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Review Article

Niti: A Savior in Endodontics

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Abstract

A wide array of NiTi instruments has been introduced for shaping root canals. Many variables and physical properties influence the clinical performance of NiTi rotaries. It is the clinical experience, handling properties, safety, and case outcomes that decide the fate of a particular instrument design. This review article appraises the mechanical properties and advancement of NiTi instruments.

Key words: Advances in niti, Mechanical properties, Nickel–titanium, Rotary instruments

INTRODUCTION

One of the primary goals of endodontic therapy is the complete debridement of pulp tissue from the canal, coupled with shaping of the root canal system.[1]

The introduction of nickel–titanium (NiTi) alloys and the subsequent automation of mechanical preparation was the first steps toward a new era in endodontics.[2,3] Recent advances in manufacturing process of NiTi alloys have allowed for development of rotary endodontic files that are more flexible, less likely to fracture and more capable of maintaining the original canal position than their predecessors.[4,5]

HISTORY

In 1963, NiTi alloy was generally developed for the U.S. space program at the Naval Ordnance Laboratory and named as "Nitinol."[6] It was 1st used in 1971 by Andreasen and Hilleman in manufacture of orthodontic wires.[7] Later, in 1988 Walia, Brantley and Gerstein introduced 1st handheld NiTi made by matching orthodontic wire. A new concept in file design, that is, ProTaper system (Dentsply, Sirona) was introduced in 2001.[8]

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In 2011, the Swiss dental specialist COLTENE developed method for modifying DNA of NiTi, in which files were given true shape memory and thus allowed exceptionally precise working.[9] Most recently in 2016 same manufacture introduced Hyflex electrical discharge machining (EDM) system, also made from NiTi CM 495 alloy.[3]

MECHANICAL PROPERTIES OF NITI

NiTi alloy used in endodontics contain approximately 56 wt.% nickel and 44 wt% titanium resulting in a nearly one to one atomic ratio.[10] The equiatomic NiTi alloy can exist in 2 different temperature-dependent crystal structures named austenite (parent phase with cubic B2 crystal structure) and martensite phase (low temperature phase with monoclinic B19 crystal structure)[11] and possesses typical characteristics which are super elasticity (SE) and shape memory effect (SME).[12,13] These properties occur as a result of the austenite-to-martensite transition (martensitic transformation), which can be introduced by stress or temperature.[14,15]

ADVANCES IN NITI ALLOY

More recently, a new generation of the Race system – the booster tip (BT)-RaCe instruments – was introduced.[3,16] These instruments have a special non-cutting "booster tip" (BT) up to 0.17 mm in length with six cutting edges and a reduced diameter, which, according to the manufacturer, facilitates progression of the instrument to the apical region of the root canal while maintaining its original curvature.[3]

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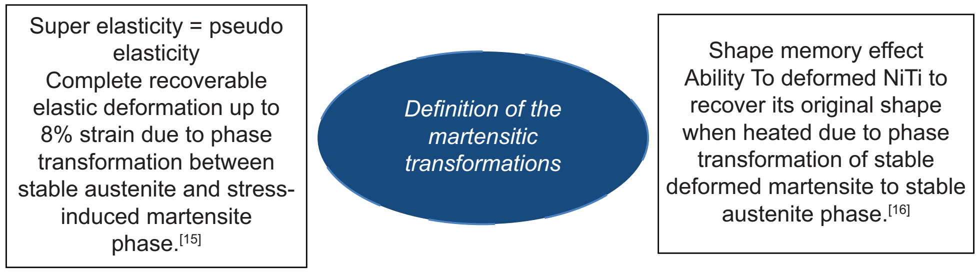

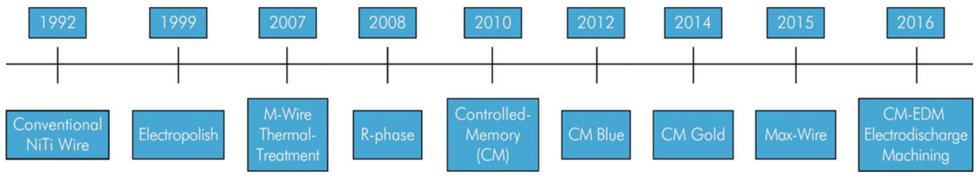

Similar to the Race system, the EndoSequence instruments (Brasseler, Savannah, GA, USA) also undergo electrochemical treatment after machining, which consists of immersion in an ionic solution through which an electric current pass to remove any irregularities generated during the manufacturing process.[3]

