Effects of a Simulated Oral Environment and Sterilization on Load-deflection Properties of Superelastic Nickel Titanium–based Orthodontic Wires

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Abstract: *The aim of this study was to evaluate the load-deflection characteristics of three types of nickel-titanium wires and investigate the effects of recycling on superelastic properties of them.* ***Materials and Methods:*** *Thirty specimens for any of the single-strand Ni-Ti (Rematitan "Lite"), multi-strand Ni-Ti (SPEED Supercable) and Copper Ni-Ti (Damon Copper Ni-Ti) were tested. Ten specimens of each wire were subjected to three point bending test in the as-received condition (T0). The remaining wires were kept in a simulated oral environment for 2 months. Then, half of these specimens were tested for their load-deflection properties (T1), while the others were autoclave sterilized before testing (T2). Statistical analysis was performed by one-way ANOVA and Tukey test.* ***Results:*** *Rematitan "Lite" showed significantly greater force than Damon Copper Ni-Ti and Damon Copper Ni-Ti, demonstrated significantly greater force than Supercable ($p<0.05$). The effect of recycling on bending properties of nickel-titanium wires was significant ($p<0.05$). T1 wires were generally associated with significantly lower forces than T0 specimens in deflections less than 2.0 mm, while load-deflection characteristics of T2 wires were not considerably different from those of T0 specimens.* ***Conclusions:*** *Supercable is useful when very light force is needed during orthodontic treatment, for example in severe crowding cases and traumatized teeth. Damon Copper Ni-Ti may be suitable for routine orthodontic treatment in adolescent and adult patients. It is suggested that clinicians who want to recycle nickel-titanium wires use autoclave sterilization.*

Introduction

Having been developed by the Naval Ordinance Laboratory in the early 1960s,[1] nickel-titanium (Ni-Ti) alloys were introduced to the orthodontic specialty by Andreasen and Hilleman in 1971.[2] Their excellent mechanical properties, including superelasticity and shape memory, combined with high corrosion resistance and good biocompatibility have resulted in substantial popularity of nickel-titanium wires among orthodontists. The unique properties of Ni-Ti arch wires are attributed to a reversible phase transformation between the body-centered cubic austenitic form to the hexagonal close-packed martensitic structure of nickel-titanium when the wire is subjected to stress or temperature changes.[1,3]

Although the presence of superelasticity makes it possible to apply constant force levels to teeth in long activation distances,[1,4] Segner and Ibe[5] concluded that the force level of the superelastic plateau and the amount of deflection at the start of the plateau are also important parameters to take proper advantage of superelasticity in orthodontic treatment. In some previous studies, the force level of the unloading plateau was far beyond the optimal force value for orthodontic tooth movement.[5,6] There have been ample attempts to solve this problem by searching superelastic arch wires with low force magnitude. It is clear that introducing multiple strands into nickel-titanium wire configuration will lower the wire stiffness. Oltjen et al., reported that the multi-strand nickel-titanium wire demonstrated the lowest stiffness among the various wires they tested.[7] In an attempt to achieve an optimal force level for the initial phase of orthodontic treatment, Ormco introduced Damon Copper Ni-Ti arch wires especially for use with Damon self–ligating brackets. Little information is available about bending characteristics of these new orthodontic arch wires.

Most of the available information on the mechanical properties of nickel-titanium wires is limited to the wires in the as-received condition, while orthodontic arch wires usually remain in the oral cavity for several months. The corrosive oral environment with high amount of stress and strain can affect the load deflection properties of Ni-Ti wires in such a way that the wire does not show the initial efficiency. In a previous study, Harris et al. demonstrated that Nitinol wires deflected for 1 to 4 months in a simulated oral environment had a significantly lower modulus of elasticity, yield strength and ultimate tensile strength compared with control wires.[8] In addition, the high cost of nickel-titanium wires has led many clinicians to reuse these wires.[9,10] This is especially true for newer versions of Ni-Ti wires such as multi-strand and Copper Ni-Ti types, since their cost is considerably high. Buckthal et al. found that deterioration of mechanical properties was a great concern among clinicians who recycle nickel-titanium arch wires.[10]

