Nitinol Total Control: A New Orthodontic Alloy

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A superior orthodontic archwire has the capability to be deflected over long distances without permanent deformation, is flexible enough to allow the bracket slot to be filled with low force levels, and is highly formable.[1-10] The work-hardened nickel titanium alloy introduced in 1971[11] demonstrated the desirable qualities of high springback and low stiffness, but fractured readily when bent over a sharp edge.[5] Kapila and Sachdeva stated that "the poor formability of Nitinol wires implies that they are best suited for preadjusted appliance systems. Any first-, second-, and third-order bends have to be overprescribed to obtain the desired permanent bend."[9]

Second-generation nickel titanium archwires, developed in the 1980s,[7,8] exhibit superelastic properties that allow a constant force to be delivered over a long period of time. Thus, the clinician can use lower force levels while filling the bracket slot for greater control of tooth movements.[10,12-15] While the number and frequency of archwire changes are reduced,[16] the inability of the wires to accept permanent bends is still a limitation.

With current technologies, at least, it seems futile to expect a fully programmed appliance to eliminate all archwire bends.[17] Variations in tooth morphology, bracket positioning, and bracket engagement necessitate alternatives to conventional straightwire techniques.

In 1988, Miura, Mogi, and Ohura demonstrated the use of electrical-resistance heat treatment to introduce permanent bends in their nickel titanium wires.[18] The technique requires special pliers attached to an electric power supply. Although the authors claimed that the superelastic force of the wire was not affected by the treatment, heating the wire does alter the crystalline structure of the nickel titanium lattice.

A new pseudo-superelastic nickel titanium alloy, Nitinol Total Control,* accepts specific 1st-, 2nd-, and 3rd-order bends while maintaining its desirable superelastic properties.

Materials and Methods

Laboratory tests were set up to compare NTC archwires to four currently available archwires: TMA,** TiNB,** SE NiTi,* and stainless steel.*** For consistency, .016" × .022" archwires were used in all tests.

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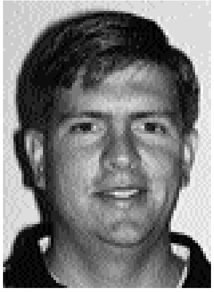
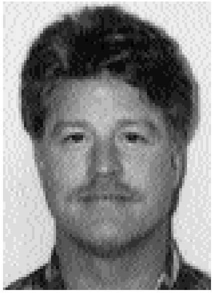


Dr. Thayer



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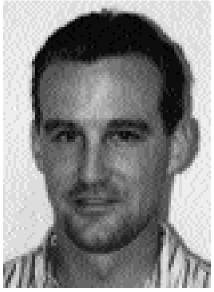

Mr. Meyer

1. Friction Testing

Twenty samples of each archwire material were tested for static frictional force, utilizing a simulated retraction device as described by Omana.[19] Each wire sample was placed in the upper Instron† vise and fed through the slot of a fixed metal bracket secured by an elastomeric ligature (Table 1, Fig. 1).

2. Three-Point Bend Testing

Five samples of each wire type were tested for three-point bending, as described by Miura et al.,[8] using a QT/1 Qtest single-screw force-testing machine. Strain levels were recorded at 6% to obtain mean unload force levels, using the following formula for rectangular wire:

$$X = \frac{6 \times d \times s}{L^2}$$

TABLE 1
FRICTIONAL FORCE (G)

Wire Type	Mean	S.D.	Min.	Max.
NTC	94.65	7.32	77.0	103.0
TMA	128.65	12.95	97.0	145.0
TiNB	204.80	30.18	125.0	255.0
SE NiTi	70.50	5.92	62.0	80.0
Stainless steel	39.20	9.85	25.0	59.0

where X is percent strain, d is wire thickness or diameter, s is maximum deflection, and L is fixture span. The unload force was measured at a distance halfway between maximum deflection and zero force (Table 2, Fig. 2).

For bendable wires, a "return gap" was also determined. The return gap is the distance at which the *x*-axis reading returns to zero force on

