Supplemental Information

Preoperative Vascular Surgery Model Using a Single Polymer Tough Hydrogel with Controllable Elastic Moduli

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Supplemental Video Descriptions

Video S.1 The gel made with 29% w/w acrylamide and 1:10,800 cross-linking ratio was punctured with a 22-gauge steel needle, and the needle was moved around to demonstrate that the fracture did not occur during perturbation.

Video S.2 After the gel made with 29% w/w acrylamide and 1:10,800 cross-linking ratio was punctured it with a needle as showed in Video S.1, it was further stretched by hand. The area of the puncture remained constant.

Video S.3 The gel made with 9% w/w acrylamide and 1:63 cross-linking ratio was punctured with a 22-gauge steel needle. This resulted in a crack that rapidly propagated during perturbation.

Video S.4 A gel tube was made with 29% w/w acrylamide and 1:10,800 cross-linking ratio using a glass mold. The resulting tube could be sucked up into a syringe by pulling out the plunger and released from the syringe by pushing in the plunger. The gel structure remained in-tact, despite the large deformation.

Video S.5 The hydrogel formed with 9% w/w acrylamide and 1:63 cross-linking ratio was sutured on one end and gripped by the mechanical tensile tester on the other. The string of the sutured end was clamped by the upper grip of the mechanical tester. The sample was then elongated until fracture. Video shown at 8 times the original speed.

Video S.6 The hydrogel formed with 29% w/w acrylamide and 1:10,800 cross-linking ratio was sutured on one end and gripped by the mechanical tensile tester on the other. The string of the sutured end was clamped by the upper grip of the mechanical tester. The sample was then elongated until fracture. Video shown at 20 times the original speed.

Video S.7 The hydrogel formed with 44% w/w acrylamide and 1:10,800 cross-linking ratio was sutured on one end and gripped by the mechanical tensile tester on the other. The strand of the sutured end was clamped by the upper grip of the mechanical tester. The sample was then elongated until fracture. Video shown at 8 times the original speed.

Video S.8 The hydrogel formed with 55% w/w acrylamide and 1:10,800 cross-linking ratio was sutured on one end and gripped by the mechanical tensile tester on the other. The strand of the sutured end was clamped by the upper grip of the mechanical tester. The sample was then elongated until fracture. Video shown at 8 times the original speed.

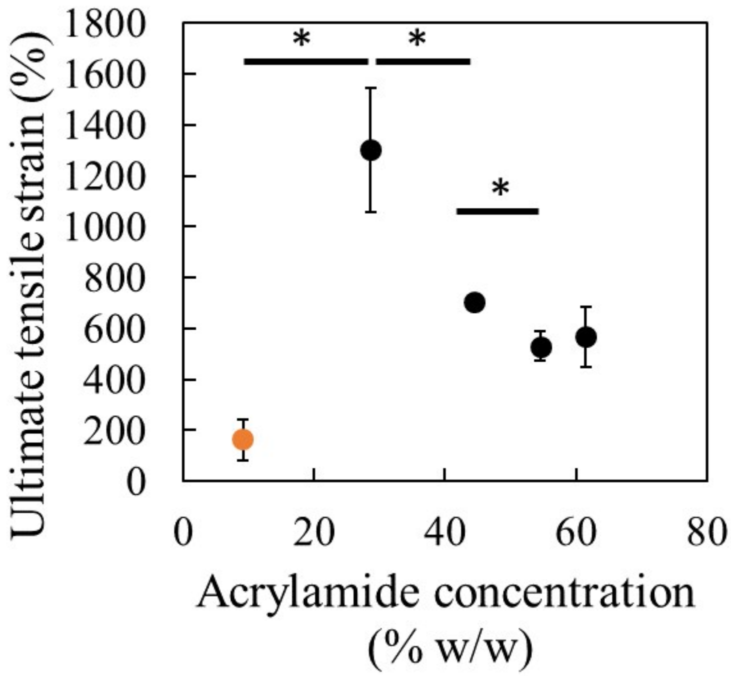
Video S.9 The hydrogel formed with 62% w/w acrylamide and 1:10,800 cross-linking ratio was sutured on one end and gripped by the mechanical tensile tester on the other. The strand of the sutured end was clamped by the upper grip of the mechanical tester. The sample was then elongated until fracture. Video shown at 8 times the original speed.

