Aligning, leveling, and torque control—a pilot study

By George F. Andreasen, DDS, MSD and Reid M. Amborn, DMD, MS

The aligning and leveling of bracket slots is necessary in all fixed edgewise orthodontic treatment. An important phase of treatment is the torque control over the roots of all teeth from the onset of treatment.[1-5] The problem of initiating torque control at the onset of treatment is that the typical arch wire is too stiff to engage all bracket slots.[6]

Initial wire leveling and torque control requires a rectangular or square wire that nearly fills the bracket slot. At the present time, two types of wires are available for use as an initial wire with torque control: the thermodynamic rectangular ni-ti wires and the rectangular multi-stranded stainless steel wires.

The purpose of this descriptive clinical pilot report is to evaluate the potential of a rectangular, thermal ni-ti wire to serve as a leveling, aligning, and torque control arch wire. Increasing the size of the wire to fill the bracket slot decreases the wire's flexibility and reduces the elastic range over which the wire works.[1] Thermal ni-ti wire, because of its unique heat-activated memory capabilities[7-9] appears to have the potential to perform these necessary functions despite the increase in size. A brief discussion of the development of arch wires will be considered in this clinical report.

In the early years of orthodontics, gold alloy was the most commonly used material for arch wires[3,10-12]. A limitation of this wire was its lack of springback. Because of increasing cost, use of gold alloy wires declined; in the 1940s stainless steel wires began to replace those made of gold alloy. To gain more elasticity, the size of the arch wires was reduced, then the shape was changed from rectangular to round. Additional progress was made by the development of loops to increase the range of activation[13]. Loop techniques were used and refined by Thurow,[14] Begg,[15] Stoner,[16] Jarabak,[17] Burstone,[18] and Waters.[19,20] These techniques all served to decrease stiffness of the wire and increase its working range. A disadvantage of loops is that they are easily dis-

Abstract

Aligning, leveling, and anterior torque control of teeth from the onset of treatment is suggested with thermal ni-ti rectangular low stiffness wires. Before and after superimpositions show the degree that torque control was achieved on four clinical patients.

Key Words

Parallel roots • Root torque • Aligning • Leveling • Root control

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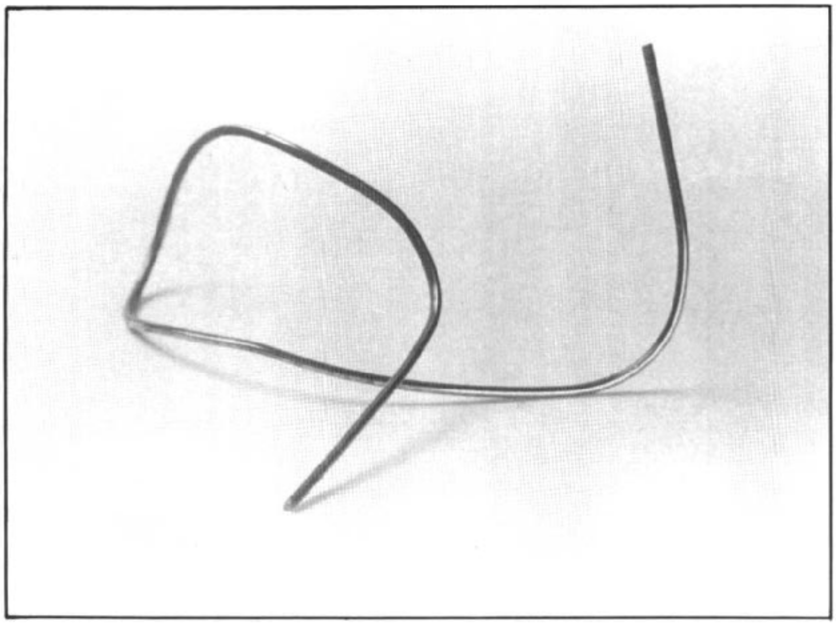