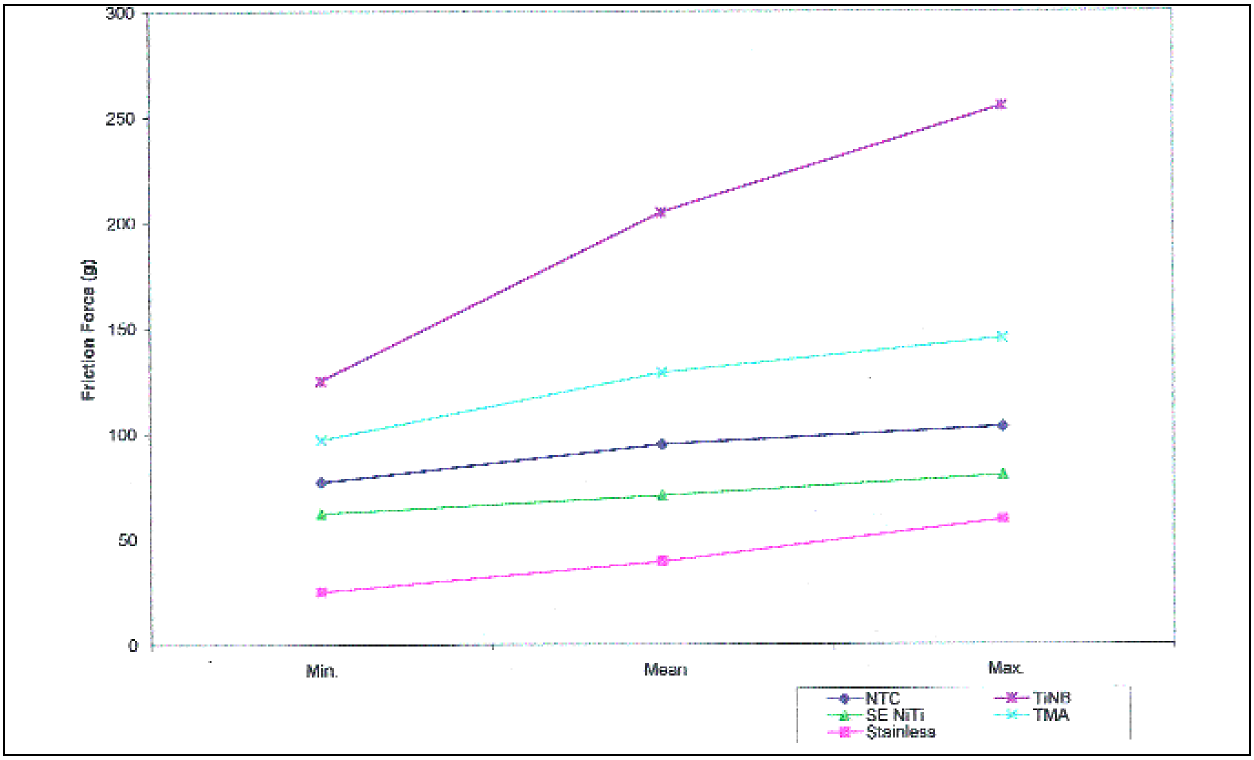

Fig. 1 Frictional forces by wire type.

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†Instron Corp., Canton, MA.

the unloading cycle. A return gap of zero indicates superelasticity.

3. Bendability Testing

Each of the five archwire types was tested at multiple strain levels to determine the bendability or "working range" of the specific alloy. Three-point bend tests were performed over a range of 1.5-12% strain, in 1.5% increments. Deflections were calculated according to the formula shown above.

"Imposed strain" is another way of measuring the percentage strain delivered to the archwire material during loading. "Residual strain" is the amount of permanent deformation that remains in the archwire material after unloading. In other words, bendability is indicated by increased levels of residual strain.

TABLE 2
PEAK AND UNLOAD FORCES (G) AND RETURN GAPS

Wire Type	Mean Peak Load	Mean Unload Force	Mean Return Gap
NTC	682.7	343.3	0.017"
TMA	1,253.7	632.3	0.009"
TiNB	976.6	482.6	0.029"
SE NiTi	617.3	298.5	0.000"
Stainless steel	1,989.0	990.2	0.030"

NTC, TMA, TiNB, and stainless steel all showed various levels of residual strain (perma-

