Metal vs. Motion: The Driving Forces in NiTi Instrumentation

Learning Objectives:

1. Understand the basic characteristics of the NiTinol alloy and the differences between Shape Memory (austenite) and Controlled Memory (martensite) NiTi instruments.
2. Understand the file design and clinical protocol for the ESX System.
3. Understand the difference between the 3 different motions available for driving NiTi instrumentation (rotary, reciprocation and OTR).

Origin and Features of the NiTinol alloy:

In 1958 scientist at the Naval Ordinance Laboratory were looking for a metal that could be used to improve US missile nose cones. They wanted a metal that could resist fatigue, heat and the force of impact. They ultimately discovered what we know today as NiTi.

NiTi is an exotic metal in that it does not behave like normal alloys. Normal alloys become more ductile (and eventually melt) when they are heated. NiTi does the opposite. At high temperatures NiTi transitions to a cubic molecular structure which is more robust and resistant to torsional stress. This is known as the Austinite or parent phase (Figure A). At cooler temperatures NiTi transitions to a more complicated molecular structure known as the Martensite phase or daughter phase (Figure B). In this M phase the metal is ductile and highly resistant to cyclic fatigue (think of a wet noodle). The temperature at which NiTi transitions from the M phase to the A phase can be altered with proprietary processes. During the manufacturing process NiTi can be formed into a desired parent state (A phase) shape. At lower temperatures the metal can be manipulated but once exposed to a predefined (warmer) temperature it will transition to the A phase and morph into the predetermined shape.

Figure A

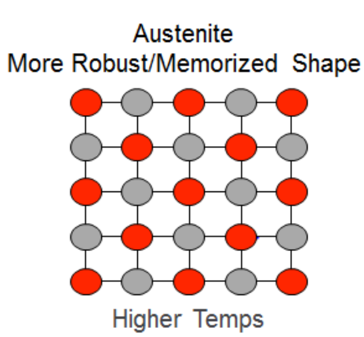
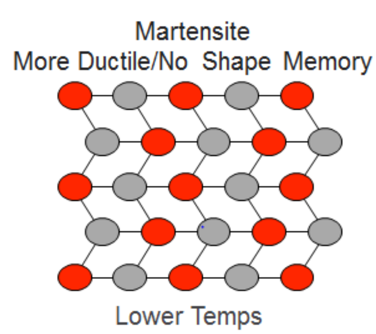


Figure B



Shape Memory vs. Controlled Memory NiTi:

There are clear benefits and disadvantages to both shape memory and controlled memory files:

NiTi Type	Shape Memory	Controlled Memory
Featues	**Pros and Cons**	
Cutting Edge Sharpness	✓	✗
Cutting Edge Fidelity	✓	✗
Ability to Pre-bend	✗	✓
Tendency to transport	✓	✓
Tendency to unwind	✓	✗
Tendency to separate	✗	✓
Length Control Fidelity	✓	✗

There is no perfect NiTi file for every operator and many clinicians will chose to incorporate a combination of shape memory and controlled memory instruments into their armamentarium. By understanding the benefits of each type of instrument clinicians can make more informed decisions (Figure C). It's very common for clinicians to use a shape memory file (KontrolFlex) when they want to pre-curve the instrument for difficult access or severe curvatures. However, for maximum cutting efficiency an austenite file is preferred (ESX) due to its resistance to torsional fatigue and cutting edge fidelity (won't unwind/deform as easily).

