Dentistry
ISSN: 2161-1122

Dagna et al., Dentistry 2013, 4:1
DOI: 10.4172/2161-1122.1000184

Research Article Open Access

Cyclic Fatigue Resistance of Three Niti Single-File Systems after Immersion in EDTA

Dagna A, Poggio C*, Beltrami R, Chiesa M and Bianchi S
Department of Clinical, Surgical, Diagnostic and Pediatric Sciences-Section of Dentistry, University of Pavia, Italy

Abstract

Objective: To evaluate and to compare in vitro the cyclic fatigue resistance of three NiTI single-file systems (One Shape, Reciproc and Wave One) after immersion in 10% EDTA solution over different time periods.

Materials and Methods: Cyclic fatigue test of three NiTi single-file systems was performed in a curved stainless steel artificial canal with 60° angle and 5 mm radius of curvature. 45 OneShape, 45 Reciproc R25 and 45 WaveOne Primary were tested after three different immersion protocols: 1 min in 10% EDTA at 37°C, 5 min in 10% EDTA at 37°C, no immersion. The number of cycles to fracture (NCF) was determined by measuring the time to fracture. The data were compared for differences by using 2-way analysis of variance (P=0.05).

Results: In general, resistance to cyclic fatigue was not significantly affected by immersion in 10% EDTA. Reciproc R25 showed the highest cyclic fatigue resistance in all groups.

Conclusions: 10% EDTA did not decrease/increase the cyclic fatigue resistance of NiTI single-file systems appreciably in vitro. Reciproc R25 was more resistant, but the new rotary OneShape instruments showed good mechanical resistance, similar to WaveOne Primary files developed for reciprocating motion.

Keywords: Cyclic fatigue; EDTA; NiTi; Single-use instruments; Single-file systems

Introduction

NiTi rotary instruments are universally used for root canal shaping in modern endodontics [1]. They are more flexible and have increased cutting efficiency than conventional stainless steel files [2,3]. Thanks to their superelasticity it's easy to produce the desirable tapered root canal form with a reduced tendency to canal transportation [4]. Despite these advantages, NiTi instruments have a high risk of separation [5,6], mainly because of fatigue and torsional shear stresses [7-10]. Many variables such as the operational speed, the metal surface treatment and the metallurgic characterization of the NiTi alloys that could possibly influence the fatigue resistance of NiTi rotary files have been investigated [11]. Canal curvature is suspected to be the predominant risk factor for instrument failure because of flexural stresses and cyclic fatigue [12,13]. One additional factor potentially limiting resistance to fatigue fracture is corrosion that may occur in the presence of irrigating solution [14]. The use of NaOCl and EDTA to irrigate root canals is currently the gold standard to achieve tissue dissolution and disinfection [1,15]. NiTi instruments come into contact with irrigating solutions during instrumentation of the root canal and the corrosion patterns, involving selective removal of nickel from the surface, can create micro pitting that weakens the structure of the instrument [16]. The clinician can do very little to prevent or reduce such stresses [17].

In the last years the reciprocating motion of the NiTi rotary instrument has been shown to decrease the impact of cyclic fatigue compared with rotational motion [18,19]. Therefore, it has been recently proposed that the single-file shaping technique may simplify instrumentation protocols and avoid the risk of cross-contamination [7,17]. Moreover, the use of only one NiTi instrument is more cost-effective, and the learning curve is considerably reduced [19]. To improve fracture resistance, use of endodontic files in a reciprocating motion, along with new alloys, and new manufacturing processes has been introduced recently [11,20]. M-wire is a NiTi alloy prepared by a special thermal process that is claimed to increase flexibility and resistance to cyclic fatigue [21]. Reciprocation was shown to extend the life span of a NiTi instrument, hence resistance to fatigue, in comparison with continuous rotation [18,19]. Recently, two M-wire NiTi endodontic file systems in reciprocating motion were introduced: Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) [22]. The reciprocating working motion consists of a counterclockwise (cutting direction) and a clockwise motion (release of the instrument), while the angle of the counterclockwise cutting direction is greater than the angle of the reverse direction. Due to the fact that the counterclockwise angle is greater than the clockwise one, it is claimed that the instrument continuously progresses towards the terminus of the root canal. Both instruments have been evaluated in previous studies [17-19,22-26] and the results regarding lifespan, cyclic fatigue resistance, shaping ability and cleaning efficiency were satisfactory.

