Cyclic Fatigue of ProFile Vortex and Vortex Blue Nickel-Titanium Files in Single and Double Curvatures

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Abstract

Introduction: The aims of this study were to determine the flexibility of ProFile Vortex (VX) and Vortex Blue (VB) files (Dentsply Tulsa Dental Specialties, Tulsa, OK) and then to evaluate and compare their fatigue resistance in artificial single curvature and 2 different artificial double curvature canals. **Methods:** Flexibility of the files (size 25/.04) in bending was assessed according to ISO 3630-1. Both files were subjected to fatigue tests inside artificial canals with a single curvature (group 1: 60° curvature, 5-mm radius) and with 2 different double curvatures (group 2: first [coronal] curve of 60° curvature and 5-mm radius and the second one [apical] of 30° curvature and 2-mm radius and group 3: first curve of 60° curvature and 5-mm radius and the second one of 60° curvature and 2-mm radius). The number of cycles to fracture (NCF) was recorded, and the fracture surface of all fragments was examined with a scanning electron microscope. **Results:** The bending load was significantly lower for VB files than VX files ($P < .05$), and the 2 types of files followed different trajectories in identical canals. In group 1, the 2 files had significantly higher NCF than in groups 2 and 3 ($P < .05$). Both files had significantly higher NCF in group 2 than in group 3 ($P < .05$). In group 1, VB files had fatigue resistance superior to VX files ($P < .05$), whereas in groups 2 and 3 their fatigue resistance was not statistically different from each other. The crack initiation of a vast majority of files that fractured in double curvature canals (groups 2 and 3) was localized on either 1 of 2 of the 3 cutting edges. **Conclusions:** Double curvature canals represent a much more stressful and challenging anatomy than single curvature canals, and, in them, fatigue resistance may be affected by the degrees and the radii of curvatures as well as by the bending properties of the files. *(J Endod 2015;41:1686–1690)*

Key Words

Bending property, double curvature, fatigue resistance, nickel-titanium files, ProFile Vortex, Vortex Blue

Thermomechanical processing is frequently used to optimize the microstructure and transformation behavior of nickel-titanium (NiTi) alloys, which, in turn, has a great influence on the reliability and mechanical properties of NiTi files (1–7). In 2009, ProFile Vortex (VX) files (Dentsply Tulsa Dental Specialties, Tulsa, OK), the "next generation" in the ProFile file series, were introduced (7–9). These files are manufactured from M-wire, and they have a triangular cross section without radial lands. In 2011, Vortex Blue (VB) files (Dentsply Tulsa Dental Specialties) were introduced; they are also made from M-wire and have similar design features to VX files. VB files have a unique blue color not seen in traditional superelastic NiTi files (3), which is a result of a proprietary manufacturing process that creates an oxide surface layer. These files have been reported to have improved material properties that increase their fatigue resistance and flexibility compared with VX files (3, 10).

The majority of teeth have curved canals, not only in 1 but in multiple orientations relative to the root canal system and in different planes (11–13). Cunningham and Senia (11) studied canal curvature in mesial roots of mandibular first and second molars by an *in vitro* radiographic technique. They found that the root canal curvature was 3-dimensional, and the curvature in the proximal view could not be predicted by examining radiographs in a clinical view. The secondary curvatures were more frequently seen in the proximal view compared with the clinical view (30% vs 2.5%). The unique morphology of dilacerated or S-shaped (double curvatures) root canals can be troublesome and challenging; it involves at least 2 curves, with the apical curve being the most vulnerable to deviations in anatomy, loss of working length, and potential for file separation. Fatigue has been implicated to be the main reason for the fracture of clinically used endodontic files (14, 15), with fatigue in the low-cycle region being frequently implicated. Flexural fatigue fractures occur after repeated subthreshold loads have caused metal fatigue. The degree of root curvature and file stiffness have both been implicated in canal preparation errors and file fracture. In a single curvature canal, the degree of curvature can affect the fatigue life of files (16, 17), but little information is available on the effect of a double curvature canal on fatigue. Therefore, the aims of this study were to determine the flexibility of VX and VB files and then to evaluate and compare their fatigue resistance in artificial single curvature canals and in 2 different artificial double curvature canals.

Materials and Methods

Two NiTi files, VX and VB, size 25/.04, were used. Flexibility was determined via a bending test performed using a torsiometer (Sabri Dental Enterprises, Downers Grove, IL) at room temperature according to ISO 3630-1 (18). The files were secured at a distance of 3 mm from the tip and then bent 45° about their long axis. The bending

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moment at an angular deflection of 45° was recorded. Twelve files for each group were tested.

Three types of artificial canals, with size 30/.06, were milled in stainless steel blocks using a benchtop numeric computer control machine: an artificial single curvature canal model (group 1: 60° curvature, 5-mm radius) (Fig. 1*A1*) and 2 double curvature models (group 2: first [coronal] curve of 60° curvature and 5-mm radius and second [apical] curve of 30° curvature and 2-mm radius (Fig. 1*B1*) and group 3: first curve of 60° curvature and 5-mm radius and second curve of 60° curvature and 2-mm radius [Fig. 1*C1*]).

