The Effect of Cyclic Loading on the Material Properties of Isolated Arterial Elastin

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Statement of Purpose: Elastin is a stable and resilient protein that undergoes large deformations under low force. In the arterial tree, elastin allows the arterial wall to expand and recover as high-pressured blood is pumped from the heart. In addition, elastin stores elastic-strain energy, allowing arteries to smooth the pulsatile flow of blood from the heart, lowering peak BP, and the mechanical work of the heart. As a material, elastin is extremely durable, capable of undergoing over a billion cycles under normal hemostatic conditions, and is an attractive scaffold material for tissue engineering applications [1, 2]. However, little research has been done to understand the effects of cyclic loading on the mechanical properties of elastin. During fatigue testing of materials, it has been demonstrated that mechanical properties such as modulus, residual and ultimate strength change with increasing number of cycles. In this study, the effects of extended cyclic loading on the mechanical properties of isolated arterial elastin are examined.

Methods: Porcine aortas were obtained from a local abattoir, immediately following slaughter, and transported to the lab on ice. The arteries were prepared by removing adherent tissue from the aortas and creating "dog-bone" shaped samples using a custom die. Isolated elastin samples, were then prepared from the cut arterial samples using the method of Lu et al. [2]. Mechanical testing was completed on the isolated elastin samples using a custom-built material testing system [3]. All samples were cycled loaded in tension under displacement control to a maximum displacement of 3mm at 1 Hz for 25k, 50k, or 100k cycles and then monotonically tested in tension to failure at a strain rate of 0.05mm/sec. Stress (σ = load/initial cross-sectional area) and stretch ratio (λ = current length/initial length) were calculated for each specimen from load and displacement values collected during mechanical testing. For isolated elastin, the stress-stretch response is approximately linear [4], thus a linear model was used to determine the modulus (M), or stiffness of the elastin samples. The maximum stress (σ_{max}), or stress at fracture, was also calculated and compared.

Results: Experimental σ_{max} and M results for isolated elastin samples are plotted together in Figure 1. Table 1 shows the average values for the maximum stress and modulus for each group

	25k	50k	100k
σ_{max} (Mpa)	2.27e+05 ± 6.53E+04	2.57e+05 ± 2.37E+04	1.93e+05 ± 8.38E+04
M (MPa)	1.84e+05 ± 3.23E+04	1.69e+05 ± 2.38E+04	1.39e+05 ± 3.45E+04

Table 1. Average values for maximum stress and modulus

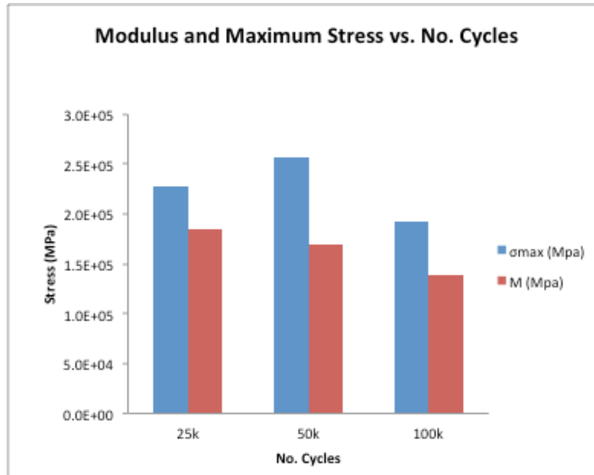

Figure 1. Plot of maximum stress (blue) and modulus (red) vs. number of cycles for isolated elastin.

Discussion: Figure 1 shows a gradual decline in the overall modulus between 25k and 100k cycles. Initially, there is an increase in σ_{max} between 25k and 50k cycles followed by an overall decrease between 50k and 100k cycles. This supports the theory that the static material properties change with increasing number of cycles.

Analysis of variance failed to show that the decrease in modulus and σ_{max} were significant at $p<0.05$, but the values of the modulus were significantly different for $p<0.10$. The statistical findings may be due to low number of samples used for each group (n=5). Another possibility may be attributed to the low number of cycles compared to the suggested fatigue life of elastin of $>10^9$ [1]. Although the results were significant only at $p<0.10$, the data suggests a trend of decrease of stiffness at a modest number of cycles. If elastin is used as a tissue engineering scaffold in a cyclic loading environment, for example, and if the biological response is related to the stiffness of the elastin, then that response may change over time.

Conclusion: The results of this study help characterize the role of elastin in the mechanical response of arteries and present a method to test the cyclic loading response of isolated elastin for further study. Future work will continue to study the effect of cyclic loading on the mechanical properties of arterial elastin .

References:

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