There are contradictory reports regarding the effects of recycling on mechanical properties of nickel-titanium wires. Kapila et al. demonstrated that clinical use of Ni-Ti wires followed by cold sterilization produced significant changes in bending characteristics and resulted in increased pitting of these wires.[11] In another study, Kapila et al. demonstrated that clinical recycling reduced the superelasticity and increased the stiffness of nickel-titanium arch wires.[12] However, Lee and Chang reported that recycling had no significant effect on mechanical properties of various nickel-titanium wires.[13] Similarly, Smith et al. found no clinically significant differences between as-received and clinically used-then-sterilized orthodontic arch wires.[14]

According to our data, there is little information on load-deflection properties of multi-strand Ni-Ti and Copper Ni-Ti arch wires and the effect of simulated oral environment and autoclave sterilization on superelastic properties of these wires are not clear. The aim of this study was to evaluate the load-deflection properties of single-strand Ni-Ti, multi-strand Ni-Ti and Copper Ni-Ti wires in the as-received condition, after 2 months of storage in a simulated oral environment, and after 2 months of storage in a simulated oral environment followed by autoclave sterilization.

Material and Methods

Three types of nickel-titanium-based arch wires were tested. The wires were Rematitan "Lite"[1], SPEED Supercable[2] and Damon Copper Ni-Ti[3] (Figure 1). The first two wires are marketed as superelastic. The last is a thermo-sensitive nickel-titanium wire, but there is little information on its temperature transition range (www.Ormco.com). These wires are supplied as single-strand or multi-strand, as listed in Table I. Only preformed maxillary 0.016 inch round wires were used for testing.

Fifteen wires of each type were cut in midline and posterior parts to give 30 specimens with 3.0 cm length from the anterior curved part of the wires. The specimens were subsequently divided into three groups. The wires in the first group (T0) were tested in the as-received condition and served as the control group. The remaining wires were deflected using acrylic plates (Figure 2) on which 10 rows of brackets, each containing three standard edgewise 0.018-inch twin maxillary central incisor brackets,[4] were bonded with a no-mix adhesive.[5] The brackets on each row were positioned at the same level with their long axis parallel. The three millimeter step on the middle part of the acrylic model allowed for relevant deflection of the specimens, simulating moderate crowding in the anterior region of the maxilla. The wires were held on acrylic plates with elastomeric ligatures. The rows of brackets were spaced so that each specimen was several millimeters apart from its neighbors. The acrylic plates were immersed in artificial saliva and maintained in an incubator at 37°C for two months. The artificial saliva used in this study consisted of 1 g sodium carboxymethylcellulose, 4.3 g xylitol, 0.1 g potassium chloride, 5 mg calcium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate and 100 g distilled de-ionized water. After 2 months of immersion, half of these specimens were tested for their load deflection properties (T1), while the others were autoclave sterilized before mechanical testing (T2). Autoclaving was performed at 121°C (250°F) and 15 to 20 psi for 20 minutes. Ten specimens were tested in each of the three conditions, resulting in 90 tests.

Fig 1. Close up view of tested arch wires.

Table I.
Nickel-titanium arch wires tested in this study classified by commercial name, composition, and number of strands

Commercial Name	Composition	Number of strands	Manufacturer
Rematitan "Lite"	Ni-Ti	Single-strand	Dentaurum
Supercable	Ni-Ti	Multi-strand	Strite Industries
Damon Copper Ni-Ti	Copper Ni-Ti	Single-strand	Ormco

