A Use Hypothesis for 55 Nitinol Wire for Orthodontics

George F. Andreasen, D.D.S., M.S.D.

Patrick R. Brady, D.D.S., M.S.

Introduction

The possibility of using a corrosion resistant 55 cobalt substituted Nitinol wire for orthodontics has been put forth in the literature.[1] The advantage of this wire over stainless steel wires is its corrosion resistance and its increased elastic limit over comparable stiffness wires. The previous concept of using the 55 cobalt substituted Nitinol wire did not involve the use of another property of the wire, i.e., its TTR or transition temperature range. The TTR is the temperature range at which the wire will return to its original length or shape if it is stretched or permanently deformed a maximum of 7% to 8% of its length below the TTR.

Purpose

It is the purpose of this paper to suggest a hypothesis for the use of two other types of Nitinol wire. The first is a 55 Nitinol wire with a TTR of 16° to 27° C., and the second is a 55 Nitinol wire with a TTR of 32° to 42° C. The hypothesis of utilization would be to use each wire as a closing force much the same way as a molar to molar elastic is now used. To illustrate, an arch length from molar to molar can vary from a minimum of 65 mm with four premolars extracted and all spaces closed to a maximum of 105 mm with four premolars extracted and no spaces closed.[2] For example, if an arch length was 108 mm from the distal of one molar tube to the distal of the other molar tube, a 100 mm Nitinol wire could be stretched 8% of its length below its TTR or, in this case, it could be stretched from 100 to 108 mm or a total of 8 mm. By inserting the wire in the mouth below its TTR and fixing its ends distal to each of the molar tubes it would shrink like an elastic as the temperature of the wire increased from room temperature to body temperature and passed through the TTR or, in this case, it could close spaces a maximum of approximately 8 mm by the use of the "memory" of the wire which is brought about by mouth heat that would transform heat energy to mechanical energy.

Material and procedure

The variables to be tested for the Nitinol wire are as follows: a) independent variable was temperature; b) two dependent variables tested were time between temperature intervals, and force generated by the shrinking wire at each temperature interval.

The materials used in the test were: a) .020-55 Nitinol wire with a TTR of 16° to 27° C., and b) .020-55 Nitinol wire with a TTR of 32° to 42° C.

Apparatus Used

The apparatus used in this investigation is shown in Figure 1. It consists of two clamps to hold the wire, a Chatillion gauge (read to the nearest ½ pound) to measure the stretching force exerted by the sand as the wire was stretched at a temperature below the TTR, and a sand container which was used for the weight necessary to stretch the wire.

The next step in measuring the dependent variables was to remove the sand container, fix the gauge to the cross bar by screws, insert a centigrade

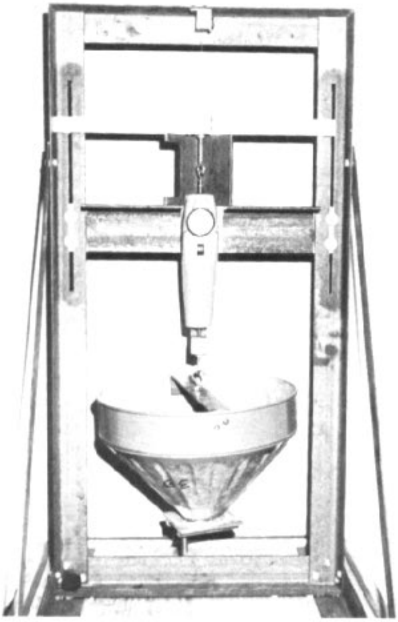


Fig. 1 Set up overview of the apparatus used to stretch the wire without the environmental cover.

thermometer, and add a heater to the floor of the apparatus (Fig. 2). The apparatus was now ready to record the two dependent variables, i.e., time between 5° C. temperature increments and force in pounds exerted between each 5° C. rise in temperature through and past the TTR. In beginning the experiment an environmental cover was placed over the apparatus with a window in it so that recordings could be made of temperature increases and recovery forces at each 5° C. temperature increase (Fig. 3). The temperature increases were activated by plugging a heater plug into the wall.

On a sample of two .020-55 Nitinol wires with different TTR's, (16° to 27° C. and 32° to 42° C.) double determination measurements were performed.

On the first type of sample wire (TTR 16° to 27° C.) five independent measurements were observed by each investigator. A total number of ten ob-

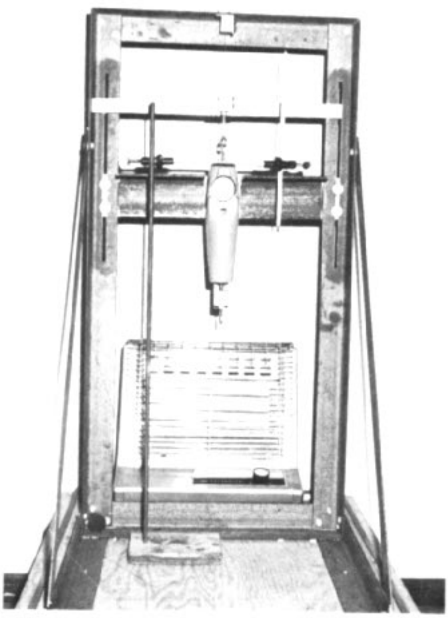


Fig. 2 Stretched wire connected to the force gauge which is fixed to the crossbar. The heater and thermometer are in place.

