Cyclic Fatigue Resistance of Nickel-Titanium Instruments after Immersion in Irrigant Solutions with or without Surfactants

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Abstract

Introduction: The aim of the study was to assess cyclic fatigue resistance of reciprocating (Reciproc and WaveOne) and continuous rotating (ProTaper) nickel-titanium files after immersion in different irrigation solutions with or without surfactants during several short time periods. **Methods:** A total of 270 new Reciproc R25, WaveOne Primary, and ProTaper F2 files were tested. Instruments of each brand were divided into 1 control group (n = 10) formed by new files and 4 test groups (n = 20) formed by instruments dynamically immersed at 37°C for 16 mm in 5.25% sodium hypochlorite (NaOCl), Hypoclean (5.25% NaOCl with surfactant), 17% EDTA, or EDTA Plus (17% EDTA with surfactant). Each test group was subdivided into 2 subgroups (n = 10) on the basis of the time of dynamic immersion in the endodontic irrigant solution (45 seconds or 3 minutes). Resistance to cyclic fatigue was determined by recording time to fracture in a stainless steel artificial canal with a 60° angle of curvature and 5-mm radius of curvature. The fracture surface was examined by using scanning electron microscopy. **Results:** Immersion in NaOCl did not reduce the cyclic fatigue of reciprocating or continuous nickel-titanium files. The 17% EDTA reduced the fatigue resistance of all instruments after 3 minutes. The immersion in irrigants with surfactants did not influence the cyclic fatigue of instruments except for Reciproc immersed in Hypoclean solution. **Conclusions:** EDTA immersion reduced the cyclic fatigue resistance of all instruments after 3 minutes. Addition of surfactants did not influence the cyclic fatigue of files except when added to NaOCl when it contacts Reciproc instruments. *(J Endod 2014;40:1245–1249)*

Key Words

Cyclic fatigue, EDTA, nickel-titanium, reciprocating instruments, sodium hypochlorite, surfactant

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Cyclic fatigue failure occurs unexpectedly, showing no signs of previous permanent deformation when the instrument rotates inside a curved root canal and it is affected by an excessive number of tension-compression strain cycles in the region of maximum root canal curvature (1–4).

Operational speed, metal surface treatments, and the metallurgic characterization of the nickel-titanium (NiTi) alloys are some of the investigated variables that might influence the fatigue resistance of NiTi rotary files (5). Corrosion, an additional factor potentially limiting resistance to fatigue fracture, may occur in the presence of sodium hypochlorite (NaOCl) or 17% EDTA solutions (6) in the pulp chamber and in the root canal during instrumentation (7, 8).

Recently, common endodontic irrigants such as NaOCl and EDTA have been added with surfactant agents to lower their surface tension and improve their efficacy by increasing their ability to penetrate into the dentinal tubules. Hypoclean (Ogna, Muggiò, Milan, Italy) is a detergents-based endodontic irrigant composed of 5.25% NaOCl and 2 detergents (9, 10). EDTA Plus (Essential Dental System, South Hackensack, NJ) is a 17% EDTA solution in water with surfactant (11). To improve fracture resistance of files, reciprocating motion, new alloys, and new manufacturing processes have been introduced (5, 12, 13). Recently, 2 new M-wire NiTi endodontic file systems were introduced for use in reciprocating motion, Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) (14). Corrosion may negatively affect the physical properties of NiTi files (15). The corrosive effect of NaOCl or EDTA on traditional endodontic NiTi instruments has been studied by several authors (15–17). However, after immersion in endodontic irrigants with surfactants, no data were reported on the fatigue behavior of traditional NiTi or M-wire instruments in continuous rotating or reciprocating motion. Therefore, the aim of this study was to assess the resistance to cyclic fatigue of reciprocating M-wire (Reciproc and WaveOne) and continuous rotating traditional NiTi files (ProTaper F2; Dentsply Maillefer) after immersion in NaOCl or EDTA solutions with or without surfactant agents for short times that reflect those used in clinical practice.

