Hyflex CM and EDM from Shape Memory to Control Memory

Jamal A. Abu Al-Timan [(1)], Iman M. Al-Zaka [(2)], Baidaa M. Zeidan[(2)]

ABSTRACT

The new era in endodontics has been established with the introduction of nickel titanium (NiTi) alloys, and later on the automation of mechanical preparation. By changing the phase transformation temperatures of NiTi alloy, the manufacturers alter the phase composition to have a NiTi with new mechanical properties. These mechanical properties can be achieved either by thermal, mechanical treatments or both. Moreover, many machining procedures (e.g. twisting, electrical discharge machining), were developed. The higher flexibility of Thermomechanically treated NiTi alloys was found as the main advantages of these alloys with the improvement of cyclic fatigue resistance when compared to conventional NiTi. Austenitic alloys have superelastic properties due to stress-induced martensite transformation and consequently try to springback to their original shape after distortion. In contrast, the martensitic instruments have ability to reorientation of martensite variants when heated. So these instruments easily deformed and show a shape memory effect. Moreover, the use of martensitic alloy results in more flexible files, with an increased cyclic fatigue resistance compared with austenitic alloy. So, continued development in the manufacturing treatment of NiTi alloys has resulted in the producing of controlled memory (CM) wire. These materials do not possess superelastic properties at neither room nor body temperature. This article reviews the development process, features and properties of Hyflex file and Hyflex EDM file made from CM wire.

KEYWORDS: NiTi alloy; CM wire; Hyflex EDM; Heat treated NiTi

[(1)]Endodontist, Department of Dentistry, Al-Yarmok University College.
[(2)] Department of Conservative Dentistry, College of Dentistry, Mustansiriyah University, Baghdad, Iraq.

INTRODUCTION

The new era in endodontics has been established with the introduction of nickel titanium (NiTi) alloys, and later on the automation of mechanical preparation.[1] These alloys are more flexible with the increasing of bending properties compared to stainless steel alloy.[2] NiTi alloy present in two different temperature-dependent crystal structures:[3]

• Austenite (high temperature phase) which is a parent phase with cubic B2 crystal structure.

• Martensite (low temperature phase) with monoclinic B19 crystal structure.

The ambient temperature and whether the alloy is cooled or heated to this temperature, is determine the phase composition and consequently the mechanical properties of Ni-Ti alloy. The alloy become stiff, hard and has superior super elastic (SE) properties, when it is above the austenite finish temperature (Af).[4] While in the martensitic state the alloy is soft, ductile, can easily be deformed and possesses the shape memory effect (SME)[3,4] and this induce when the temperature is below martensitic finish temperature (Mf). Because of the reorientation capacity of the twinned phase structure, martensite has a superior cyclic fatigue resistance compared with austenite. And have a lower modulus of elasticity (30-40 GPa) than austenite (80-90 GPa).[5] So many manufacturers depend on the change of transformation temperatures (Ms, Mf, As, Af) of

the utilized NiTi alloy, to alter the composition of phase to obtain a NiTi alloy with new properties. And this can be achieved by thermal and mechanical treatment or variation in the chemical composition.[6,7] Other method to modify the mechanical properties of NiTi alloy, manufacturers introduced several machining procedures (e.g. twisting, electrical discharge machining), as well as techniques for final surface finishing.[7]

Continued development in the manufacturing process of NiTi files has resulted in the production of controlled memory (CM) wire. CM wire was introduced by DS Dental in 2010. That does not possess superelastic properties at neither room nor body temperature.[8]

After machining of Nitinol SE508, a heating and cooling process gives the alloy control over the shape-memory effect, allowing the instruments to be pre-bent,[8,9,10], in contrast to austenitic NiTi files, CM Wire instruments do not tend to fully straighten during the preparation of curved root canals. The controlled memory effect helps the endodontic instrument to retain the shape of the canal even when it is taken out from the canal. This property helps avoid procedural errors such as ledge formation, transportation, and perforations.[7] the modified phase composition allows the CM wire to deform and reorientation of the martensite variant.[9, 11]