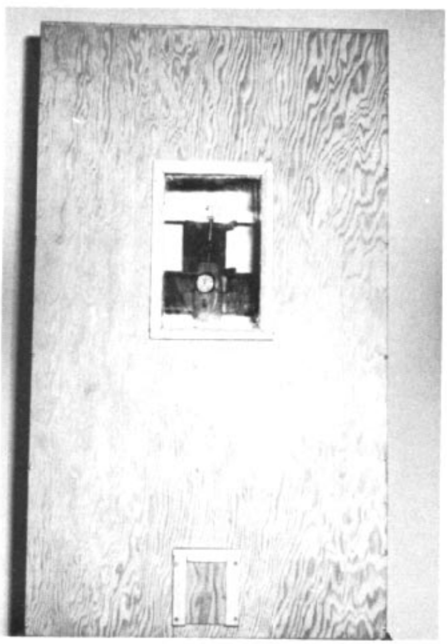


Fig. 3 Environmental cover in place with the heater ready to be plugged into the wall. The force gauge and thermometer can be viewed through the window.

Temperature		10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°
Shrink Force	$\bar{X}$	0	2.40	4.30	5.70	6.40	7.00	7.60	8.30	8.80	9.30	10.00	10.70	11.40
	S	0	0.60	1.53	1.25	1.33	1.28	1.32	1.34	1.38	1.29	1.22	1.18	1.07
Time	$\bar{X}$	0	14.00	28.90	26.50	24.00	23.50	24.50	25.00	25.00	26.50	27.50	28.50	30.50
	S	0	8.22	4.86	4.11	2.11	3.37	2.83	5.27	4.71	4.11	6.34	4.11	4.37

Independent Variable = Temperature = Degrees C.
Dependent Variable = Force = Pounds
Dependent Variable = Time = Seconds
N = 10 Trials per 5° Temperature Change

Table 1

55 Nitinol (TTR 16°C. - 27°C.) Wire
Recovery Forces for 108 MM. Fixed Length Wire

servations measured for each 5° C. rise in temperature from 15° to 70° C. were, therefore, made. The measurements for all temperature increments totaled 120 for the two investigators for the .020-55 Nitinol wire with the 16° to 27° C. TTR.

On the second type of sample wire (TTR 32° to 42° C.) five independent measurements were observed by each investigator. A total number of ten observations measured for each 5° C. rise in temperature from 32° to 42° C. was repeated. The measurements for all temperatures totaled 100 for this type.

Between-observer variability was examined for selected temperatures of 30° C., 40° C., and 70° C. for each of the types of wires studied. These t-tests are reported in the findings.

Findings

Means and standard deviations are reported for the wire shrinkage forces for: 1) The .020-55 Nitinol wire with a TTR of 16° to 27° C., and 2) the .020-55 Nitinol wire with a TTR of 32° to 42° C. for each 5° C. rise in temperature increment. In addition, average time increments and their standard deviations are reported for each change of 5° C. in temperature (Tables 1 and 2). The average shrinkage forces are graphed for each type of wire (Graphs 1 and 2).

The weight needed to stretch each wire (TTR 32° to 42° C.) at 26° C. from 100 to 110 mm approximated 13 pounds. Residual forces left in the wire made it shrink immediately to approximately 108 mm at 26° C. after the stretching weight was removed.

The weight needed to stretch each (TTR 16° to 27° C.) wire at 7° C. from 100 to 110 mm approximated 26 pounds. Residual forces left in this wire also made it shrink immediately to approximately 108 mm at 7° C. after the stretching weight was removed.

For a *fixed* 108 mm length of wire with a TTR of 16° to 27° C., mean maximum shrinkage forces of 11.4 pounds were generated for the heat range of 15° to 70° C.

For a *fixed* 108 mm length wire with a TTR of 32° to 42° C., shrinkage forces of a mean maximum 11.3 pounds were generated for a heat range of 30° to 75° C.

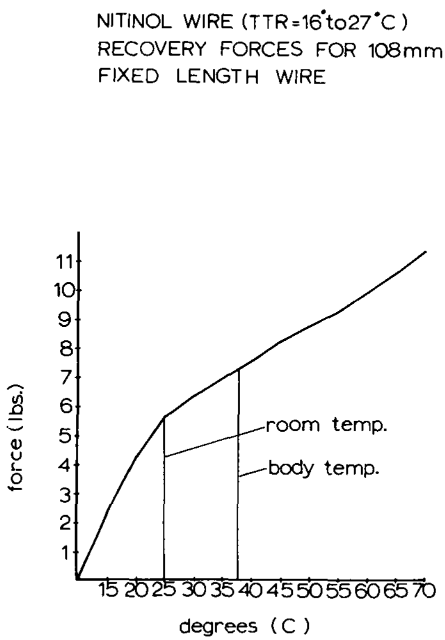
At body temperature the recovery or shrinkage forces were 7.3 pounds for the .020-55 Nitinol wire with a TTR of 16° to 27° C. However, from room temperature to body temperature, the same wire had recovery forces approximating 1.6 pounds as the wire would

