NOVEL DESIGNS OF NEURAL INTERFACE DEVICES AND THE COMPUTATIONAL SIMULATION WITH FINITE ELEMENT MODEL

COMPUTATIONAL AND HISTOLOGICAL ANALYSES FOR INVESTIGATING MECHANICAL INTERACTION OF THERMALLY DRAWN FIBER IMPLANTS WITH BRAIN TISSUE

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This research focuses on improving the long-term performance of neural probes through effective design strategies supported by a realistic computational model.

Abstract

Neural probes are devices that help us study the brain, treat brain diseases, and even enable communication between our brains and computers. The major challenge is the loss of functionality over extended periods due to immune responses. This study introduces a computational tool to enhance the design of neural probes for prolonged performance. I used finite element analysis (FEA) to predict the long-term performance of neural probes. FEA calculates mechanical impacts, like deformation (strain) of brain tissue and the force (stress) exerted by an implanted neural probe, both of which are associated with tissue damage. However, previous research predominantly employed just simplified finite element models (FE models) and didn't correlate computed outcomes with actual tissue reactions. I developed a new FE model for neural probes that accurately reflects real-world implant situations. To align our FEA numerical results with chronic immune response, I conducted a histological analysis (a detailed microscopic examination of tissue involving sectioning and staining) on the rodent brain tissue exposed to various materials: Stainless Steel, Silica, Polycarbonate (PC), and Hydrogel. Tests showed that the computational and immunological results follow a similar trend and spotlight hydrogel as a promising chronically implantable neural probe material. I also assessed design factors, including coefficient of friction (COF) and cross-section geometry, which potentially influence biocompatibility. Results suggest improved chronic functionality appears achievable with a balanced, rounded cross-section design coated with biocompatible materials to decrease the slip during the micromotion of the brain tissue.