

Supporting Information for

Biodegradable 3D Printed Polymer Microneedles for Transdermal Drug Delivery

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Instrumentation

Differential Scanning Calorimetry

For thermal analysis a differential scanning calorimetry (Mettler Toledo Inc, Plano, TX) was used on polylactic acid.

Figures and Tables

SEM Images of Unetched MNs

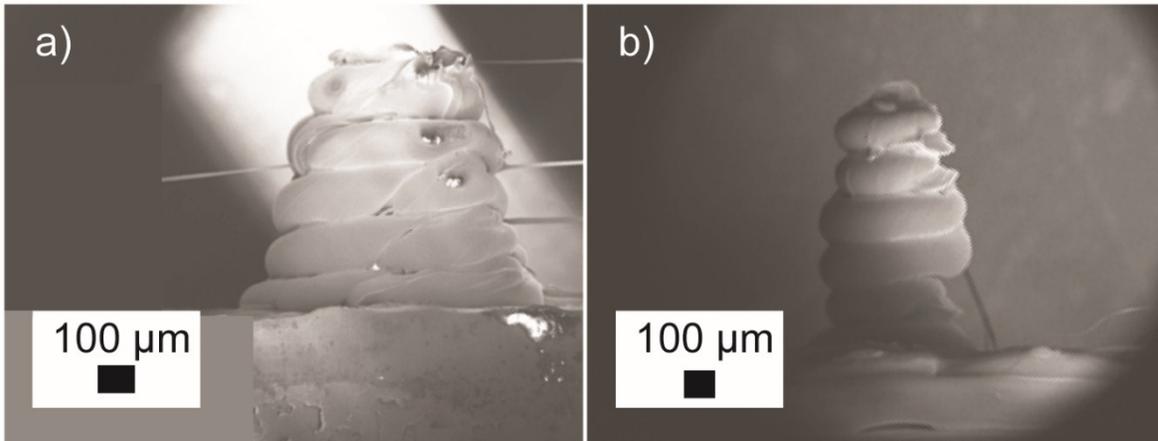


Figure S1: SEM images of unetched FDM fabricated MNs: Type 5 with a) 3 layers at 0.8 mm followed by 2 layers at 0.5 mm and Type 6 with b) 1 layer at 0.5 mm, 2 layers at 0.8 mm, and 2 layers at 0.5 mm.

Etching Analysis

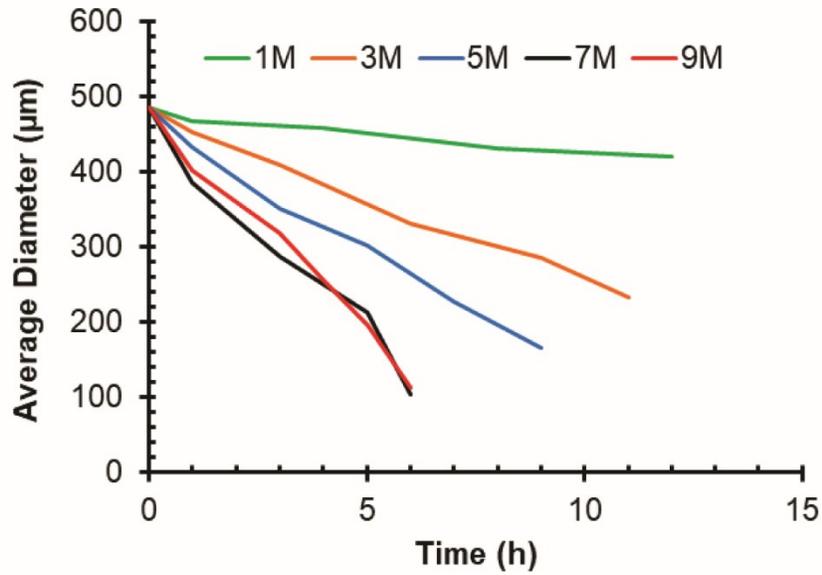


Figure S2: Type 7 MNs were etched at various concentrations of KOH to determine the change in diameter of the mid area of the needle over time.

