From Biodegradation to Immunomodulation: Evaluating Novel Polymeric Blends for Cardiovascular Applications

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Introduction & Motivation

Clinical Need

We need better materials. Conventional biodegradable polymers struggle to achieve the necessary balance of mechanical performance, controlled degradation, and *in vivo* compatibility required for safe cardiovascular implants.

Goals

- Demonstrate in-house developed bioresorbable hyperelastic **polymer blend PLLA-*co*-CL/PDLA** as a candidate for cardiovascular implantable applications
- Evaluate degradation, immune activation, cytocompatibility and hemocompatibility of the polymer
- Compare different blend ratios and processing methods (films vs. electrospun meshes) for optimal performance

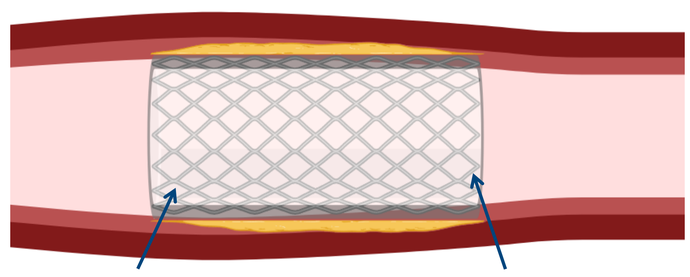


Figure 1: *Example application of polymer coverings in cardiovascular implants: vascular stent to restore lumen*

Novel Polymer System [1]

- In-house developed novel soft polymer material PLLA-*co*-CL/PDLA
- Hyperelastic behaviour enables large deformations (strains in range of 1000 %)
- **PLLA-*co*-CL**: 56-62% L-lactide, high molar mass
- **PDLA**: blending (5–10%) tailors thermal and mechanical properties
- **Stereocomplex** formation enhances strength and stability

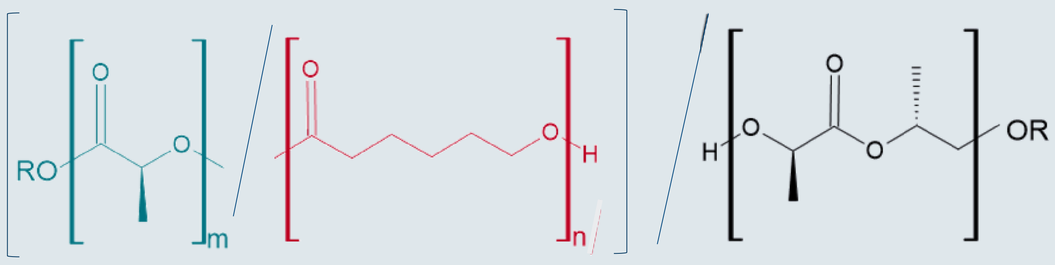
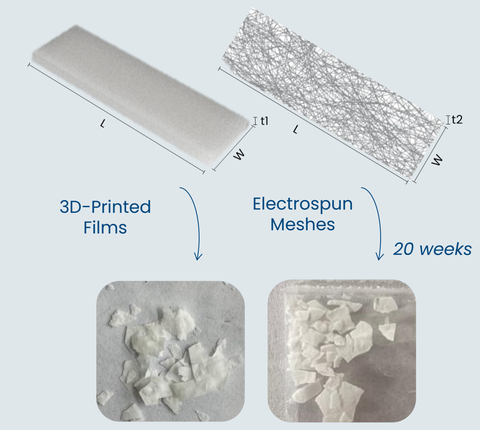


Figure 2: *Chemical structure of Poly[(L-lactide)-co-(ε-caprolactone)]/Poly(D-lactide)*

Results: Material Stability & Degradation Behaviour

1. Bulk Degradation



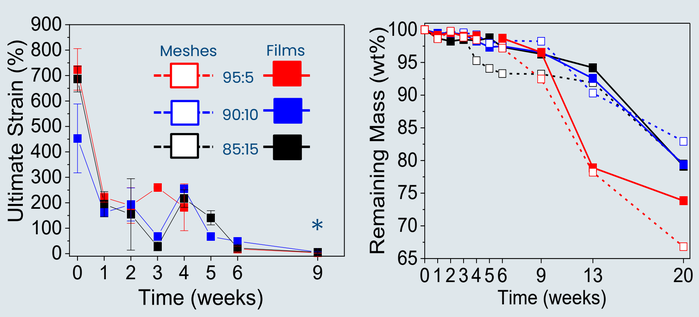


Figure 3: *Films and meshes before and after degradation*

- Higher PDLA content slows material degradation
- Initial high strains for expandable applications
- * Loss of integrity after 9 weeks in PBS [2]

2. Ultrathin Film Degradation

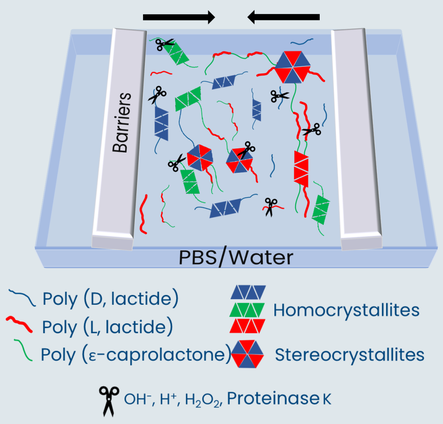
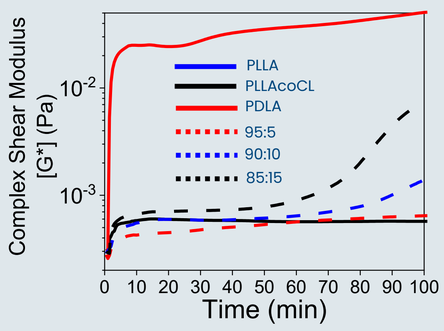


