Toward a Bioinspired Tissue Engineered Mitral Valve: In Silico Optimization of the Chordal Apparatus in a Polymeric Mitral Valve

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Tissue-engineered heart valve (TEHV) scaffolds are designed as off-the-shelf alternatives, eliminating the need for organ donors and promoting native tissue regeneration. This study presents an in silico investigation of a bioinspired, polymeric, stentless mitral valve (MV) prosthesis, focusing on engineering the chordal apparatus (CA) to optimize valve performance. Specifically, the study explores the influence of chordae tendineae (CT) number, length, and anchoring position on functional outcomes.

Numerical simulations were conducted using Abaqus/Explicit. The mitral leaflets and CT were modeled using shell (S4) and truss (T3D2) elements, respectively. To replicate the anisotropic mechanical behavior of native mitral leaflets, an anisotropic Fan–Sacks constitutive model was employed. The CTs were described with an Ogden hyperelastic model. Boundary conditions included an encastered annulus and papillary muscles (PM) pinned at their time-averaged positions. The leaflets were loaded with physiological atrial and ventricular pressures.

Parametric variations included CT number (2, 4, 6, 8), CT length (80%, 100%, 120% of physiological length), and anchoring distribution along the leaflet free edge. Performance metrics evaluated included von Mises stress (σ_{VM}), bulging height (BH), coaptation length (CL), and geometric orifice area (GOA), benchmarked against native valve thresholds.

The optimal configuration featured 8 CT (4 per leaflet), at 80% of physiological length, with anchoring points along the free edge. This setup enhanced CL (>5 mm) and GOA (>1.5 cm²), while reducing σ_{VM} (<1.5 MPa) and BH (<2 mm). These results provide crucial guidance for the design of the engineered BIOMITRAL valve incorporating a bioinspired CA.