Biomodulated Implant Increases Bone Formation and Integration

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Introduction

- Despite the progress in surgical techniques and implants, aseptic loosening is a problem mainly due to wear particles and early micromotion

Aims

- Functionalize a novel implant filled with a calcium sulphate (CaS)/hydroxyapatite (HA)[2] carrier containing bioactive molecules like zoledronic acid (ZA) and bone morphogenic protein-2 (rhBMP-2) to enhance peri-implant bone formation
- Compare local delivery of ZA with systemic administration of ZA

Methods

- 55 Male Sprague-Dawley divided into 5 groups*:*
  G1. Empty Implant (I)**, G2.** I+CaS/HA,
  G3. I+CaS/HA+Systemic ZA (0.1 mg/kg),
  G4. I+CaS/HA+Local ZA (10 µg),
  G5. I+CaS/HA+ Local ZA (10 µg)+rhBMP-2 (5 µg)
- Implant: Hollow PEEK cylinders with 3 equally spaced holes distally were press-fitted in the proximal tibia (Fig. 1)
- Animal Sacrifice: 6-weeks post-op
- Analysis methods: Micro-CT (Fig. 2), pull-out testing (Fig. 2) and histology to study the peri-implant bone formation

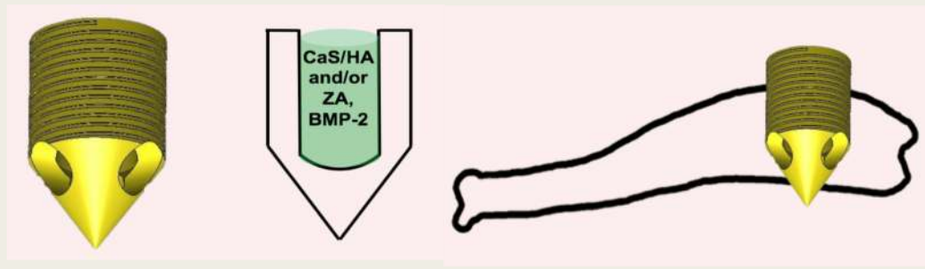


Fig. 1: Schematic of the implant and in-vivo implantation

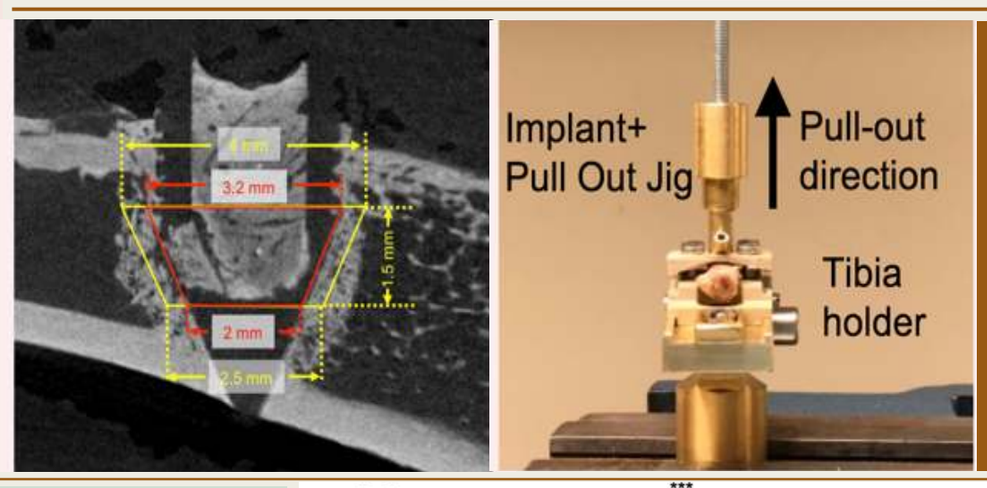


Fig. 2: Micro-CT regions of interest (ROI) and mechanical testing setup

Results

- *Micro-CT:* Treatment groups G3-G5 led to significantly higher peri-implant bone formation compared to control groups G1 and G2. G4 led to more bone formation than G3 (Fig. 3)
- *Pull-out testing*: Peak pull out force was significantly higher in groups G3 and G4 compared to empty control group G1 (Fig. 4)
- *Histology:* Histological images indicated more peri-implant bone formation in groups G3-G5 compared to G1 and G2 (Fig. 5)

