Multiscale characterization of osseointegration in porous Ti6Al4V implants

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Introduction

(i) Contact between newly regenerated **bone** and the **implant** interface implant occurs across **multiple length scales**[1].

(ii) Novel **additive manufacturing** (AM) techniques can produce low-stiffness metallic implants[2] with an **interconnected pore network** in their interior – providing more surface area for bone growth.

How does osseointegration occur within additively manufactured porous titanium implants?

3D Imaging – Microcomputed Tomography

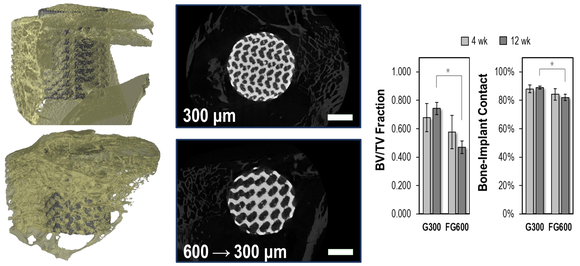

Fig. 3 – Microcomputed tomography reconstructions, representative slices and histomorphometric measurements of bone volume fraction (BV/TV) and bone-implant contact (BIC). Scale bars 2 mm.

3D reconstruction of the bone-implant interface shows **osteogenesis** occurring within the **pore** network. **Bone volume fractions** and percentage of **bone-implant contact** are higher in the uniformly-sized pores after 12 wk.

3D Imaging – Ion/Electron Microscopy (FIB-SEM)

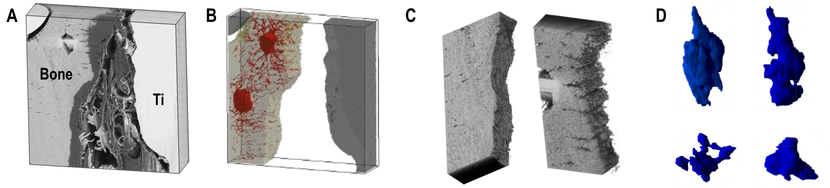

Fig. 4 – PFIB tomography of the bone implant interface. (A) 3D Volume slice. (B) Segmented cells. (C) Two different morphologies at the mineralization front. (D) Newly nucleated mineral.

3D imaging with **nanoscale** resolution using PFIB tomography shows two distinct morphologies occurring at active and dormant **mineralization fronts**. Newly forming **mineral clusters** range in shape from **ellipsoids** to **quasi-spherical** entities.

Methods

Fig. 1 – Overview schematic of methods.

Titanium **porous implants** fabricated with: (i) Pore size of 300 µm; (ii) Graded pore size of 600-300 µm using **powder bed fusion** and implanted into the **tibiae** of New Zealand white rabbits for **4 or 12 weeks** (n = 5).

Retrieved for analysis with **optical** microscopy, **microcomputed tomography**, and plasma **focused ion beam** (PFIB) microscopy.

2D Imaging – Histology

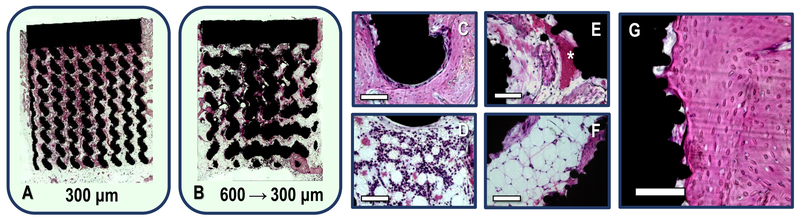

Fig. 2 – H&E stained sections. (A-E) 4 wk of implantation. (F-G) 12 wk of implantation. Scale bars 100 µm.

Minor inflammation, extensive **neovascularization** (*), and some **bone regrowth** occurs at the exterior and interior of both scaffolds at 4 wk. **Myeloid** tissue is abundant inside the scaffold and **bone** is present outside the scaffold at 12 wk.

Conclusions

Inflammatory tissue, **bone**, and **neovessels** all form in the implant after 4 wk, transitioning to bone and myeloid tissue at 12 wk.

Higher bone volume fractions and bone-implant contact occur in **pore sizes of 300 µm** than in larger, graded pores.

Newly forming mineral structures take on a variety of shapes/sizes at **nanoscale** sites of **active mineralization** in bone.

[1] Shah et al. (2019). *Acta Biomaterialia, 84(15).*

[2] Al-Ketan et al. (2018). *Addit Manuf, 19.*

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