Title: A Rat Model of Hip Hemiarthroplasty Using 3D Printed Titanium Implants

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Structured Abstract:

Introduction: Joint replacement is a commonly performed surgery with over 120,000 people receiving joint replacement annually in Canada. Although joint replacement surgery is highly successful, implants do not last a lifetime, and often have to be replaced via costly revision surgeries. Before innovations aimed at extending the life of implants are applied to the clinic, testing must be performed in animal models. Clinically representative small animal models of joint replacement would be ideal in the initial stages of research and development, due to ease of handling and low costs, but few such models have been established in the literature. We describe the development of a rat model of hip hemiarthroplasty and longitudinal post-operative assessment of implant position via micro-CT analysis.

Methods: Ti6Al4V titanium implants were press-fit into the medullary canal of skeletally mature male Sprague-Dawley rats (n=6), using a posterior approach to access the hip joint. Animals were evaluated post-operatively (day 1) and at 3, 6, 9 and 12 weeks following surgery with in vivo micro-computed tomography to assess implant stability. Animals were sacrificed after 12 weeks and post-mortem analysis was conducted to assess fixation of each implant. Normality was assessed using the Kolmogorov-Smirnov test; all data were found to be consistent with a Gaussian distribution. Column statistics were analyzed using repeated-measures ANOVA, with a Bonferroni multiple-comparison post-hoc test. Significance between data at all time-points was determined at the p <0.05 level.

Results: Surgery was successful in all animals, and micro-CT imaging revealed stable implant positioning at 1 day and 1 week, post-operatively. Return to gait was observed in all cases, and rats remained ambulatory throughout the study. No incidences of implant failure were observed through the 3-week time-point. Micro-CT did, however, reveal implant subsidence in three of six animals at the 6-week time-point, with significant (p<0.05) distal implant translation observed at post-operative weeks 6, 9 and 12 compared to post-operative day 1. Post-mortem analysis revealed variable amounts of micro-motion when implants were manipulated with forceps, with more gross movement detected in subsided implants.

Discussion: We report the first clinically representative rat hip hemiarthroplasty surgeries using custom 3D-printed titanium alloy implants. Micro-CT imaging was able to reveal clinically relevant complications were observed (subsidence) that mimic complications of larger joint models. Although implant stability was not observed in all cases, the ability to install implants consistently supports further development of this model as a preclinical platform for studies of osseointegration, metal-cartilage interactions, and joint infection around a functional implant.