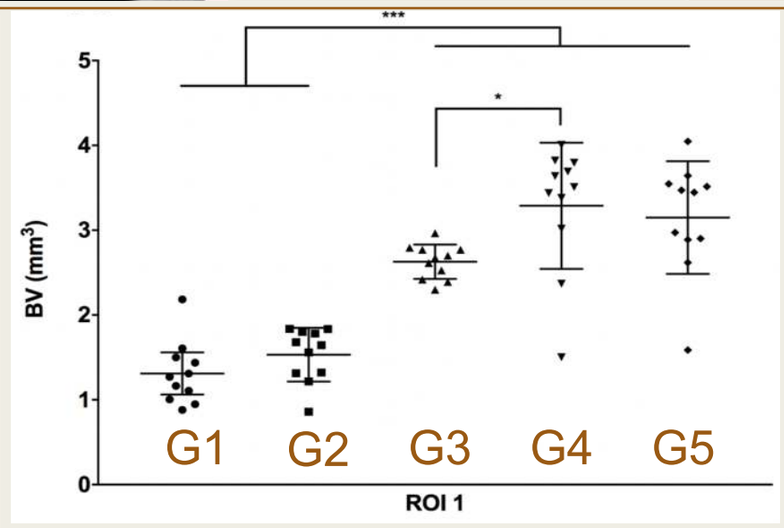


Fig. 3: Micro-CT results 6-weeks post harvest

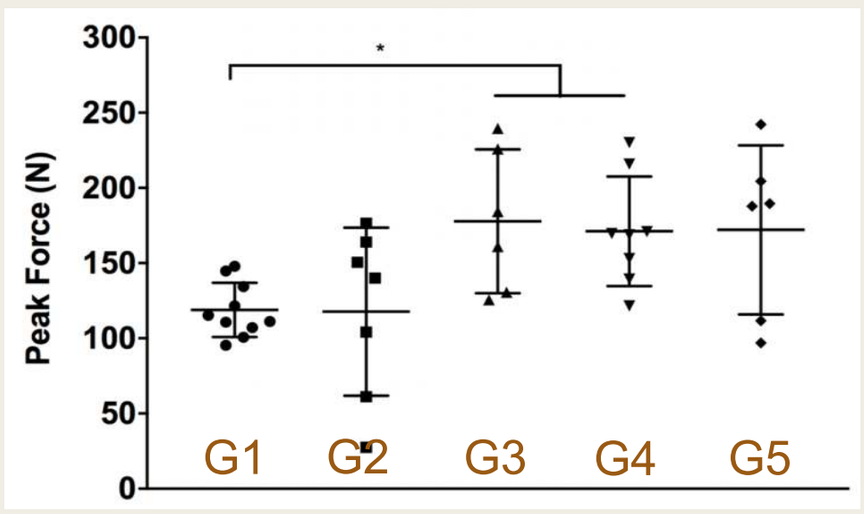
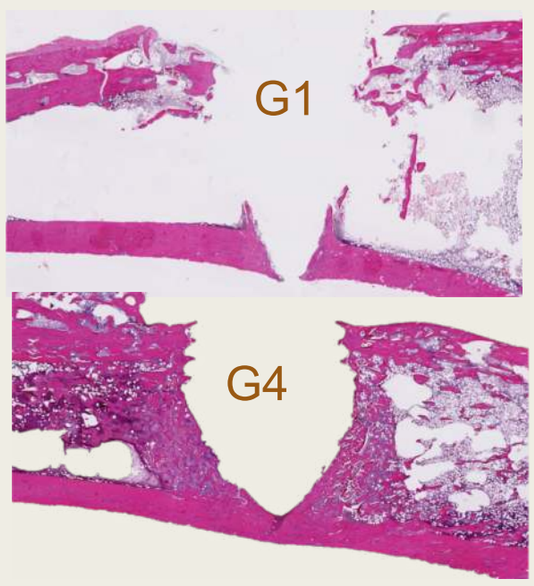


Fig. 4: Pull-out testing results



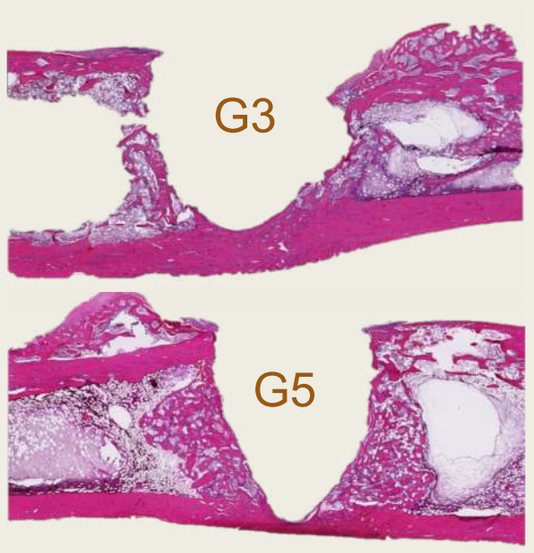


Fig. 5: Representative histological images indicating the extent of peri-implant bone formation in different treatment groups

Discussion

- Functionalized implant delivering low dose of ZA alone is enough to promote osseointegration and additional BMP-2 is not necessary to ensure early integration of the implant with the surrounding bone in this model
- A low dose of locally delivered ZA performed better than systemic administration of ZA in terms of peri-implant bone formation but both groups performed similar in biomechanical testing. A five times lower dose of ZA delivered locally performs on par with systemic ZA delivery

Clinical Significance

- Delivery of bone active molecules using using a biphasic ceramic carrier filled within a fenestrated implant improved early osseointegration and pull out strength. This could be clinically relevant for primary total joint arthroplasty (TJA) fixation and of major importance in revisions

References

1. Raina et al., Scientific Reports, 2016.

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