On the Relaxation of Orthodontic Elastic Threads

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The use of latex and natural rubber and polymeric "elastic" elements in orthodontic mechanics has become commonplace in recent years, largely independent of the practitioner's treatment philosophy. These elements, geometrically classified as bands, rings, modules, chains, and strings or threads, are all known to possess nonlinear force-elongation characteristics and experience internal (stored, strain) energy losses in the activation-deactivation process which generally increase with the total time involved in the complete cycle. In the actual treatment setting, when employed to retract a cuspid, for example, the decay in force magnitude over time from the initial level is the superimposition of two components: that from the relative displacement of dental units with respect to anchorage and the relaxation of the appliance element itself.

Relaxation is defined as a decrease in force value carried or transmitted over time with the element maintained in a fixed, activated state of constant strain. If an orthodontic elastic is stretched between two rigid points or supports and the force induced is monitored, the force magnitude will be found to lessen as the time from "activation" increases. The general relaxation pattern for the materials of interest here is well-known: the force-versus-time plot is nonlinear with the force-loss rate greatest immediately after stretching and decreasing, often to some asymptotic value dependent upon the material itself and/or the extent of the activation over a period of hours or days.

Previous research relevant to the present study began approximately ten years ago with an investigation of force-loss characteristics of molded polymeric elastics and latex rubber bands, tested in a 37-degree-Celsius water bath simulating the oral environment.[1] Other efforts followed in which the relaxation patterns of the various elastic elements were quantified and compared in bench-test (in-air) experimentation and in oral cavity simulations.[2-5] The research reported herein was motivated in part by the work of Wong,[6] which apparently first examined relaxation of orthodontic elastic threads and strings in the laboratory, and Ash and Nikolai,[7] who found differences between relaxation characteristics of elastic modules and chains in the true oral environment versus dry-air results, and those of the water-bath oral-cavity simulation.

Elastic threads or strings have received mixed reactions of practitioners as reported by the vendors of orthodontic supplies. In theory the thread provides the clinician with an element having an infinitely variable and controllable unstretched length and initial force level, contrasted to other elastic elements which are individually available in several, passive-state sizes. On the other hand, the thread must be tied and the knot must hold and not interfere with the mechanics. The present investigation was designed to quantify and compare relaxation characteristics of threads and to evaluate their clinical usefulness over extended periods of time in the oral cavity.

Threads and Test Conditions

Nylon-covered latex and extruded polymeric threads were tested and compared in this study. Before finalizing the research design, several sizes of thread and specimen lengths were examined in short-term bench testing. In moderate loading the polymeric thread was found to possess a substantially greater average material stiffness than the latex thread. Actually employed in the testing program were a thread of "medium" cross-sectional dimensions composed of two strands of latex encased in a woven nylon covering

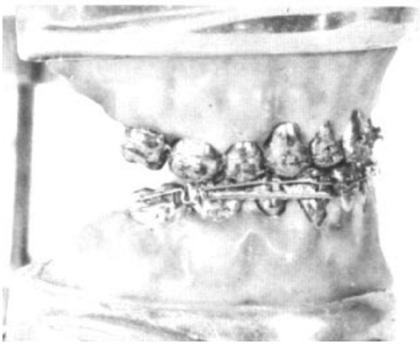

Fig. 1 Test specimens, in vivo on the left and bench (in air) on the right. The latex threads are white.

(Elastomeric Thread, marketed by Rocky Mountain Orthodontics) and a polymeric thread .020 inches in diameter (Zing String, marketed by TP Laboratories).

The bench testing was set up on hardwood frames into which were embedded rows of steel pins. Specimens were cut randomly from a total of four spools of the threads, but to predetermined, undeformed lengths to maintain some degree of initial force control. The specimens were then doubled and their ends clamped in metal eyelets (Fig. 1). The bench experimentation was carried out under dry conditions (low relative humidity) and normal room temperatures (at or near 24°C). Unstretched and stretched specimen lengths and approximate initial force levels are given in Table I. Six subsamples of 15 specimens each were evaluated over twelve-week periods in the *in vitro* portion of the study.

For the *in vivo* segment of this investigation, two subsamples of 16 equal unstretched lengths each of the threads were tied; typical specimens are shown in Figure 1. Jigs were fabricated of .0215 by .0275 inch rectangular, stainless steel wire with stops soldered in place to hold the stretched specimens. Initial conditions for the *in vivo* specimens are also presented in Table I. Intraoral testing was accomplished through the cooperation of patients in active treatment at the Saint Louis University orthodontic clinic. The group consisted of six females and four males, known to be good cooperators and ranging in age from 12 to 24 years at initiation of active treatment. Jigs were clamped onto their archwires gingivally; the stretched, test threads were not integral parts of the appliance in any case. Four patients wore two jig/thread assemblies concurrently while six wore four assemblies each; location of a typical assembly is shown on a typodont in Figure 2. In each patient differing threads were worn concurrently on opposite sides of the arch and, for those individuals wearing four assemblies, also differing threads in the two arches on the same side. Moreover, arrangements of thread types were alternated between arches and side to side within the overall patient sample.