Temperature		25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°
Shrink Force	$\bar{X}$	0	2.00	4.10	5.40	6.70	7.70	8.40	9.20	10.10	10.70	11.30
	S	0	0.58	1.17	1.57	1.18	1.08	0.96	0.68	0.50	0.57	0.67
Time	$\bar{X}$	0	24.00	27.30	23.00	25.70	23.00	26.30	25.80	23.80	24.20	27.30
	S	0	8.43	5.33	4.83	4.40	4.22	4.24	5.34	4.89	7.01	6.55

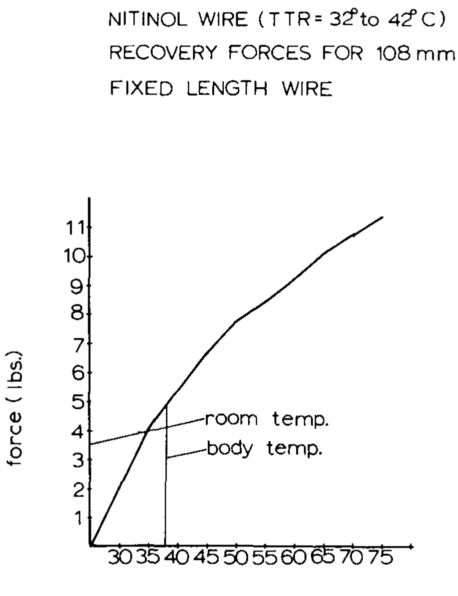
Independent Variable = Temperature = Degrees C.
Dependent Variable = Force = Pounds
Dependent Variable = Time = Seconds
N = 10 Trials per 5° Temperature Change

Table 2

55 Nitinol (TTR 32°C. - 42°C.) Wire
Recovery Forces for 108 MM. Fixed Length Wire



Graph 1 Mean Nitinol wire (TTR 16° C.-27° C.) recovery forces for 108 mm fixed length wire.



Graph 2 Mean Nitinol wire (TTR 32° C.-42° C.) recovery forces for 108 mm fixed length wire.

shrink. At body temperature the recovery force was 4.8 pounds for the wire with a TTR of 32° to 42° C.

The variances of shrinkage forces were approximately the same for the wire with a TTR of 16° to 27° C.

The variances of shrinkage forces consistently decreased after the wire with a TTR of 32° to 42° C. has exceeded 45° C. or the maximum temperature of the TTR.

There was an increased rate of recovery for both wires per degree of temperature increase throughout their TTR's, i.e., the curves for both types of wires were steeper during the TTR.

There were recovery forces with a lesser magnitude per temperature increment remaining in both of the wires after the maximum value of the TTR was reached.

Between-examiner measurement variability was insignificant at the .01 level, i.e., the probability of obtaining a larger value of T than 3.25 is 1 in 100, relative to the measurement methods and sample size (10) used in this study.

The time between 5° C. increment increases varied from 23.5 seconds to 30.5 seconds inside the environmental chamber that covered the apparatus. The variability of time was insignificant for this particular study.

Summary and Conclusions

A hypothesis has been put forth for the use of two types of 55 Nitinol wire. The fundamentals in the assumption are found in the fact that this wire can be stretched from 7 to 8% of its length if it is done at a temperature below the transition temperature range of the wire; heat energy will transform the molecular structure of the wire so it shrinks or returns to its original length. This much has been clearly shown by Beuhler and his associates;[3-8] if the wire is to be used in orthodontics, the first thing one needs to know is the force generated as the wire shrinks to determine if that force is in a reasonable range of magnitude conducive to accepted forces used in tooth movement.

From this study it appears a range of forces can be selected by choosing one of two 55 Nitinol wires with different TTR's. The range of forces for a 108 mm stretched wire would be from approximately 1.5 pounds to 5.0 pounds between the temperature limits of room temperature and body temperature.

Since the wire could shrink 8% of its length, it can be hypothesized a 108 mm Nitinol wire fixed at the ends of molar tubes could close extraction spaces a maximum of 8 mm; however, the critical factor of application of the wire to orthodontics would be found in the analysis of the time the clinician takes in fixing the ends of the wire distal to the molar tubes at a temperature below the TTR of a given length of stretched Nitinol wire.

The stiffness rate of this wire is at a much lower rate than even the smallest diameter of twist-o-flex wires. Therefore, it is suggested that it be used only for its closing forces and not for its leveling forces. In this context the closing wire would have to be used as an auxiliary wire rather than the main archwire. Therefore, it is concluded that further investigation is needed to test the use hypothesis for 55 Nitinol wire.

College of Dentistry
Univ. of Iowa
Iowa City, Iowa
52240

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