

Tunable stiffness of PhotoGel-INKs

BIONOVA X | PhotoGel-INK 50% & 95% DS

Summary

This study characterizes the compressive stiffness of PhotoGel-INK 50% and 95% DS, demonstrating how bioink selection, print mode and exposure parameters influence mechanical outcomes.

- Printing PhotoGel-INKs using BIONOVA X enables a wide, tunable stiffness range across layer-by-layer and continuous print modes, producing constructs suitable for soft to moderately stiff tissue models.
- Increasing accumulated light exposure consistently increases construct stiffness, consistent with more complete crosslinking.
- Bioink selection is a major contributor to stiffness: PhotoGel-INK 95% DS produces stiffer constructs (**15–45 kPa**) than PhotoGel-INK 50% DS (**2–16 kPa**).
- For each bioink and print strategy, a broad, overlapping stiffness range can be achieved, allowing print mode to be selected based on application needs without compromising mechanical properties.

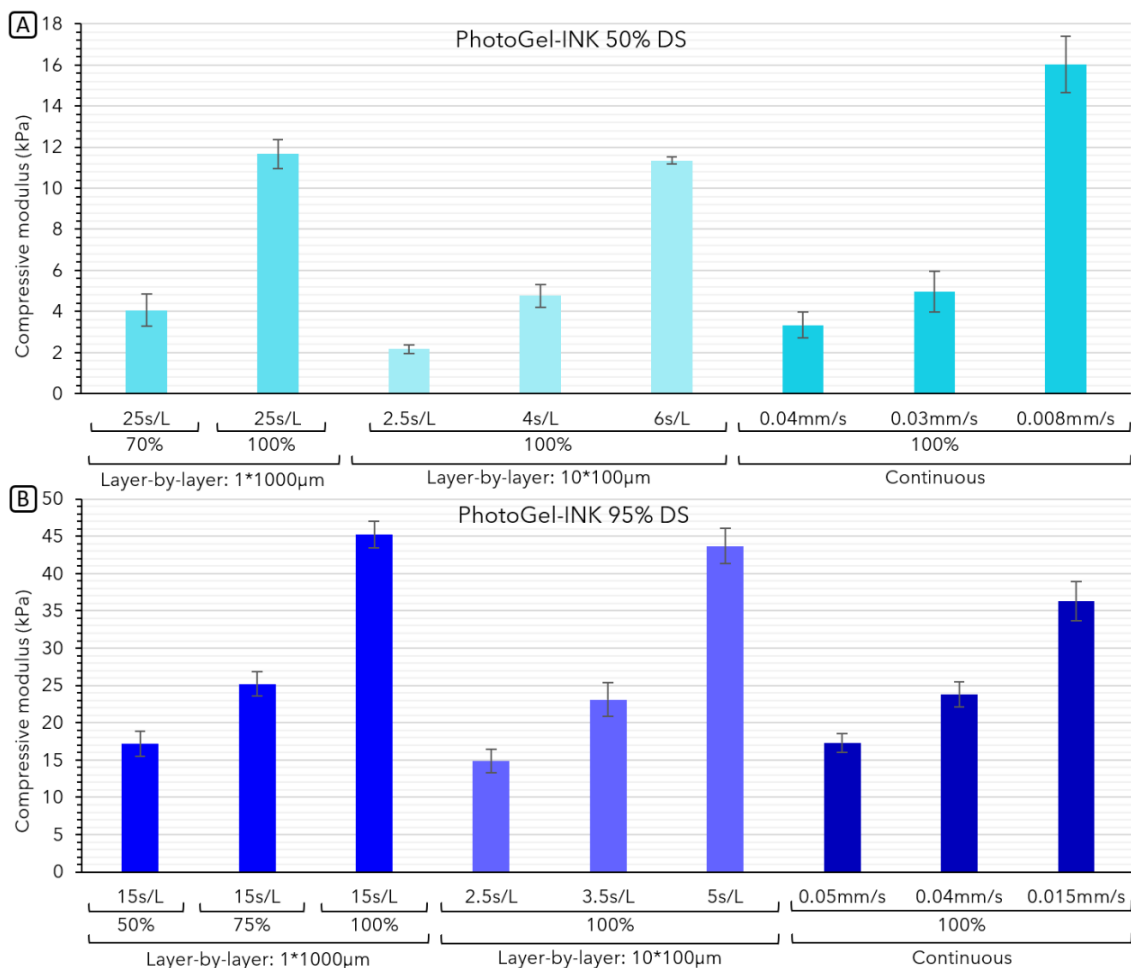


Figure 1. Compressive modulus of PhotoGel-INK 50% (A) and 95% DS (B) discs (5 mm diameter, 1 mm height) printed with BIONOVA X using layer-by-layer (1*1000 µm or 10*100 µm layers) and continuous print modes with varying intensities (%), exposure times (seconds per layer = s/L) and speeds (mm/s).

