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Consistent and wide PEGDA material stiffness ranges enabled by DLP bioprinting

LUMEN X | PEGDA X | PEGDA Soft

Summary

This study characterizes the compressive stiffness of acellular PEGDA X and PEGDA Soft photoinks, highlighting the broad mechanical range accessible through material choice and resolution-driven printing protocols using DLP bioprinting.

- Consistent fabrication by LUMEN X of scaffolds spanning kilopascal- to megapascal-level stiffness range relevant for both soft-tissue mimics and high-stiffness scaffold applications.
- PEGDA X results in a compressive moduli of 8-17 MPa while PEGDA Soft reaches 6-19 kPa, delivering an approximately 1000-fold stiffness range within a single DLP bioprinting workflow.
- Decreasing layer thickness enables higher print resolution and tends to increase the measured compressive stiffness for both materials, consistent with higher accumulated light dose.

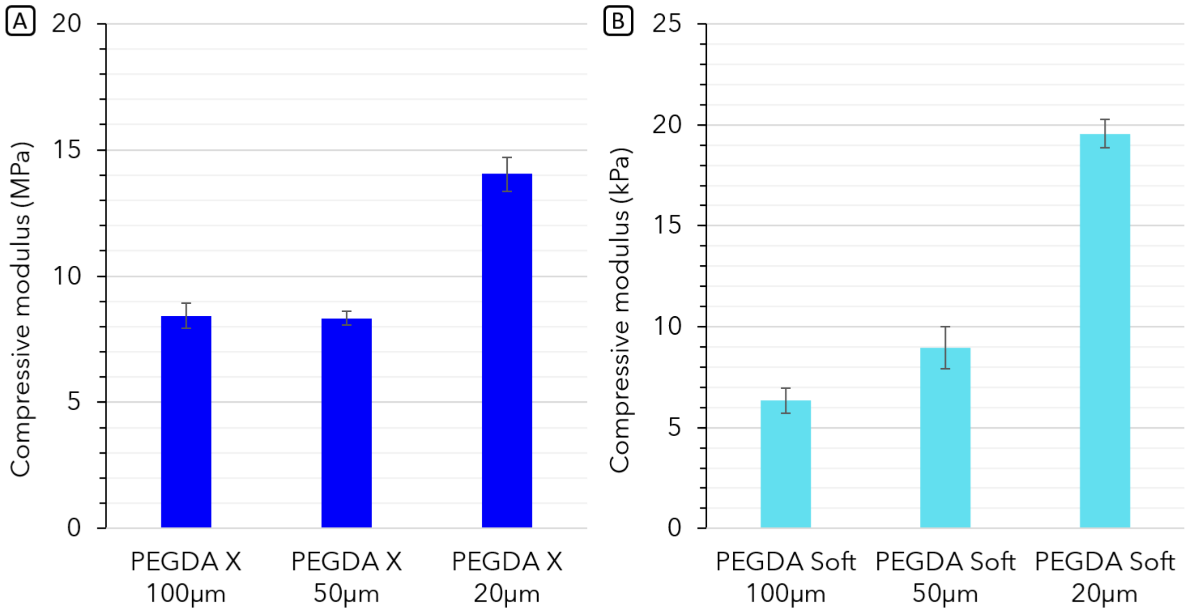

Figure 1. *Compressive modulus of PEGDA X (A) and PEGDA Soft (B). Discs of 5 mm diameter and 2 mm height were printed with LUMEN X, using layer heights of 20 µm, 50 µm or 100 µm, under resolution-optimized printing conditions, resulting in higher accumulated light exposure at reduced layer thicknesses. Technical triplicates were used for mean values and standard deviation error bars.*

Results and Conclusions

The compressive stiffness of PEGDA X and PEGDA Soft photoinks printed using the LUMEN X Gen 3 was evaluated as a function of material formulation and printing parameters (layer thickness with individually set exposure time and light intensity). Both materials were printed as acellular constructs using CELLINK's LUMEN X photopolymerization platform, which enables controlled variation of layer thickness and exposure conditions to support resolution-driven printing.

Representative images of printed PEGDA X and PEGDA Soft constructs after overnight PBS incubation are shown in **Figure 2**, illustrating construct integrity prior to mechanical testing. The volume swelling ratio of PEGDA X samples is 4%, while PEGDA Soft shows 30-50% swelling depending on level of crosslinking.