A modified three-point bending test was used to determine the load deflection properties of the wires, using Zwick Testing Machine[6] fitted with a 250-Kg load cell. The 0.018-inch standard edgewise molar tubes[7] were bonded to teeth of a plastic phantom head jaw in positions of teeth 6 and 8. Therefore, the portion holding the right lateral incisor bracket was free to move with the vertical application of forces. Accurate tube alignment was achieved by inserting a full-size arch wire into tubes before the cement set. The molar tubes were used to eliminate friction which existed if brackets and elastomeric ligatures were used for testing. This setting simulated the application of passive self-ligating brackets in the clinical condition. The 15.5 mm distance between the midpoint of the tubes was selected to represent average tooth dimensions for a male's maxillary permanent dentition.[15] The mid-portion of the wire specimen was then deflected using the movable part of the testing machine, which had a groove to accommodate the wire. A crosshead speed of 1 mm/min was chosen to deflect the wires a maximum distance of 3 mm. The 3 mm deflection was chosen to partially reflect a clinical situation with moderate crowding of anterior teeth. Figure 3 shows the test area and depicts a wire specimen in its partially restrained and deflected state within the system. All tests were done on a constant temperature chamber of 37°C. The water temperature was controlled by a thermometer with accuracy of ± 0.5°C. The loading and unloading forces were registered by the load cell and transmitted to a personal computer using an analogue/digital convertor card. Load-deflection curves were drawn for all specimens.

Statistical analysis

Means and standard deviations of the forces generated at intervals of 0.5 mm deflection during unloading (from 2.5 mm to 0.5 mm) were determined to represent load deflection properties of each wire. Statistical calculations were performed with a software package (SPSS, Version 11.0, SPSS Inc, Chicago, Illinois, USA). Repeated measures ANOVA showed a significant interaction between deflection, wire treatment (T0, T1 and T2) and wire type, making it necessary to evaluate these variables separately. Therefore, one-way ANOVA was used to analyze differences between loads of the three wires at different deflections for T0, T1 and T2 groups and to test changes that occurred after recycling of each wire. Post hoc Tukey pairwise comparison test was performed to identify significant between-group differences. P-values less than 0.05 were considered significant.

Results

Table II shows mean load values at intervals of 0.5 mm deflection during unloading for the three wires in the as-received condition (T0), after treatment in artificial saliva (T1) and after treatment in artificial saliva followed by autoclaving (T2). The most obvious differences are observed between Supercable and the other wire types. Generally, the maximum force among the three 0.016 inch wires was exerted by Rematitan "Lite" supplied by Dentaurum and the minimum force was exerted by Supercable supplied by Strite Industries. T0 Supercable specimens had a load value less than 40 g under a displacement of 2.0 mm. Comparison of load values of the three wires at 1.0 mm deflection during unloading for T0, T1 and T2 groups is presented in Figure 4.

The load-deflection graphs for the new and used wires, Rematitan "Lite," Supercable and Damon Copper Ni-Ti, are shown in Figures 5 to 7. The unloading portion of the load-deflection graphs for the three wires in T0 and T2 groups contained a nearly horizontal region or plateau

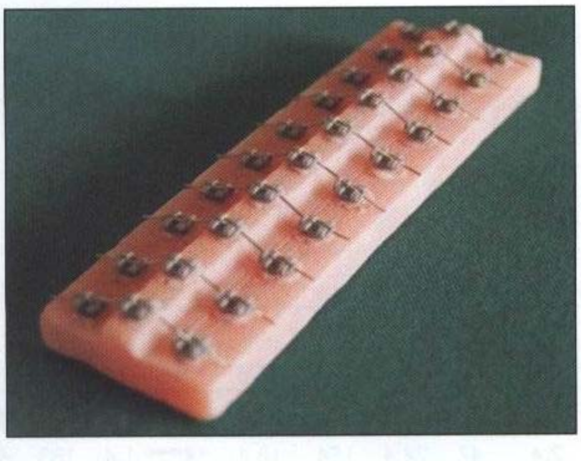

Fig 2. An acrylic plate for holding wire specimens in deflected state.

Fig 3. Close up view of the modified three-point bending model on the phantom head jaw with the specimen deflected.

range where deactivation occurred at nearly constant force values. However, this plateau range was not well evident in T1 Supercable (Figure 6b) and Damon Copper Ni-Ti specimens (Figure 7b) and some loss of superelasticity was also noted for T1 Rematitan "Lite" group (Figure 5b). The load at the center of the unloading plateau was approximately 300 g for Rematitan "Lite," 40 g for Supercable and 190 g for Damon Copper Ni-Ti, at T0 condition.