A new concept of single-file instrumentation is that a single instrument is to be used in a full clockwise rotation. OneShape (Micro Mega, Besancon, France) belong to this group of single-file systems. The OneShape system consists of only one instrument made of a conventional austenite 55-NiTi alloy. It is characterized by different cross-sectional designs over the entire length of the working part. In the tip region, the cross section represents three cutting edges while in the middle of the cross-sectional design progressively changes from a three-cutting-edge design to two cutting edges. At the shank, the S-shaped cross section shows two cutting edges, resembling the cross-sectional design of Reciproc instruments. This design is alleged to eliminate threading and binding of the instrument in continuous rotation [27].

Previous studies have investigated the effect of EDTA on traditional endodontic NiTi instruments [16,28]. The aim of this study was to assess the resistance to cyclic fatigue of three single-file systems,

***Corresponding author:** Claudio Poggio, Department of Clinical, Surgical, Diagnostic and Pediatric Sciences, Policlinico "San Matteo", Piazzale Golgi 3, 27100 Pavia, Italy, Tel: +39 0382 516257, +39 3398124925; Fax: +39 0382 516224; E-mail: claudio.poggio@unipv.it

Received December 02, 2013; **Accepted** December 26, 2013; **Published** December 28, 2013

Citation: Dagna A, Poggio C, Beltrami R, Chiesa M, Bianchi S (2013) Cyclic Fatigue Resistance of Three Niti Single-File Systems after Immersion in EDTA. Dentistry 4: 184. doi:10.4172/2161-1122.1000184

OneShape, Reciproc and WaveOne, after immersion in EDTA solutions for times that reflect those used in clinical practice. The null hypothesis is that there are differences in the cyclic fatigue resistance between the instruments immersed and those ones not immersed in EDTA solution.

Materials and Methods

Three NiTi single-file systems were tested, two reciprocating files and one new rotary file. A total of 135 new NiTi instruments were used: 45 OneShape (Micro Mega, Besancon, France), 45 Reciproc R25 (VDW, Munich, Germany), 45 WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland (Table 1).

Each instrument was inspected for defects or deformities before the experiment with a stereo zoom microscope, and none were discarded. The 45 files of the same brand, all from the same production lot, were randomly assigned to three different groups of 15 each:

- **Group 1:** instruments dynamically immersed in 10% EDTA (Tubuliclean; OGNA laboratory, Muggiò, Milan, Italy) at 37°C for 1 min;
- **Group 2:** instruments dynamically immersed in 10% EDTA (Tubuliclean; OGNA laboratory, Muggiò, Milan, Italy) at 37°C for 5 min;
- **Group 3:** instruments not immersed in 10% EDTA (control).

According to the protocol of Pedullà et al. for dynamic immersion [29], OneShape were rotated while Reciproc R25 and WaveOne Primary were reciprocated respecting manufacturers' settings in small glass containers with the amount of the EDTA solution necessary to contact 16 mm of the instruments length. OneShape was mounted on the Endo Mate DT motor (NSK, Kanuma, Japan) set to 350 rpm and a 2 N/cm torque with a 16:1 contra-angle in clockwise rotation. Reciproc R25 was mounted on the dedicated reciprocating motor (Silver Reciproc, VDW) used with the manufacturer configuration setup (at the preset program "Reciproc ALL" specific to the Reciproc instruments). WaveOne Primary was mounted on the dedicated reciprocating motor (Silver Reciproc, VDW) used with the manufacturer configuration setup (at the preset program "WaveOne ALL" specific to the WaveOne instruments).

Immediately after removal from the solutions, all files were rinsed in bi-distilled water to neutralize the effect of EDTA, dried and stored

Instrument	Manufacturer	Taper	Apical diameter	Motion
OneShape	Micro Mega, Besancon, France	0.06	25	Continuous rotation
Reciproc R25	WDV, Munich, Germany	0.08	25	Reciprocating motion
WaveOne Primary	Densply Maillefer, Ballaigues, Switzerland	0.08	25	Reciprocating motion

Table 1: Single-use instruments tested.

	NCF ± standard deviation		
	Group 1	Group 2	Group 3
OneShape	777.73 ± 65.47[a]	719.61 ± 68.39[b]	632.46 ± 40.27[c]
Reciproc R25	917.86 ± 54.85	893.44 ± 42.26	749.39 ± 47.13
Wave One Primary	730.67 ± 48.58[a]	739.06 ± 41.55[b]	590.67 ± 53.43[c]

The same superscript letters indicate no significant differences (P > 0.05) between groups. Groups with no superscript letter indicate significant differences between groups in vertical row (P < 0.05).

Table 2: Mean ± standard deviation of NCF in each experimental group.

