

Tunable stiffness of PEGDA-INK

BIONOVA X | PEGDA-INK

Summary

This study characterizes the compressive stiffness of PEGDA-INK printed with BIONOVA X and demonstrates how exposure settings can be used to tailor the mechanical properties of PEGDA hydrogel scaffolds.

- PEGDA-INK produced rigid hydrogel constructs with compressive moduli ranging 6-14 MPa across the evaluated printing conditions.
- Stiffness increased with accumulated light exposure, allowing mechanical properties to be adjusted through light intensity, layer exposure time, and print speed.
- Comparable stiffness ranges can be achieved using both layer-by-layer and continuous print modes, providing flexibility in how constructs are fabricated.
- PEGDA-INK enables fabrication of high-resolution hydrogel scaffolds with tunable MPa-scale stiffness for applications requiring precise architecture, structural stability, and controlled mechanical properties, or for development of models targeting stiffer tissues such as cartilage and bone.

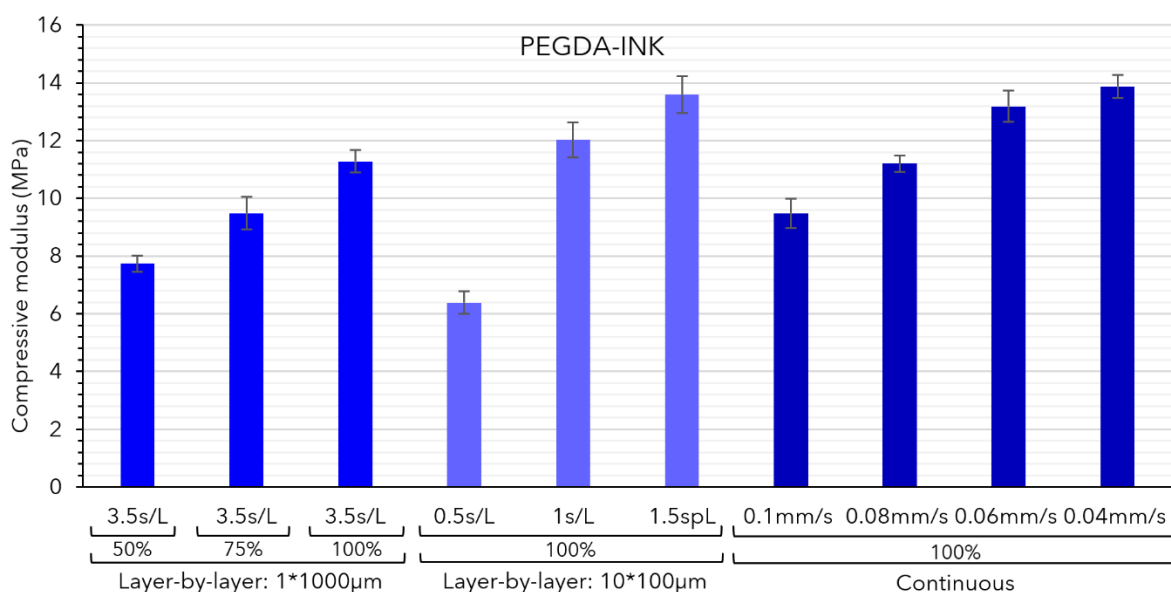


Figure 1. Compressive modulus of PEGDA-INK discs (5 mm diameter, 1 mm height) printed with BIONOVA X using layer-by-layer (1*1000 µm or 10*100 µm layers) and continuous print modes with varying intensities (%), exposure times (seconds per layer = s/L) and speeds (mm/s).

Results and conclusions

Constructs were fabricated using CELLINK's BIONOVA X DLP bioprinter under controlled and reproducible printing conditions. The compressive stiffness of PEGDA-INK constructs was evaluated across different print modes and exposure settings to assess the influence of processing parameters on the resulting mechanical properties.

Representative images of printed PEGDA-INK constructs after overnight PBS incubation are shown in **Figure 2**, demonstrating the integrity of the printed structures prior to compression testing.



Figure 2. Representative images of PEGDA-INK constructs (5 mm diameter, 1 mm height) using layer-by-layer mode with 1 layer of 1 mm exposed for 3.5 s with 75% intensity (A), 10 layers of 100 μ m exposed for 1 s per layer with 100% intensity (B) and continuous mode with 0.06 mm/s (C), after overnight PBS incubation.

Compression testing showed that PEGDA-INK produced mechanically robust hydrogel scaffolds across all evaluated conditions, with compressive moduli ranging from approximately 6 to 14 MPa (**Figure 1**). These results demonstrate that PEGDA-INK can be used to fabricate structurally stable hydrogel scaffolds while maintaining reproducible print performance across multiple printing approaches.

Within both print modes, construct stiffness increased with accumulated light exposure, consistent with increased PEGDA crosslinking at higher exposure levels. In layer-by-layer printing, increasing light intensity or extending

layer exposure time resulted in progressively stiffer scaffolds. Similarly, in continuous mode, reducing print speed increased construct stiffness by increasing the accumulated light dose delivered during fabrication.

Similar stiffness ranges could be achieved using both layer-by-layer and continuous print modes. This allows the fabrication approach to be selected based on construct design and manufacturing needs rather than scaffold mechanics alone. Within the layer-by-layer workflow, single-layer prints enable rapid fabrication of simple geometries, while multi-layer printing supports more complex scaffold architectures. Continuous printing enables fabrication of complex, well-defined structures with smooth, layerless transitions and patterning in the z-direction while maintaining comparable mechanical properties.

Overall, the results demonstrate that PEGDA-INK can be used to fabricate high-resolution hydrogel scaffolds with tunable MPa-scale stiffness across multiple printing workflows. By adjusting exposure settings, users can tailor scaffold mechanics while maintaining structural stability, supporting applications where precise architecture, mechanical robustness, or stiffer tissue-mimetic environments are desired.

Methods

Bioink preparation

PEGDA-INK was used as ready-to-print bioink with 0.5% LAP. The material was homogenized by gently inverting the tube 5 times before loading into the [BIONOVA X 24-well plates](#) using a positive displacement pipet.

Bioprinting with BIONOVA X

Printing of discs (5 mm diameter, 1 mm height) in 3 replicates per condition was performed following the [PEGDA-INK](#) bioprinting protocol, using layer-by-layer (1 layer of 1 mm or 10 layers of 100 μ m

each) and continuous print modes with exposure times, light intensities, and print speeds specified in **Table 1**.

Table 1. Print exposure parameters for PEGDA-INK on BIONOVA X using continuous and layer-by-layer print modes. 100% intensity corresponds to ≈ 16 mW/cm² irradiance.

Print mode	Layer height	Parameter settings	
		Exposure time	Intensity
Layer-by-layer	1 layer of 1000 μ m	3.5 s/layer	50% 75% 100%
	10 layers of 100 μ m	0.5 s/layer 1.0 s/layer 1.5 s/layer	100%
Continuous	N/A	0.04 mm/s 0.06 mm/s 0.08 mm/s 0.1 mm/s	100%

Compression testing

Compressive modulus was measured using the HR10 rheometer (TA Instruments) and 20 mm plate geometry, at 25°C. Geometry gap was decreased until a positive axial force was detected. Unconfined compression testing was performed with 1% strain/s until 25% strain, and the compressive modulus calculated from the linear region of the stress-strain curves between 5-10% strain.



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