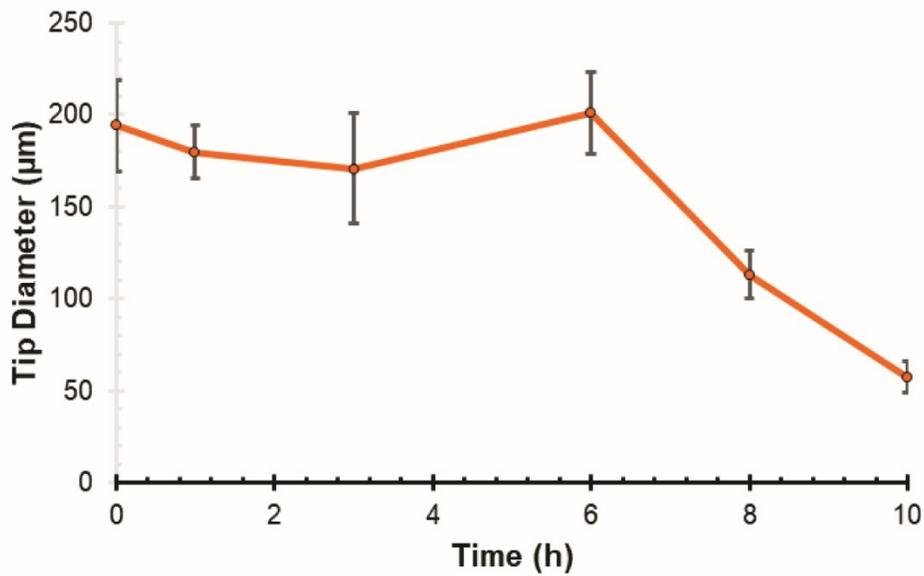


Figure S3: To determine the amount of time for tips to reach a diameter below 75 µm, the tip size of Type 7 MNs were measured over time while etching with 5M KOH.