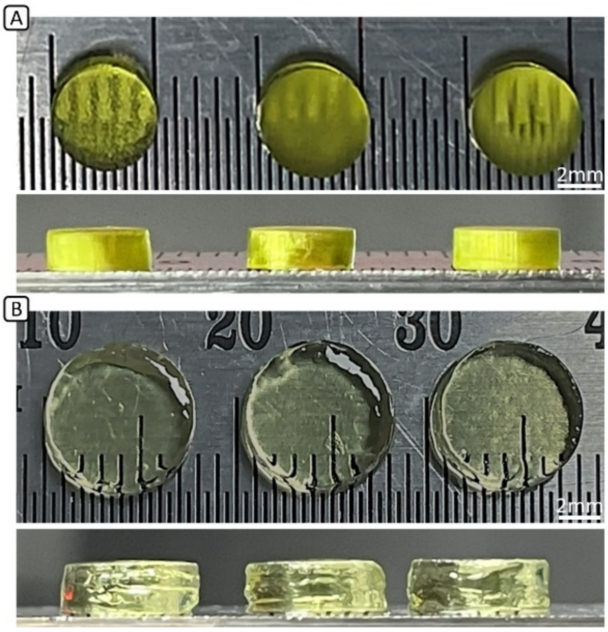

Figure 2. *Representative images of PEGDA X (A) and PEGDA Soft (B) printed with 20 µm layer height, after over-night PBS incubation.*

Compression testing revealed distinct and consistent mechanical regimes for the two PEGDA formulations (**Figure 1**). PEGDA X constructs exhibited high compressive stiffness, with moduli ranging from 8–17 MPa depending on printing conditions and layer thickness. In contrast, PEGDA Soft constructs displayed much lower stiffness values in the range of 6–19 kPa. The approximately three-order-of-magnitude difference in compressive modulus highlights the strong influence of material formulation and enables access to both soft and highly rigid scaffold properties using the same printing platform.

The effect of printing resolution was assessed by varying the layer thickness between 100 µm, 50 µm, and 20 µm for both PEGDA X and PEGDA Soft. Reduced layer thicknesses are commonly selected when higher geometric detail or finer feature definition is required. Under the applied printing protocols, prints fabricated with smaller layer heights generally showed higher compressive stiffness for both materials. PEGDA X and PEGDA Soft. This behavior aligns with the increased cumulative light exposure required for reliable crosslinking at finer layers heights. When normalized per 100 µm build height, the accumulated dose increased relative to 100 µm layers by approximately 1.3x (for both materials) at 50 µm, and by 2.5x (PEGDA X) and 1.8x (PEGDA Soft) at 20 µm, reflecting protocol-specific exposure settings.

Accordingly, the measured stiffness values reflect the combined influence of material formulation and printing protocols, rather than from inherent constraints of any individual layer thickness. Using the LUMEN X Gen 3, PEGDA structures could be produced reproducibly across a broad mechanical window by combining material selection with resolution-oriented parameter adjustment.

Taken together, PEGDA X and PEGDA Soft cover a wide mechanical space ranging from kilopascal- to megapascal-level stiffness. This enables the fabrication of both compliant and highly rigid acellular constructs, supporting applications that require mechanically defined scaffolds which can later be modified or coated to enable cell attachment.

Methods

Bioink preparation

The ready-to-use PEGDA X photoink was inverted 5 times before use. PEGDA Soft was mixed according to **Table 1** and inverted 20 times to mix. Both materials were allowed to settle for 5 min to remove potential bubbles before loading onto the LUMEN X vat for printing.

Table 1. *PEGDA Soft photoink recipe intended for 2 mL of PEGDA Soft photoink.*

Component	Volume (mL)
PEGDA Soft Stock Solution	1.00
Xcite	0.250
Xsorb	0.025
PBS	0.725

Bioprinting with LUMEN X

Printing of discs (5mm diameter, 2mm height) in 3 replicates per condition was performed following the Printing Protocol PEGDA X LUMEN X and Printing Protocol PEGDA Soft LUMEN X, using exposure times for each layer height as specified in **Tables 2** and **3**, respectively. For 20 µm PEGDA Soft, a transitional layer between the build platform layer and standard exposure layers was added with 9.5 s exposure.

Table 2. *Print parameters for PEGDA X on LUMEN X by layer thickness printed with 70% intensity. 70% intensity correlates to ~20 mW/cm².*

Layer thickness (µm)	Exposure (s)	Build platform adhesion (s)	Intensity (%)
100	3.0	6.0	70%
50	2.0	6.0	70%
20	1.5	6.0	70%

Table 3. *Print parameters for PEGDA Soft on LUMEN X by layer thickness printed with 70% intensity. 70% intensity correlates to ~20 mW/cm².*

Layer thickness (µm)	Exposure (s)	Transition layer (s)	Build platform adhesion (s)	Intensity (%)
100	11	-	14	70%
50	7	-	14	70%
20	4	9.5	14	70%

Compression testing

CellScale UniVert was used for compression testing at 25 °C. For PEGDA X, a 200 N load cell and 1 N pre-load were used, while for PEGDA Soft a 1 N load cell and 0.05 N pre-load. Displacement was performed at a rate of 1% strain/s based on sample height after pre-load, up to 60% strain, to generate force-displacement curves. These were converted to stress-strain curves using measured sample diameters, and tangent modulus values were extracted by linear regression between 3-6% for PEGDA X and 3-8% strain for PEGDA Soft, in 3 technical replicates. Technical triplicates were used for mean values and standard deviation error bars.

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