Materials and Methods

One of the most common continuous rotating traditional NiTi files (ProTaper F2) and 2 types of M-wire reciprocating NiTi files (Reciproc R25 and WaveOne Primary) were tested. A total of 270 new Reciproc R25, WaveOne Primary, and ProTaper F2 files were selected (90 new instruments for each brand). Reciproc R25 and WaveOne Primary instruments, both with ISO size #25 at the tip, taper of 0.08 in the apical 3 mm, and length of 25 mm, were selected. In addition, ProTaper F2 was also tested because it shares the same characteristics as the other 2 instruments tested.

Before the experiment, each instrument was inspected for defects with a stereomicroscope (SZR-10; Optika SRL, Ponteranica (Bg), Italy) at ×200 magnification, and none were discarded. Ten of the 90 files of the same brand were randomly assigned to group 1 (control, new instruments without immersion). The remaining 80 files of the same brand were randomly divided into 4 test groups (n = 20) on the basis of the irrigant solution used for the instruments' dynamic immersion at 37°C for 16 mm: 5.25% NaOCl (Niclor 5; Ogna, Muggiò, Milan, Italy), 5.25% NaOCl with surfactant

(Hypoclean), 17% EDTA (Ogna, Muggiò, Milan, Italy), or 17% EDTA with surfactant (EDTA Plus). Each test group was subdivided into 2 subgroups (n = 10) on the basis of the time of dynamic immersion in the endodontic irrigant solution (45 seconds or 3 minutes). Each file was placed in a small separate glass container filled with the amount of the testing irrigant solution necessary to contact 16 mm of the instrument's length.

During dynamic immersion, the endodontic instruments were used with a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany), powered by VDW.SILVER RECIPROC motor (VDW, Munich, Germany) with the following recommended settings: ProTaper with 300 rpm continuous rotation, Reciproc files with the "RECIPROC ALL" mode, and WaveOne with the "WAVEONE ALL" mode.

All files were rinsed in bi-distilled water to neutralize the effect of irrigant immediately after removal from the solutions. Afterwards, they were dried and stored in glass vials.

Each instrument was then subjected to cyclic fatigue test by a mechanical device already used in other studies and specifically developed to enable a reproducible simulation of an instrument in a curved canal (18). During the test, endodontic instruments were connected to the same handpiece and motor that were set with the same programs used for the dynamic immersion. Files performed rotating and reciprocating motion freely within a tempered stainless steel artificial canal at a constant pressure. The artificial stainless steel canal measures 2 mm in diameter and 16 mm in total length. It provided the instrument with a suitable simulated root canal with 60° angle of curvature and 5-mm radius of curvature measured according to the Schneider method (19). The center of the curvature was 5 mm from the end of the artificial canal, and the curved segment was approximately 7 mm in length. All instruments were inserted 16 mm into the artificial canal.

To reduce the friction of the file, special high-flow synthetic oil designed for lubrication (Super Oil; Singer Co Ltd, Elizabethport, NJ) was sprayed into the simulated canal. For each instrument, the time to fracture (TF) in seconds from the start of the test until the moment of breakage was measured by a chronometer with an accuracy of 0.1 second. The fracture surfaces of all instruments were examined under the scanning electron microscope (SEM) (JMS-6060LV; JEOL Technics Ltd, Akishima-Shi, Tokyo, Japan) for the topographic features of the fractured files after the fatigue test. Two-way analysis of variance and Bonferroni post hoc tests at α = 0.05 (MedCalc Software, Mariakerke, Belgium) were used to evaluate the effect of immersion in endodontic irrigants with or without surfactants on fatigue resistance.