Differential Scanning Calorimetry

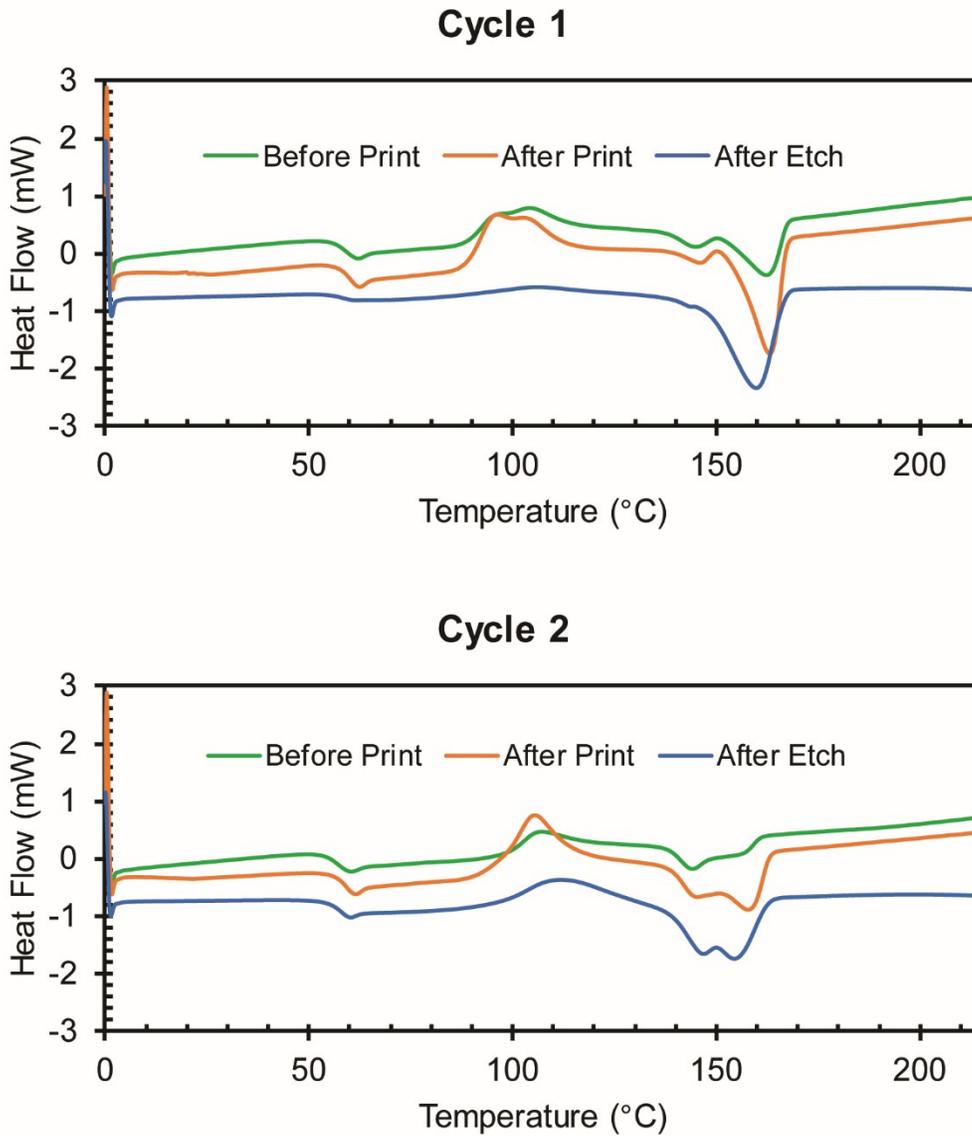


Figure S4: Differential scanning calorimetry curves were measured using a heating rate of $10\text{ }^{\circ}\text{C}\text{ min}^{-1}$. PLA was scanned for 2 cycles before printing, after printing, and after etching.

3D Printed MN Array Density

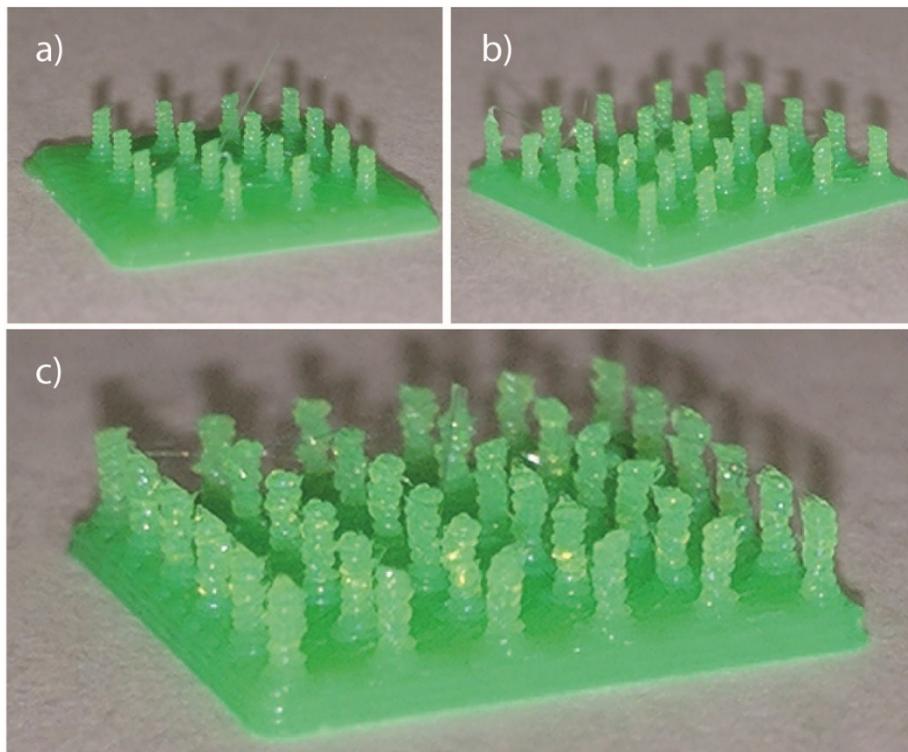


Figure S5: Images of unetched FDM fabricated MN arrays at densities of a) 4 x 4, b) 5 x 5, and c) 6 x 6.

