

Conference abstract

Finite Element Analyses of Hybridized Three-Dimensionally-Printed Coronary Bypass Grafts Under Complex Loading Conditions

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INTRODUCTION

SVG used in CABG continue to exhibit high occlusions rates compared to arterial grafts. A primary cause of graft failure is due to intimal hyperplasia formation at the proximal and distal anastomoses, as a result from the mechanical compliance mismatch between the SVG and coronary artery. This mismatch generates a mechanical environment that promotes adverse remodeling and subsequent reduction in graft patency. Finite Element Analysis (FEA) provides a robust and cost-effective computational framework for modeling shear stress and strain energy mechanical responses, which are surrogate indicators of compliance.

Prior FEA studies conducted by our team predicted that 3DP-BG composed of hybridized bioinks Polycaprolactone-Gelatin (PCL-GEL) and PCL-Collagen (PCL-COL) exhibit improved shear stress and strain energy responses compared to the SVG under isolated intraluminal blood pressure loading conditions. These findings suggest potential for improved mechanical compliance compared to SVG which indicates potential for 3DP-BG to address the compliance mismatch known to cause SVG patency failure.

METHODS

FEA (ANSYS Mechanical 2025R1) was conducted on a Computer-Aided Design (CAD) model of a 3DP-BG anastomosed in end-to-side fashion to the coronary artery. Three loading conditions were applied to mimic the physiological intrathoracic environment: Intraluminal pressure of 100 mmHg (0.0133 MPa) to mimic blood pressure.

Generalized hydrostatic pressure based on blood density (1.060x10⁻⁶ kg/mm³) and longitudinal inlet acceleration

(315 mm/s²). Localized tensile forces (2.2 N) of both proximal and distal anastomoses to mimic forces by anastomotic sutures. Total deformation mechanical behavior of PCL-GEL and PCL-COL grafts were compared with the behavior of Left Internal Mammary Arterial (LIMA) grafts and SVG.

RESULTS

PCL-GEL 3DP-BG demonstrated deformation (1.50x10⁻² mm;) most similar to LIMA (1.55x10⁻² mm;), while PCL-COL 3DP-BG demonstrated improved deformation (1.39x10⁻² mm) response over SVG (1.16x10⁻² mm;). PCL-GEL and PCL-COL maintain improved deformation response under complex loading. These results suggest improved compliance and potential for improved patency compared to SVG.

CONCLUSIONS

FEA simulation models predict that PCL-GEL and PCL-COL 3DP-BG continue to exhibit improved mechanical behavior compared to SVG under physiologically relevant loading conditions. PCL-GEL biomechanical behavior is most similar to the LIMA, and PCL-COL biomechanical behavior is potentially superior to the SVG. These results suggest that hybridized tissue-engineered grafts may address the compliance mismatch seen with SVG failure. Future work includes Computational Fluid Dynamics (CFD) and FEA studies of layered scaffolds with tuned geometric volume to optimize graft geometry and further validate clinical applicability.



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