Video S.10 Two hydrogels formed using 29% w/w acrylamide and 1:10,800 cross-linking ratio were sutured together and stretched. There was no crack formation or gel fracture despite the presence of multiple sutures.

Video S.11 A 1 mm diameter hydrogel tube formed using 29% w/w acrylamide and 1:10,800 cross-linking ratio was cut then sutured back together with a 9-0 USP nylon suture.

Video S.12 Demonstration of pulling on the sutured hydrogel tube described in **Video S.11** without rupture.

Video S.13 Demonstration of pulling on the sutures used to anastomose the hydrogel tube as described in **Video S.11** without rupture.



Orange points depict samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800.

Figure S.1 *Ultimate tensile strain of hydrogels*
Tensile tests were performed on hydrogels prepared with various concentrations of acrylamide and a cross-linking ratio of 1:10,800 until fracture. The train rate was kept constant at 0.1 s^{-1}. A brittle gel (depicted as the orange point) was prepared by cross-linking 9 %w/w acrylamide solution at 1:63 was used as a control. The data depicted are the ultimate tensile strain.

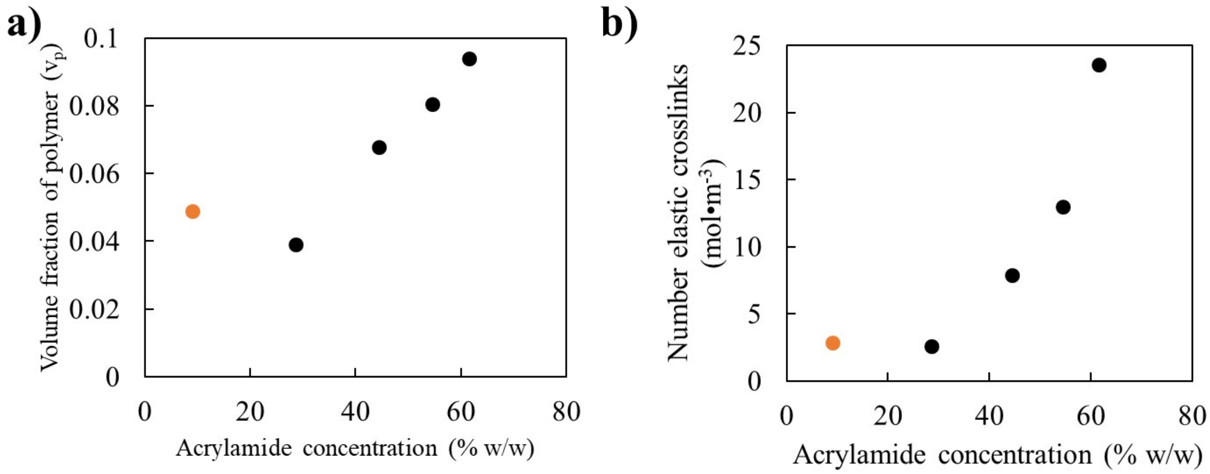


Figure S.2 *Calculation of volume fraction of polymer and number of cross-links for various hydrogel compositions*
Orange points depict samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800. **(a)** The volume fraction of the polymer in the various gel compositions was measured from the dry and hydrated weights of the hydrogels. **(b)** The number of elastic cross-links per volume for gels of various concentrations was calculated by relating the shear modulus and volume fraction of polymer from rubber elasticity theory.