Mechanical Analysis

Axial and Transverse Fracture Test

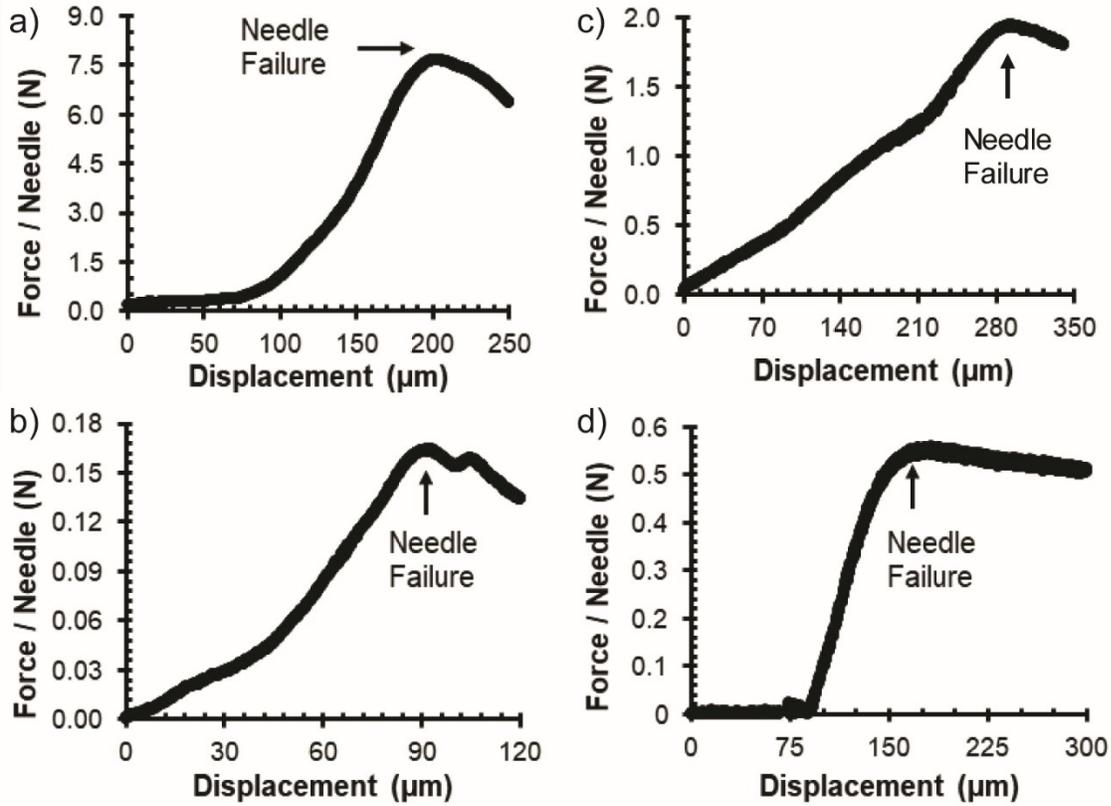


Figure S6: Fracture force was determined for a) unetched and b) etched axial fracture, and c) unetched and d) etched transverse fracture using Type 7 MNs (1.4mm in length). The failure point for the needle is noted for each mechanical test

Type 7: lengths (mm)	Axial Force (N)	Transverse Force (N)
Etched 0.6	0.22 ± 0.0040	0.51 ± 0.054
Etched 1.0	0.21 ± 0.0040	0.65 ± 0.096
Etched 1.4	0.23 ± 0.0020	0.64 ± 0.018
Unetched 0.6	9.0 ± 0.92	0.69 ± 0.049
Unetched 1.0	9.9 ± 0.97	1.1 ± 0.13
Unetched 1.4	7.2 ± 0.85	1.3 ± 0.12

Table S1: Axial and transverse fracture force for MNs at different lengths.