Other advantage properties of CM wire is raise the transformation temperatures (Af to about 50 °C) and obtain stable martensite at the body temperature.[11, 12] Studies found that the Af temperature of Hyflex CM (Coltene Whaledent, Cuyahoga Falls, OH) was about 47°C, suggesting that this instrument at body temperature will be in a mixed martensitic R-phase and austenitic structure.[9, 13, 14] These data are consistent with the previous studies, which showed that instruments made from SE-NiTi exhibit an austenitic phase at room temperature, whereas MW and CM instruments, in addition to the austenite, also contained martensite and R phase.[15]

Hyflex CM files exhibit a lower percent in weight of Nickel (52 Ni % wt) when compared with other commonly used NiTi files (54.5-57 Ni % wt).[16] Decreasing the Nickel content creates a softer metal and lower sits hardness.[17] A softer metal may be less aggressive in cutting dentin but may stay centered within the canal during instrumentation. Another benefit marketed by Hyflex CM is the ability of the metal to regain its original shape after sterilization. Deformation or unwinding of a NiTi file is a common finding after the file has been subjected to a curved canal.[9] An unwound file is typically discarded to prevent future file separation within the canal.

The CM-treated instruments have lower tensile strength (1094 MPa) in comparing to conventional NiTi (1415 MPa), the superior flexibility of these instruments.[14] allowed it to withstand deformation before fracture (58.4% to 84.7%) than conventional ones (16.7% to 27.5%). Other studies confirm that CM instruments have >300% greater resistance to cyclic fatigue when compared to SE instruments.[18, 14]

The system consists of Orifice Shaper #25.08 with a triangular cross-section that remove the cervical interferences, followed by preparation of the middle and apical thirds, and ending with more tapered instruments for final shaping. In narrower regions .04 taper and a quadrangular cross-section is used which improves resistance to the narrower regions of the root canal. Final for shaping and finishing an instrument with a triangular cross-section is used, with .04 and .06 taper, and a larger tip diameter.[19] The Hyflex CM instrument, when compared to other NiTi SE systems, exhibit greater resistance to cyclic fatigue.[20, 21, 22]

In 2016 another file manufactured by Coltene Whaledent from CM wire called Hyflex EDM was available in the market. This file considers as a novel instrument, since is the first instrument that is manufactured via an electrical discharge machining (EDM). Which also known as spark eroding.[7.23, 24] EDM can be used to manufacture all types of conductive materials (e.g., metals, alloy, graphite, and so on) of any hardness with high precision.[25]

With an electrical spark a local melting occurred, with partially evaporation of small portions of material that are eliminated from this area living a typical crater-like surface finish.[26] In the presence of pulsed electrical discharge a metal removal is es-

tablished. This procedure needs to put both workpiece and cutting tool in a dielectric liquid and voltage. The liquid removes the metal and produces non-directional surface finish.[7] In an acid bath and ultrasonic cleaning of instrument is accomplished. Before or after the cleaning process the instrument is heat treated at temperature ranging between 300-600 ˚C for10 min to 5 hours[27] explained that EDM does not require direct contact with the workpiece, which eliminates the chance of mechanical stress as in the traditional grinding process.[27]

By using three-dimensional optical profilometry, the surface topographies of intact Hyflex CM and EDM files before and after root canal preparation was examined. The results found that the increase of surface roughness values in the Hyflex EDM group was not significant, meanwhile Hyflex CM had significantly higher surface alterations compared with Hyflex EDM after preparation of severely curved root canals.[28] The As for Hyflex EDM instruments was found to be higher than for Hyflex CM (42 ˚C and 21 ˚C respectively) with higher Af temperature 52 ˚C for Hyflex EDM that indicating a changed phase composition. So, EDM file inside the canal found to be martensite phase.[29]

Pirani *et al*, in a metallographic analysis of new and used files showed that the main composition of these file is a lenticular martensite gains and some residual austenite which homogenously. And it shows 700% higher fatigue resistance than CM instruments.[24] In accordance with previous findings, several studies proved that Hyflex EDM exhibits a significantly increased cyclic fatigue resistance compared with Hyflex CM, M-Wire and conventional Ni-Ti instruments.[24, 29, 30, 31,32,33,34]

