

TOPOLOGY OPTIMIZATION OF SURGICAL SUTURE DISTRIBUTION

Brandon Parks, Markus Gümoes Holm, Niels Aage

Technical University of Denmark

Keywords: Topology optimization, boundary optimization, hyperelasticity, finite strain, MMA

Abstract

Suture placement and tightening decisions are commonly made intraoperatively based on surgeon experience, despite the strongly nonlinear mechanical response of skin and the highly discrete nature of suture loading. This work presents a gradient-based topology optimization framework for distributing surgical sutures to close a wound while reducing adverse strain concentrations in the surrounding tissue. The skin is modeled as a compressible hyperelastic continuum under finite strains and discretized using a standard Galerkin finite element formulation. Sutures are represented by augmenting the system's principle of virtual work with spring-like penalty terms. Design variables modulate the local suture penalty stiffnesses, enabling a continuous relaxation of discrete suture decisions. The resulting constrained optimization problem minimizes a p-mean aggregation of an effective strain measure in the skin region surrounding the wound, subject to structural equilibrium, a suture-count (volume-type) constraint, and a constraint on deformed wound area to prevent unacceptable reopening and gapping. The Method of Moving Asymptotes (MMA) is employed together with a mesh-independent design variable filter to promote discrete and realistic suture patterns. Parametric studies varying wound aspect ratios and allowable suture count illustrate how the proposed formulation identifies suture layouts that satisfy closure while reducing the effective strains in critical regions. The results show that optimized suture locations correspond to those used in vivo.