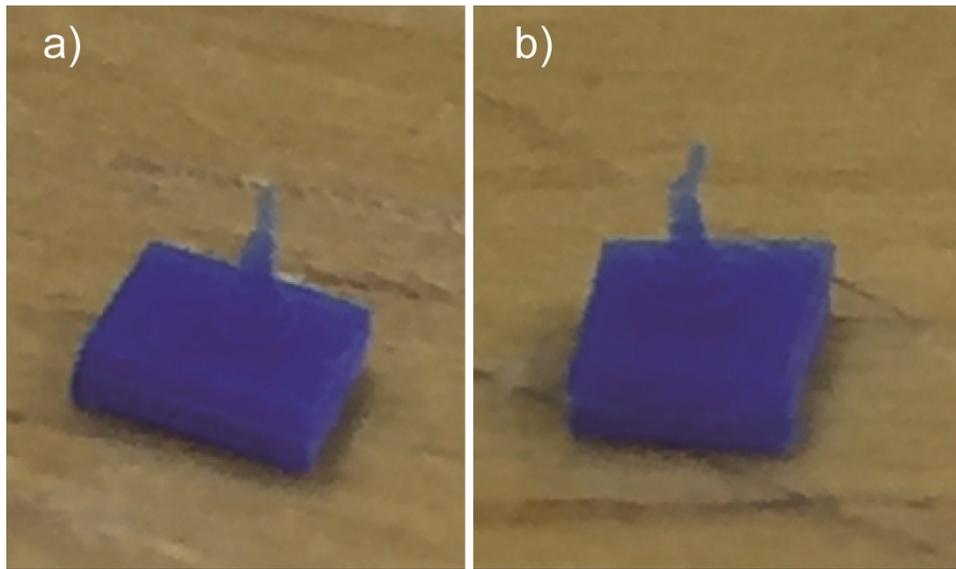


Figure S7: a) Before and b) after images of axial fracture force test for Type 7 MNs (1.4mm).

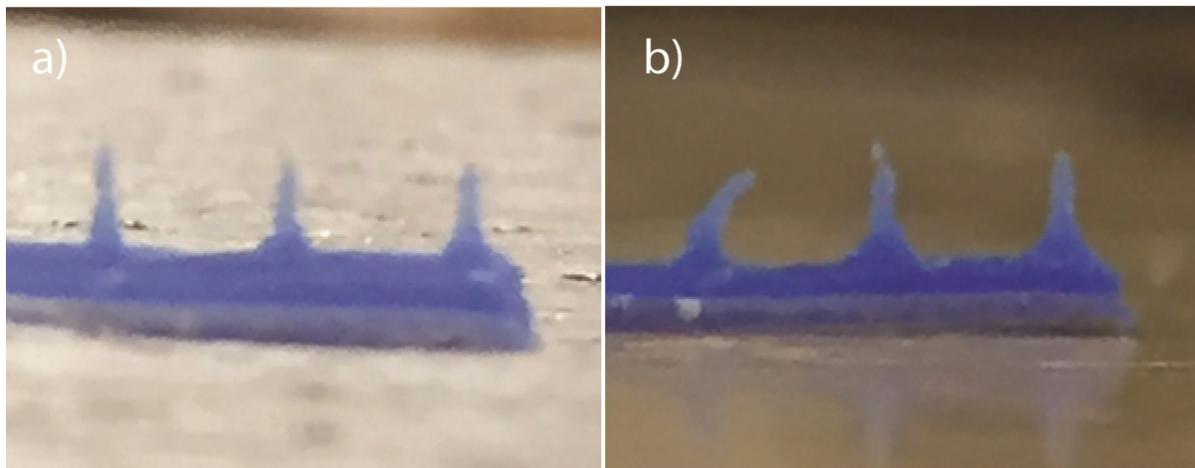


Figure S8: a) Before and b) after images of transverse fracture force for Type 7 MNs (1.4mm).

