

# Custom Three-Dimensional Printed Bone Grafts for Mandibulofacial Reconstruction Integrate into Native Bone and Strengthen in a Miniature Swine Model

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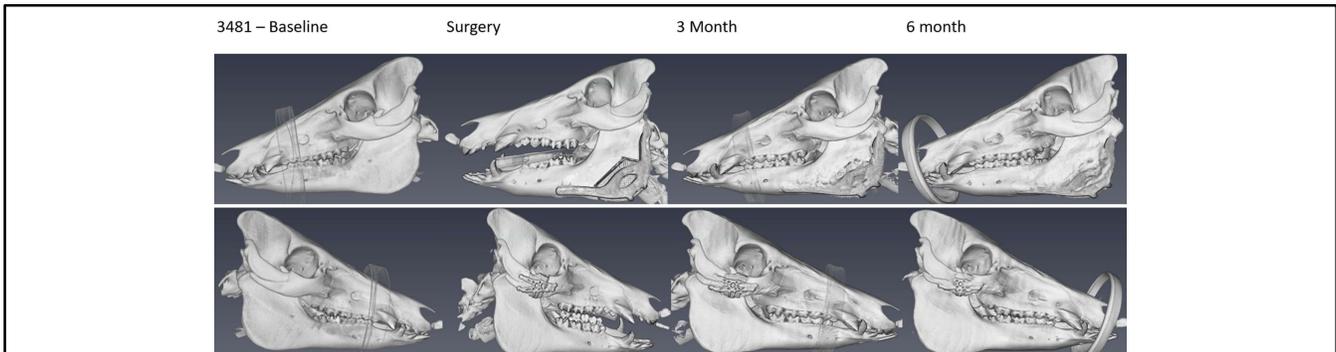
**INTRODUCTION:** Bony mandibulofacial reconstruction is challenged by insufficient autologous graft material, harvest morbidity, and complex anatomy. The study goal was to evaluate healing of zygomatic and mandibular critical bony defects following implantation of custom three-dimensional (3D) printed  $\beta$ -tricalcium phosphate ( $\beta$ TCP) implants in a porcine model.

**METHODS:** Following IACUC approval, implants were 3D printed from preoperative computed tomography (CT) scan models. They were stabilized within full thickness zygomatic (right) and mandibular angle (left) osteotomies of 8 adult male Yucatan swine with prebent titanium ladder and mandibular reconstruction plates, respectively. Males were used for comparison to previous work. Preoperatively and immediately, 3, and 6 months postoperatively, CT imaging was performed. Implant new bone deposition was objectively evaluated with light microscopy (H&E, Masson's trichrome, Picrosirius red staining) and micro-computed tomography ( $\mu$ CT). Mechanical properties of implants and native bone were quantified from single cycle to failure compressive load testing.

**RESULTS:** Implants were stable and integrated into parent bone as evident on longitudinal CT models (Fig. 1). Histologic analysis confirmed implant integration and vascularization with minimal pathology (Table 1). Native bone and implant bone volume (BV), trabecular volume (TV) and BV/TV were similar after 6 months (Fig. 2). The material properties of the harvest implant were higher than new implants (Fig. 2)

**DISCUSSION:** Custom 3-D printed  $\beta$ -TCP mandibular angle and zygoma implants integrate into and assume native bone microstructure and material properties increase 6 months after implantation.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Three-dimensional printing of custom implants that integrate into native bone will augment current treatment options.

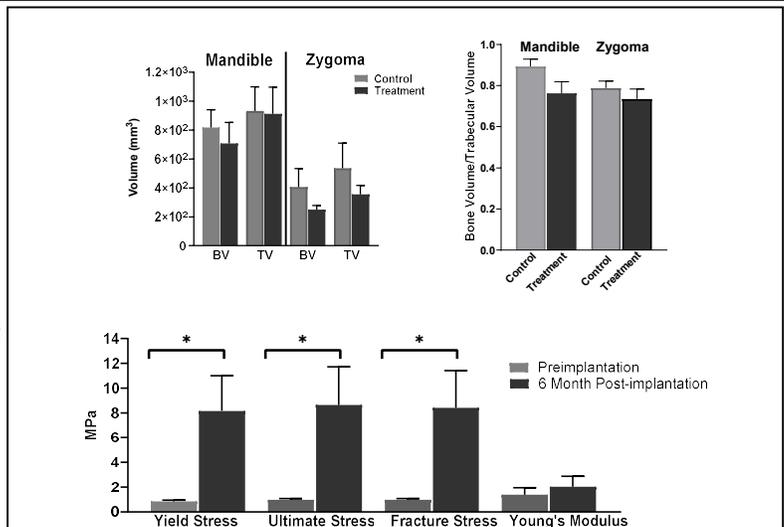


**Figure 1.** Three-dimensional models of longitudinal computed tomography imaging performed preoperatively (Baseline), and immediately (surgery), 3, and 6 months after implantation of mandibular angle (upper) and zygomatic (lower) 3D printed  $\beta$ -tricalcium phosphate synthetic bone grafts.

**Table 1.** Histology Scores (mean  $\pm$  SEM)

Parameter	Mandible	Zygoma
Bone quality at interface	2.75 $\pm$ 0.31	2.13 $\pm$ 0.40
Inflammation	0.88 $\pm$ 0.22	1.13 $\pm$ 0.23
Neovascularization	1.75 $\pm$ 0.31	1.5 $\pm$ 0.27
Fibrosis	2.0 $\pm$ 0.38	2.25 $\pm$ 0.41
Fatty Infiltrate	0.14 $\pm$ 0.14	0.86 $\pm$ 0.40
Other features (necrosis, mineralization, granulomas, hemorrhage, foreign debris other than implant)	0.2 $\pm$ 0.07	0.1 $\pm$ 0.06

Scoring Rubric: 0 = Absent, 1 = Minimal (1–25%), 2 = Mild (26–50%), 3 = Moderate (51–75%), 4 = Marked (76–100%)



**Figure 2.** Mean  $\pm$  SEM mandible and zygoma bone volume (BV) and trabecular volume (TV, upper left) and bone volume/trabecular volume (BV/TV, upper right) of custom 3D printed beta-tricalcium phosphate implants (treatment) and native bone (control) 6 months after implantation. Yield, ultimate, and fracture stress and Young's Modulus (mean  $\pm$  SEM, lower) of 3D printed implants before (Preimplantation) and 6 months after (6 Month Post-implantation) implantation in a Yucatan swine model. \* = Significant difference ( $p < 0.05$ )