Force readings were taken at time zero (at activation) and thereafter at three days,

TABLE I

Total Test Sample with Subsample Specifications

Thread	Specimens per Subsample	Environment	Unstretched Length (mm)	Stretched Length (mm)	Initial Force (oz)
				61.0	2
	15	Bench	41.5	70.5	5
Latex				77.0	9
	16	In Vivo	31.0	36.0*	6
				43.5	3.5
	15	Bench	41.5	47.0	9
Polymeric				49.5	11
	16	In Vivo	31.0	34.0*	6

*plus knot

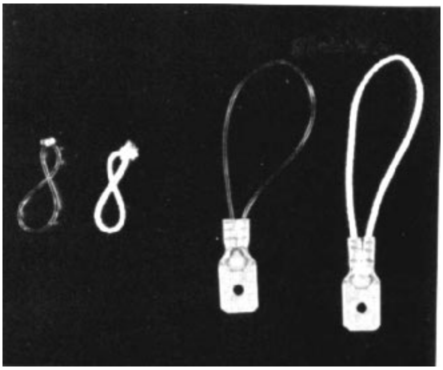

Fig. 2 A typical jig and thread with the former attached to a mandibular arch wire, the assembly on a typodont illustrating the placement of an intraoral test specimen.

one week, three weeks, six weeks, and twelve weeks with the threads maintained at the initial stretched lengths throughout the entire test period. Intraoral threads were inspected at the nine-week mark, but force measurements were not taken. Readings were obtained via a calibrated, spring-tension gauge.

Following experimentation, mean force values and standard deviations were obtained at the six time points for each of the eight subsamples. A three-way analysis of variance and simple-effects computations were carried out to evaluate, statistically, force-level differences to compare subsample relaxation characteristics.[8]

Results and Discussion

Subsamples of two elastic threads were each subjected to relaxation testing under four initial environmental conditions: three on the bench in air under light (two to four ounces), medium (five to nine ounces), and heavy (nine to twelve ounces) time-zero force magnitudes and one *in vivo* under initial loading of approximately six ounces. Following activation, elongations were maintained and force readings were taken over twelve-week periods. Raw data were subsequently reduced and statistical analyses carried out.

Relaxation patterns from the bench-test, reduced data are presented in Figure 3. In all six subsamples the relaxation rate is seen to be highest during the first three days after initial loading in agreement with previous research. At least for the initial three-day period, force losses were generally greater, the higher the level of activation. Also apparent is somewhat greater relaxation of the polymeric than the latex thread for comparable initial force values.

Given in Tables II and III are the force means and standard deviations and the normalized means over twelve weeks for the latex and polymeric thread subsamples, respectively. In the cases of the nylon-covered latex threads the normalized relaxation patterns in air for the medium and heavy initial-load subsamples are virtually coincident with no further force loss occurring after three days. Again on a normalized basis, the light-initial-force latex subsample reflects less relaxation through six weeks, but continues to lose force and at twelve weeks has relaxed to the extent of the medium and heavy subsamples. And, whereas the relaxation of the latex threads in air apparently approaches an asymptote at approximately eighteen percent loss of initial force, *in vivo* results reflect continued relaxation throughout the twelve-week period.

Examination of Table III shows that, with medium and heavy initial forces, the relaxation data for the two polymeric thread subsamples are very similar; the force loss for the light-initial-force subsample is substantially less. The normalized results through twelve weeks indicate no apparent termination of the relaxation of the polymeric thread in either environment, in contrast to the asymptotic behavior observed with the latex, in-air subsamples.

Figure 4 provides visual comparisons, on a normalized basis, of the relaxation behavior of the two threads in the two environments. Throughout the twelve weeks both threads continue to lose force *in vivo*, at a decreasing rate over the entire period