Results and conclusions

Constructs were fabricated using CELLINK's BIONOVA X DLP bioprinter, which provides precise control over exposure and print speed while maintaining reproducible processing conditions across samples. The compressive stiffness of PhotoGel-INK 50% and 95% DS was evaluated as a function of a print mode and printing parameters (exposure time, light intensity, and print speed).

Representative images of printed PhotoGel-INK 50% and 95% DS constructs after overnight PBS incubation are shown in **Figure 2**, illustrating the integrity of the printed structures prior to compression testing.

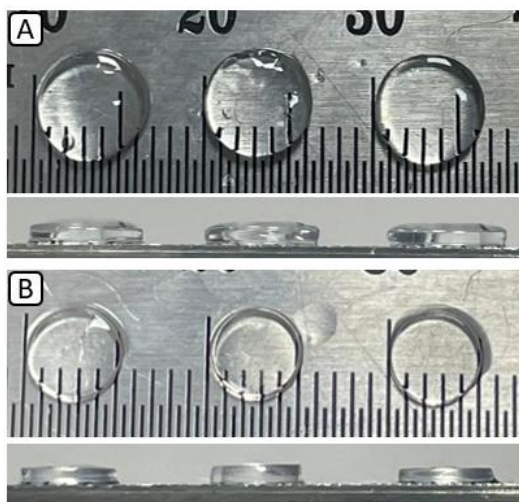


Figure 2. Representative images of constructs (5 mm diameter, 1 mm height) printed using layer-by-layer print mode with 1 layer of 1 mm with PhotoGel-INK 50% DS using 25 s at 70% (A) and PhotoGel-INK 95% DS using 15 s at 75% (B) after overnight PBS incubation.

Compression testing demonstrates that compressive modulus can be tuned across a wide stiffness range through the choice of bioink and printing parameters (**Figure 1**). Bioink selection is a major contributor to construct stiffness: at matched printing conditions, PhotoGel-INK 95% DS consistently produces stiffer constructs than PhotoGel-INK 50% DS, ranging within 15–45 kPa and 2–16 kPa, respectively, giving users a straightforward first lever for targeting

a desired stiffness range before fine-tuning with printing parameters.

Within each ink, both print modes — layer-by-layer and continuous — can be tuned to achieve a broad, overlapping stiffness range by adjusting exposure time, intensity, or print speed. This allows selection of a print mode based on the needs of the application without the need to compromise on mechanical properties of a final construct. For example, a single layer for the fastest fabrication of simple geometries such as discs or grids, multiple layers for structured multi-layered builds, and continuous mode for smooth, layerless transitions and patterning in z-direction. Across all modes, increasing accumulated light exposure — via longer exposure time, higher intensity, or slower print speed — consistently increases construct stiffness, attributed to a more complete crosslinking of the GelMA network at higher exposure doses.

However, exposure conditions above certain thresholds should be used with caution when printing with embedded cells: for continuous mode, print speeds slower than 0.03 mm/s, and for layer-by-layer mode, exposure times above 4 s/layer, result in a high accumulated light dose that may negatively affect cell viability. While higher exposure improves print resolution and construct stiffness, reduced exposure is generally more favorable for cell viability, and users should balance these two factors according to the requirements of their application.

Overall, the results demonstrate that PhotoGel-INK 50% and 95% DS can be printed consistently using the BIONOVA X to span wide, tunable compressive stiffness ranges across multiple print modes, at a fixed 10% polymer concentration. This provides flexibility to balance print resolution, throughput, and mechanical properties within validated processing windows, enabling the fabrication of constructs suitable for soft to moderately stiff tissue models using CELLINK's BIONOVA X bioprinter.

