Influence of Topography on 3D printed Titanium Foot and Ankle Implants

Bijan Abar; Cambre N. Kelly; Nicholas B. Allen; Helena Barber; Alexander P. Kelly; Ken Gall; Samuel B. Adams, MD

Category: Basic Sciences/Biologics; Ankle; Trauma

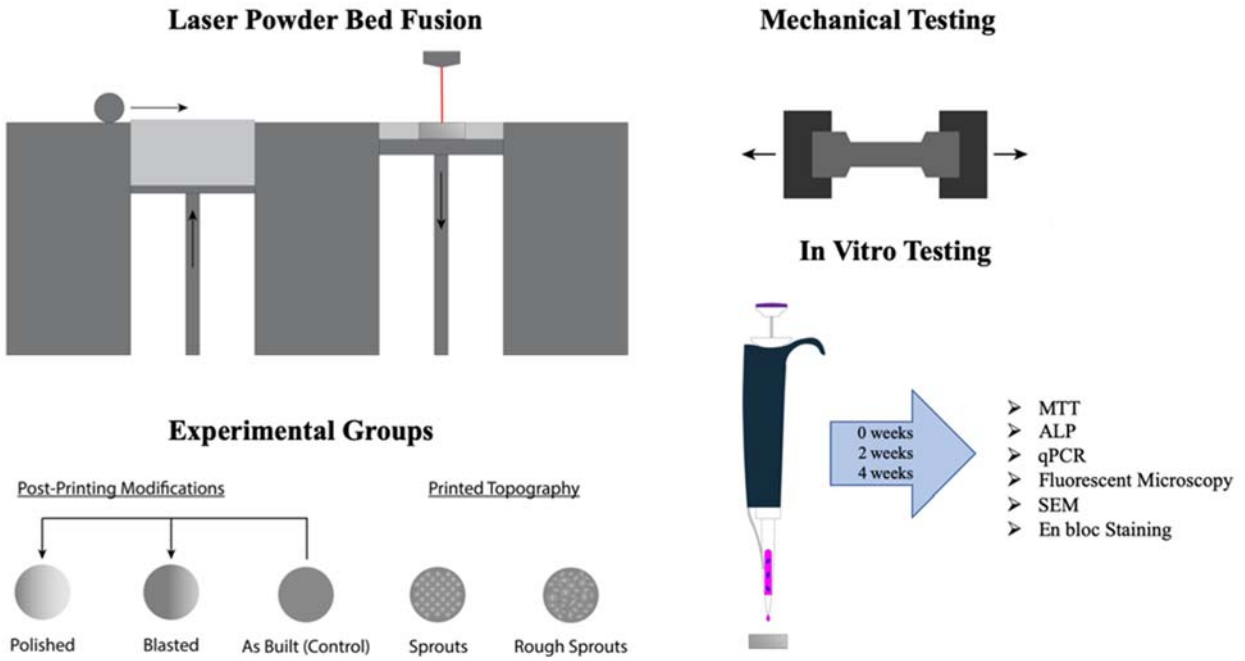
Keywords: Arthrodesis; Biomechanics; Fusion

Introduction/Purpose: Foot and ankle etiologies such as traumatic fractures, Charcot Arthropathy, nonunion after high risk arthrodesis and infectious debridement can result in critical sized bone defect (CSD). CSD is defined as bone loss greater than 1-2 cm in length or greater than 50% loss in circumference of bone. CSD remain a significant challenge in Orthopaedics. Custom 3D printed porous Titanium implants are currently being implemented when allograft is not an option. However, in a subset of cases, Titanium implants need to be removed due to infection or poor osseous integration where surrounding bone does not grow onto or through the scaffold. There is no one clear reason for poor osseous integration. This study explores effects of 3D printed topography on mechanical and biological properties.

Methods: Titanium dog bones and discs were printed via laser powder bed fusion. Roughness groups were polished, blasted, as built, sprouts and rough sprouts. Roughness was measured with line measurement using a confocal microscope. To assess mechanical properties, tensile testing of samples from each roughness group produced stress strain curves. MC3T3 preosteoblast were seeded on discs. Samples were analyzed at 0, 2, and 4 weeks. A cell viability assay and confocal florescent microscopy assessed cell growth. Alkaline Phosphatase (ALP) assay and Quantitative Polymerase Chain Reaction (qPCR) examined cell differentiation. Extracellular matrix (ECM) was stained for collagen and calcium. Scanning Electron Microcopy (SEM) was done on sputter coated discs.

Results: Rz, maximum peak to valley distance of the sample profile, for the polished, blasted, as built, sprouts and rough sprouts were 2.6, 22.6, 33.0, 41.4 and 65.1 μm respectively. The addition of printed roughness in the sprouts and rough sprouts group significantly diminished ductility resulting in early strain to failure during tensile testing. Cells adhered and proliferated on discs regardless of roughness group. There was no statically difference in ALP activity, but qPCR showed that rough groups (sprouts and rough sprouts) had diminished Osteocalcin gene expression at week 2 and 4. The ECM observed with SEM in the rough groups was more resistant to repeated washes and was more extensive compared to the less rough groups.

Conclusion: The addition of 3D printed artificial roughness leads to inferior mechanical properties and confers no clear benefit regarding cellular proliferation. Printed topography increases the initiation of fractures resulting in diminished tensile strength and ductility. Concurrently, the resolution of LBF is not fine enough at this time to create surface features that enhance cell behavior. Therefore, data in this study suggest that artificially printing roughness is not an effective strategy to enhance osseous integration into Titanium implants for critical sized defects.



Foot & Ankle Orthopaedics, 5(4)
DOI: 10.1177/2473011420S00016