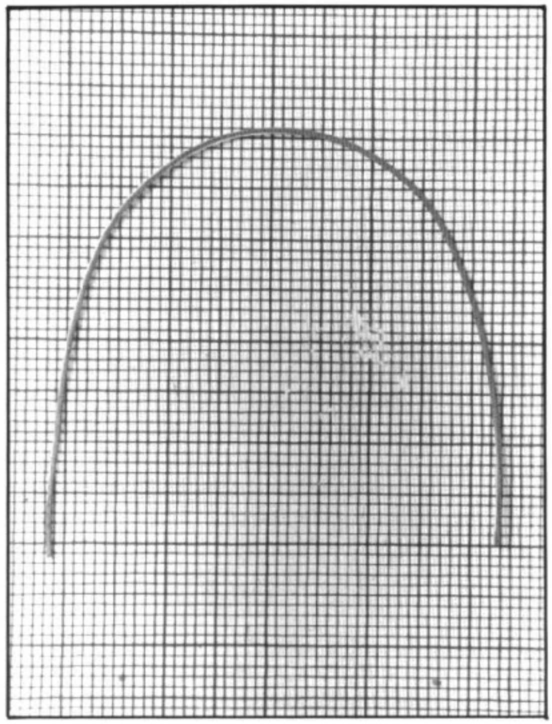

Figure 1.
Deformed rectangular nitinol wire at room temperature.

Figure 2.
Rectangular Nitinol wire after activation at body temperature.

torted by the patient altering force direction vectors.[21,22] The braided or twisted wire is a later development that gave the stainless steel arch wire more flexibility and working range.[6,23,24] Arch wires made of the alloy, Elgiloy*, have excellent formability in the soft condition and can be heated to 480° C to obtain strength properties comparable to stainless steel.[3] Elgiloy is usually used as a finishing wire.[10]

In 1976 a new orthodontic wire made from Nitinol** was introduced.[25] Nitinol had been developed by William F. Buehler at the Naval Ordnance Laboratory in the early 1960s.[26] Since the introduction of Nitinol wires, a number of ni-ti arch wires have been marketed for orthodonic use. To date, the most commonly used form of Nitinol wire has been the super elastic form which is not affected by temperature.[27]

Advantages of ni-ti include its physical stability (low degree of corrosion), and minimal tissue reaction, comparable to that of stainless steel.[28] Ni-ti wires generate less frictional resistance than stainless steel when using sliding mechanics,[29] thereby allowing tooth movement with less force.

Materials and Methods

Thermal ni-ti is another form of ni-ti wire. form This is not commonly available to the orthodontist. The most unusual feature of thermal Nitinol wire is its unique mechanical thermal memory, the capability to recover an original shape configuration after mechanical distortion. Recovery is achieved by heating the wire above its transition temperature range (TTR).[26] Below its TTR, the wire is highly ductile and easily undergoes plastic deformation. When heated above its TTR, the wire returns to its original shape and becomes quite stiff and resilient.[9] If the TTR of a thermodynamic Nitinol wire is set near body temperature, then near room temperature the wire can be deformed easily and tied into the brackets of all malposed teeth. As the body temperature heats the wire to its TTR, the wire seeks to return to its original shape, pulling the teeth with it.[8] Through a high temperature heat treatment, the wire can be set to return to any desired form.[8,30]

Four representative arch wires made of .017x.025 inch thermal ni-ti wire were obtained for this study. Each wire was measured with a micrometer to verify size. Accuracy of the TTR's was verified in a water bath heated to 37° C. Figure 1 shows the wire at room temperature and Figure 2 illustrates the wire's activation near body temperature.

A Tinius-Olsen six inch-pound moment capacity stiffness tester was used to determine force deflection curves for each of the wires. A bending span of ½ inch was used. The tests were carried out at three temperatures: (1) body temperature, 37°C; (2) room temperature, 23°C; and (3) cold water temperature, 13°C.