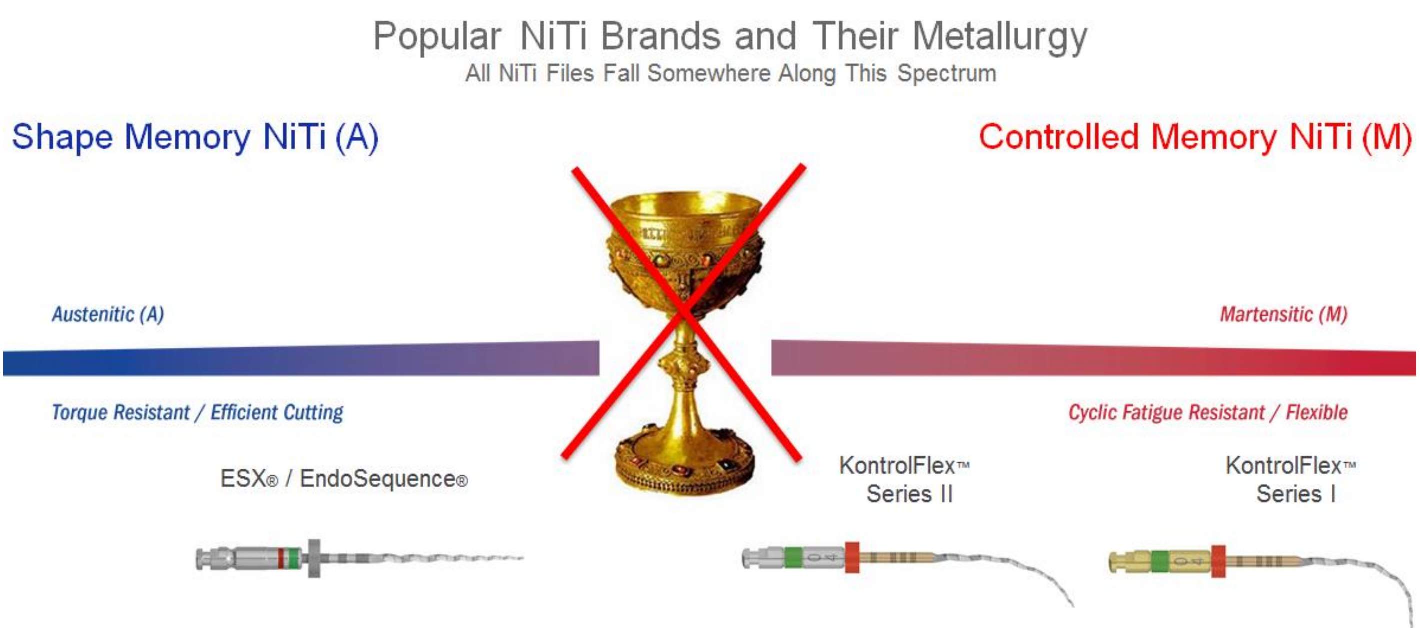


Figure C: The Shape Memory vs. Controlled Memory Continuum

File Design:

Setting metallurgy aside there are countless file designs available in today's market. The latest file designs feature an asymmetric cutting axis with a larger chip space for debris removal. These files can cut slightly outside of their central axis and require lower torque because the cutting flutes can disengage along the axis of the canal. Some popular brands in this category include: ESX (Figure D), EndoSequence, ProTaper Next, and TruShape.

Figure D: ESX Alternating Contact Point (ACP) Design

The tip of a file is equally as important as the cutting flute design. The ESX file features the patented Booster Tip which helps guide the file around curvatures and keeps it centered in the canal (Figure E). The tip has 6 cutting edges that transition to a true reamer (triangular cross section) within 1 mm of the tip thereby allowing the instrument to function as both a scouting and finishing file. This patented tip reduces the number of instruments needed to shape the canal.

