of each fractured fragment was recorded. Data were analyzed by using one-way analysis of variance and Tukey post hoc tests. **Results:** The resistance to cyclic fatigue of the PTN X2 and HCM instruments was significantly greater than the OS and PTU F2 instruments in the apical curvature ($P < .05$). There was no statistical difference in the cyclic fatigue resistance of the PTN X2 and HCM instruments in the apical curvature ($P > .05$). In addition, there was no statistical difference between the OS and PTU F2 instruments in the apical curvature ($P > .05$). PTN X2, OS, HCM, and PTU F2 instruments showed similar cyclic fatigue resistance values in the coronal curvature ($P > .05$). **Conclusions:** This study showed that PTN X2 and HCM instruments exhibit greater resistance to cyclic fatigue than OS and PTU F2 instruments in the apical curvature of an artificial canal with a double curvature. *(J Endod 2016;42:969–971)*

Key Words

Cyclic fatigue, Hyflex CM, NiTi files, ProTaper Next, S-shaped canal

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Root canal shaping is one of the most important steps in root canal therapy. Traditionally, root canal shaping has been carried out by using stainless steel hand files. However, during the 1980s nickel-titanium (NiTi) files were introduced (1). NiTi files offer significant advantages such as the ability to maintain the original root canal shape and prevent the creation of irregularities (eg, zipping, ledge formation, and perforation). NiTi file systems vary in terms of cross-section, blade, and pitch designs and taper angles. In spite of these innovations, management of teeth with curved canals remains a challenge (2).

ProTaper Universal (PTU) (Dentsply Maillefer, Ballaigues, Switzerland) is a variable-taper rotary file system. This design is supposed to reduce torsional loads, instrument fatigue, and potential breakage (3). OneShape instruments (OS) (Micro-Mega, Besancon, France) are used in a traditional continuous rotation motion. They have a triangle cutting edge in the apical part, 2 cutting edges in the coronal part, and a cross section that progressively changes from 3 to 2 cutting edges between the apical and coronal parts; this design offers an optimal cutting action (4). Hyflex CM files (HCM) (Coltene-Whaledent, Allstetten, Switzerland) are made from a new type of NiTi wire, namely controlled memory (CM) wire, which has been subjected to proprietary thermomechanical processing. It has been manufactured by a unique process that controls the material's memory, making the files extremely flexible but without the shape memory typical of other NiTi files (5). ProTaper Next (PTN) (Dentsply Maillefer) was developed by using the new M-Wire alloy. Its design features include variable tapers and an off-centered rectangular cross section (6).

Fracture of canal instruments used in rotary motion occurs in 2 ways, fracture caused by torsion and fracture caused by cyclic fatigue (7, 8). Cyclic fatigue occurs when metal is subjected to repeated cycles of tension and compression, causing its structure to break down and ultimately leading to fracture (9).

To date there is no study comparing the resistance of PTN, OS, HCM, and PTU instruments to cyclic fatigue in an artificial root canal with a double (S-shaped) curvature. Therefore, the aim of this study was to compare the resistance to cyclic fatigue of PTN X2, OS, HCM, and PTU F2 instruments in an artificial canal with a double curvature. The null hypothesis tested was that there is no difference in the cyclic fatigue resistance of the PTN X2, OS, HCM, and PTU F2 instruments.

Materials and Methods

A total of 160 new PTN, OS, HCM, and PTU instruments were tested in a double-curved (S-shaped) artificial canal. The instruments selected were PTN X2 (size 25, .06 taper), OS (size 25, .06 taper), HCM (size 25, .06 taper), and PTU F2 (size 25, .08 taper). Before the experiment, each instrument was inspected for defects and deformities by using a stereomicroscope (BX60; Olympus, Tokyo, Japan) at ×30 magnification, and none were discarded.

Forty instruments from each system were subjected to cyclic fatigue testing by using a stainless steel block containing an S-shaped artificial canal specifically developed for the purpose that has been used in previous studies (10, 11). All instruments