In 2007, Tulsa Dental developed a new NiTi alloy known as M-Wire, composed of Nitinol 508 (55.8% Ni by weight, Ti completing the balance), which undergoes unique thermal treatments at various temperatures, done before the instruments are machined.[3] This material contains both the martensite and R phases, while maintaining pseudoelasticity.[17] Compared to instruments fabricated from conventional NiTi alloys, instruments made from M-Wire alloy have higher cyclic fatigue resistance and improved mechanical properties.[18]

In 2008, Sybron Endo introduced a series of mechanical NiTi instruments subjected to a special heat treatment after completion of the machining process, which creates an additional phase change in the crystal structure of the alloy to improve flexibility and strength, besides accommodating some of the internal stress caused by machining.[3,19] As noted above, this phase of the NiTi alloy (the R phase) is an intermediate phase between martensite and austenite and occurs during martensitic transformation when cooling to the R phase, as well as from the R phase to marten site.[20]

In 2010, instruments manufactured with controlled memory (CM)-wire thermal treatment technology were introduced by DS Dental (Johnson City, TN, USA).[21] 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, which confers greater fatigue resistance and flexibility, contributing to a more centered canal preparation and lower rates of transportation.[3] These instruments also contain less nickel (52%) than conventional SE alloys (54–57%), which improves the mechanical properties of the alloy.[22]

In 2011, Coltene/Whaledent (Cuyahoga Falls, OH) introduced the Hyflex line with instruments made from (CM-Wire, Johnson City, TN, USA).[23] The system consists of instruments developed to work specific regions of the root canal, starting with removal of cervical interferences with an orifice shaper, followed by preparation of the middle and apical thirds, and ending with more tapered instruments for final shaping.[3,24]

In 2012, Dentsply Sirona introduced a new heat treatment process for NiTi CM alloys, whereby instruments are repeatedly heat-treated and then cooled, which results in a surface color corresponding to the thickness of the layer of titanium oxide.[3] The Vortex Blue (Dentsply Sirona), Sequence Rotary File and X1 Blue File (MK Life, Porto Alegre, RS, Brazil), Reciproc Blue (VDW), ProTaper Gold (Dentsply Sirona), and WaveOne Gold systems are manufactured using this technology.[3] In the NiTi Blue Wire alloy, the thickness of the titanium oxide layer is 60–80 nm, whereas in the NiTi Gold alloy, this thickness is 100–140 nm.[3,25]

More recently, in 2016, the same manufacturer introduced the Hyflex EDM system (Coltene/Whaledent, Cuyahoga Falls, OH), also made from NiTi CM 495 alloy, but manufactured using spark-erosion technology, widely used in engineering.[3] This EDM, or EDM, is a non-contact thermal erosion process employed in the manufacture of electrically conductive materials which use controlled electric discharges in the presence of a dielectric fluid.[26,27] This processes "melts" the surface of the metal (in this case, a NiTi alloy), partially evaporating small portions of the metal and leaving behind an eroded surface.[3]

Recently, a special NiTi alloy known as MaxWire (Martensite-Austenite Electropolishing-Flex, FKG) was developed for the manufacture of instruments in the XP-endo family (FKG): XP-endo Finisher (XP-F), XP-endo Finisher Retreatment (XP-R), and XP-endo Shaper (XP-S).[3] As a result of the alloy treatment, at temperatures equal to or greater than 35°C, it shifts from the martensitic to the austenitic phase, giving the instrument a semi-circular shape that allows it to project against the walls of the root canal when rotating, performing eccentric rotary motion.[3,28] Thus, XP-endo instruments are able to adapt to the morphology of the root canal system, expanding, or contracting as they advance along the working length.[29] The XP-endo Finisher has an ISO 25 diameter and zero taper (25/0.00). Its main purpose is to provide supplementary cleaning of the canal at the end of chemical and mechanical preparation by touching hard-to-reach areas of the root canal walls, preserving dentin, and the internal anatomy of the canal.[3] It has been reported that the mechanical action of XP-F, when combined with agitation of the irrigant, promoted greater bacterial reduction and biofilm removal from the main canal and dentin tubules.[3,30]

CONCLUSION

Recent advancements in the manufacturing process of NiTi alloys will enhance the quality of endodontic treatment by the development of newer endodontic instruments with superior mechanical properties. Post-machining thermomechanical heat treatment will increase durability of the instrument by increasing the flexural/cyclic fatigue resistance. SE and SME of the NiTi instruments will result from phase transformation on heat treatment, which offered a promising result in enhancement of fatigue resistance during root canal preparation in complicated curved canals. In future, further research has to be needed for heat treatment of retreatment file systems and to improve the efficiency, safety, and quality of endodontic instruments.

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