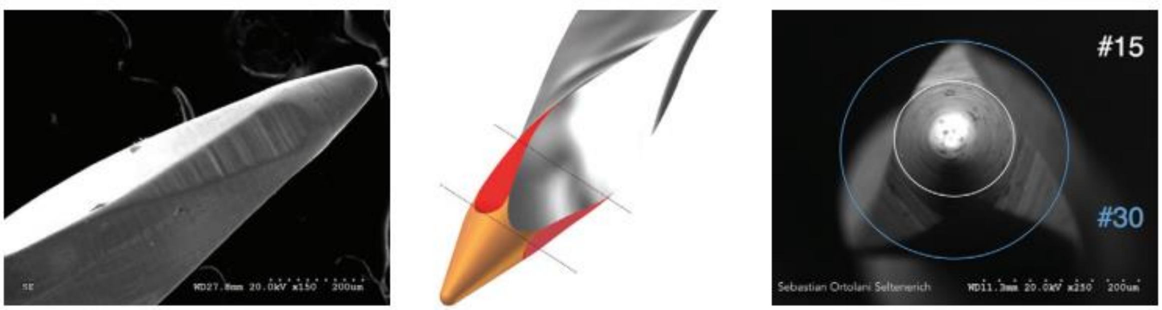
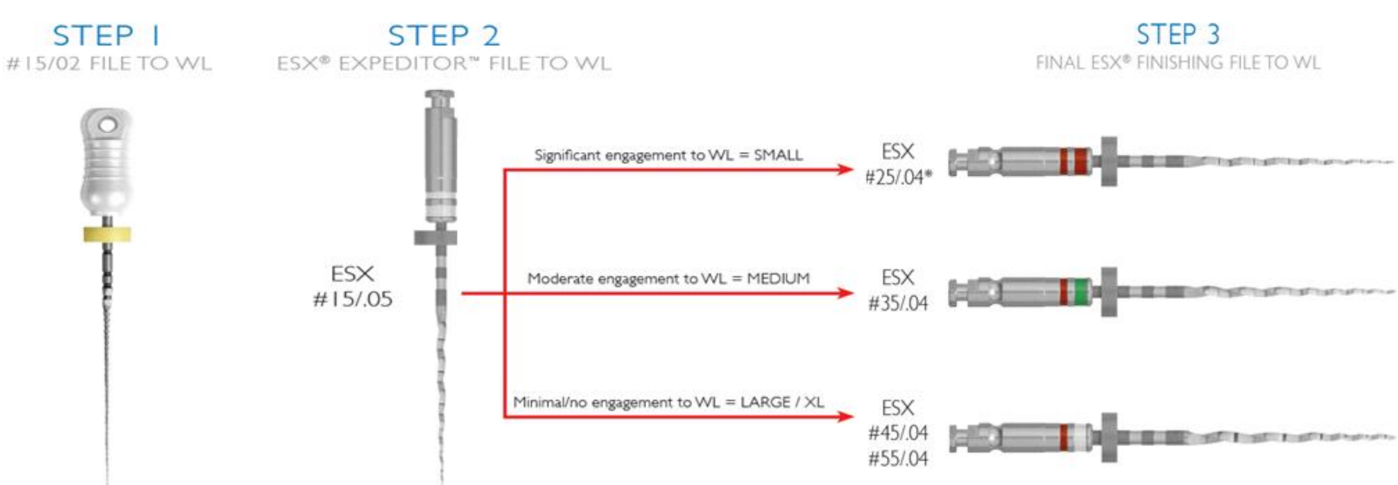


Figure E: ESX Booster Tip

ESX Technique

The ESX system is a true 2 file shaping system. All instruments should be used at 500-600 RPMs at a torque of 1.5-2.5 Ncm with a gentle touch and the single stroke and clean technique. After achieving apical patency with a #15/02, use the ESX Expeditor to achieve full working length noting the level of engagement. Next select the appropriate ESX finishing instrument based on the level of engagement (significant=small, moderate=medium, minimal=large) and complete he preparation. Note: ESX finishing instruments are also available in size #30 and #40.



Motion: Rotary, Reciprocation and OTR (Optimized Torque Reverse)

There are 3 different modes of movement for NiTi instrumentation (Figure F). Both rotary and reciprocation have clearly documented drawbacks. The newest motion (OTR-Optimized Torque Reverse) takes advantage of the benefits of both rotary and reciprocation while eliminating the disadvantages of each. OTR allows for maximum safety and efficiency and can be thought of as anti-lock brakes for your Niti files. Ideally the OTR mode is never engaged but if you get into trouble (torque) OTR kicks in and safely disengages and reengages the file without interrupting your work flow. *Note*: OTR is a unique feature of Brasseler USA's EndoSync handpiece which is synchronized with the EndoSync A.I. Apex locator for real time depth readings.

