Quantitative CT Analysis and Mechanical Coupling of Implanted Bioresorbable Composite Scaffolds to Bone

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INTRODUCTION

- Large critical size bone defects do not heal
- Previous studies have shown that 3D printed polybutylene terephthalate (PBT) scaffolds coated with beta-tricalcium phosphate (TCP) and in combination with autologous adipose derived stem cells are able to bridge a 4.2 cm defect in sheep in 3 months
- Although PBT scaffolds effectively facilitate rapid bone growth, PBT is not resorbable
- We have produced composite resorbable strand for scaffold printing using polylactic acid (PLA) and TCP, showing promising results in cell culture studies
- The purpose of current study is to test whether scaffolds printed from composite strand will facilitate rapid bone formation into and around scaffold pores *in vivo* in a rat model

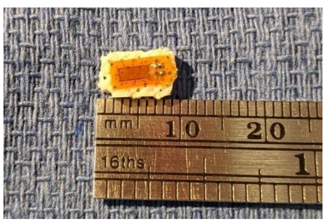

Figure 1: Image of 3D printed scaffold

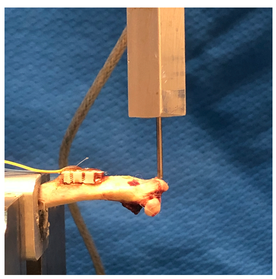

Figure 2: Cantilever bend testing with sensor in tension

METHODS

- Scaffolds were produced from PBT coated in TCP (PBT/TCP, control), pure PLA, 50:50 PLA:TCP, and 75:25 PLA:TCP
- 6 scaffolds were produced from each material (24 total) and trimmed to measure 0.9 x 0.35 x 0.25 cm
- Waterproof strain gauges were attached to the superficial surface of the scaffolds (Figure 1), which were sterilized using ethylene oxide prior to implanting one scaffold per rat onto one femur.
- After 3 months bilateral femora were explanted, and a scaffold of the same type that was implanted was glued on the control bone in the same position
- Femurs were tested in cantilever bending 6 times at a load rate of 6.0 N/s to peak load of 6.0 N with the strain gauge in tension and then repeated with the sensor in compression (Figure 2)
- Bones were imaged at 42 μm resolution
- Quantitative μCT analysis included bone tissue volume (mm3) and normalized bone volume to tissue volume (BV/TV,%)

RESULTS

- 23 out of 24 scaffolds were firmly attached to bone, one 75:25 scaffold did not attach to the femur
- Similar strain transfer between TCP coated PBT scaffolds and 50:50 PLA:TCP composite scaffolds (Figure 3)
- 75:25 PLA:TCP scaffolds showed the second lowest strain transfer followed by the pure PLA scaffolds (Figure 3)
- Cortical bone volume was higher in scaffolds produced from the polymer-ceramic composites (Table 1)
- μCT reconstructions demonstrated bone growth within scaffold pores (Figure 4)

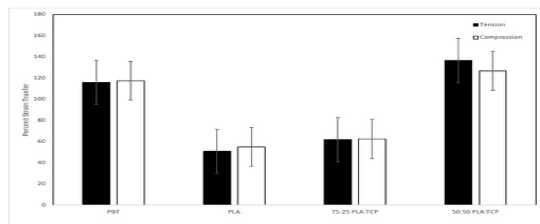

Figure 3:The % strain transfer in cantilever bend testing with standard error bars. Testing was done in tension (black bars) and compression (white bars).

Table 1: μCT Measurements

Material	Bone Volume (mm3)	BV/TV (%)
PBT	70.21+/-8.03	65.65+/-4.68
PLA	71.09+/-7.08	65.49+/-3.76
75-25	74.93+/-7.45	69.15+/-3.72
50-50	74.93+/-6.66	63.76+/-3.76

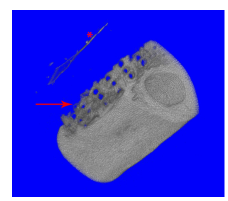

Figure 4. 3D μCT image showing bone growth into the pores of a PLA scaffold (arrow). A strain gauge can be seen on the superficial surface of the scaffold (asterisk). The radiopaque scaffold cannot be seen.

DISCUSSION

- This study demonstrated that composite PLA:TCP scaffolds have similar strain transfer through bone as PBT scaffolds in a rat model
- At three months the composite scaffolds supported bone growth and bonding *in vivo*
- μCT quantitative analysis confirm both composite materials show higher cortical bone volume and comparable BV/TV values to previously used PBT material
- Similar performance of resorbable scaffolds to our current TCP coated PBT scaffolds warrants additional evaluation in a large animal model

ACKNOWLEDGMENTS

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