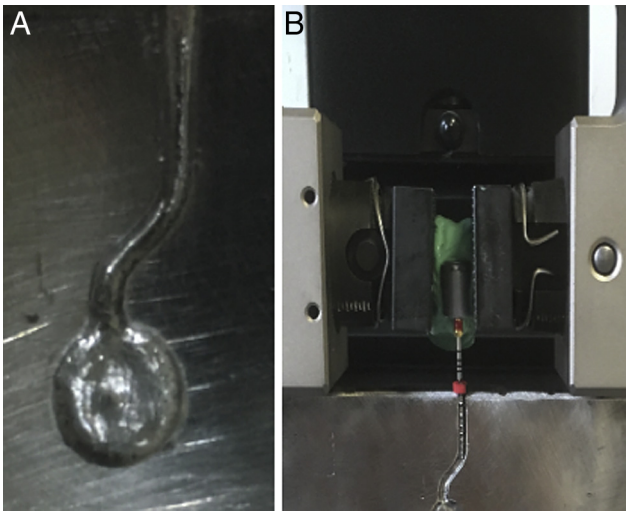

Figure 1. *(A* and *B)* Cyclic fatigue testing device.

were tested inside an artificial canal with a double curvature; the first was a coronal curve with a 50° angle of curvature and a radius of 5 mm and was located 8 mm from the tip of the instrument; the second was an apical curve with a 70° angle of curvature, a radius of 2 mm, and a center 2 mm from the tip.

The electric handpiece was mounted on a device to allow for precise and reproducible placement of each file inside the S-shaped artificial canal (Fig. 1), ensuring 3-dimensional alignment and positioning of each instrument to the same depth each time. All the instruments were operated with a torque-controlled electric motor (X-Smart; Dentsply Maillefer) and were used according to the manufacturers' recommendations as follows: PTN at 300 rpm and 2 N/cm torque, PTU at 300 rpm and 3 N/cm torque, HCM at 500 rpm and 2.5 N/cm torque, and OS at 350 rpm and 2.5 N/cm torque. To reduce friction and prevent overheating while working inside the S-shaped artificial canal, oil (WD-40 Company, Milton Keynes, England) was used for lubrication. The procedure was timed, and the clock was stopped as soon as a fracture was visually detected. The length of time between the beginning of the procedure until instrument fracture occurred was recorded. The experimental procedure was performed by a single operator to avoid inter-operator variability. The number of cycles to fracture (NCF) was then calculated by using the following formula: NCF = time (seconds) to failure × rotational speed/60. Moreover, in double-curved artificial canals, if the fracture occurred first in the apical curve, the time to fracture and NCF were also registered for the coronal fragment. The length of each fractured tip was measured by using a digital caliper (Absolute Digimatic; Mitutoyo Corp, Kawasaki, Japan).

Statistical Analysis

The NCF and the fractured fragment length data were analyzed by using one-way analysis of variance and Tukey post hoc tests. The level of significance was set at $P < .05$. All statistical analyses were performed by using SPSS 16.0 software (SPSS Inc, Chicago, IL).

Results

The mean NCF and length of the fractured fragments for PTN X2, OS, HCM, and PTU F2 instruments are presented in Table 1. All files fractured first in the apical curvature and then in the coronal curvature. One-way analysis of variance and Tukey post hoc tests showed that PTN X2 and HCM had significantly higher NCF than OS and PTU F2 instruments in the apical curvature ($P < .05$). PTN X2 and HCM had similar cyclic fatigue resistance values in the apical curvature ($P > .05$). There was no statistical difference between OS and PTU F2 instruments in the apical curvature ($P > .05$). PTN X2, OS, HCM, and PTU F2 instruments had similar cyclic fatigue resistance values in the coronal curvature ($P > .05$). There was no statistical difference between the PTN X2, OS, HCM, and PTU F2 instruments with respect to the lengths of the fractured file fragments in either the apical or coronal curvatures ($P > .05$).

Discussion

It is well-known that the extent of the curvature in the area of operation is one of the primary variables that contribute to instrument fatigue fracture. Under clinical conditions, 2 curves can exist in the same root canal trajectory. This type of geometry is denoted as being "S"-shaped, which is one of the most challenging clinical conditions in which to use NiTi instruments (12). An additional challenge is that in many cases, double curvatures are not visible in conventional radiographs. Al-Sudani et al (10) stated that fatigue of NiTi instruments when used in S-shaped canals occurs very quickly. Consequently, instrument fracture might occur after a very short time of use inside the apical curvature. In the literature, there is limited information on cyclic fatigue resistance of NiTi instruments during preparation of S-shaped canals. Moreover, the cyclic fatigue resistance of PTN, OS, HCM, and PTU instruments made of different NiTi alloys when used in S-shaped canals had not been previously compared.