The results of the ANOVA (Table III) demonstrated significant differences in force levels of the three wires both before and after recycling ($p<0.05$). The post-hoc Tukey tests showed that in T0, T1 and T2 groups at all deflections, Rematitan "Lite" had significantly greater force than Damon Copper Ni-Ti and Damon Copper Ni-Ti had significantly greater force than Supercable ($p<0.05$). The only exceptions were T1 groups at deflections of 1 and 0.5 mm, where there were no statistical differences between the three wires ($p>0.05$).

ANOVA indicated that recycling produced significant changes in load-deflection characteristics of the three wires ($p<0.05$). Rankings were assigned to force values of each wire at different treatment groups based on the results of the post hoc analysis (Tables IV through VI). Two months immersion of specimens in the simulated oral environment significantly affected their load values. In fact, T1 wires were generally associated with significantly lower forces in deflections less than 2.0 mm, compared with control (T0) specimens. For example, unloading forces at a deflection of 1.0 mm were 271 g for Rematitan "Lite," 31 g for Supercable and 154 g for Damon Copper Ni-Ti wires at T0 condition. At T1 condition, the measured force values were decreased to 29 g in Rematitan "Lite," 7 g in Supercable and 4 g in Damon Copper Ni-Ti groups. This implies an 89% reduction in the forces associated with Rematitan "Lite," 77% reduction in the forces of Supercable and 97% reduction in the forces of Damon Copper Ni-Ti specimens. The effect of autoclave sterilization on bending properties of the specimens that were kept in the simulated oral environment was very similar in three types of wires and tended to recover the load-deflection properties of them. As can be seen in Tables IV and V, load-deflection characteristics of T2 Rematitan "Lite" and Supercable were not significantly different from those of T0 specimens at nearly all deflections. This is evident in bending plots of these wires where little difference can be seen between T0 and T2 graphs (Figures 5a,c and 6a,c). However, in Damon Copper Ni-Ti wire, T2 group showed significantly greater force than control group (T0) at all unloading deflections (Table VI and Figure 7a,c).

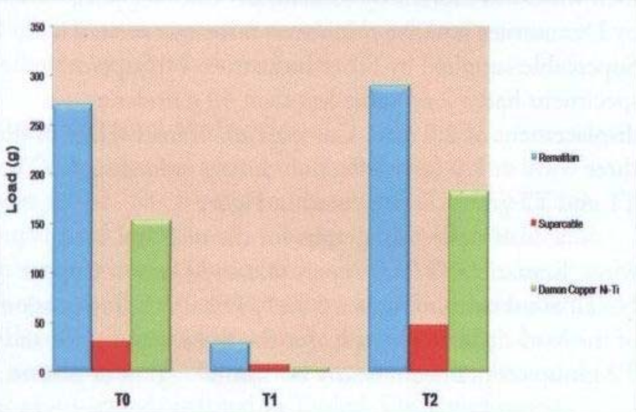

Fig 4. Comparison of mean load values for Rematitan "Lite," Supercable and Damon Copper Ni-Ti wires at 1 mm deflection during unloading for T0, T1 and T2 groups.

Discussion

A modified three-point bending test was used in the present study to assess the performance of various arch wires. This test provides reproducibility and simplifies comparison with other studies,[16-18] although its appropriateness as the standard wire test has been

Table II.
Means and standard deviations (g) of loads at intervals of 0.5 mm deflection during unloading for Rematitan "Lite", Supercable, and Damon Copper Ni-Ti wires at T0, T1 and T2 conditions

Deflection	Rematitan "Lite"						Supercable						Damon Copper Ni-Ti					
(mm)	T0		T1		T2		T0		T1		T2		T0		T1		T2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2.5	349	7.9	406	19.2	374	34.7	48	15.4	66	10	67	11	238	24	277	30.9	275	7.7
2	320	16.9	314	29.1	347	24.7	45	14.7	34	6.7	60	10	200	21.8	191	27.9	243	7.9
1.5	316	10	199	40.7	334	18.1	39	15.2	12	5.5	58	17	202	20.2	103	51.4	244	4.8
1	271	9.7	29	13.9	290	19	31	13.4	7	2.4	47	24.4	154	18.4	4	1.4	183	6.5
0.5	189	10.1	0	0.0	198	16	15	11.2	6	1.5	19	14	105	18.8	2	1.2	119	6.5

questioned by some authors.[15,19] Instead of brackets, molar tubes were bonded on central and canine teeth to eliminate binding and friction that affects force delivery properties of orthodontic wires.[20-23] This way, the testing machine could more accurately register the forces produced by the arch wires.[24] In accordance with previous studies,[23-26] the tests were performed at 37°C water temperature to more closely approximate the clinical conditions. Only unloading forces were reported in this study, since unloading of the wire provides the forces necessary for tooth alignment.