Clinical evaluation

Four representative subjects with 4–6 mm of dental crowding in each arch were selected. These cases were chosen in order to test the

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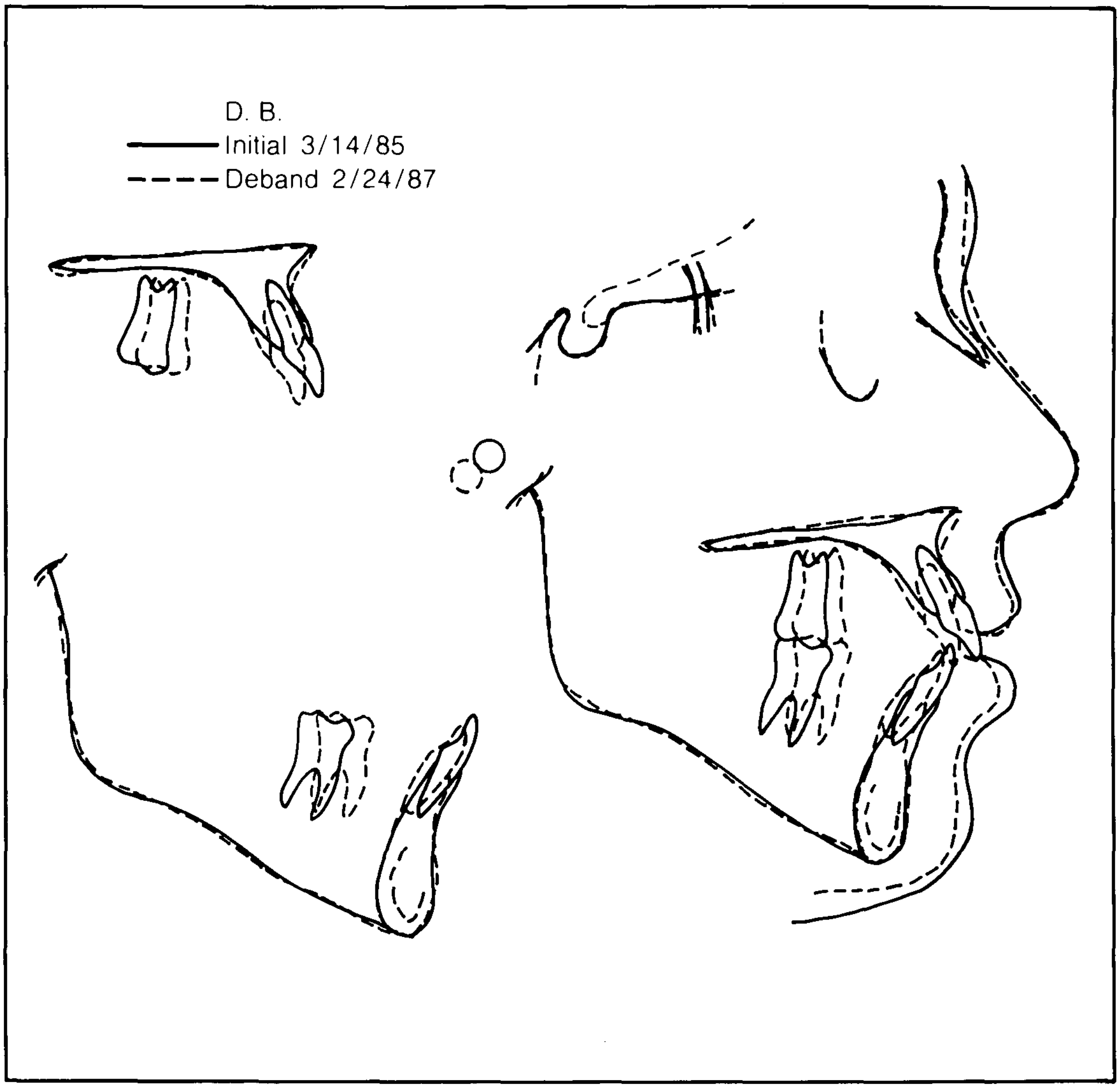

Figure 3.
Superimpositions of torque control before treatment and after debanding on patient D.B.