Base Plate Test

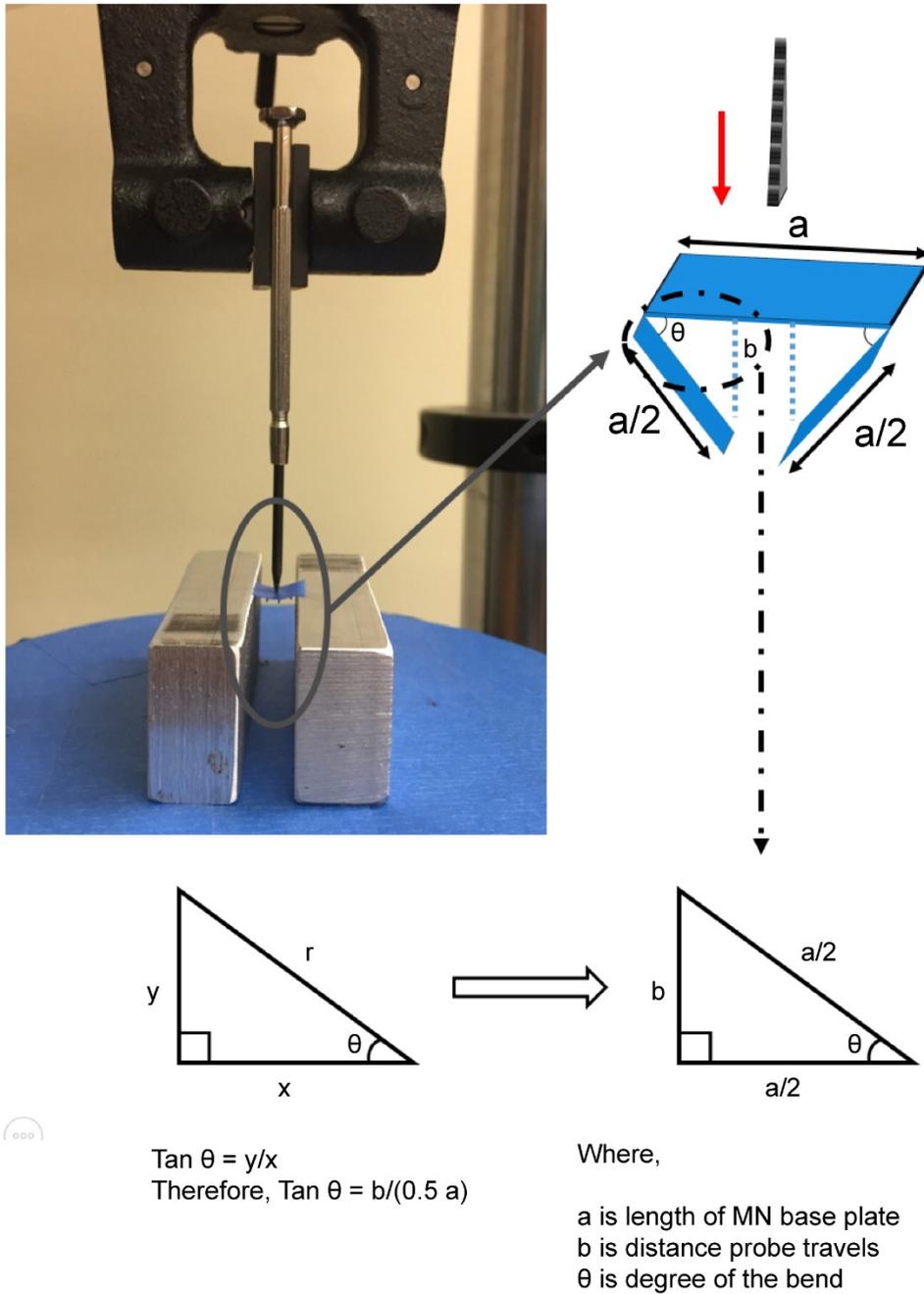


Figure S9: A MN array is placed on top of two aluminum blocks. A force is applied on the center of the backing layer by a piston moving at 300 $\mu\text{m/s}$ until a fracture occurs. The above equation calculates the angle that the MN array backing layer is able to bend before fracturing.