In this study, the measured force value of the single-strand Ni-Ti wire (Rematitan "Lite") in the as-received condition was at least 7 times greater than the multi-strand Ni-Ti wire (Supercable) and about 1.5 times greater than the Copper Ni-Ti wire (Damon Copper Ni-Ti). In a previous study by Berger et al,[27] Supercable exerted dramatically lower force levels compared with other equal diameter nickel-titanium arch wires. It has been accepted that light continuous forces permit an efficient tooth movement, with less damage to the teeth or periodontium,[28] and with maximum patient comfort.[29] However, the magnitude of the optimal force for tooth movement is under debate.[30-32] Crabb and Wilson[33] found that 0.3 N provided the most rapid tooth movement. Storey and Smith[34] suggested 1.5 to 2 N as an optimal force range for canine retraction, while Rock and Wilson[35] assumed that force magnitude of about 4 N may be appropriate to be used with fixed orthodontic appliances.

The force level of multi-strand Ni-Ti wire (Supercable) in the as-received condition ranged from 48 g at 2.5 mm deflection to 15 g at 0.5 mm deflection. These force levels are very light, but they may be optimal for tooth alignment. It can be drawn that multi-strand Ni-Ti wire is especially useful when a very light force is needed in orthodontic treatment, for example in severe crowding cases or adult patients with periodontal problems and also in cases with traumatized teeth for prevention of possible root resorption. The force level of control Damon Copper

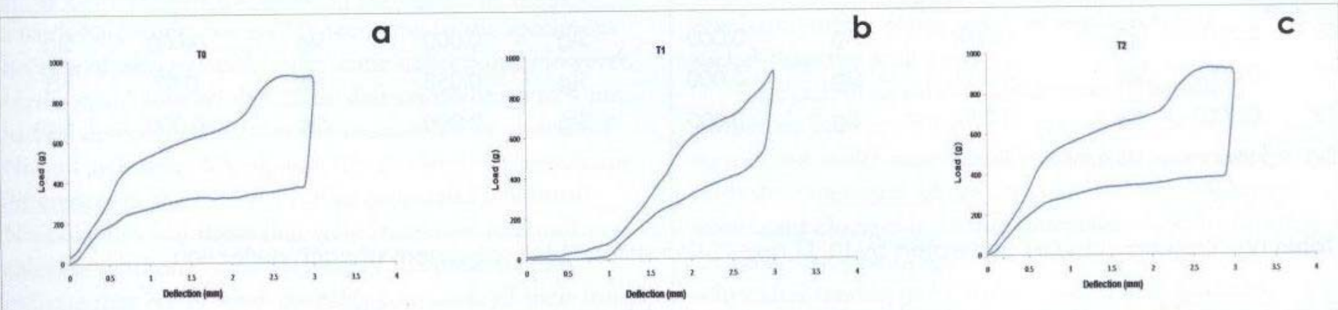

Fig 5. Load-deflection curves of single-strand Ni-Ti (Rematitan "Lite") wire at T0 (a), T1 (b) and T2 (c) conditions.

