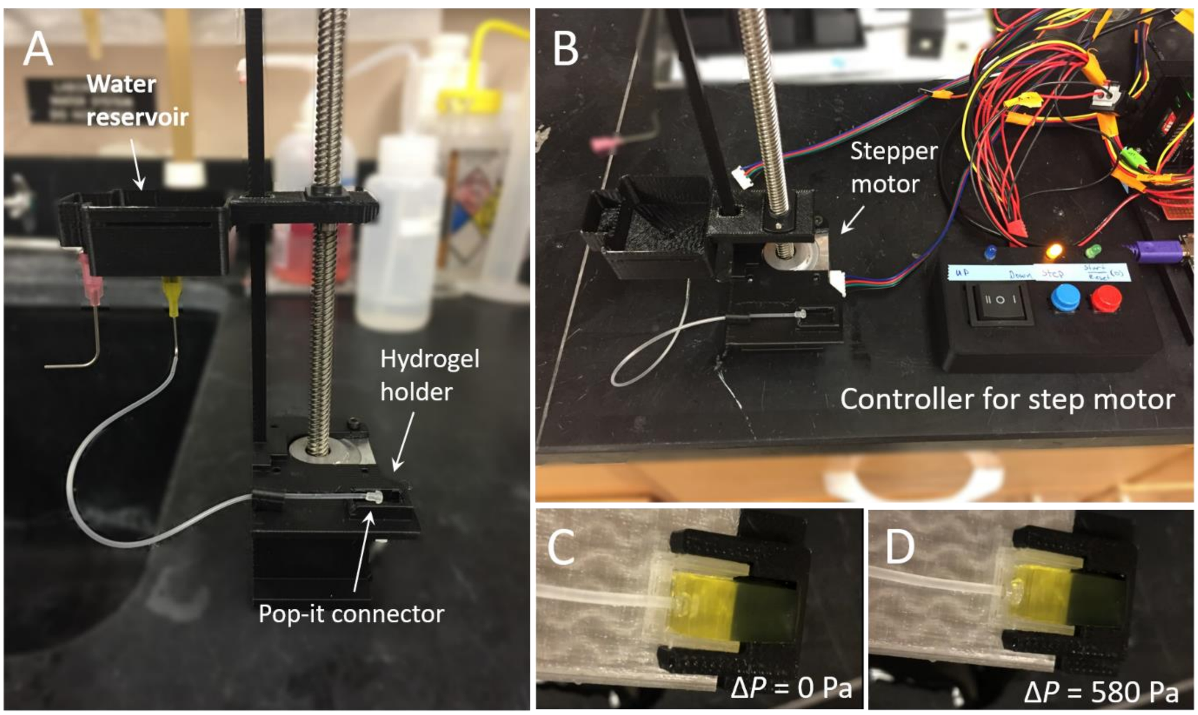
# SUPPLEMENTARY INFORMATION

## 1. Hydrostatic pressure measurements:

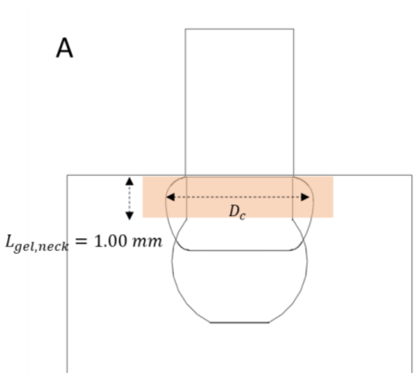
To determine the pressure required for connector failure, we constructed a custom experimental setup capable of applying well-defined hydrostatic pressures (**SI Fig. 1**). The mechanized system consisted of a microcontroller (Elegoo UNO R3), a stepper motor driver (TB6600), and two stepper motors with lead screws (NEMA 17 with 150mm T8 lead Screws). The lead screws provided controlled linear movement with a minimum step size of 2.5 μm. A water reservoir was mounted to the stepper motor lead screws and connected to the hydrogel through tubing and a pop-it connector. The reservoir was incrementally raised using the stepper motors until the connection between the pop-it connector and the hydrogel failed. The height of the reservoir at failure could then be calculated from the number of steps the stepper motors had taken. The height differential between the top of the water reservoir and the pop-it connector was used to determine the hydrostatic pressure $P_h$ required for connection failure using the simple equation $P_h = \rho g h$, where $\rho$ is density of the fluid, $g$ is gravitational force and $h$ is the height of the fluid. A video of a representative experiment is shown in **Video S1**.




**SI Fig. 1**. Hydrostatic pressure setup. (**A**) 3D printed parts were assembled together with a stepper motor and microcontroller to control the height of the water reservoir and generate a hydrostatic pressure on the hydrogel inlet. (**B**) Movement of the stepper motor was controlled by an Elegoo UNO R3 microcontroller and a TB6600 stepper motor driver to provide precise control of the height. (**C**) A hydrogel with an attached pop-it connector remains stable when no hydrostatic pressure is applied ($\Delta P$ = 0 Pa), and is (**D**) expelled from hydrogel when $\Delta P$ = 580 Pa

## 2. Estimating contact area between connector and gel:

Method used to estimate the contact area, $A$ between the connector and gel at maximum deformation during connector insertion (**SI Fig. 2**). These values of $A$ were then used to calculate the stress, $\tau = F_{\max}/A$, and the values plotted in Fig 3d.