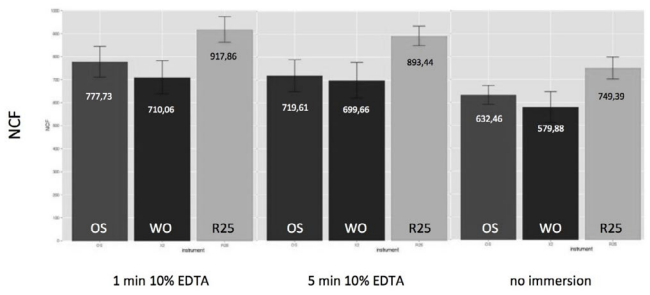

Figure 1: Mean NCF ± standard deviations for each instrument type in each canal.

in glass vials. Instruments of all three groups of each brand were then subjected to cyclic fatigue testing using a mechanical device specifically developed for the purpose that allowed a reproducible simulation of an instrument confined in a curved canal [30]. The apparatus was connected to the same motors set with the same programmer used for the dynamic immersion. In this way, the endodontic instruments were able to rotate/reciprocate freely within a tempered stainless steel artificial canal at a constant pressure. The artificial canal was manufactured by reproducing an instrument's size and taper. It provided the instrument with a suitable simulated root canal with a 60° angle of curvature and 5 mm radius of curvature measured according to the method of Schneider [31]. The centre of the curvature was 6 mm from the tip of the instrument, and the curved segment of the canal was approximately 6 mm in length. The diameter of the simulated canals is larger than the instruments, allowing free rotation. To reduce friction as the instruments contacted the metal canal walls, lubricant oil filled the canal space after each use. Each instrument was allowed to rotate/reciprocate with spontaneous pecking movement until fracture. The time to fracture was recorded visually with a 1/100-s chronometer and timing was stopped as fracture is detected visually and/or audibly. The number of cycles to fracture (NCF) was calculated by multiplying the time (seconds) to fracture by the number of rotations or cycles per second, regardless of the rotation direction. Note: the manufacturers claim that the Reciproc mode has 300 rpm and WaveOne mode has 350 rpm [23].

Data were analyzed by using 2-way analysis of variance test with software (SPSS 15.0, Chicago, IL). Post hoc Bonferroni test was applied to identify the groups that were significantly different from others. Statistical significance was set at P value less than 5%.

Results

The means and standard deviations of NCF values for each group are presented in Table 2 and Figure 1. A higher NCF is caused by a higher resistance to cyclic fatigue of the tested instruments.

The 2-way analysis of variance showed the absence of statistically significant differences of NCF values between groups with and without EDTA solution (P>0.05). Reciproc R25 had the best fatigue resistance in groups 1, 2 and 3 (P<0.05). WaveOne and OneShape had similar cyclic fatigue resistance values in all the groups (P>0.05).

Discussion

The null hypothesis of the study was rejected. There are no differences in the cyclic fatigue resistance between the instruments immersed and the instruments not immersed in EDTA solution. This

study showed significant differences in the cyclic fatigue resistance between the instruments: Reciproc R25 exhibited higher NCF values than OneShape and Wave One Primary.

The aim of this study was to evaluate if immersion in an EDTA solution could affect cyclic fatigue resistance of three NiTi single-file systems. EDTA is an important chelating solution used to remove the mineralized portion of the smear layer [1]. All NiTi files during root canal preparation are exposed to, and can corrode by irrigating solutions. Corrosion reduces the resistance of the files [16]. Although there are no reports in the literature about corrosion failure of instruments, it seems reasonable to assume that pitting or crevice corrosion might occur first and promote fatigue failure, altering the fracture mechanism from conventional fatigue failure to corrosion failure [16,28].

Although previous studies investigated cyclic fatigue resistance after immersion in NaOCl, none investigated cyclic fatigue resistance after immersion in EDTA. Pedullà et al. [29] tested Reciproc R25 and WaveOne Primary NiTi instruments after immersion in 5% NaOCl solution for 1 or 5 min and then concluded that NaOCl did not affect cyclic fatigue resistance of both instruments. In this study dynamic immersion in EDTA was performed according to the metod of Pedullà et al. [29] Immersion for 1 or 5 min did not reduce the cyclic fatigue resistance of tested NiTi files significantly. It's interesting to note that if EDTA did not reduce the in vitro resistance of the instruments, it's logical to assume that this irrigating solution could extend the life of the file. EDTA is useful in negotiating narrow, tortuous and calcified canals to establish patency. It works as a lubricant into the root canal, so it can help the instruments in root canal shaping.