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fullest extent of the capacity of the thermal Nitinol wire to serve as a leveling and aligning arch wire with torque control. The subjects were all adolescents with Class I crowded dentitions, 1-3 mm overbite, and were specifically chosen for a minimum of 3-5 mm overjet requiring retraction along with upright root contol of incisors. Straight pull headgear and thermal .017x.025 ni-ti wire was used to retract the maxillary incisors bodily. Three of the treatment plans did not include any extractions. One patient had a maxillary left premolar missing and her left molars were finished in a Class II molar relationship. Four premolars were extracted in the fourth patient.

Thermal wire was used in the maxillary dental arch of each of four patients while the mandibular dental arch was treated with a standard twisted multi-strand stainless steel arch wire. An .018x.025 inch siamese straight wire bracket was used on each patient. The .017x.025 thermal ni-ti wire fills the bracket slot of an .018 inch

UPPER INCISOR TO S.N. PLANE

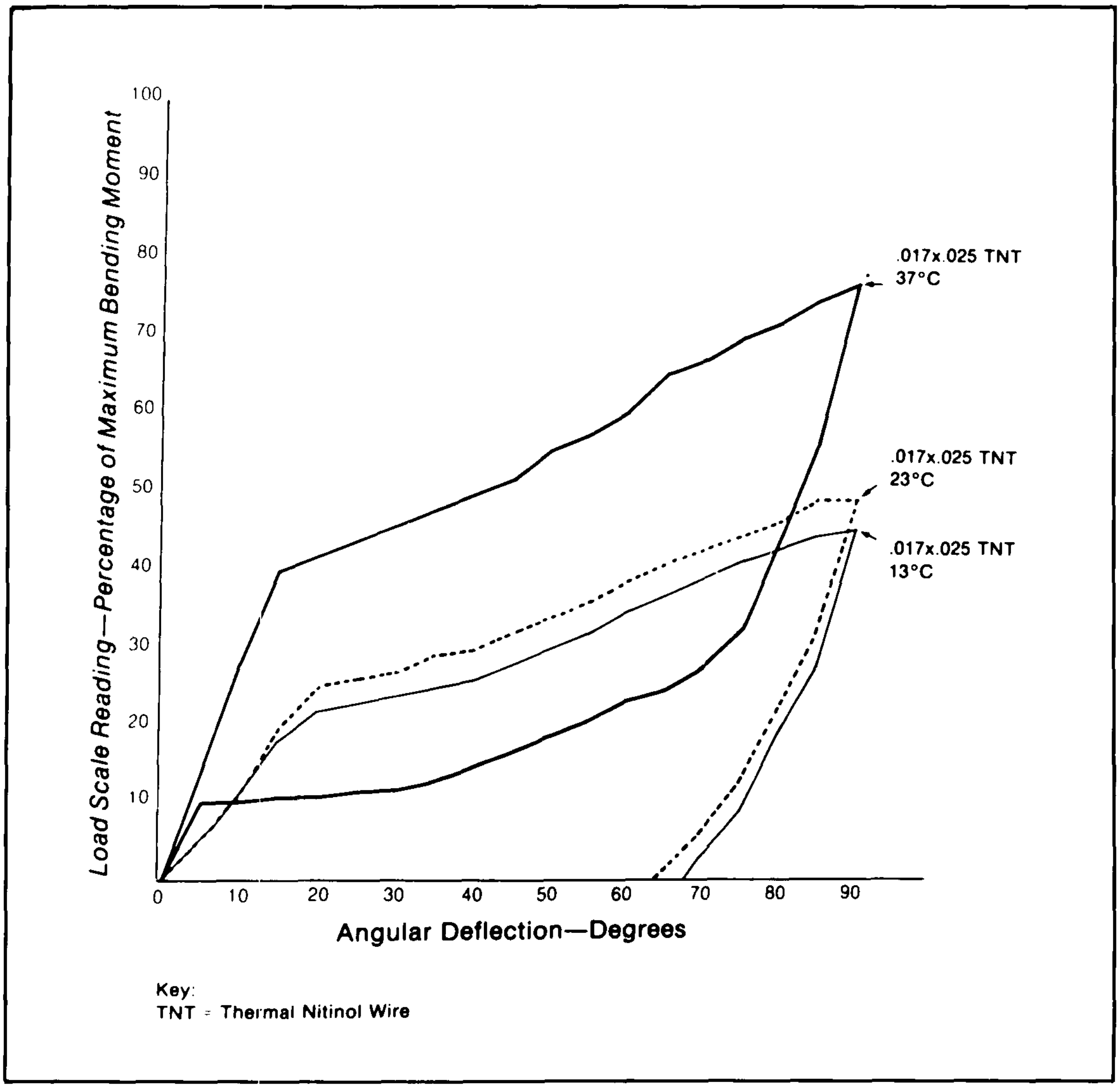
	Initial	After Debanding
S.B.	98°	102°
J.L.	96°	95°
L.R.	105°	109°
D.B.	108°	105°