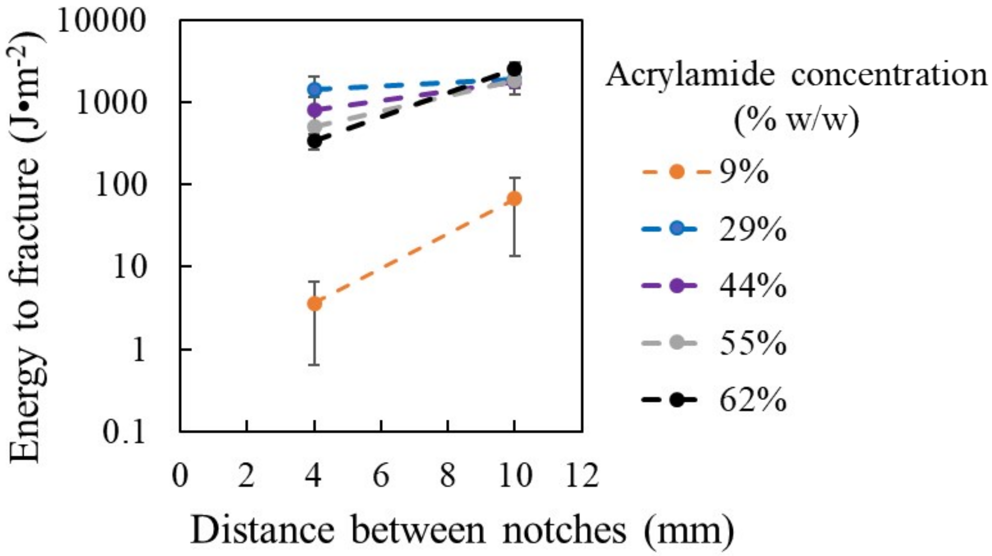


Figure S.3 *Calculation of dissipated work from tensile tests on hydrogels with varied notch length.*
Orange points depict samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800. Tensile tests were performed after cutting notches with a length between notches of 4 mm and without notches. The energy to fracture was measured by the tensile test at a strain rate of 0.1 s^{-1}.

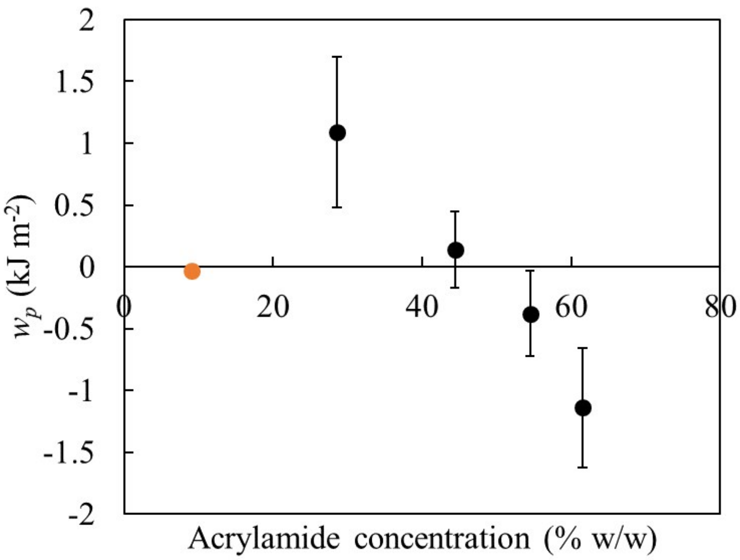
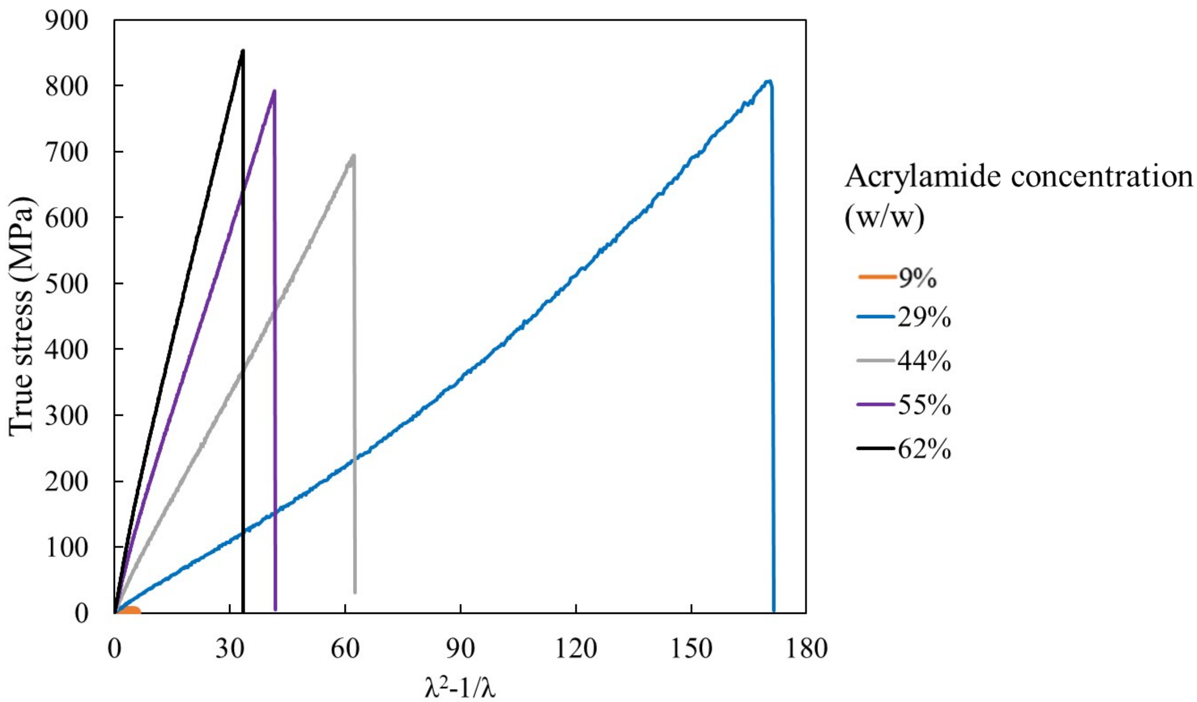