We don't know if EDTA has no corrosive effect on these new single-file systems. Reciproc files and WaveOne files are made of the new Mwire NiTi alloy. One Shape files are made of a conventional austenite 55-NiTi alloy but their electro-polishing procedure is unknown. Today no literature is available regarding the effect of EDTA on those instruments. The results of the present study showed no significant differences between immersed and non-immersed files. It means that exposure to EDTA, in this study, had no influence on cyclic fatigue resistance. But, within the limitations of this study, it isn't possible to state that EDTA did not corrode these NiTi files. Bonaccorso et al. [16] verified that EDTA did not increase nor decrease the corrosion resistance of NiTi files.

Significant differences in resistance to cyclic fatigue were found between the different NiTi single-file systems. Reciproc R25 was more resistant to cyclic fatigue than WaveOne Primary and OneShape. The results are in agreement with recent reports that showed a higher cyclic fatigue resistance for Reciproc than WaveOne [23,26]. As these instruments have the same tip size, apical taper and the same alloy, these differences are probably due to their different cross-sectional design. Reciproc and WaveOne are made of the same innovative M-wire NiTi alloy but have different cross sections. Reciproc instruments have got an S-shape cross-section, WaveOne a concave triangular section.

It was reported that the larger cross-sectional area would have a higher flexural and torsional stiffness, and thus the file design (cross-sectional shape, diameters of core, etc) would have a significant influence on the torsional and bending (hence, fatigue) resistance [26]. Kim et al. [26] assessed that Reciproc R25 exhibited significantly higher cyclic fatigue resistance than WaveOne, primarily because because their geometry. OneShape instruments showed good results in this study, with no significant differences from Wave One Primary. A reciprocating motion may decrease the impact of cyclic fatigue on NiTi rotary instrument life compared with rotational motion [32]. But Oh et al. [33] verified that the instrument design, particularly the cross-sectional area (CSA), can also affect the fatigue behavior when subjected to torsion or bending. Sections with a larger CSA are more susceptible to fatigue fracture than smaller sections when rotating at the same curvature. Moreover, an electropolishing procedure has been attempted during the manufacturing process to reduce the number of machining defects and residual stress of ground NiTi rotary instruments: the grinding of file blanks during the manufacture of NiTi rotary instruments causes many machining defects. This electropolishing procedure removes the outer layer of a metal, leaving the surface free of contaminants, microcracks, and work-induced residual stress. This means that the resistance to fatigue failure can be enhanced by a smooth defect-free surface. If a single-file system made for continuous rotation gives results similar to a single-file system developed for reciprocating motion it probably means that is more important the geometry/design of the instruments than its motion.

Conclusions

Immersion in EDTA for 1 or 5 min did not affect the cyclic fatigue resistance of NiTi single-file systems. The NCF of Reciproc R25 was greater than OneShape and WaveOne Primary. OneShape rotary files showed interesting mechanical resistance similar to WaveOne Primary files developed for reciprocating motion.

References

1. Torabinejad M, Walton RE (2009) Endodontics: principles and practice. (4thedn), St. Louis, Missouri.
2. Peters OA (2004) Current challenges and concepts in the preparation of root canal systems: a review. J Endod 30: 559-567.
3. Schafer E, Schulz-Bongert U, Tulus G (2004) Comparison of hand stainless steel and nickel titanium rotary instrumentation: a clinical study. J Endod 30: 432-435.
4. Chen JL, Messer HH (2002) A comparison of stainless steel hand and rotary nickel- titanium instrumentation using a silicone impression technique. Aust Dent J 47: 12-20.
5. Arens FC, Hoen MM, Steiman HR, Dietz GC Jr (2003) Evaluation of single-use rotary nickel- titanium instruments. J Endod 29: 664-666.
6. Sattapan B, Nervo GJ, Palamara JE, Messer HH (2000) Defects in rotary nickel-titanium files after clinical use. J Endod 26: 161-165.
7. Berutti E, Paolino DS, Chiandussi G, Alovisi M, Cantatore G, et al. (2012) Root canal anatomy preservation of WaveOne reciprocating files with or without glyde path. J Endod 38: 101-104.
8. Peters OA, Barbakow F (2002) Dynamic torque and apical forces of ProFile 0.04 rotary instruments during prepara- tion of curved canals. Int Endod J 35: 379-389.
9. Varela-Patino P, Ibanez-Parraga A, Rivas-Mundina B, Cantatore G, Otero XL, et al. (2010) Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 36: 157-159.
10. Lopes HP, Moreira EJ, Elias CN, de Almeida RA, Neves MS (2007) Cyclic fatigue of ProTaper instruments. J Endod 33: 55-57.
11. Gambarini G, Grande NM, Plotino G, Somma F, Garala M, et al. (2008) Fatigue resistance of engine-driven rotary nickel–titanium instruments produced by new manufacturing methods. J Endod 34: 1003-1005.
12. Hulsmann M, Peters OA, Dummer PMH (2005) Mechanical preparation of root canals: shaping goals, techniques and means. Endod Top 10: 30-76.
13. Peters OA, Peters CI, Schonenberger K, Barbakow F (2003) ProTaper rotary root canal preparation: assessment of torque and force in relation to canal anatomy. Int Endod J 36: 93-99.
14. Sonntag D, Heithecker K (2006) Korrosion von Nickel-Titan-Instrumenten. Endodontie 15: 23-30.
15. Zehnder M (2006) Root canal irrigants. J Endod 32: 389-398.

