Load-Extension-Time Behavior of Orthodontic Alastiks

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The load-extension curves of Alastiks were found to be sensitive to both the degree and rate of extension. When halting at a constant extension, the exponential load decay was also dependent on the initial deformation rate. The results suggest that clinically these modules should be stretched slowly to position.

Before attempting the more complicated analyses of intra-arch forces and tooth movements, it is imperative to first understand the behavior of the force device itself. In the present investigation, we have chosen to study Unitek's K2 regular Alastik modules[a] since they are in popular use in our clinics and since the manufacturer claims them to be capable of producing long-lasting, accurate forces in the oral environment.[1]

Materials and Methods

Special grips shown in Figure 1 were machined to measure Alastik forces in a tensile testing machine[b] under a variety of loading and stretching conditions. A 0.046-inch diameter hole drilled perpendicular to the longitudinal axis permits the insertion of a no. 56 drill through the eyelet of the module to hold it in place during testing. When a 3-inch diameter plastic cylinder is slipped onto the rubber stopper of the lower grip, liquid of any moderate temperature can be introduced to surround the specimen.

To assess the response to loading and the ultimate strength of the modules, the K2 regular Alastiks, which are of approximately three fourth inch initial length, were stretched at room temperature in tension to breaking at cross-head speeds of 0.2, 2 and 20 inches per minute.

To simulate clinical application of forces available for tooth movement, other groups of modules soaked in 37 C saliva for one week were stretched in tension at room temperature exactly 1 inch at the three different cross-head speeds and were maintained up to several weeks at that constant deformation. The resulting decay in load was continuously monitored.

A minimum of eight specimens were tested for each set of variables. This led to a total of some 50 specimens tested in the course of the current work. Before loading, they were all sized with a calibrated, traveling microscope[c] and found to be quite uniform in diameter, 0.0423 ± 0.0024 inch, along the entire shaft and uniform in distance between centers of the eyelets, 0.6302 ± 0.0226 inch.

Results

Figure 2 shows the average values of the load-extension curves for the Alastik modules run at the three different cross-head speeds. The box at the tip of each curve demonstrated that the standard deviations in load and extension at breakage were quite small between specimens tested at a given speed. After leaving the initial elastic region, however, there is a crossover with respect to testing speed in the 1.3- to 1.5-inch extension range that eventually leads to the more slowly stretched specimens being the strongest at breakage.

Figure 3 shows the results of the clinical simulation where the Alastiks were stretched to a constant elongation well below the breakage point. The elongation of 1 inch was selected as reasonable via a survey of our

Received for publication September 19, 1975.
Accepted for publication March 11, 1976.

[a] Unitek Corp., Monrovia, Calif.

[b] Instron Universal Testing Machine, Instron Corp., Canton, Mass.

[c] Universal Measuring Microscope, Unitron Inst. Co., Newland Highlands, Mass.

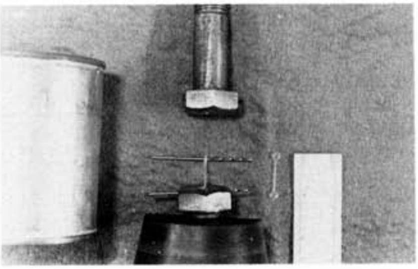

Fig 1.—Alastik module in process of being secured in specially designed grips.

clinical faculty. It is, perhaps, important to also realize that the 1-inch extension is below the crossover region mentioned for Figure 2. Because of the strain rate sensitivity, the faster initial deformation speed specimens are stronger on stopping at 1 inch of extension; but, subsequently the load at this constant extension falls off much more rapidly for the initially faster rate of deformation. In fact, as seen in Figure 3, the early decay in the 20 in/min modules is so great that load levels quickly decrease to below the 0.2 in/min values and remain below for all time. (The 2 in/min results fall somewhere in between the two extremes but were omitted for the sake of graphic clarity.)

In all instances the load decay is rather dramatic. In the table, the time for the load, P, to decrease to one half and one third its initial value, P_o (that is, load at 1 inch when time = 0) is given.

After the first five seconds of load decay, the remaining load decay data plots as a straight line on log-log paper (Fig 4) for time periods extending up to 14 days. Adherence to this straight line rule, which could be described by the parabolic equation of

$$\text{load} = \text{constant} \times (\text{time})^n \qquad (1)$$

where n is a fixed exponent for a given set of variables, was verified at least once for two weeks of load decay from each of the three different cross-head speeds. Ten minutes was more than adequate to establish the parameters of the straight line for all the remaining specimens of each group. The table gives values for the constant and n. These parameters facilitate extrapolation of load decay data to long times but are not applicable to the first few seconds.

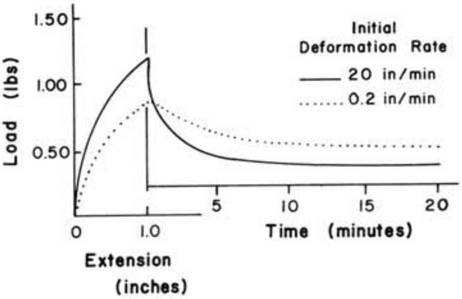

Fig 3.—Load decay of K2 regular Alastiks stretched at two different speeds as they are held at 1-inch extension.