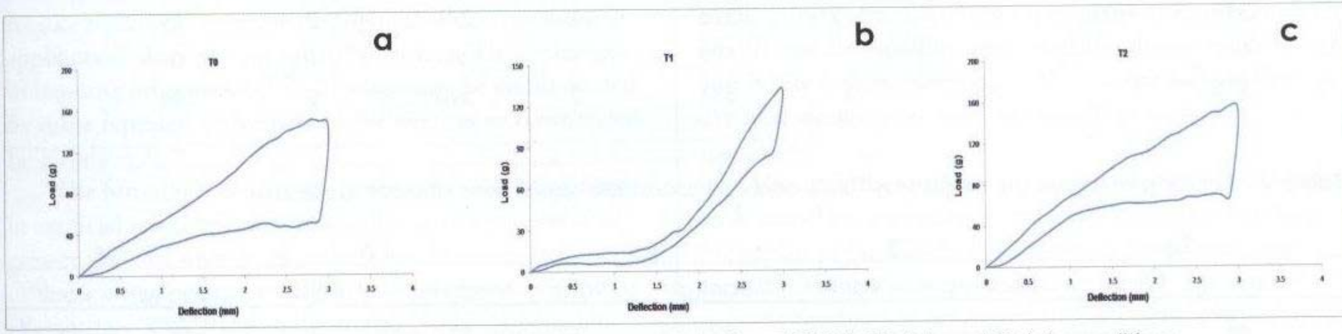

Fig 6. Load-deflection curves of multi-strand Ni-Ti (Supercable) wire at T0 (a), T1 (b) and T2 (c) conditions.

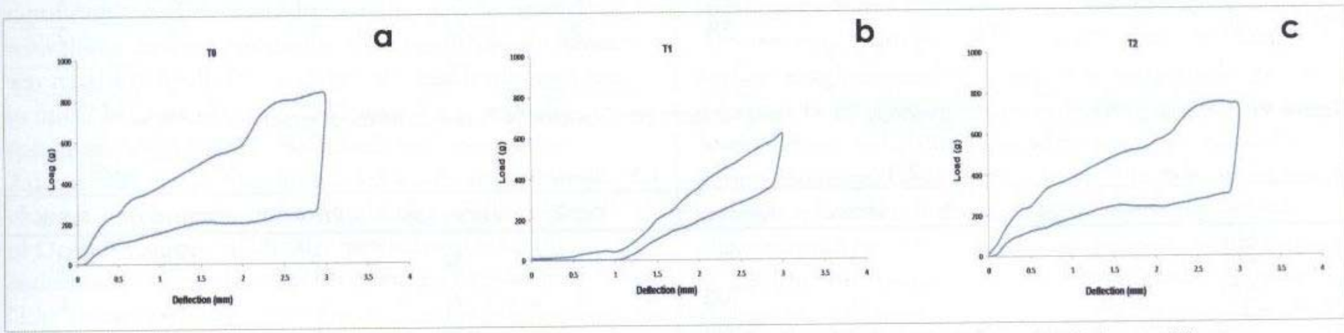

Fig 7. Load-deflection curves of Copper Ni-Ti (Damon Copper Ni-Ti) wire at T0 (a), T1 (b) and T2 (c) conditions.

Ni-Ti wire varied from 238 g at 2.5 mm deflection to 105 g at 0.5 mm deflection, implying that this type of Ni-Ti wire can be recommended for routine orthodontic treatment in adolescent and adult patients with various degrees of crowding. The force level of single-strand Ni-Ti wire (Rematitan "Lite") in the as-received condition was higher than other types of wires, ranging from 349 to 189 g at 2.5 and 0.5 mm deflections, respectively. However, this force magnitude seems to be appropriate for cases with mild to moderate crowding and also for correction of rotations. It should be kept in mind that the forces measured in a three-point bending test are not directly transferable to the clinical conditions. Therefore, it has been stated that greater emphasis should be placed on rank order of wires than on actual force values expressed in grams in data tables.[15,21]

The Ni-Ti wires tested in this study are all superelastic. Damon Copper Ni-Ti is also thermosensitive. A great advantage of thermosensitive wires is that they are soft at room temperature and are easily ligated to severely malaligned teeth. At mouth temperature, the stiffness of the wire increases and consequently the wire exerts more force on the teeth, while moving them from positions of malocclusion into the dental arch. In the present study, we did not examine the behavior of Ni-Ti wires at different temperatures. Several studies have demonstrated that temperature variations had a significant effect on force values exerted by heat activated superelastic wires.[3,6,15] The

Table III. Results of ANOVA for comparison of force levels of Rematitan "Lite", Supercable and Damon Copper Ni-Ti wires at different deflections at T0, T1 and T2 conditions.