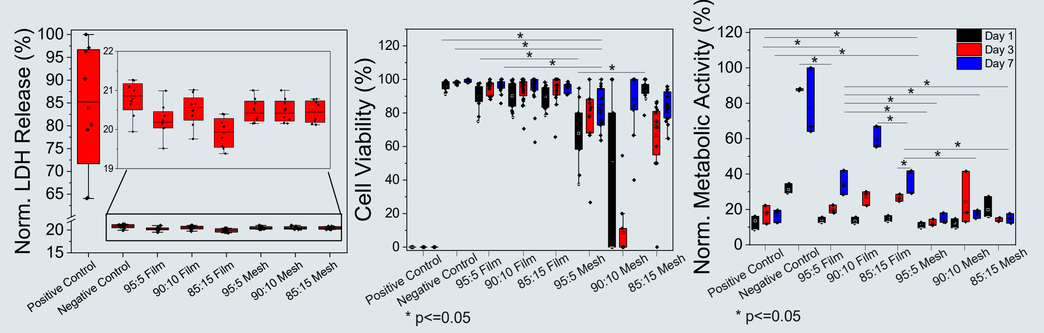
Figure 4: *Langmuir Technique schematics*



- Degradation with high-content PLLA-*co*-CL
- Increase in PDLA content slows degradation [2]
- Tested different environments

Results: Cell–Material Interactions & Immunology

1. Cytotoxicity and Cell Viability



- Non-toxic material, supports healthy cellular function
- Films enhance cell growth and viability [3]

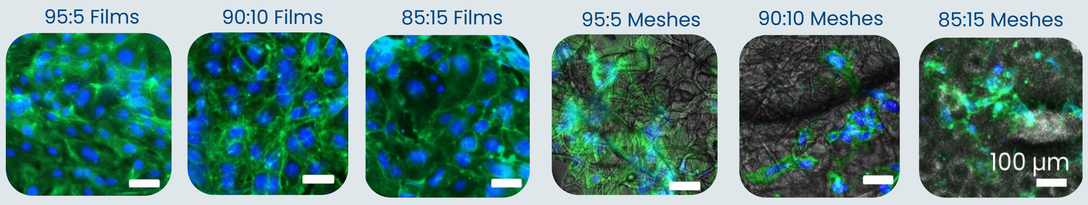
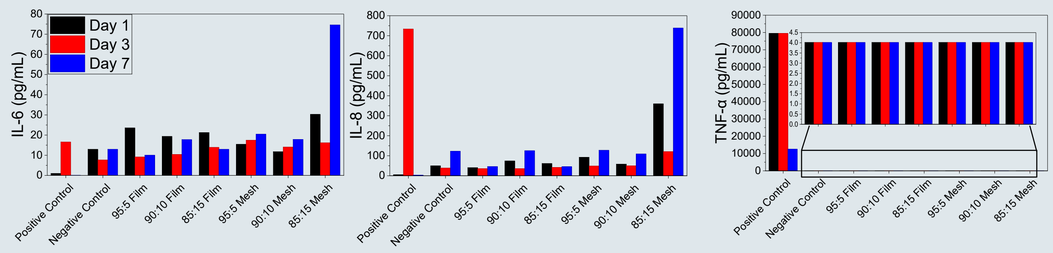


Figure 5: *Confluency of HUVECs on films and meshes at day 14 across different blend ratios*

2. Multiplex Immunoassays

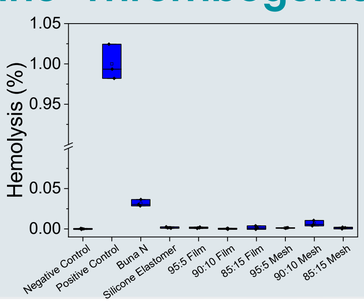


- Films are non-immunogenic, no induction of inflammatory cytokines (IL-6, IL-8, and TNF-α)
- 85:15 meshes elicit an immune response by day 7, do not induce TNF-α expression

Results: Hemocompatibility & Immuno-Thrombogenic Profile

1. Hemoscan analysis

All polymer films and meshes showed hemolysis values <2%, comparable to non-hemolytic controls, confirming no red blood cell membrane damage under test conditions.



2. Platelet-Rich Plasma (PRP) Activation

- Minimal platelet adhesion and no fibrin formation, confirming a non-thrombogenic surface on 95:5 films and meshes
- Platelets remain round/discoid, with underlying material topography clearly visible, indicating no activation

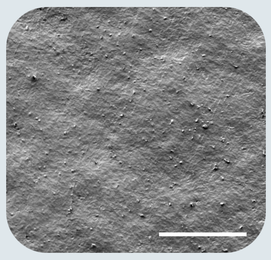


Figure 6: *SEM analysis of 95:5 films following PRP exposure*

Conclusion

PLLA-*co*-CL/PDLA blend films and meshes show strong potential as **cardiac implant coverings**, combining **tunable mechanical properties**, **biodegradability**, and excellent **endothelial compatibility**. Unlike traditional materials, these blends support bioactive endothelial function and reduce thrombogenic risk. The 95:5 film formulation emerged as the most promising, balancing mechanical integrity with enhanced cytocompatibility and vaso-protective behaviour—making it a compelling candidate for next-generation cardiovascular implants.

References

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