Table 1.
Data of the measurement of the upper incisor to the SN plane.

slotted straight wire appliance, thereby providing three-dimensional torque control for maxillary tooth movement. The round twisted wire used in the mandibular arch gives two-dimensional control over tooth movement.

Each patient was seen weekly for a sixteen week testing period. At each appointment, patients were asked to compare the amount of discomfort present in the maxillary arch with discomfort in the mandibular dental arch. Every fourth week the lower twisted stainless steel wires and .016

Figure 4.
Force Deflection curves for a representative rectangular thermal nitinol wire.



stainless steel leveling wires were changed. At the end of the 16th week, treatment with traditional wires was initiated to finish the cases.

Results

Figure 3 shows superimpositions of the torque control before treatment and after debanding. Table 1 provides data obtained from the superimpositions by measuring the angle of the maxillary incisors to the SN plane before treatment and after debanding These records demonstrate angular torque control of the maxillary incisors. Included in the total treatment are the 16-week thermal ni-ti aligning, leveling, and torque control treatment trials.[31]

Periapical radiographs taken before and after the 16th week of the clinical trial showed no visible signs of root resorption on three of the four patients; however, there was slight root resorption of the maxillary anterior teeth after one year 11 months of treatment of one patient.

Discussion

Torque control is an important aspect of any orthodontic treatment. With the pretorqued brackets of a straight wire appliance, root control is obtained by using a rectangular thermal ni-ti wire that fills the bracket slot. In many cases it is desirable to begin root torque control as early as possible in treatment.[1-5] Two types of rectangular wire available have the potential, in selected cases, to be used as an initial wire that will align and level the dental arches and incorporate root torque control into the tooth movement. These are a nonthermal mechanical nickel-titanium alloy and a multi-strand stainless steel wire.

For the thermal ni-ti wire to be as effective as possible clinically, the temperature at which the TTR is set is vitally important.[32,33] If the TTR is too far above body temperature, the wire will become too stiff. If the TTR is too low, the handling characteristics of the wire will not be good because the wire will never be fully active during placement. As a result, the wire will be too stiff to be tied into malpositioned brackets.