A major drawback of most laboratory studies that have tested the fatigue behavior of NiTi rotary instruments is that all of the different contributing factors (ie, the material properties and design and dimensions of each instrument, which are specific to each brand tested) cannot be totally eliminated. This makes it difficult to quantify the effect of a single variable on fatigue behavior (13). The clinical relevance of the results of such tests is difficult to assess because this condition differs from intracanal instrumentation in which the fracture occurs because of several factors (including torsional stress) that act together at the same time (14). Although the use of extracted

TABLE 1. Number of Cycles to Fracture (NCF) and Length (mm) of Fractured Fragments of Instruments during Cyclic Fatigue Testing

	Coronal curvature				Apical curvature			
	NCF		FL (mm)		NCF		FL (mm)	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ProTaper Next	876.12	213.46	6.12	1.01	756.28	171.64	2.02	0.46
ProTaper Universal	911.62	269.33	5.83	0.98	516.35	124.18	2.15	0.49
HyFlex CM	902.27	286.21	5.79	1.18	793.47	204.47	2.56	0.61
OneShape	862.31	198.37	5.73	1.21	524.64	165.46	2.14	0.37

FL, fracture length; SD, standard deviation.

teeth simulates clinical situations, they are not anatomically standardized (15). The use of simulated canals is particularly important when investigating S-shaped canals because it is nearly impossible to select an adequate sample of anatomically standardized human teeth all with S-shaped canals and with similar canal lengths, degree and radius of both curvatures, and diameters (16). Therefore, extracted teeth are not ideal for testing the cyclic fatigue of NiTi instruments. The use of standardized artificial canals in cyclic fatigue experiments minimizes the influence of other variables not related to the instrument itself. The cyclic fatigue test was performed by using a stainless steel block containing the double curvature artificial canal. All instruments tested in the present study fractured in the apical curvature area. The explanation for this may be that the apical curvature was more abrupt than the coronal curvature, which is in agreement with previous studies evaluating cyclic fatigue resistance of various files in double curvature canals (10, 17).

Cheung et al (13) determined that instruments with a triangular cross-sectional design possessed greater cyclic fatigue resistance than those with a square cross-sectional design. This difference is related to the reduced metal mass of the files with a triangular cross section compared with files with a square cross section and similar diameter (18). The PTN, OS, HCM, and PTU files have rectangular, asymmetrical, symmetrical triangular, and triangular convex cross-section designs, respectively. The results of the current study show that PTN files (rectangular cross-sectional design) and HCM files (symmetrical triangular cross-sectional design) exhibit greater cyclic fatigue resistance than OS and PTU instruments in the apical curvature but not in the coronal curvature. In addition, this could be due to metallurgical differences between instruments. PTN and HCM instruments are made with M-Wire and heat-treated NiTi alloys, respectively, whereas OS and PTU instruments are made with a conventional NiTi alloy. Elnaghy (19) stated that the improved cyclic fatigue resistance of PTN files might be associated with its non-uniform design and the reduced number of contact points between the instrument and the root canal walls. On the basis of the findings of the current study, the null hypothesis was rejected, because the PTN X2 and HCM instruments exhibited greater cyclic fatigue resistance than the OS and PTU F2 instruments in the apical curvature but not the coronal curvature. Plotino et al (20) evaluated the cyclic fatigue resistance of HCM, ProFile, and Vortex systems in a simulated root canal with a 60° angle of curvature and determined that HCM exhibited greater cyclic fatigue resistance than ProFile and Vortex systems. Nguyen et al (21) compared the fracture resistance with cyclic fatigue of PTN, PTU, and Vortex Blue rotary instruments in a simulated root canal with a 90° angle of curvature and determined that PTN X2 instruments were more resistant to cyclic fatigue than PTU F2 instruments. Peters et al (22) stated that HCM instruments were highly bendable and had higher fatigue resistance than files made of conventional NiTi alloy. This is compatible with the findings of the current study.

Neelakantan et al (11) evaluated the cyclic fatigue of a rotary (OS made of conventional NiTi alloy) and reciprocating (Reciproc made of M-Wire) single file system in a simulated S-shaped canal and determined that Reciproc had a longer fatigue life than the OS system. In the present study, PTN (M-Wire) and HCM instruments had greater cyclic fatigue resistance than PTU (conventional NiTi alloy) and OS (conventional NiTi alloy) instruments in the apical curvature.

In the current study, the fractured fragments showed no significant difference in the mean length of all files tested. The fractured length of the file was at the center of the curvature or just below this point, which confirms the positioning of the instruments in a precise trajectory.

Conclusions

Under the experimental conditions of the current study, it can be concluded that the PTN X2 and HCM instruments exhibited greater cyclic fatigue resistance than the OS and PTU F2 instruments in the apical curvature of an artificial canal with a double curvature.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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