Title: A 3D Metal-Printed Implant System for a Small Animal Model of Hip Hemiarthroplasty

Trainee Name: Adam D.M. Paish

Supervisor(s): David Holdsworth

Structured Abstract:

Introduction: Traditionally, large and companion animal models have been used to study joint replacement surgery, before new innovations can be applied in the clinic. The use of a small animal model, such as the rat, has several advantages, namely lower cost, in the early stages of research into areas such as osseointegration, metal-cartilage wear and infection. However, load-bearing implants are difficult to manufacture in the sizes required for small animal testing via traditional methods. Fortunately this barrier can be overcome with recent advances in additive manufacturing (3D metal printing). Thus, our objective is to create a 3D printed rat hip hemi-arthroplasty system, to allow for in vivo testing of functional implant properties in a small animal model.

Methods: A database of n=25 previously-acquired, 154\(\mu\)m micro-CT volumes of male Sprague-Dawley rats (390-610g) were analyzed to guide the creation a femoral implant template in computer-aided design software. Several different variations were created, including collared and collarless designs. Initial prototypes were 3D printed 316L stainless steel, with subsequent iterations printed in Ti6Al4V titanium and F75 cobalt-chrome. Surgical implantation was performed in n=3 live Sprague-Dawley rats (900g, 500g, 750g). Micro-CT imaging and X-ray fluoroscopy were performed post-operatively evaluate the position of each component within the bone, and to observe rodent gait.

Results: Installation of components was successful and each animal was observed to ambulate on its affected limb immediately following recovery from surgery. The 900g rat, given a 316L component, was kept for 11 months post-op, before succumbing to old age, with no evidence of implant subsidence based on micro-CT and fluoroscopic findings. The 500g animal, also given an uncollared 316L implant, showed evidence of implant subsidence at three weeks, followed by evidence of full subsidence and hip dislocation at 12 weeks. The 750g rat was given a collared F75 implant, and showed no evidence of failure at three weeks.

Discussion: We report the first hip hemi-arthroplasty procedures in a rat using a 3D printed metal implant. This model aims to provide a low-cost translational test platform for investigating osseointegration, metal-cartilage interactions, and infection using a functional, loaded implant. A study with larger sample sizes is needed before the utility of this approach can be validated. Future works will include surface preparations and porosities on the stem of implants, with micro-CT to track longitudinal changes at the bone-metal interface, and gait analysis to quantify post-operative kinematics.