	2.5		2.0		1.5		1.0		0.5	
	P value	Sig	P value	Sig	P value	Sig	P value	Sig	P value	Sig
T0	0.000	Sig	0.000	Sig	0.000	Sig	0.000	Sig	0.000	Sig
T1	0.000	Sig	0.000	Sig	0.000	Sig	0.058	NS	0.07	NS
T2	0.000	Sig	0.000	Sig	0.000	Sig	0.000	Sig	0.000	Sig

Sig, significance; NS, not significant

Table IV. Ranking of forces generated by T0, T1 and T2 Rematitan "Lite" specimens at each deflection

	2.5		2.0		1.5		1.0		0.5	
	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank
T0	349	1	320	1, 2	316	2	271	2	189	2
T1	406	2	314	1	199	1	29	1	0	1
T2	374	1	347	2	334	2	290	2	198	2

Table V. Ranking of forces generated by T0, T1 and T2 Supercable specimens at each deflection

	2.5		2.0		1.5		1.0		0.5	
	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank
T0	48	1	45	1, 2	39	2	31	2	15	2
T1	66	2	34	1	12	1	7	1	6	1
T2	67	2	60	2	58	2	47	2	19	2

Table VI. Ranking of forces generated by T0, T1 and T2 Damon Copper Ni-Ti specimens at each deflection

	2.5		2.0		1.5		1.0		0.5	
	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank	Mean (g)	Rank
T0	238	1	200	1	202	2	154	2	105	2
T1	277	2	191	1	103	1	4	1	2	1
T2	275	2	243	2	244	3	183	3	119	3

load-deflection properties of conventional and superelastic wires are also affected by temperature variations, but the variation is considerably lower. Parvizi and Rock indicated that increasing temperature from 20°C to 40°C increased the forces exerted by conventional and thermoelastic Ni-Ti wires by 29% and 70%, respectively.[6] In the study of Meling and Odegaard[3] the conventional nickel-titanium wire was minimally affected by brief cooling or heating, but the superelastic wires were strongly affected by short term application of cold or hot water. Therefore, the clinical performance of the arch wires tested in this study may vary in the clinical condition, due to temperature variations as a result of ingesting hot or cold food.

The simulated oral environment used in this study had a significant effect on load-deflection properties of the three Ni-Ti wires and resulted in some loss of superelasticity, as represented on load-deflection graphs (Figures 5b, 6b and 7b). The force level of T1 wires was lower than control wires, especially in deflections less than 1.0 mm, where it seemed that the wires do not apply any forces on the teeth. This may be the result of a work-hardening process[11,26] occurring in the specimens because of being placed under static deflections. However, Harris et al.[8] showed that static deflections of up to 4 mm had no detectable effect on the mechanical properties of Nitinol arch wire. Schwaninger et al. found no significant differences in the load-deflection properties of control Nitinol wires and those that were immersed in a sodium chloride solution.[36] The findings of the present study indicate that Ni-Ti wires probably lose some of their initial efficiency after exposure to oral environment. Therefore, the suggestion that patients treated with Damon system require fewer appointments compared with conventional appliances[37] does not appear to be correct. These changes in bending properties of Ni-Ti wires may be counteracted by more repeated activations of the wire, as recommended by Kapila et al.[11]

The force level of wire specimens that had been kept in artificial saliva followed by sterilization was somewhat greater than T0 ones at all deflections. However, this difference was not statistically significant for single-strand (Rematitan "Lite") and multi-strand Ni-Ti (Supercable) wires and although Damon Copper Ni-Ti showed significantly greater force after sterilization compared with the as-received condition, the magnitude of changes was relatively small. For example, the maximum increase in forces between T0 and T2 Damon Copper Ni-Ti specimens was 43 g (21.5%) which was observed at 2.0 mm deflection. The clinical relevance of such small changes is to be questioned. In addition, the force level of Damon Copper Ni-Ti after sterilization was still considerably lower than the force value of Rematitan "Lite" in the as-received condition. The load-deflection graphs of T2 groups of all wires showed a distinct superelastic plateau (Figures 5c, 6c and 7c), similar to the control groups.