Results

Descriptive statistics of TF for each file are summarized in Table 1. The average TF of all Reciproc R25 groups was higher than that of WaveOne Primary or ProTaper groups ($P < .0001$). The inferential analysis revealed statistically significant differences among the 5 groups of the same brand, considering the type of irrigant (2-way analysis of variance, $P < .001$; interaction, 0.062) or the immersion time (2-way analysis of variance, $P < .0001$) as independent variable. Post hoc analysis showed that cyclic fatigue resistance of the new instruments was not affected ($P > .05$) by immersion in 5.25% NaOCl or EDTA Plus for 45 seconds or 3 minutes in all brands. However, immersion in 17% EDTA significantly reduced the cyclic fatigue resistance of all instruments after 3 minutes ($P < .0001$), whereas the fatigue of all instruments was not reduced after 45-second immersion ($P > .05$).

Among the files tested, Reciproc R25 showed reduced cyclic fatigue after 3 minutes or 45 seconds of immersion in Hypoclean ($P < .01$). Moreover, immersion in EDTA Plus also for 3 minutes did not affect fatigue resistance of Reciproc R25 ($P > .05$). Protaper F2 and WaveOne Primary did not reduce their cyclic fatigue after immersion in Hypoclean or EDTA Plus for 45 seconds or for 3 minutes ($P > .05$).

SEM of the fracture surface showed similar and typical features of cyclic fatigue failure for the 3 brands. Crack initiation area and overload fast fracture zone for cyclic fatigue fractures, concentric abrasion marks, and fibrous dimple marks at the center of rotation are shown in Figure 1.

TABLE 1. Descriptive Statistics of Cyclic Fatigue Resistance: TF for New Instruments and Those Immersed in Different Endodontic Irrigants

Brand	Group	Immersion	*n*	Mean (sec)	Median (sec)	Standard deviation (sec)	Standard error of mean (sec)	Minimum (sec)	Maximum (sec)
Reciproc	New	No	10	313.8	316.5	25.74	10.51	270	340
	5% NaOCl	45 sec	10	335.5	330.5	46.36	18.63	296	379
		3 min	10	322.5	317.0	30.90	15.44	301	339
	Hypoclean	45 sec	10	261.8	271.5	45.48	18.56	200	308
		3 min	10	221.0	238.0	48.95	19.98	139	276
	17% EDTA	45 sec	10	298.0	274.5	50.90	20.78	246	368
		3 min	10	200.3	215.0	39.82	16.25	143	240
	EDTA Plus	45 sec	10	302.0	292.0	33.96	13.86	272	356
		3 min	10	288.8	275.0	31.71	16.13	249	329
WaveOne	New	No	10	169.0	176.0	21.50	8.77	140	190
	5% NaOCl	45 sec	10	174.1	174.5	20.33	8.30	144	205
		3 min	10	150.0	146.5	12.97	5.29	134	168
	Hypoclean	45 sec	10	161.5	154.0	44.08	17.99	115	238
		3 min	10	142.3	141.0	28.93	11.81	106	177
	17% EDTA	45 sec	10	145.5	139.0	43.48	16.10	101	228
		3 min	10	106.0	95.0	37.35	15.25	68	155
	EDTA Plus	45 sec	10	145.0	142.5	29.73	10.91	113	171
		3 min	10	149.1	151.5	15.56	6.00	126	165
ProTaper	New	No	10	54.5	54.5	3.83	1.56	50	60
	5% NaOCl	45 sec	10	59.6	58.5	10.28	4.20	49	71
		3 min	10	41.6	40.5	7.20	2.82	34	49
	Hypoclean	45 sec	10	49.1	48.5	10.22	4.17	33	62
		3 min	10	42.3	41.5	14.37	5.86	29	60
	17% EDTA	45 sec	10	47.1	45.0	11.84	4.60	31	56
		3 min	10	20.1	21.0	5.87	2.40	11	28
	EDTA Plus	45 sec	10	45.0	45.5	8.94	3.65	34	60
		3 min	10	41.3	40.0	10.66	4.53	35	51