Base Layers	Area (cm ²)	Distance (mm)	Angle
2	1	1.99 ± 0.133	21.7 ± 0.675 °
3	1	1.51 ± 0.0316	16.8 ± 0.335 °
4	1	1.40 ± 0.0096	15.6 ± 0.119 °

Table S2: The angle that the MN array backing layer can bend at various layers.

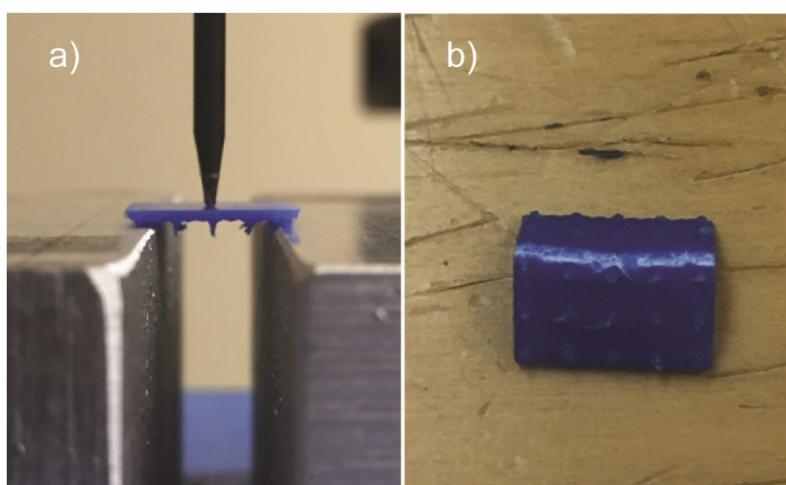


Figure S10: a) Before and b) after images of MN array base plate test with 4 layers.

Loading and Release

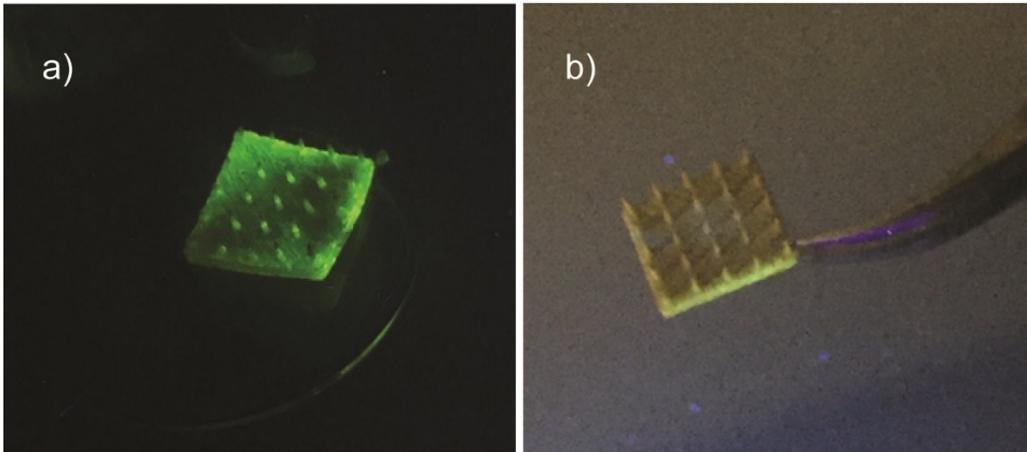


Figure S11: Fluorescence of MN arrays a) before evaporation and b) after evaporation. Before evaporation the MNs appear to be colorless under ambient light and fluoresce under UV light (365 nm). After evaporation MNs appear orange under ambient light and no longer fluoresce under UV light due to the removal of acetone. Under UV light fluorescein does not fluoresce in the solid state.

