3D printed Poly(glycerol-sebacate)/Polycaprolactone Scaffolds for Skin Tissue Engineering

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INTRODUCTION

- Skin tissue damage resulting from injuries such as trauma, burns, or chronic wounds present a significant clinical challenge.
- These injuries often lead to pain, impaired functionality, reduced quality of life, and increased risk of infection.
- Skin tissue engineering using scaffolds has emerged as a promising approach to guide skin regeneration, offering support for repair and integration of engineered tissue into the host while promoting natural healing processes.
- Poly(glycerol sebacate) (PGS) and polycaprolactone (PCL) are biodegradable polymers widely used in tissue engineering, due to their excellent biocompatibility.
- The primary Objective of this study is to investigate the effects of different printing parameters, such as pressure, speed, and voltage on the physical and mechanical properties of the resulting PGS-PCL scaffolds.

METHODS

- PGS was synthesized using a polycondensation reaction of glycerol and sebacic acid under nitrogen at 120 °C.
- PGS was then mixed with PCL at 0.5% to 10% weight ratios and loaded into the Axo-A3 3D bioprinter.
- Scaffolds were printed using Melt Electrowriting 3D printing (MEW), and observed under a stereomicroscope, where filament size, distribution, and shape were recorded.
- Degradation rate, density, mechanical properties, and wettability of the 3D-printed composites were analyzed.
- Skin fibroblasts were used to assess cell adhesion, proliferation, and cytotoxicity. Cells were fixed onto the scaffolds using 4% paraformaldehyde, then stained with DAPI and observed under a fluorescent microscope.

RESULTS

- Across multiple prints, the key findings revealed that lower speeds and pressures, coupled with higher voltages, resulted in the formation of curly filaments.
- Conversely, higher pressures and speeds, combined with lower voltages, produced straight filaments.
- Notably, a combination of low pressures and high speeds generated a mixture of both filament types.
- Scaffolds with straight filaments resulted in higher density (5.7 mg.cm^{-3}) compared to curly and mix shapes (2.74, and 2.81 mg.cm^{-3}, respectively).

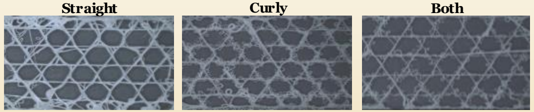

Figure 1: Pictures of the scaffolds fabricated using the aligned rectangle infill resulting in straight, curly, and both shaped filaments. Printability was maintained at 95% for all printing conditions.

- Higher concentrations of PGS-PCL exhibited superior mechanical properties, increased hydrophilicity, and faster degradation rates.

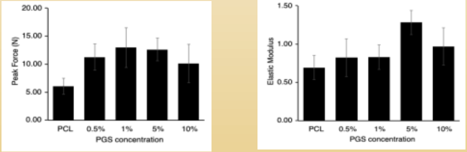

Figure 2: Peak force and elastic modulus of 3D printed scaffolds.

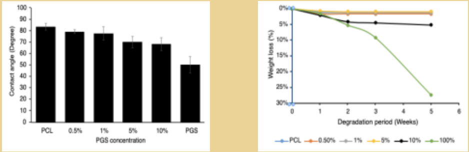

Figure 3: Hydrophilicity Testing and degradation rate of 3D printed scaffolds.

- Straight filaments demonstrated enhanced fibroblast adhesion compared to curly filaments.

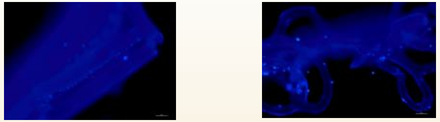

Figure 4: Fibroblast adhesion to 5% PGS-PCL straight and curly filaments.

CONCLUSION

- This study highlights the critical influence of fabrication parameters and material composition on the physical, mechanical, and biological properties of PGS-PCL scaffolds for skin regeneration.
- MEW 3D printing facilitates the ability to modulate filament morphology through variations in speed, pressure, and voltage to provide a tunable approach and a higher degree of precision and consistency to scaffold design.

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REFERENCES

1. Godinho B, Gama N, Ferreira A. Different methods of synthesizing poly(glycerol sebacate) (PGS): A review. Front Bioeng Biotechnol. 2022 Nov 30;10:1033827.
2. Siddiqui N, Asawa S, Birru B, Baadhe R, Rao S. PCL-Based Composite Scaffold Matrices for Tissue Engineering Applications. Mol Biotechnol. 2018 Jul;60(7):506-532.
3. Loewner S, Heene S, Baroth T, Heymann H, Cholewa F, Blume H, Blume C. Recent advances in melt electro writing for tissue engineering for 3D printing of microporous scaffolds for tissue engineering. Front Bioeng Biotechnol. 2022 Aug 17;10:896719.