16. Bonaccorso A, Tripi TR, Rondelli G, Condorelli GC, Cantatore C, et al. (2008) Pitting corrosion resistance of nickel-titanium rotary instruments with different surface treatments in seventeen percent ethylenediaminetetraacetic Acid and sodium chloride solutions. J Endod 34: 208-211.

17. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, et al. (2012) Canal shaping with WaveOne reciprocating files and Pro Taper system: a comparative study. J Endod 38: 505-509.

18. You SY, Bae KS, Baek SH, Kum KY, Shon WJ, et al. (2010) Lifespan of one nickel-titanium rotary file with reciprocating motion in curved root canals. J Endod 36: 1991-1994.

19. De-Deus G, Moreira EJ, Lopes HP, Elias CN (2010) Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement. Int Endod J 43: 1063-1068.

20. Franco V, Fabiani C, Taschieri S, Malentacca A, Bortolin M, et al. (2011) Investigation on the shaping ability of nickel-titanium files when used with a reciprocating motion. J Endod 37: 1398-1401.

21. Al-Hadlaq SM, Aljarbou FA, AlThumairy RI (2010) Evaluation of cyclic flexural fatigue of M-wire nickel-titanium rotary instruments. J Endod 36: 305-307.

22. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, et al. (2012) Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. J Endod 38: 541-544.

23. Plotino G, Grande NM, Testarelli L, Gambarini G (2012) Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. Int Endod J 45: 614-618.

24. Burklein S, Hinschitza K, Dammaschke T, Schafer E (2012) Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. Int Endod J 45: 449-461.

25. Dietrich MA, Kirkpatrick TC, Yaccino JM (2012) In vitro canal and isthmus debris removal of the Self Adjusting File, K3, and WaveOne files in the mesial root of human mandibular molars. J Endod 38: 1140-1144.

26. Kim HC, Hwang YJ, Jung DW, You SY, Kim HC, et al. (2012) Micro-computed tomography and scanning electron microscopy comparisons of two nickel-titanium rotary root canal instruments used with reciprocating motion. Scanning 35: 112-118.

27. Burklein S, Hiller C, Huda M, Schafer E (2011) Shaping ability and cleaning effectiveness of Mtwo versus coated and uncoated EasyShape instruments in severely curved root canals of extracted teeth. Int Endod J 44: 447-457.

28. Darabara M, Bourithis L, Zinelis S, Papadimitriou GD (2004) Susceptibility to localized corrosion of stainless steel and NiTi endodontic instruments in irrigating solutions. Int Endod J 37: 705-710.

29. Pedullà E, Grande NM, Plotino G, Palermo F, Gambarini G, et al. (2013) Cyclic fatigue resistance of two reciprocating nickel-titanium instruments after immersion in sodium hypochlorite. Int Endod J 46: 155-159.

30. Plotino G, Grande NM, Cordaro M, Testarelli L, Gambarini G (2009) A review of cyclic fatigue testing of nickel-titanium rotary instruments. J Endod 35: 1469-1476.

31. Schneider SW (1971) A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol Endod 32: 271-275.

32. Castello-Escrivà R, Alegre-Domingo T, Faus-Matoses V, Roman-Richon S, Faus-Llacer VJ (2012) In vitro comparison of cyclic fatigue resistance of ProTaper. WaveOne and Twisted Files. J Endod 38: 1521-1524.

33. Oh SR, Chang SW, Lee Y, Gu Y, Son WJ, et al. (2010) A comparison of nickel-titanium rotary instruments manufactured using different methods and cross-sectional areas: ability to resist cyclic fatigue. Oral Surg Oral Med Oral Pathol Endod 109: 622-628.