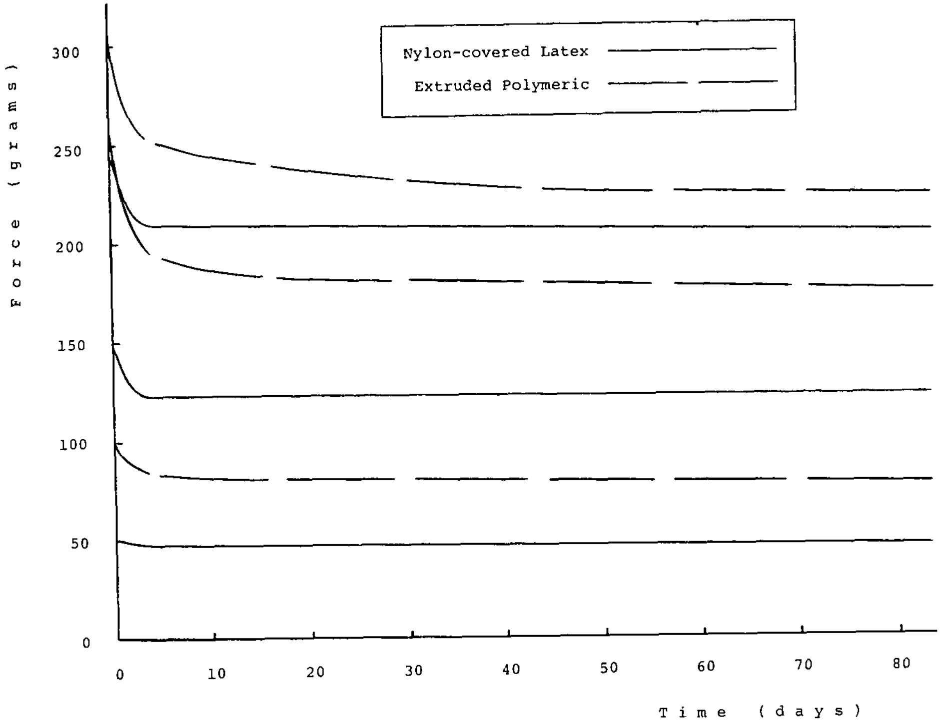

Fig. 3 Relaxation patterns in air of the thread subsamples subjected to light, medium, and heavy initial loading.

in the case of the latex, but with the polymeric thread, beyond the three-week mark, at a constant rate. Noteworthy also, with both threads, is the greater force loss in air than *in vivo* early in the test period; only after eight days does the total force loss by the latex thread become greater *in vivo*, and with the polymeric thread the relaxation in the oral cavity trails the bench-test results for approximately three and one-half weeks following activation. There is no simple explanation for this "cross-over phenomenon" which was also observed by Ash and Nikolai[7] in their investigation of polymeric module and chain relaxation in three environments.

Comparisons of data for the two threads from the in-air testing alone prompt the conclusion that the relaxation of the polymeric material is generally greater than that of the latex. Wong's results of tests in a 37°C water bath also reflected greater relaxation of the polymeric thread.[6] However, with the mean initial forces nearly identical in the present *in vivo* subsamples, although the tabular results and Figure 4 hint otherwise, no statistically significant difference in force loss was found between the threads through the six-week data point.

Comments and Conclusions

Again, the advantage to the clinician of the threads as active elements of the orthodontic appliance is in the finer control of initial force levels than is possible with elastic modules, bands, or chains. Some facility in knot-tying must, of course, be achieved. The relatively rough, nylon covering helps to maintain the knot in the latex thread; with the polymeric thread the

TABLE II

Reduced Force versus Time Data for Latex Thread

	Mean Force ± Standard Deviation (Grams) Percentage of Time-Zero Force (%)					
Time (Days)	0	3	7	21	42	84
"Light"	51±6	46±5	48±5	47±4	47±5	42±3
(Bench)	100	90	94	92	92	82
"Medium"	147±29	123±24	120±25	123±27	123±28	125±29
(Bench)	100	84	82	84	84	85
"Heavy"	248±42	207±36	207±36	208±35	203±34	203±33
(Bench)	100	83	83	84	82	82
In Vivo	175±55	154±57	150±54	137±44	130±49	122±47
	100	88	85	78	74	69

TABLE III

Reduced Force versus Time Data for Polymeric Thread

	Mean Force± Standard Deviation (Grams) Percentage of Time-Zero Force (%)					
Times (Days)	0	3	7	21	42	84
"Light"	99±28	84±22	85±22	80±20	78±19	76±17
(Bench)	100	85	86	81	79	77
"Medium"	258±29	198±24	192±26	181±25	178±27	173±28
(Bench)	100	77	74	70	69	67
"Heavy"	320±33	253±29	250±29	237±22	225±21	221±25
(Bench)	100	79	78	74	70	69
In Vivo	177±20	145±25	140±27	131±29	121±29	101±35
	100	82	79	74	68	57