Methods

Bioink preparation

PhotoGel-INK 50% and 95% DS were used as ready-to-print bioinks at 10% (w/v) polymer concentration. The [BIONOVA X 24-well plates](#) and photoinks were pre-warmed to 37°C and photoink vials were gently inverted 5 times to homogenize before photoinks were transferred to 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 bioprinting protocols ([PhotoGel-INK 50%](#) and [PhotoGel-INK 95% DS](#)), using layer-by-layer and continuous print modes with layer heights, exposure times, intensities, and print speeds specified in **Table 1** and **Table 2**, respectively. Note that the highest exposure conditions tested (continuous mode below 0.03 mm/s; 10-layer mode above 4 s/layer) should be used with caution for cellular printing, as they may compromise cell viability. Cell viability performance for PhotoGel-INK bioinks has been evaluated separately and is reported in *Supporting cell viability data* ([PhotoGel-INK 50%](#) and [PhotoGel-INK 95% DS](#)).

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 60% strain, and the compressive modulus calculated from the linear region of the stress-strain curves between 5-10% strain.

Table 1. Print exposure parameters for PhotoGel-INK 50% on BIONOVA X using continuous and layer-by-layer print modes. 100% intensity corresponds to ≈ 16 mW/cm² irradiance. Recommended cell-safe range: continuous mode ≥ 0.03 mm/s; layer-by-layer mode ≤ 4 s/layer.

Print mode	Layer height	Parameter settings	
		Exposure time	Intensity
Layer-by-layer	1 layer of 1000 μ m	25 s/layer	70% 100%
	10 layers of 100 μ m	2.5 s/layer 4 s/layer 6 s/layer	100%
Continuous	N/A	0.04 mm/s 0.03 mm/s 0.008 mm/s	100%

Table 2. Print exposure parameters for PhotoGel-INK 95% DS on BIONOVA X using continuous and layer-by-layer print modes. 100% intensity corresponds to ≈ 16 mW/cm² irradiance. Recommended cell-safe range: continuous mode ≥ 0.03 mm/s; layer-by-layer mode ≤ 4 s/layer.

Print mode	Layer height	Parameter settings	
		Exposure time	Intensity
Layer-by-layer	1 layer of 1000 μ m	15 s/layer	50% 75% 100%
	10 layers of 100 μ m	2.5 s/layer 3.5 s/layer 5 s/layer	100%
Continuous	N/A	0.05 mm/s 0.04 mm/s 0.015 mm/s	100%



CELLINK BY BICO

© 2026 CELLINK Bioprinting AB. All rights reserved. Duplication and/or reproduction of all or any portion of this document without the express written consent of CELLINK is strictly forbidden. Nothing contained herein shall constitute any warranty, express or implied, as to the performance of any products described herein. Any and all warranties applicable to any products are set forth in the applicable terms and conditions of sale accompanying the purchase of such product. CELLINK provides no warranty and hereby disclaims any and all warranties as to the use of any third-party products or protocols described herein. The use of products described herein is subject to certain restrictions set forth in the applicable terms and conditions of sale accompanying the purchase of such product. CELLINK may refer to the products or services offered by other companies by their brand name or company name solely for clarity and does not claim any rights to those third-party marks or names. CELLINK products may be covered by one or more patents. The use of products described herein is subject to CELLINK's terms and conditions of sale and such other terms that have been agreed to in writing between CELLINK and user. All products and services described herein are intended FOR RESEARCH USE ONLY and NOT FOR USE IN DIAGNOSTIC PROCEDURES.

The use of CELLINK products in practicing the methods set forth herein has not been validated by CELLINK, and such nonvalidated use is NOT COVERED BY CELLINK'S STANDARD WARRANTY, AND CELLINK HEREBY DISCLAIMS ANY AND ALL WARRANTIES FOR SUCH USE. Nothing in this document should be construed as altering, waiving or amending in any manner CELLINK's terms and conditions of sale for the instruments, consumables or software mentioned, including without limitation such terms and conditions relating to certain use restrictions, limited license, warranty and limitation of liability, and nothing in this document shall be deemed to be Documentation, as that term is set forth in such terms and conditions of sale. Nothing in this document shall be construed as any representation by CELLINK that it currently or will at any time in the future offer or in any way support any application set forth herein.