The Hyflex designed and marketed to shape and prepare root canals using a single-file technique in continuous rotation.[35] Hyflex EDM files have a tip size of 25, with a constant taper 0.08 in the apical 4mm of the instruments. That reduces progressively up to 0.04 in the coronal part of the instrument. This file has 3 different cross-sectional zones over the entire length of the working part (rectangular in the apical part and 2 different trapezoidal cross section in the middle and coronal part of the instrument working portion) to increase its fracture resistance and cutting efficiency.[35]

Declaration of competing interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

References

1. Gavini G, Santos MD, Caldeira CL, Lima Machado ME. Nickel–titanium instruments in endodontics: a concise review of the state of the art. Braz. Oral Res. 2018;32(suppl):e67.

2. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod. 1988 Jul;14 (7):346–51.

3. Zhou H, Peng B, Zheng YF. An overview of the mechanical properties of nickel-titanium endodontic instruments. Endodontic Topics. 2013;29, 42–54.

4. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod. 2013a; 39, 163–72.

5. Kuhn G, Jordan L. Fatigue and mechanical properties of nickel-titanium endodontic instruments. J Endod. 2002; 28, 716–20.

6. Kim HC, Yum J, Hur B, Cheung GS. Cyclic fatigue and fracture characteristics of ground and twisted nickel-titanium rotary files. J Endod. 2010; 36, 147–52.

7. Ashok L , Krishnan V , Nair RS , Angelo CM. An Overview of Thermomechanically Heat-treated Nickel–Titanium Alloy Used in Endodontics. Conservative Dentistry and Endodontic Journal. 4(2) (July–December 2019).

8. Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Mechanical properties of controlled memory and superelastic nickel-titanium wires used in the manufacture of rotary endodontic instruments. J Endod. 2012; 38, 1535–40.

9. Shen Y, Coil JM, Zhou H, Zheng Y, Haapasalo M (2013b) HyFlex nickel-titanium rotary instruments after clinical use: metallurgical properties. International Endodontic Journal. 2013b; 46, 720–9.

10. Pereira ÉS, Viana AC, Buono VT, Peters OA, Bahia MG. Behavior of nickel-titanium instruments manufactured with different thermal treatments. J Endod. 2015; 41(1):67-71.

11. Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Mechanical properties of controlled memory and superelastic nickel-titanium wires used in the manufacture of rotary endodontic instruments. J Endod. 2012; 38, 1535–40.