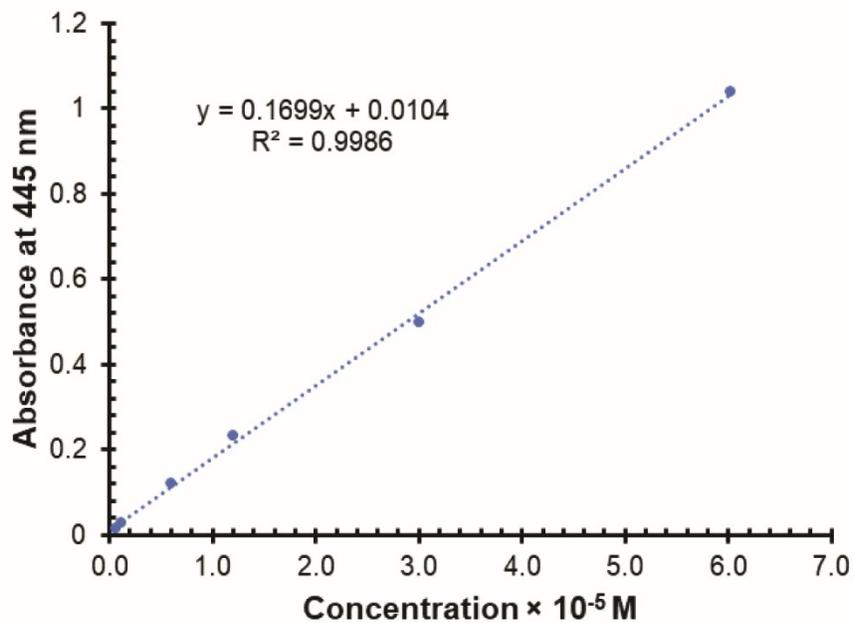


Figure S12: Standard curve of fluorescein at different concentration in sodium acetate / acetic acid buffer solution (pH 4.0).

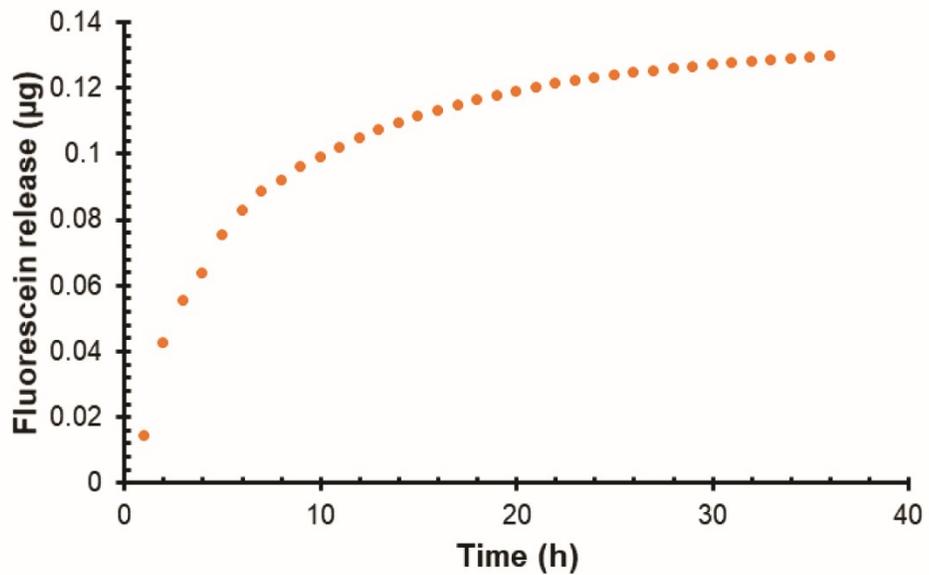


Figure S13: A measurement was taken every hour for 100 MNs that were placed in a cuvette filled with sodium acetate / acetic acid buffer solution (pH 4.0). At 4 h 1 needle released 0.06 µg of fluorescein and after 36 h released 0.13 µg of fluorescein.