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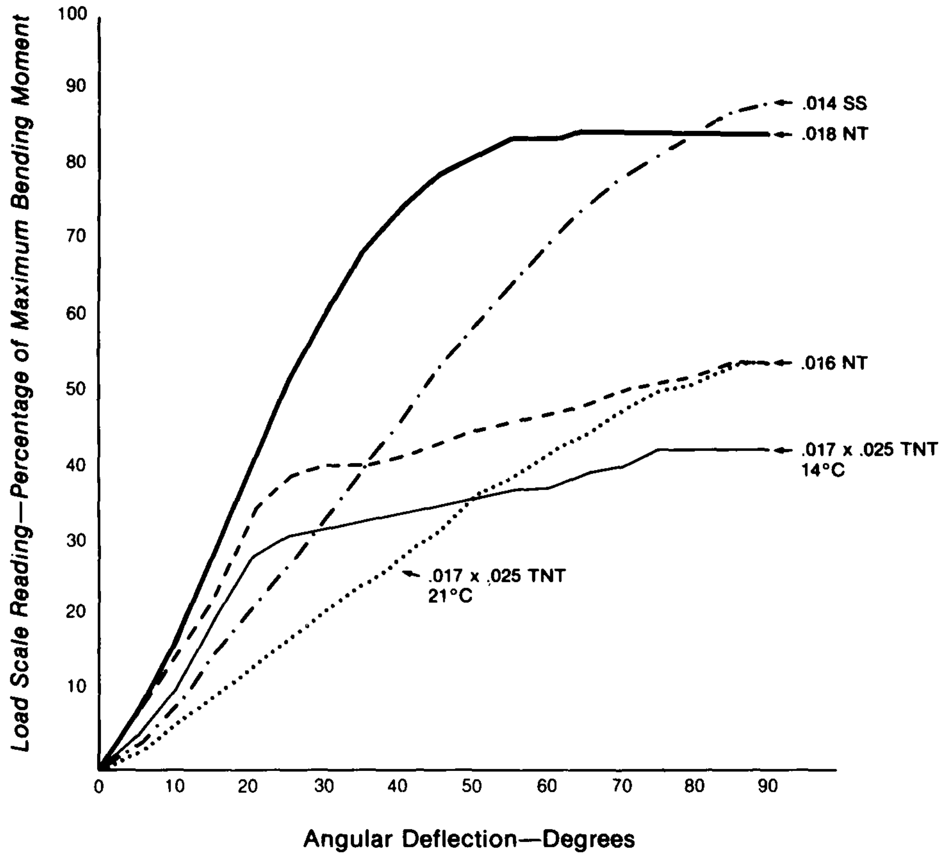

Figure 5.
Stiffness curves of four different types of wire.

Thermal Nitinol orthodontic wires are beginning to appear on the market. A desirable TTR is difficult for the manufacturer to obtain and the clinician must be aware of the TTR range in these wires. The four wires tested in this study had TTRs in the approximate desired range with the low end of the TTR near room temperature and the high end near body temperature. Stiffness curves for the thermal ni-ti wire are shown in Figure 4.

Looking at the force-deflection curves for the thermal nitinol wire at three different temperatures (Figure 4), it is obvious that temperature affects the properties of the wire. This change in properties is clinically significant. At forces below the body temperature, or at 23°C it takes less force to load the wire than near body temperature 37°C (near the TTR). Thus, at room temperature the wire is easily loaded and tied into malpositioned brackets. Near body temperature, the elasticity and force present during the loading decreases. The wire displays near 100 percent spring back and exerts a lower force during the entire spring back. Therefore, once the wire is tied into the brackets, it will exert an effective force on the teeth until the teeth are aligned, leveled and torqued with the rectangular wire.

Figure 5 and Tables 2, 3, 4, 5 and 6 show the second order loading curve for .017x.025 thermal nitinol wire at 21°C and 14°C. The force necessary to load the wire between 0° and 35° is in between the force needed to load an .018 Nitinol and an .014 stainless steel wire the same distance. For a load between 35° and 90°, the loading force needed is between an .018 Nitinol and an .016 stainless steel wire. If the temperature of the thermal nitinol wire is lowered to 14°C, for a load of 50° or more, the loading force is less than the loading force needed to load an .016 Nitinol wire.

Two other factors make the tying in of thermal ni-ti wire easier. Cold water can be syringed over the wire while it is being tied in. This corresponds to the curve at 13°C. It appears to have more

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.017 x .025 Thermal Nitinol Wire - 0° to 90° Second Order Bending at 14°C With .10 in. Lbs.

