The performance of a new generation of 3D printed and drug and stem cell loaded implants in vitro and in vivo

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Introduction

Craniofacial bone loss is a common condition with many causes such as trauma and bone tumor resection. Bone regeneration is often impaired if there is extensive damage or infection. Treating such bone loss is difficult, complications and revision surgeries are common and non-optimal anatomic and aesthetic outcomes result in functional problems and poor quality-of-life. This poster details the creation of a new generation of personalized bone implants made using patient CT-scans and a mixture of solid fatty acids and tricalcium phosphate. The implants are endogenous, resorbable and provide energy, calcium and phosphate for new bone formation. Their functionality may be further enhanced using mesenchymal stem cell seeding and drug loading. Our results indicate that such implants may enable the reconstruction of patients to their pre-traumatic anatomy.

Results & Discussion

Fabrication – A CT-scan is 3D modelled to design a patient fitted implant. A solid fatty acid/tricalcium phosphate suspension is then heated to melt and 3D printed according to the implant design. The implants may be sintered to remove the fatty acid or be used non-sintered.

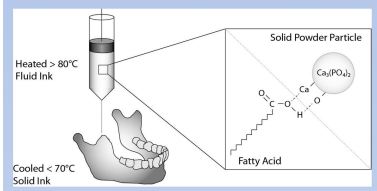
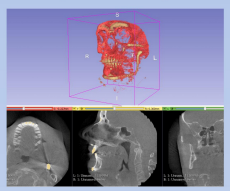
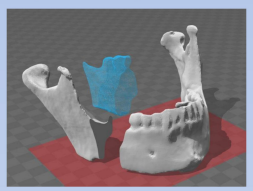


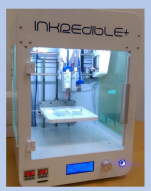
Diagram of 3D Printing Process



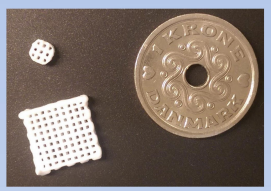
Patient CT-Scan



Implant Design



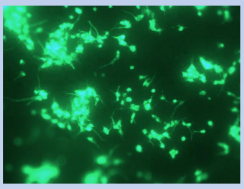
3D Printer

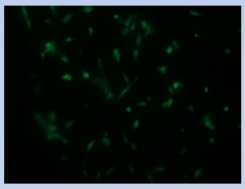


3D Printed Implant

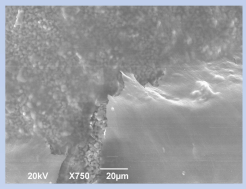
Sintering

In Vitro Osteogenesis – Mesenchymal stem cells (MSCs) attach to sintered and non-sintered implants and form bone when stimulated

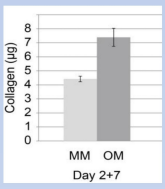


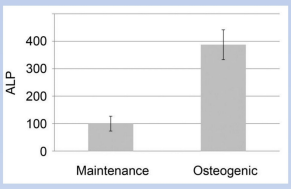


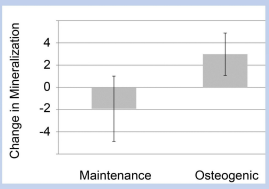
MSCs (GFP⁺) on sintered & non-sintered



SEM of MSCs on sample

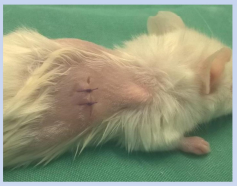




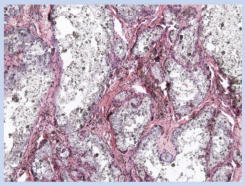


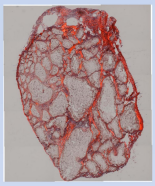
Osteogenic response of MSCs on sintered implants upon stimulation

Sub-Cutaneous Implantation – Sintered and non-sintered implants both form cellularized, vascularized and collagen rich tissues in vivo

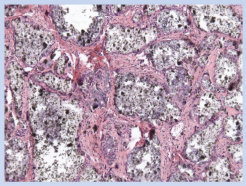


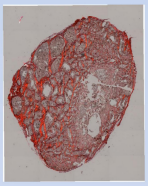
SC Animal Model



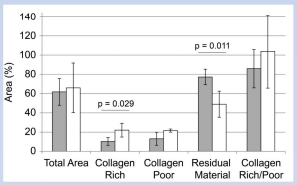


H&E and SR Stain of SA/TCP





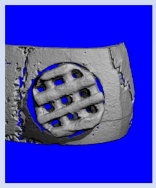
H&E and SR Stain of sintered TCP

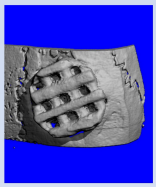


Similar tissue formation

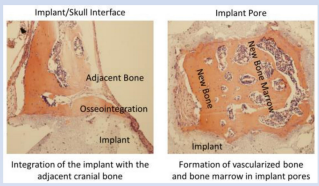
Cranial Implantation – Implants regenerate 4mm cranial defect in 8 weeks with osseointegration and the formation of new vascularized bone and marrow. Seeded luciferase expressing MSCs proliferate on the implants in vivo and contribute to new bone formation

Model

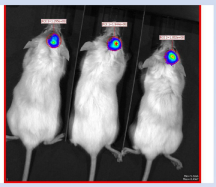


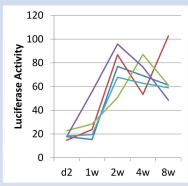


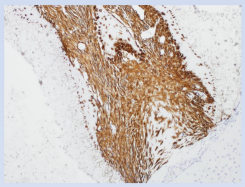
CT-Scan at week 0 and 8



H&E stain at week 0 and 8

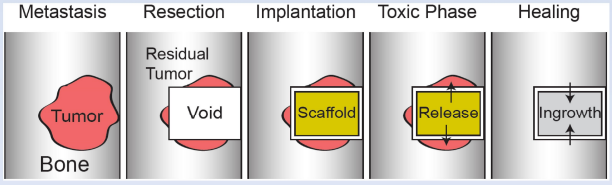


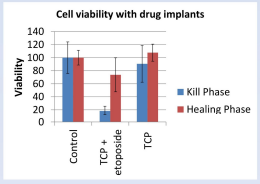




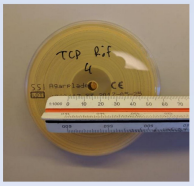
IVIS and hVim stain of human MSCs (Luc⁺) seeded on implants

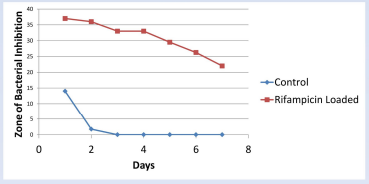
Drug Loading – Implants may be loaded with anti-cancer drugs and antibiotics to prevent cancer recurrence and infection





Anti-Cancer Recurrence Concept & Results (Etoposide vs Oral Carcinoma)





Anti-Infection In Vitro Results (Rifampicin vs S. aureus)