

**Title:** Iterative Design of a Small-Animal Hip Hemi-Arthroplasty Model for Preclinical Orthopaedic Research

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**Structured Abstract:**

**Introduction:** Each year, over 110,000 Canadians receive joint replacement surgery. In order to ensure implants last as long as possible, without complications like loosening or infection, animal models are required before new innovations can be applied to the clinic. Traditionally, studies are done in large-animal models, but are expensive, requiring that animals be housed in special facilities. In contrast, using a small-animal model, such as the rat, in the early stages of research has several advantages, including lower cost and broad use across the basic sciences. However, load-bearing implants are difficult to manufacture in the sizes required for small-animal testing. Fortunately, this barrier can be overcome using micro-CT imaging to create species-specific custom hip implants, in combination with additive manufacturing (3D metal-printing) to produce miniature prototype components in surgical-grade metal alloys.

**Objectives:** We aim to create and optimize a 3D-printed hip hemi-arthroplasty system and surgery, that will allow for in vivo testing of functional implants in a common lab-rat model.

**Materials & Methods:** A database of n=25 micro-CT volumes (154µm 80kVp, 50mA, 16s) of male Sprague-Dawley rats (390-610g) were analyzed to guide the creation of a femoral implant template in computer-aided design software. Several variants were created, including collared and collarless designs, and in a range of sizes to accommodate rats of various weights. Initial prototypes were 3D-printed in Ti6Al4V titanium alloy. Next a pilot study was performed in n=5 live Sprague-Dawley (SD) rats (430-900g) to determine model feasibility. Micro-CT imaging was performed at 1 day, and 1, 3, 6 and 9 weeks post-operatively to track implant positioning, with alongside x-ray fluoroscopy and optical tracking (CatWalkXT) to assess the restoration of hind limb mobility following the hemi-arthroplasty procedure.

**Results:** Implantation was achieved in all cases, and each animal was observed to ambulate on its affected limb post-operatively. Secondary fixation of the implant varied, with micro-CT imaging revealing implant subsidence as early as 3 weeks post-operatively in some cases.

**Discussion & Conclusions:** We report the first hip hemi-arthroplasties in a rat using custom 3D-printed implants. This model has the potential to provide a low-cost preclinical platform for investigating the bone-metal and metal-cartilage interfaces. The 3D printed titanium surface may require modification, in order to better promote secondary fixation through osseointegration, and avoid early implant subsidence. Efforts are underway to quantify bone changes around implants longitudinally on micro-CT scans. Future work will also include a peri-prosthetic infection study using bioluminescence imaging to evaluate bacterial growth around components, before and after treatment with antimicrobial agents.