WaveOne Rotary Instruments after Clinical Use

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Abstract

Introduction: The purpose of this study was to evaluate the incidence and mode of WaveOne (Dentsply Tulsa Dental Specialties, Tulsa, OK) instrument defects after single use at different endodontic clinics. **Methods:** A total of 438 WaveOne instruments were collected after clinical use from the 4 specialist clinics over a 12-month period and from 1 graduate program over a 20-month period. The incidence and type of instrument defects were analyzed. The lateral surfaces of part of the defective instruments and fracture surfaces of fractured files were examined using scanning electron microscopy. Unused and clinically used files were examined by a nanoindentation test. **Results:** Of the 438 WaveOne instruments collected, 42 (9.6%) had defects: 40 (9.1%) were distorted and 2 (0.5%) files had fractured, 1 Small and 1 Primary file. Clear differences in the frequency of defects were found among the 3 file sizes; the occurrence of distortion and fracture were highest with the Small file (21.2% and 0.7%, respectively) followed by the Primary file (4.4% and 0.4%, respectively) ($P < .05$). No defects were detected on the Large file. The cause of the 2 fractures was shear stress. Instruments from various clinics showed no significantly different occurrence of instrument deformation. Unwinding occurred at 1.2–3.1 mm from the tip. No significant difference in nanohardness was detected among unused and used instruments. **Conclusions:** The risk of WaveOne fracture is very low when files are singly used by endodontists and residents. Unwinding of the files occurred most frequently in the Small file. The frequency of defects of WaveOne instruments were not influenced by the operator. *(J Endod 2016;42:186–189)*

Key Words

Clinical use, fracture, nickel-titanium instrument, operator, shear failure, WaveOne

Reciprocation, defined as any repetitive back-and-forth motion, has been clinically used to drive stainless steel files since 1958 (1). The use of reciprocating motion as an alternative to conventional continuous rotation has been recently suggested to be convenient in the instrumentation of curved canals with the employment of a single nickel-titanium (NiTi) file (2). Reciprocating motion was shown to extend the life span of an NiTi instrument and its resistance to fatigue in comparison with continuous rotation (3–6). In 2011, WaveOne files (Dentsply Maillefer, Ballaigues, Switzerland) were introduced to the market as a single-use, single-file system that follows the reciprocation concept. There are 3 files available in the WaveOne system: Small (tip size of 21 mm and 0.06 taper), Primary (tip size of 25 mm and 0.08 taper), and Large (tip size of 40 mm and 0.08 taper). The instruments are designed to work with a reverse cutting action and are manufactured with M-wire technology, which has been shown to improve resistance to cyclic fatigue by up to 2 to 3 times in comparison with traditional superelastic NiTi files (7). All WaveOne instruments have a modified convex triangular cross section at the tip end and a convex triangular cross section at the coronal end. This design improves instrument flexibility overall. The WaveOne system has potential advantages that include a reduced number of instruments, lower cost, reduced instrument fatigue (continuous vs reciprocating motion) (6), better canal centering ability (WaveOne vs ProTaper [Dentsply Tulsa Dental Specialities, Tulsa, OK] and ProFile [Dentsply Maillefer]) (8, 9), and reduction of taper lock.

A number of studies have examined the failed NiTi instruments collected after clinical use (10–15). Several observations have been made of factors contributing to instrument fracture, including operator proficiency, method of use, rotational speed, anatomic configuration of the canals, design of the instrument, and number of sterilization cycles. Interestingly, factors related to operators, such as experience, were ranked as the most important (11, 14, 16). The clinician's ability to understand the risks of acute curvatures (fatigue failure) and perceive binding of a rotating instrument within a root canal and to withdraw it before the level of torsional stress on the instrument reaches its elastic limit are critical skills for preventing fracture. Realistically, however, this level of perception is not always attainable and can vary depending on the proficiency of the operators. The safety of NiTi instruments in use requires an understanding of the basic mechanism for the development of defect and the factors involved. Therefore, the purpose of this study was to evaluate the incidence and mode of WaveOne instrument defects after single use at 4 endodontic clinics and a graduate endodontic program and to examine the impact of clinical use on the nanohardness of WaveOne instruments using a nanoindentation technique.

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Materials and Methods

The WaveOne system was adopted at 4 endodontic clinics and 1 graduate endodontic program. After access cavity preparation, straight-line access to the canal orifices was achieved using an orifice opener with similar geometric diameters. All WaveOne files were single use. Canal preparation was performed according to the manufacturer's recommendations. If a K-file size 10 met high resistance to movement, then a WaveOne size Small (size 21) file was used; if a K-file size 10 passively advanced to the established working length or fit loosely at length, a Primary file (size 25) was selected; and if a K-file size 20 easily went to length, the Large file (size 40) was used.