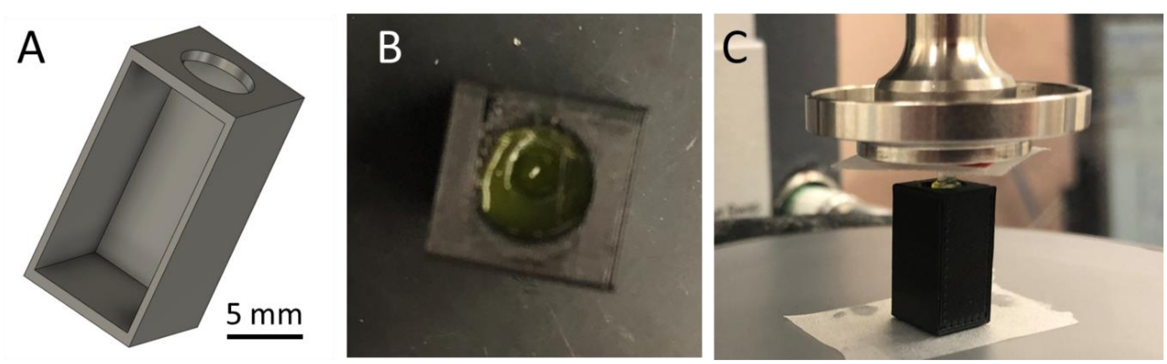

B

| $D_c$ [mm] | Contact Area, $A$ [$mm^2$] |
|---|---|
| 2.70 | 9.02 |
| 2.85 | 9.03 |
| 3.00 | 10.40 |
| 3.20 | 10.55 |
| 3.35 | 10.44 |
| 3.50 | 10.90 |

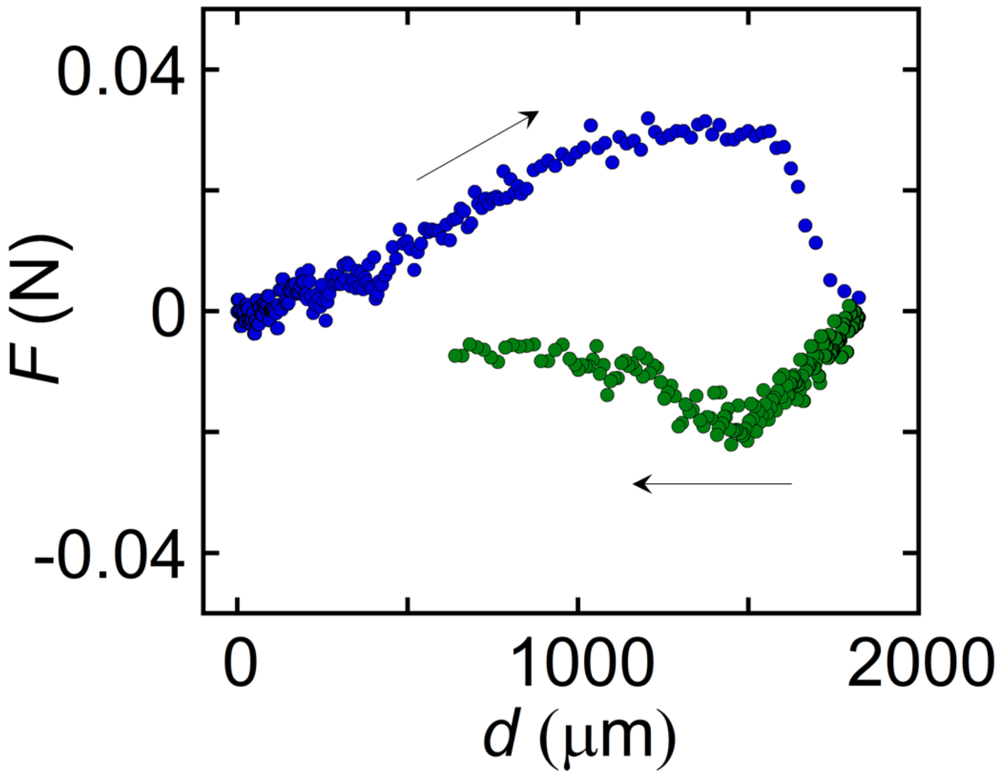
**SI Fig. 2**. Contact area, $A$ when hydrogel is at $F_{max}$ during the insertion of the pop-it connector. (**A**) Representative side view of connector and gel to shows the position of the connector in the hydrogel socket during insertion when force is at $F_{max}$. Area of the roughly highlighted zone is extracted using the software Fusion 360. (**B**) Table of $A$ values for each pop-it connector.

## 3. Evidence of hysteresis in normal forces associated with connector insertion and removal:

To compare the normal forces associated with insertion and removal of the pop-it connector, we 3D printed a PLA enclosure (dimensions: 8.5 mm x 8.5 mm x 15.5 mm; wall thickness: 0.50 mm; top hole diameter: 5.00 mm) to hold the hydrogel in place during retraction of the rheometer head (**SI Fig. 3a, b**). The pop-it connector and hydrogel holder were each taped to the rheometer head and platform, respectively as shown in **SI Fig. 3c**. For each measurement, the pop-it connector was inserted into the hydrogel in a manner similar to that described for Fig 3, and the rheometer head was then also retracted to remove the connector. A representative force measurement with clear hysteresis is plotted in **SI Fig. 4**.




**SI Figure 3**. Experimental setup for measuring normal forces associated with connector insertion and removal. (**A**) CAD design file of hydrogel holder. (**B**) Top-view of the hydrogel holder (**C**) Full experimental setup mounted on the rheometer.




**SI Figure 4**. Representative measurement of normal force, *F* as a function of displacement, *d*, for a connector inserted into a gel socket (blue data points) and then removed from the socket (green data points). For the two data sets, the upper rheometer plate is moving in opposite directions, indicated by the arrows. The measurement reveals clear hysteresis in the forces associated with insertion and removal. The reason for this hysteresis is not clear.