Figure S.4 *Calculation of dissipated work from tensile tests on hydrogels with varied notch length*
Orange points depict samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800. Tensile tests were performed after cutting notches with a length between notches of 4 mm and without notches. The energy to fracture was measured by the tensile test at a strain rate of 0.1 s^{-1}. A model was used to calculate the work inside the process zone.



The orange line depicts samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800.

Figure S.5 *Analysis of hydrogel elasticity*
Tensile tests were performed on hydrogels prepared with various concentrations of acrylamide and a cross-linking ratio until fracture. The true stress vs. elongation factor (λ^2-1/ λ) curves were used to determine the elastic response of the hydrogels.

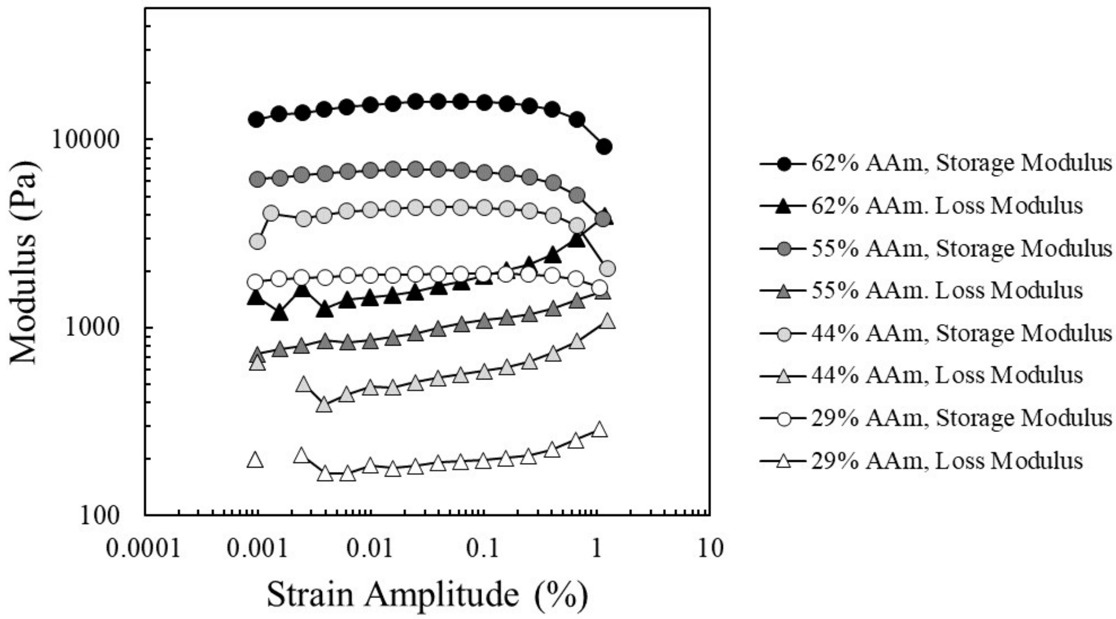


Figure S.6 *Oscillatory shear rheology of hydrogels in response to frequency sweep including loss modulus*

All samples depicted are formed with a cross-linking ratio of 1:10,800. The mechanical properties of hydrogels at various concentrations were measured under oscillatory shear using a rheometer over a range of oscillation amplitudes. The oscillation frequency was kept constant at 1 Hz.