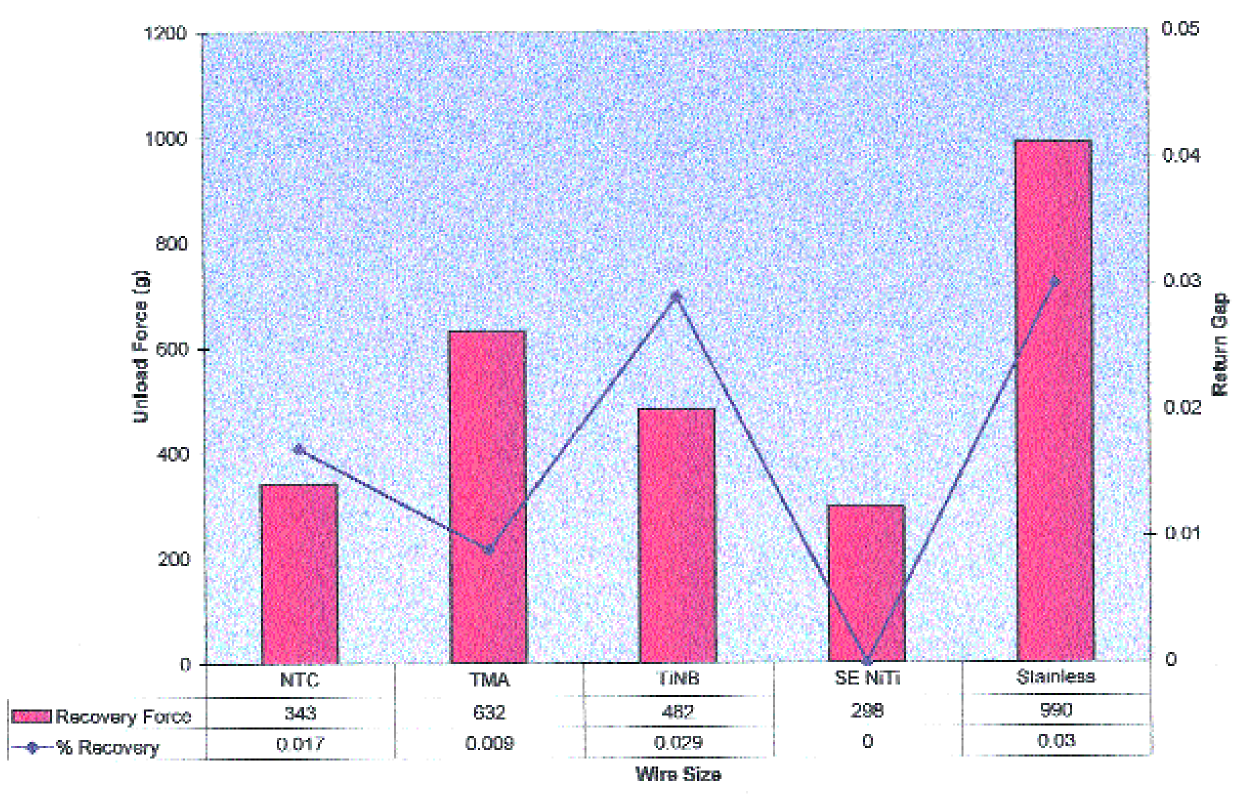

Fig. 2 Unload forces and return gaps by wire type.

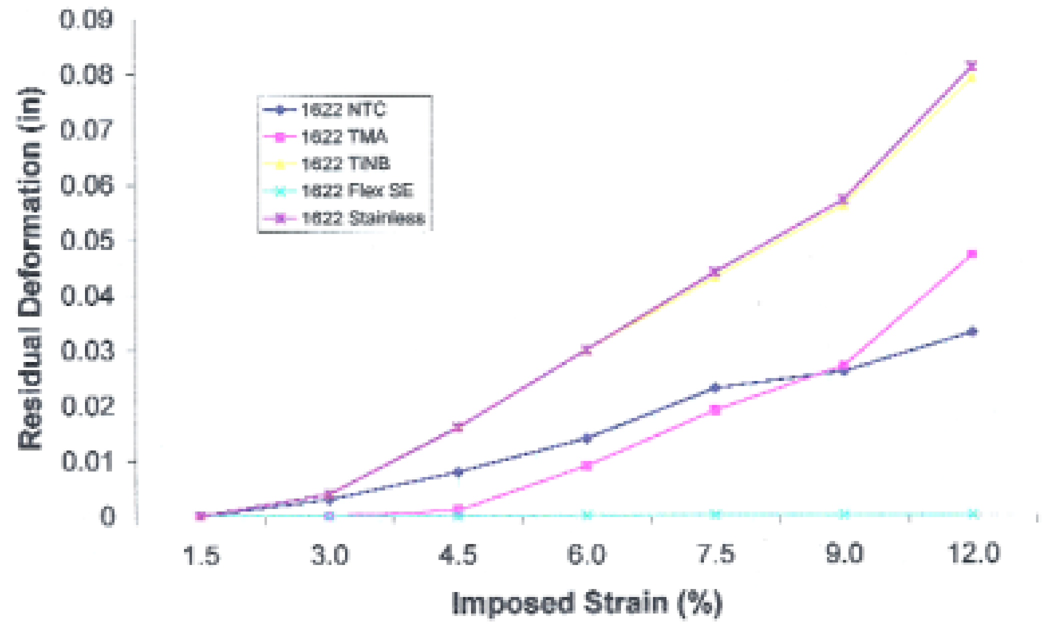

Fig. 3 Imposed vs. residual strain by wire type.

nent deformation), with NTC similar to TMA (Fig. 3). Only SE NiTi showed no residual strain.

Discussion

NTC combines the ability of superelastic nickel titanium to deliver light, continuous forces over a desired treatment range with the bendability required to account for variations in tooth morphology, archform, and bracket prescriptions. Frictional and bending tests verify that the force levels produced by NTC are within accepted ranges for optimal tooth movement. Furthermore, NTC's properties are not temperature-dependent.

Because of NTC's relatively low stiffness, it should not be used for space closure. NTC can avoid the need to change archwires, however, in the following situations:

- Repositioning due to improper bracket placement
- Repositioning brackets to maintain torque control
- Placement of extrusion, intrusion, or utility arches
- Functional finishing with detailing bends that address variations in tooth morphology and interarch occlusal relationships
- Filling the bracket slot with controlled, light force (torque without shearing the bracket)

NTC reduces archwire inventory without compromising treatment mechanics. Lower forces are generally associated with less patient discomfort. In addition, by reducing the number of archwire changes required, NTC allows the clinician to treat more patients effectively and efficiently.

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