Both VX and VB files (12 per group) were subjected to fatigue tests inside the artificial canals. A calibrated digital photograph was taken of each of the curvatures. The files were rotated at a constant speed of 500 rpm (AEU-20 Endodontic System, Dentsply Tulsa Dental Specialties) at the recommended torque values. To reduce the friction of the file as it made contact with the artificial canal walls, synthetic oil (Boyle Midway, Toronto, Canada) designed for lubrication of mechanical parts was applied. The fatigue life, given by the number of cycles to fracture (NCF), was recorded. The length of the detached fragments was measured using a stereomicroscope at 10× (Microdissection; Zeiss, Bernried, Germany). The fractured files were further cleansed in absolute alcohol in an ultrasonic bath, and fractographic examination of the fractured surfaces was performed using a scanning electron microscope at magnifications of 200–1000× operating at 3–7 kV (Helios NanoLab 650; FEI, Eindhoven, The Netherlands) (17).

Geometric analysis of the trajectory each file followed inside the artificial canal was performed on the recorded digital images. The angle and radius of the curvature were determined using the osculating circumference method via computer software (ImageJ 1.34n; National Institutes of Health, Bethesda, MD) (19, 20). The angle of curvature was defined as the number of degrees on the arc of the circle between the beginning and end points of the curvature, whereas the radius of the circle was defined as the radius of the canal curvature in millimeters.

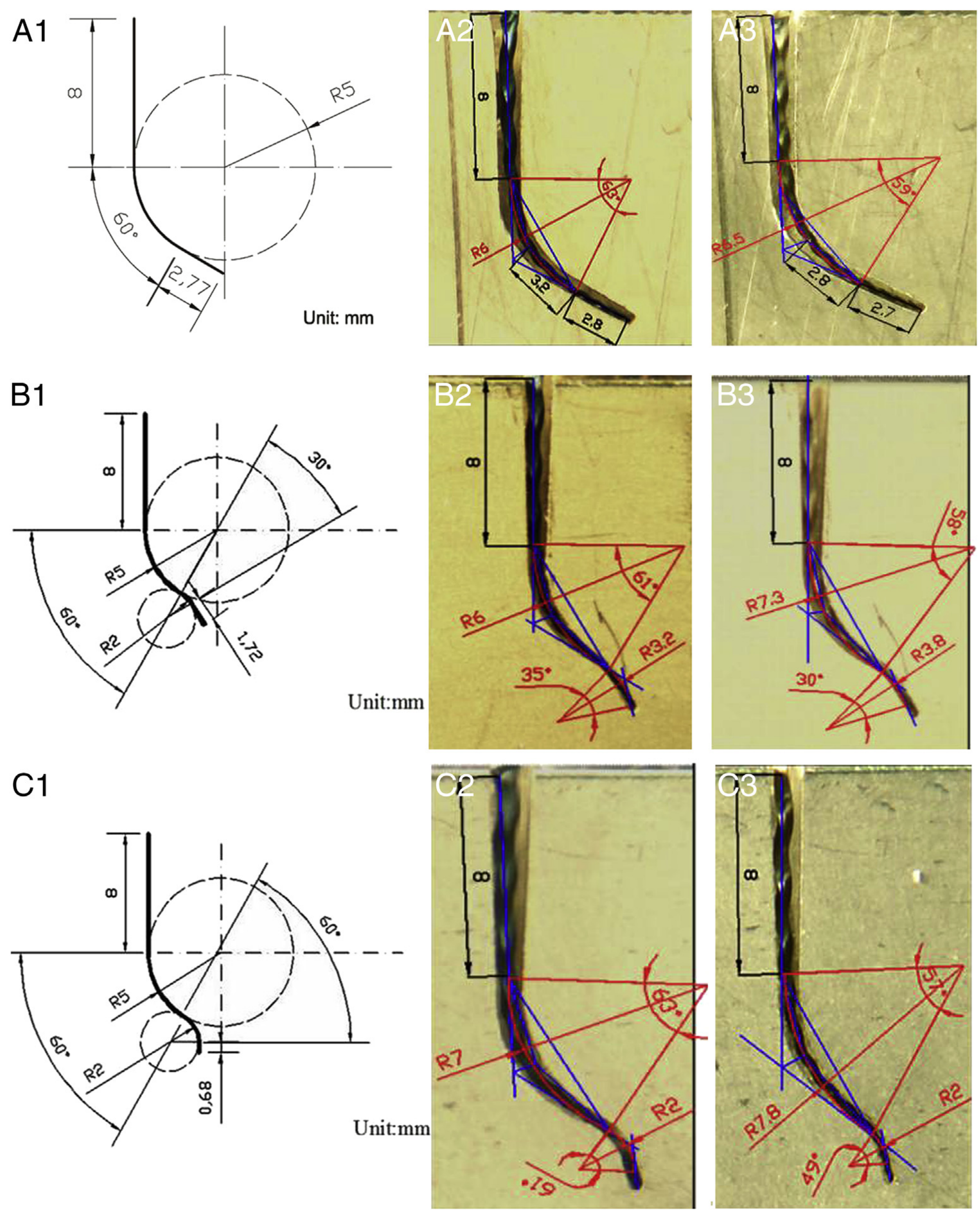

Figure 1. Schematic drawings of a (*A1*) single curvature and (*B1* and *C1*) double curvatures. The geometric parameters of the trajectories of VB files (*A2*, *B2*, and *C2*) and (*A3*, *B3*, and *C3*) ProFile VX files in the artificial canals.