Computational Modeling of Diffusion-Based Transport From Differing Designs of Drug-Containing Sutures

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Abstract

Dermal wounds have a high occurrence, and wounds that require surgical closure have been shown to result in up to 11 million keloid scars that might result from abnormal healing of these wounds. While small and superficial wounds generally heal effectively without treatment, large, deep, and complexly-shaped wounds may require sutures to initiate and aid the healing process. The use of sutures as a device for drug delivery, however, has not been fully examined, though such use has the potential for reducing complications in healing that result in non-ideal healing patterns. While treatment using scar creams and ointments applied topically is common, many clinicians and researchers agree that it is more effective to prevent a scar from occurring than to treat it once it has formed. Therefore, to investigate the potential of using sutures as a drug-delivery device to guide the wound healing process with the delivery of therapeutic formulations that could improve healing, this work describes simulation-based (via COMSOL Multiphysics, version 5.0, software) solution methodologies to describe concentration profiles of a hypothetical drug associated with diffusion from different designs of drug-containing sutures.

Specifically, three different drug-loaded suture designs (Cases 1-3) were imagined to investigate potential drug delivery properties from the suture into a hypothetical surrounding wound domain. Case 1 represents a simplistic suture design with constant release properties, Case 2 represents a drug-coated solid suture, and Case 3 represents a drug-loaded, hollow suture with a porous suture wall. The model for Case 1 incorporates equations reflecting those for species mass "transport of diluted species" through the wound domain. The results from this approach can be directly compared to those obtained using the "transport in porous media" physics module in COMSOL when the value of porosity in the wound domain is equal to one. The model for Case 2 incorporates equations reflecting those for species mass "transport in porous media" through the drug-coated portion of the suture as well as in the wound domain, as the dermal tissue is a porous media. However, for the wound domain, the porosity was set to equal a value of one as the porosity of dermal tissue is, for modeling purposes, considered variable between zero and one with the exact value being unknown. The model for Case 3 incorporated equations reflecting the "transport of dilute species" physics in both the interior of the drug-loaded suture and wound domains and equations for species mass "transport in porous media" physics through the wall of the suture. The results reveal insights to develop new devices for drug delivery to wounds.

Figures used in the abstract

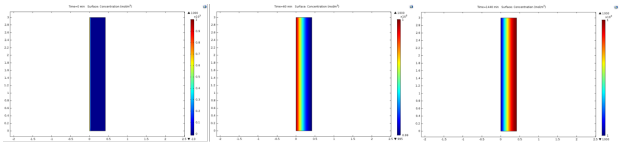

Figure 1: The time-dependent concentration of a drug simulant through the wounded tissue domain of Case 1 at a) 0 minutes, b) 60 minutes, and c) 1,440 minutes.