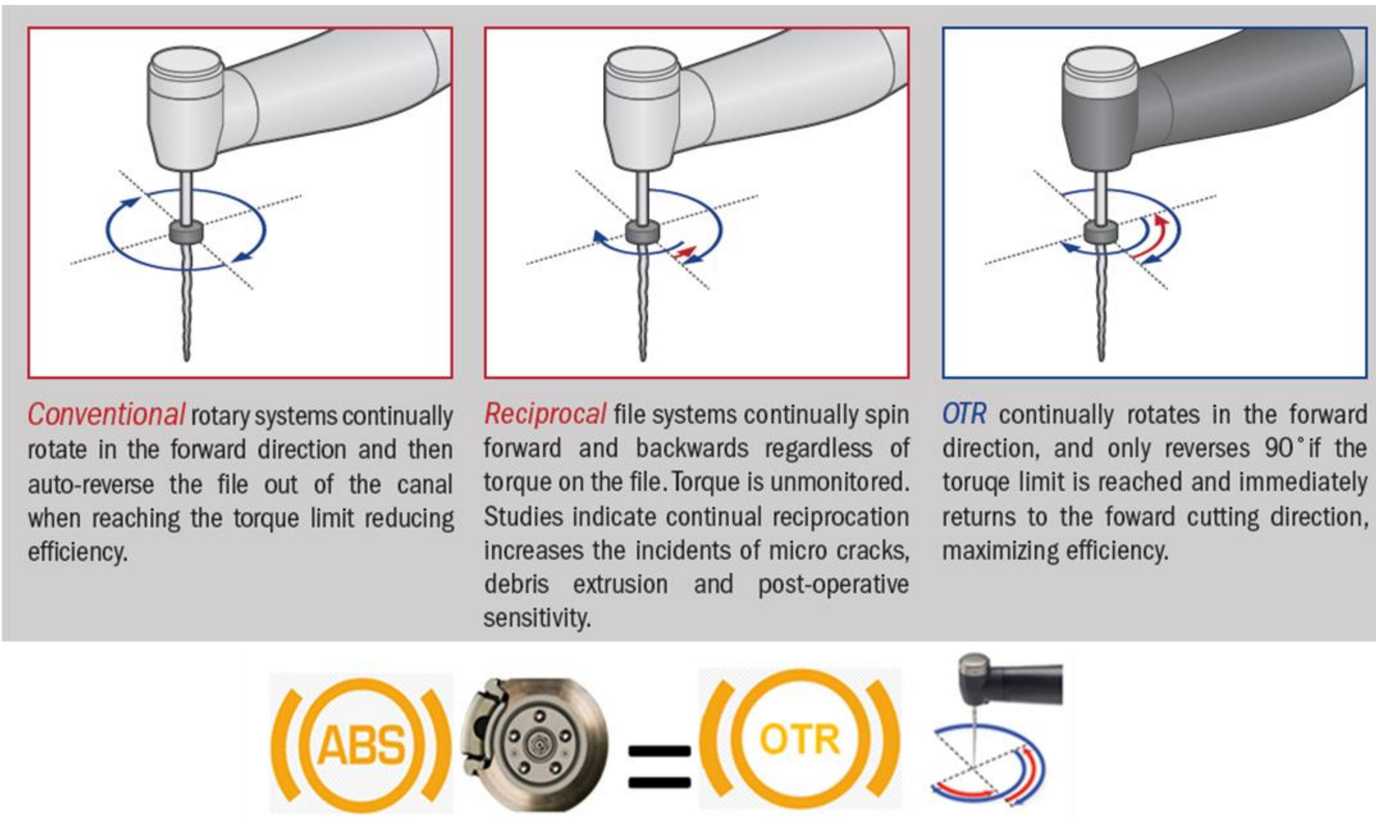


Figure F: 3 Modes of Movement

Studies References (Disadvantages of Reciprocation):

1. Robinson JP et al. Recoprocating root canal technique induces greater debris accumulatioin than a continuous rotary technique as assessed by 3-diminsional micro-computerized tomography. J Endod. 2013;39)8):1067:1070.
2. Nekoofar MH et al. Comparison of the effect of root canal preparation by using WaveOne and ProTaper on postoperative pain: a randomized clinical trial. J Endod. 2015;41(5):575-578.
3. Burklien S et al. Incidence of dentinal defects after root canal preparation: reciprocating vs rotary instrumentation J Endod.2013;39(4) 501.504.
4. Berutti E et al. Effect of canal length and curvature on working length alteration with WaveOne recporcating files. J Endod. 2011;37(12): 1687:1690.

Conclusions:

Recent advancements in NiTi metallurgy, design and handpiece technology are improving the standard of care in endodontic instrumentation. When selecting an endodontic system clinicians should be aware of the benefits and disadvantages of shape memory and controlled memory NiTi files. Clinicians should consider using files and motors that incorporate the latest technology and safety features.