Degrees of Deflection	Load Scale Measurement									
	Loading					Unloading				
	Trial 1	Trial 2	Trial 3	Trial 4	Avg.	Trial 1	Trial 2	Trial 3	Trial 4	Avg.
0	0	0	0	0	0					
5	4	6	5	3	5					
10	12	13	12	7	11					
15	23	21	23	13	20					
20	31	27	33	22	28					
25	32	28	34	31	31					
30	32	28	35	31	32					
35	33	30	37	31	33					
40	34	31	37	32	34					
45	35	32	40	32	35					
50	37	33	41	33	36					
55	38	33	41	34	37					
60	39	34	41	35	37	62-0	62-0	62-0		64-0
65	39	35	42	39	39	3	3	3	68-0	2
70	40	37	44	39	40	8	6	8	4	7
75	41	40	45	40	42	13	13	14	11	13
80	41	40	45	40	42	21	20	22	19	21
85	41	41	45	41	42	30	30	32	30	31
90	42	42	45	41	42					

Table 2.
Data for the stiffness curve of an .017x.025 thermal nitinol wire second order bending at 14°C.

effect for second order bending than for first order bending. In addition, because the wire is not stiff at room temperature, it can easily be non-permanently bent into and fill the .018 slot. Whether or not the force produced by a wire during leveling and aligning is compatible with physiologic tooth movement is difficult to determine. Some wires commonly used in orthodontics do appear to produce more clinically acceptable physiologic tooth movement.

These clinical trials demonstrate that the .017x.025 thermal ni-ti wire is effective as an initial aligning and leveling arch wire with torque control over the roots, even in cases with severely malpositioned teeth. However, the commercial availability of rectangular thermal ni-ti wire has been slowed by the cost of production and the difficulty in maintaining consistency of the TTR during manufacturing.

No suggestion is made here that only one wire be used throughout treatment. The wire is suggested primarily for leveling and torque control. It is suggested that "detailing and finishing" be done with stainless steel wires of appropriate size and shape.

Conclusion

Four arches of thermal ni-ti wire were clinically evaluated. A clinical study was performed to evaluate the thermal wire's capabilities to be used as an initial leveling wire with added torque control over the maxillary anterior roots. Each wire was found to have a clinically acceptable TTR, with a high end near body temperature and a low end above room temperature. Another rectangular wire currently available to orthodontists, the stainless steel .017x.025 D-Rect,* has low stiffness and can also be used as an initial wire with torque control.

Temperature was found to have a significant effect on the thermal ni-ti wire. At a temperature above its TTR, the wire is stiffer and exhibits 100 percent spring back from a 90° bend. Below its TTR, the wire is less stiff and under-

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.017 x .025 Thermal Nitinol Wire - 0° to 90° Second Order Bending at $21^{\circ}C$ With .10 in. Lbs.

Degrees of Deflection	Load Scale Measurement									
	Loading					Unloading				
	Trial 1	Trial 2	Trial 3	Trial 4	Avg.	Trial 1	Trial 2	Trial 3	Trial 4	Avg.
0	0	0	0	0	0					
5	3	8	8	14	8					
10	7	13	15	24	15					
15	17	19	23	34	23					
20	30	30	34	40	34					
25	37	36	42	40	39					
30	38	36	43	41	40					
35	39	37	43	41	40					
40	40	39	43	42	41					
45	43	41	45	43	43					
50	44	43	47	44	45	52°-0				
55	45	44	49	46	46	2	58°-0	58°-0	58°-0	57°-0
60	47	45	50	46	47	3	3	3	2	3
65	48	46	53	46	48	6	6	8	5	6
70	48	48	54	47	50	13	12	14	10	12
75	50	49	55	49	51	20	18	22	17	19
80	51	50	57	51	52	28	27	31	27	28
85	52	51	59	52	54	38	36	43	38	39
90	52	52	61	52	54					

Table 3.
Data for the stiffness curve of an .017x.025 thermal nitinol wire second order bending at 21° C.

goes permanent deformation. In the maxillary arch the thermal ni-ti wire was shown to have the capacity to be tied into even the most severely malpositioned bracket and then produce effective tooth movement until the bracket slots were completely aligned and leveled with torque control. No difference in discomfort between thermal ni-ti wire, twisted wire and stainless steel wire was noted by patients. In addition, no root resorption was found to occur during the 16 trial weeks, and, only after 1 year 11 months, one patient showed very slight maxillary anterior root resorption.

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.014 Stainless Steel Wire - 0° to 90° Bending With .10 in. Lbs.