A total of 438 WaveOne instruments were collected after clinical use from the 4 specialist clinics over a 12-month period and from 1 graduate program over a 20-month period. The collected instruments were ultrasonically cleaned in absolute alcohol for 90 seconds, autoclaved, and then examined blindly by 2 investigators under a stereomicroscope (Microdissection; Zeiss, Bernried, Germany) at 10× magnification. Any defect or distortion (plastic deformation) was noted and classified into 1 of the following categories:

1. Intact with no discernible distortion or unwinding
2. Intact but with unwinding defects
3. Fractured (15)

For all intact but distorted instruments, the location was determined by measuring the length between the instrument tip and the beginning of the unwound region. For those fractured instruments, the distance between the fracture and the handle was measured by using the same microscope, and the length of the broken segment was estimated from the remaining length. The fractured instruments were ultrasonically cleaned. The separated fragment was then mounted so that its long axis was normal to the microscope stage for fractographic examination under a scanning electron microscope (Hitachi SU3500 VP-SEM; Hitachi High-Technologies Canada Inc, Toronto, Canada) using magnifications of 20 to 600×. The mode of fracture was classified as fatigue or shear failure (16).

The hardness of the longitudinal section of the NiTi instruments was measured with a nanoindentation device (Nano Indenter XP; Agilent, Santa Clara, CA) using a calibrated Berkovich indenter. Five unused files, 5 used files with no deformation, and 5 used files with deformation of each size (ie, Small, Primary, and Large files) were examined. All specimens were manually ground and mechanically polished longitudinally. The specimens were then ultrasonically cleaned in distilled water for 3 minutes. The indentation points were selected using the equipped optical microscope in the nanoindentation system. Twenty successful indentations in the longitudinal section, which was 1.2–3.1 mm away from the tip, were created in each sample with a load of 100 mN and a load application time of 30 seconds. The hardness value was obtained from the load-displacement curve for each sample (17).

Data were analyzed using a chi-square, Fisher exact, 2-way analysis of variance, or post hoc test, where appropriate, in software (SPSS for Windows 11.0; SPSS, Chicago, IL). All analyses were performed at a significance level of $\alpha = 0.05$.

Results

A total of 438 WaveOne instruments were collected: 137 for Small files, 249 for Primary files, and 52 for Large files. Of the 438 NiTi instruments collected, 42 (9.6%) had some kind of defect or deformation: 40 (9.1%) were distorted and 2 (0.5%) had fractured (1 Small file and 1 Primary file) (Table 1). Large differences in the frequency of defect were found among the 3 sizes: the distortion/fracture was highest with the Small file (21.2% and 0.7%, respectively) followed by the Primary file (4.4% and 0.4%, respectively) ($P < .05$). No defects were detected on the Large file. No significant differences were found between different clinics in the number of defects ($P > .05$). One fractured instrument occurred in the specialist clinic and another in the graduate student clinic; both fractures occurred in a molar. Most of the files were used to instrument molars (258 teeth) followed by premolars (20 teeth) and anteriors (16 teeth). For 42 of the collected files, the tooth was not specified.

Of the 40 files with unwinding but no fracture, unwinding occurred at 1.2–3.1 mm from the file tip (Fig. 1*A–C*). Considerable distortion of the machine grooves and the presence of pitting defect and microcracks were observed at the unwound region (Fig. 1*C*). The length of the fractured segments was 1.9 mm for the Small file and 2.3 mm for the Primary file. Both fractured files failed as a result of shear (Fig. 1*D–F*). The microhardness of files with unwinding was slightly higher than in unused files for all sizes (Table 2), although there was no statistically significant difference in nanohardness between the 2 groups ($P > .05$).

Discussion

Mechanical stresses acting on a reciprocating motion instrument can be different from those on a continuous rotation instrument (18). Although traditional rotary instruments operate in continuous rotation and thus are subjected mainly to unidirectional torque, WaveOne instruments are used in a repeated anticlockwise-clockwise motion. The present study appears to be the first to evaluate the mode of fracture and distortion in WaveOne instruments after clinical use. This study should give an indication of the incidence of distortion and fracture for WaveOne instruments that are subjected to single use from several groups of experienced endodontic practitioners and 1 group of endodontic

TABLE 1. Summary of Instrument Defects of WaveOne Instruments from 4 Endodontic Clinics and 1 Graduate Endodontic Program (% of Total Number for Each Instrument)

	Small file*			Primary file*			Large file			Total of sample sizes (*n*)
		Defects			Defects			Defects		
Clinic	*n*	Unwinding (%)	Fracture (%)	*n*	Unwinding (%)	Fracture (%)	*n*	Unwinding (%)	Fracture (%)	
E1	29	6 (20.7)	0	53	1 (1.9)	1 (1.9)	8	0	0	90
E2	27	5 (18.5)	0	43	2 (4.7)	0	7	0	0	77
E3	20	5 (25.0)	0	57	2 (3.5)	0	10	0	0	87
E4	33	6 (18.2)	0	51	1 (1.9)	0	15	0	0	99
Residents	28	7 (25.0)	1 (3.6)	45	5 (1.1)	0	12	0	0	85
Total	137	29 (21.2)	1 (0.7)	249	11 (4.4)	1 (0.4)	52	0	0	438

E1, E2, E3, and E4, 4 specialist clinics; Residents, 1 graduate program clinic.

*Significant difference between Small file and Primary file in the frequency of defects (chi-square test, $P < .05$).