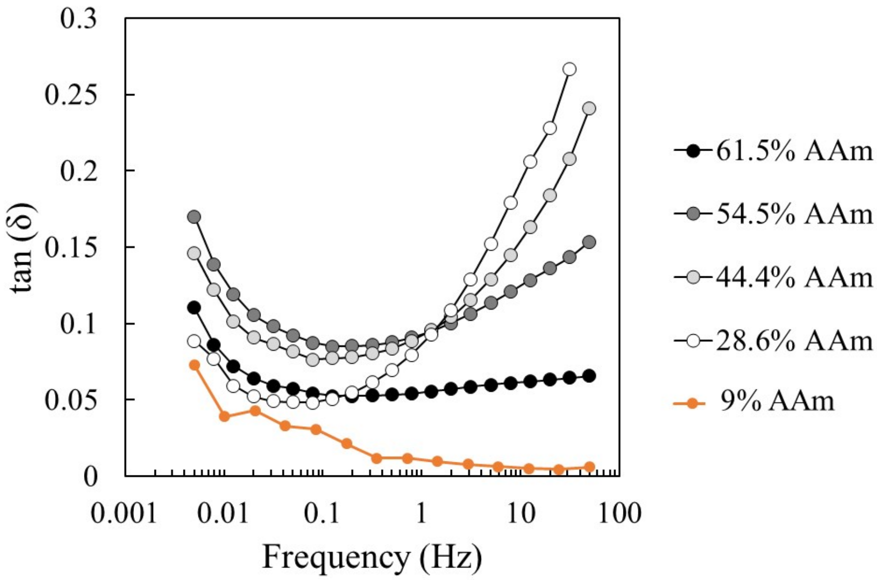


Figure S.7 *Loss factor measured from shear rheology*
Orange lines and points depict samples formed with a cross-linking ratio of 1:63. All other samples are formed with a cross-linking ratio of 1:10,800. Loss factor (i.e., tan(δ)) was calculated by dividing the loss modulus by the storage modulus.

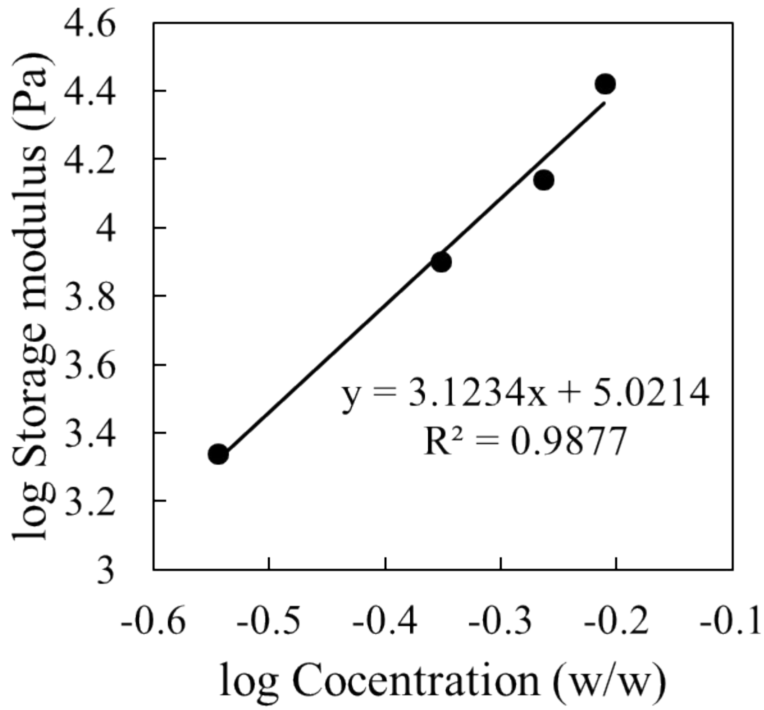


Figure S.8 *Microstructure analysis from oscillatory shear rheology*
The log-log plot of storage modulus vs. hydrogel acrylamide concentration for only the gels formed with a cross-linking ratio of 1:10,800. The storage modulus for each given gel was calculated using the plateau storage modulus from the frequency sweep where the storage modulus was constant and loss modulus was minimized. The values represent average of at least four different samples per condition.