Degrees of Deflection	Load Scale Measurement: Loading Trial 1	Loading Trial 2	Loading Trial 3	Loading Trial 4	Loading Avg.	Unloading Trial 1	Unloading Trial 2	Unloading Trial 3	Unloading Trial 4	Unloading Avg.
0	0	0	0	0	0					
5	7	7	9	6	7					
10	17	17	19	16	17					
15	27	27	30	27	28					
20	39	39	42	38	40					
25	50	50	53	50	51					
30	60	61	62	60	61					
35	67	70	70	67	69					
40	74	76	76	74	75					
45	77	80	79	78	79	49°-0			49°-0	
50	79	83	83	80	81	1	51°-0	51°-0	1	0
55	81	85	85	83	84	8	5	7	9	7
60	81	85	86	84	84	18	16	18	22	19
65	82	86	86	84	85	28	26	28	32	29
70	83	86	86	85	85	41	37	34	44	40
75	84	86	86	85	85	51	50	50	55	52
80	84	86	86	85	85	63	62	61	64	63
85	84	86	86	85	85	73	74	72	76	74
90	84	86	86	85	85					

Table 4.
Data for the stiffness curve of an .014 stainless steel wire.

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.018 Nitinol Wire - 0° to 90° Bending With .10 in. Lbs.

Degree of Deflection	Load Scale Measurement									
	Loading					Unloading				
	Trial 1	Trial 2	Trial 3	Trial 4	Avg.	Trial 1	Trial 2	Trial 3	Trial 4	Avg.
0	0	0	0	0	0	3°-0	3°-0	2°-0	4°-0	3°-0
5	3	2	2	3	3	1	1	1	1	1
10	9	6	9	9	8	3	2	5	3	3
15	15	13	15	15	15	9	7	10	7	8
20	22	19	22	20	21	16	14	17	12	15
25	29	25	29	26	27	25	21	24	18	25
30	35	31	35	32	33	30	27	33	24	29
35	40	38	42	40	40	36	34	37	31	35
40	47	44	49	45	46	42	40	45	37	41
45	55	50	55	51	53	48	45	49	43	46
50	61	56	62	57	59	52	50	55	48	51
55	66	61	67	62	64	56	53	60	50	55
60	71	67	73	67	70	62	58	65	56	60
65	75	73	78	72	75	65	63	70	61	65
70	80	77	82	75	79	70	67	71	63	68
75	84	81	85	77	82	72	70	75	65	71
80	86	85	87	83	85	73	74	81	71	75
85	88	87	80	85	88	82	81	84	76	81
90	90	90	90	86	89					

Table 5. Data for the stiffness curve of an .018 super-elastic Ni-ti wire.

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.016 Nitinol Wire - 0° to 90° Bending With .10 in. Lbs.

Degrees of Deflection	Load Scale Measurement									
	Loading					Unloading				
	Trial 1	Trial 2	Trial 3	Trial 4	Avg.	Trial 1	Trial 2	Trial 3	Trial 4	Avg.
0	0	0	0	0	0	4°-0	2°-0	3°-0	3°-0	3°-0
5	2	2	2	2	2	1	2	1	1	1
10	5	6	6	5	6	2	5	3	3	3
15	9	10	10	8	9	5	8	6	5	6
20	13	13	14	12	13	8	11	9	9	9
25	17	17	18	16	17	12	13	12	12	12
30	21	21	22	20	21	15	19	16	15	16
35	24	25	25	23	24	18	21	20	19	20
40	29	29	30	26	29	22	24	23	22	23
45	31	32	32	30	31	25	27	26	25	26
50	36	36	37	33	36	28	30	30	29	29
55	38	39	39	37	38	30	33	32	32	32
60	42	43	42	39	42	35	35	36	36	36
65	45	44	45	43	44	39	38	40	37	39
70	47	48	48	45	47	40	41	41	40	41
75	51	50	50	47	50	42	44	44	43	43
80	53	51	53	48	51	45	45	46	45	45
85	55	53	54	52	54	46	49	47	48	48
90	55	53	54	55	54					

Table 6.
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