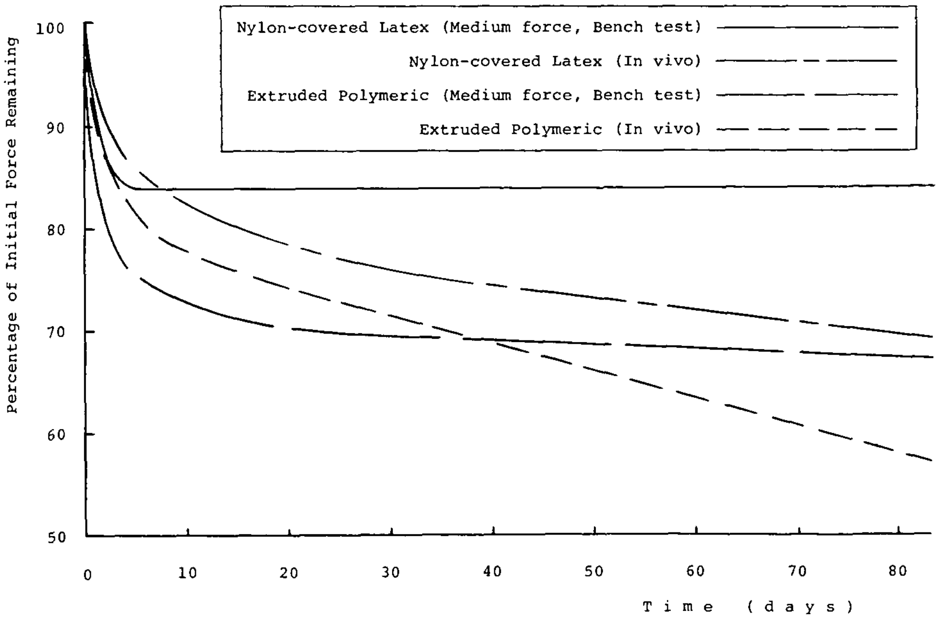

Fig. 4 Normalized relaxation comparisons of two threads in two environments, all with similar initial loadings.

inherent frictional resistance is much less and in pilot testing it was discovered that the material within the knot had to be pretensioned for the knot itself to hold. During the twelve-week, *in vivo* test periods no knots were lost and no loosening of specimens was reported or was apparent from the data.

For three of the thirty *in vivo* specimens valid force readings could not be obtained at twelve weeks. Two polymeric specimens were reported by the patients to have become dislodged from their jigs during toothbrushing. On one latex thread specimen calculus build-up occurred to the extent that it became embrittled between the nine- and twelve-week appointments. On most patients some food residue was routinely observed, particularly in and adjacent to the knots.

The results of this investigation seem to warrant the following conclusions:

1. Simulations of oral cavity conditions in laboratory studies have not accurately predicted relaxation characteristics of elastic threads *in vivo*. Besides environmental differences, mastication and toothbrushing superimpose incremental loading patterns upon the already stretched threads. Relaxation in air is apparently greater than *in vivo* over the first several days following initial loading. Accumulated force losses are substantially greater *in vivo* than in air after one week with the latex and after six weeks with the polymeric thread, and the differences in remaining force continue to grow with time.
2. The relaxation of elastic threads *in vivo*, although significant, is not catastrophic. Over a six-week period neither type, on the average, will lose much more than thirty percent of the initial force. Force loss over time for the threads is substantially less than with the polymeric modules or chains.[7]
3. In comparing the two threads evaluated in this study, based upon relaxation characteristics alone, there is no clinically significant difference between them. The practitioner may prefer the latex over the polymeric thread because the former is easier to tie and has less stiffness; however, the former also appears to be the greater food trap.
4. Elastic threads should probably not be employed continuously over a period greater than six weeks, not because of excessive relaxation but on account of hygienic considerations. Over extended time, debris collects, particularly at the knots, and mechanical behavior may become impaired owing to calculus deposits and chemical interactions with food and oral fluids.

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References

1. Bishara, S. E., and Andreasen, G. F.: A comparison of time related forces between plastic Alastiks and latex elastics. *Angle Orthod.* 40:319-328, 1970.
2. Ware, A. L.: Some properties of plastic modules used for tooth movement. *Aust. J. Orthod.* 2:200-202, 1971.
3. Varner, R. E.: Force production and decay rate in Alastik modules. Master's Thesis, *University of Oregon*, 1974.
4. Hershey, H. G., and Reynolds, W. G.: The plastic module as an orthodontic tooth-moving mechanism. *Am. J. Orthod.* 67:554-562, 1975.
5. Kovatch, J. E. et al.: Load-extension-time behavior of orthodontic elastics. *J. Dent. Res.* 55:783-786, 1976.
6. Wong, A. K.: Orthodontic elastic materials. *Angle Orthod.* 46:196-205, 1976.
7. Ash, J. L. and Nikolai, R. J.: The relaxation of orthodontic elastic modules and chains *in vitro* and *in vivo*. *J. Dent. Res.* 57:685-690, 1978.
8. Kirk, R. E.: *Experimental Design Procedures for the Behavioral Sciences*, Belmont, California, Wadsworth Publishing Co., 1968.