The increase in forces associated with T2 wires can be attributed to the effect of autoclave sterilization on load-deflection characteristics of nickel-titanium wires and the more prominent changes in Damon Copper Ni-Ti wire may be related to its thermosensitive nature. There are contradictory reports regarding the effects of heat treatment on mechanical properties of Ni-Ti wires. These effects are related to the temperature and time of treatment.[26] Burstone et al. reported that Chinese Ni-Ti wire exhibited greater permanent deformation and less springback at a temperature of 60°C than mouth temperature.[4] A recent study showed that dry heat sterilization decreased the forces exerted by superelastic Ni-Ti wires.[38] However, Miura et al.[1] found that heat treatment up to 500° C had no significant effect on bending properties of austenitic Ni-Ti wire. Mayhew and Cusy found that repeated cycles of dry heat or autoclave sterilization had no deleterious effects on modulus of elasticity, surface topography, or tensile properties of nickel-titanium arch wires.[39]

The lack of significant differences in bending properties between T0 and T2 groups for the single-strand and multi-strand Ni-Ti wires is in accordance with the experience of Lee and Chang[13] who found no significant changes in tensile properties, 3-point bending characteristics, or fatigue of various nickel-titanium wires after treatment in artificial saliva and autoclave sterilization. The small but significant increase in force level of Damon Copper Ni-Ti wire after autoclave sterilization is similar to the experiment of Kapila et al.,[12] who found that loading and unloading forces of Ni-Ti and Nitinol wires subjected to clinical use followed by dry heat sterilization were statistically greater than control specimens.

Although the simulated oral environment combined with autoclave sterilization had small effects on bending properties of Ni-Ti wires, it should be noted that long-term clinical use may cause corrosion[11,13,40,41] which can degrade mechanical properties of Ni-Ti wires. In addition, the complex loading in the oral environment including masticatory forces combined with intraoral aging of Ni-Ti wires may result in wire fracture.[42] Some increase in surface roughness and frictional coefficient could also be expected in recycled Ni-Ti wires.[13] Although the force level of three nickel-titanium wires tested in this study varied extensively, it is important to note that the statistical difference between individual wires in mechanical simulations does not guarantee the presence of differences in clinical performance.[15] Some clinical studies found no significant difference in alignment efficiency of superelastic

Ni-Ti, heat activated Ni-Ti and multi-strand steel wires.[43-45] In the clinical condition, the method of ligation is an important parameter to properly use superelasticity. Kasuya et al. found that the unloading plateau was not observed when they used elastomeric ligatures, whereas the application of slot lid resulted in the great exhibition of superelasticity.[23] Further research is needed on clinical efficiency of these new and used Ni-Ti wires.

Conclusions

1- The multi-strand Ni-Ti (Supercable) wire produced very light force, indicating that this type of Ni-Ti wire may be useful in severe crowding cases or adult patients with periodontal problems and also in cases with traumatized teeth.

2- The Copper Ni-Ti (Damon Copper Ni-Ti) wire exerted lower force than single-strand Ni-Ti (Rematitan "Lite") and can be considered as a suitable option for routine orthodontic treatment of adolescent and adult patients with various degrees of crowding.

3- Immersion of Ni-Ti wires in a simulated oral environment in deflected state significantly degraded their superelastic properties. Therefore, it is suggested that clinicians religate Ni-Ti wires regularly in the alignment stage of orthodontic treatment.

4- Steam sterilization of specimens that had been kept in a simulated oral environment tended to recover their bending properties. Thus, autoclave sterilization can be recommended for clinicians who tend to reuse Ni-Ti wires.

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Footnotes

1 Dentaurum, Ispringen, Germany
2 Strite Industries, Cambridge, Ontario, Canada
3 Ormco, Glendora, Calif
4 Dentaurum, Ispringen, Germany
5 Unite bonding adhesive, 3M Unitek, Monrovia, California, USA
6 Zwick GmbH & Co, Ulm, Germany
7 Dentaurum, Ispringen, Germany

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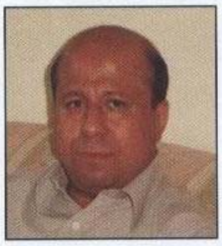

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