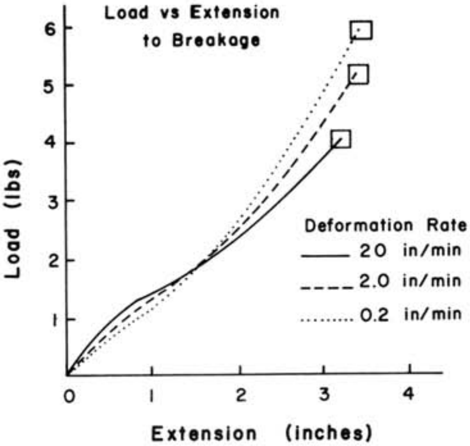

Fig 2.—Load vs extension of K2 regular Alastiks stretched at three different speeds until breakage occurred. Boxes represent standard deviations in both load and extension at breakage.

Discussion

Unitek describes Alastiks as being "space-aged elastomers."[1] Apparently, their exact composition is proprietary; however, as with nearly all lightly cross-linked rubbers, one could anticipate this elastomer to display the usual characteristics of strain rate sensitivity, stress relaxation, relatively low strength,

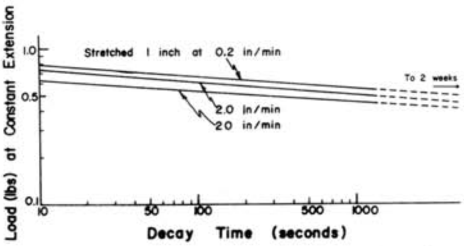

Fig 4.—Log-log plot of load decay data showing straight line response.

TABLE

LOAD DECAY OF ALASTIK K2 REGULAR MODULES

Extension Speed (in/min)	Average P_0 (lb)	Load Decay Time*		Parameters for Equation 1	
		$\frac{P}{P_0} = 1/2$ (sec)	$\frac{P}{P_0} = 1/3$ (sec)	Constant	n
0.2	0.836	3.62×10^4 (10.1 hr)	7.17×10^6 (83.0 days)	0.935	−0.077
2.0	0.911	3.36×10^3 (55.9 min)	4.48×10^5 (5.2 days)	0.893	−0.083
20	0.927	5.58×10^2 (9.3 min)	1.07×10^5 (1.2 days)	0.755	−0.077

* Times given in seconds to comply with equation 1, but the more convenient expression is given in parenthesis.

creep or flow, recovery, and so on. The investigation proved the first three to be true, whereas the other phenomena were not currently tested, but probably also exist to a significant degree. The important questions for these modules are will such elastomeric characteristics help or hurt the efficacy as an orthodontic band material, and will such materials alter their properties and resultant behavior, depending on the clinician's handling technique?

Some very fine studies[2-4] with Alastiks have already been directed toward the former question. In this investigation, we are more concerned with just the material itself, and with the latter question.

First, the accurate sizing and small standard deviations found in each group of variables indicates that the modules can be manufactured uniformly and will permit accurate prediction of the forces generated, provided the variables for the amount of extension and rate of extension are very precisely known.

Second, although the material appears sufficiently strong and capable of withstanding stretching well beyond reasonable clinical requirements, the strain rate sensitivity of the material which is further complicated by its tendency to reverse its nature with large degrees of deformation, could result in a wide variation in initial load depending on both the rate and amount of stretching. For the particular type of module studied, apparently the load-extension curve is least dependent on speed of stretching in the extension region of 1.3 to 1.5 inches. Any deviation in extension from this crossover region will render the resulting initial load less predictable because of the increasingly exacting knowledge of the rate of stretching that is required.

Third, after stretching to a constant extension of 1 inch, the material is not capable of sustaining a constant force. Instead, the material stress relaxes and rather quickly falls to one half of its initial load. Because the decrease is exponential, the fall to one third of initial load takes a good deal longer (Table) but definitely occurs more rapidly in the quickly stretched Alastiks. To slow down the rate of stress relaxation and to keep a reasonably constant, high level of loading for an extended period of time, the Alastiks should be stretched slowly to position. Even so, the clinician must be aware that by doing so he is forestalling the inevitable decrease by a few hours at most.

Although it becomes somewhat clinically unrealistic to stretch these modules much beyond 1 inch, for purposes of information preliminary tests show that for extensions well beyond the crossover, the initial rate of load decay continues to be highest in the rapidly stretched specimens. Moreover, as with other elastomers,[5] as P_0 is increased by increased extension, the initial rate of load decay becomes greater.

Conclusions

Typical elastomeric behavior displayed by Alastik orthodontic bands resulted in load-extension curves that depended on the rate of extension as well as the amount of extension. Initially, the modules tested at the faster speeds had higher moduli and were stronger; but as extension continued, the trend reversed, and at breakage the more slowly stretched modules were the strongest. Therefore, although the Alastiks appear to be uniformly produced, the clinician still needs to know his rate of deformation and degree of stretching to accurately assess the module force.

In addition, the module, once in position, will not maintain a constant force but will experience a decrease in applied load with time kept at a constant extension. Because the initial load decay is more rapid for both faster extension and higher load, it seems reasonable to suggest that care be taken by the clinician to stretch the module more slowly into place. This should result in a higher load level for a longer period of time.

Although the measured changes in loads are not necessarily of sufficient magnitude to seriously influence the clinical result, a clearer understanding of the module behavior, such as currently presented, will hopefully assist in more comprehensive clinical evaluations.

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