12. Santos L de A, Bahia MG de A, de Las Casas EB, Buono VTL. Comparison of the mechanical behavior between controlled memory and superelastic nickel-titanium files via finite element analysis. J Endod. 2013; 39(11):1444–7.
11. de Vasconcelos RA, Murphy S, Carvalho CAT, Govindjee RG, Govindjee S, Peters OA. Evidence for Reduced Fatigue Resistance of Contemporary Rotary Instruments Exposed to Body Temperature. J Endod. 2016 Mar 15.
12. Shen Y, Zhou HM, Wang Z, Campbell L, Zheng YF, Haapasalo M. Phase transformation behavior and mechanical properties of thermomechanically treated K3XF nickel-titanium instruments. J Endod. 2013;39(7):919-23.
15. Pereira ESJ, Peixoto IFC, Viana ACD, Oliveira II, Gonzalez BM, Buono VTL, et al. Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments. Int Endod J. 2012 ;45(5):469–74.
16. Zinelis S, Eliades T, Eliades G. A metallurgical characterization of ten endodontic NiTi instruments: assessing the clinical relevance of shape memory and super elastic properties of NiTi endodontics instruments. Int Endod J. 2010; 43: 125-34.
17. Gao Y, Gutmann Jl, Wilkinson K, et al. Evaluation of the impact of raw materials on the fatigue and mechanical properties of profile vortex rotary instruments. J Endod 2012; 38: 398-401.
18. Testarelli L, Plotino G, Al-Sudani D, Vincenzi V, Giansiracusa A, Grande NM, et al. Bending properties of a new nickel-titanium alloy with a lower percent by weight of nickel. J Endod. 2011;37(9):1293-5.
19. W.W.W. Coltene. Com/ file admin/ Data/ EN/ Products/ Endodontics/ Root-canal-shaping/Hyflex-EDM/ 6846-09-15-Hyflex-EN.pdf.
20. Zhao D, Shen Y, Peng B, Haapasalo M. Micro-computed tomography evaluation of the preparation of mesiobuccal root canals in maxillary first molars with Hyflex CM, Twisted Files, and K3 instruments. J Endod. 2013;39(3):385-8.
21. Bürklein S, Börjes L, Schäfer E. Comparison of preparation of curved root canals with Hyflex CM and Revo-S rotary nickel titanium instruments. Int Endod J. 2014; 47(5):470-6.
22. Yılmaz K, Özyürek T. Comparison of the cyclic fatigue resistance of nickel-titanium rotary instruments manufactured using controlled memory wire. Turk Endod J. 2017;2(1):5–9.
23. Zupanc J , Vahdat-Pajouh N, Schafer € E. New thermomechanically treated NiTi alloys – a review. Int Endod J.2018; 51, 1088–1103.
24. Pirani C , Iacono F , Generali L , Sassatelli P , Nucci1 C , Lusvarghi L , M. G. Gandolfil MG, & Prati1 C. HyFlex EDM: superficial features, metallurgical analysis and fatigue resistance of innovative electro discharge machined NiTi rotary instruments. Int Endod J. 2016; 49, 483–493.
25. Payal HS, Rajesh C, Sarabject S. Analysis of electro discharge machined surfaces of EN-31 tool steel. J Sci Ind Res. 2008; 67: 1072-7.
26. Theisen W, Schuermann A. Electro discharge machining of nickel–titanium shape memory alloys. Mater Sci Eng A. 2004;378(1-2):200–4.
27. Pernot J, Rolland X, Euvrard H. Endodontic instrument with rough surfaces, and method for producing such an instrument. Patent WO2015028743 A1, 2015.
28. Uslu G, Ozy € urek T, Yılmaz K. Comparison of alter- € ations in the surface topographies of HyFlex CM and HyFlex EDM nickel-titanium files after root canal preparation: a Three-dimensional optical profilometry study. J of Endod. 2018;44, 115–9.
29. Iacono F, Pirani C, Generali L, et al. Structural analysis of HyFlex EDM instruments. Int Endod J. 2017;50, 303–13.
30. Pedulla E, Lo Savio F, Boninelli S, et al. Torsional and cyclic fatigue resistance of a new nickel-titanium instrument manufactured by electrical discharge machining. J of Endod. 2016; 42, 156–9.
31. Gundo € gar M, Ozy € urek T. Cyclic fatigue resistance of € OneShape, HyFlex EDM, WaveOne Gold, and Reciproc Blue nickel-titanium instruments. J of Endod. 2017; 43, 1192–6.
32. Uygun AD, Unal M, Falakaloglu S, Guven Y. Comparison of the cyclic fatigue resistance of hyflex EDM, vortex blue, protaper gold, and onecurve nickel–Titanium instruments. Nigerian journal of clinical practice.2020; 23(1) : 41-45.
33. Khandagale PD, Shetty PP, Makandar SD, Bapna PA, Karobari MI et al., Evaluation of Cyclic Fatigue of Hyflex EDM, Twisted Files, and ProTaper Gold Manufactured with Different Processes: An In Vitro study. International journal of dentistry. Volume 2021 |Article ID 7402658 .
34. Soram Oh S, Moon SY , Chaniotis A, Pedullá E , Al-Ghamdi AS ,et al., Evaluation of Cyclic Fatigue and Bending Resistance of Coronal Preflaring NiTi File Manufactured with Different Heat Treatments. Appl. Sci. 2021, 11, 7694.
35. Singh H, Kapoor P. Hyflex CM and EDM Files: Revolutionizing the Art and Science of Endodontics. J Dent Health Oral Disord Ther. 2016; 5(7): 00182.