Can the Addition of a 3D−Painted Bone Scaffold Accelerate the Maturation of Regenerate Bone During Distraction Osteogenesis in a Lapine Model? A Pilot Study

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Question: Since the duration of distraction osteogenesis treatment can last months, finding a method to accelerate bone healing would be clinically valuable. Biologics and biomaterials have been used to manage bone defects. There is growing interest in their role in increasing the regenerate bone's maturation rate during limb lengthening. Hyperelastic bone™ composed of 90% hydroxyapatite (HA) and 10% polylactic co−glycolic acid (PLGA), is a 3D−printed bone graft substitute that has been used to reconstruct bone defects. Our hypothesis was that supplementing the distraction osteogenesis process with 3D−printed Hyperelastic Bone™ could accelerate the maturation of the regenerate bone in a limb−lengthening rabbit model.

Answer: Following IACUC approval, nine New Zealand white rabbits were included in this study. They were divided into three groups: one control group where lengthening occurred without the use of 3D−printed Hyperelastic bone™, and two study groups using two different 3D−printed (0.8mm inter−fiber spacing 6 x stacking) Hyperelastic bone™ morphologies. The Hyperelastic bone™ sheet was laid directly on the bone under the periosteum at the osteoplasty site prior to wound closure for both study groups. For study group 1, the Hyperelastic bone consisted of 10% PLGA and 90% calcium phosphate (hydroxyapatite). For Study Group 2, 20% of the hydroxyapatite content was replaced with Beta−Tricalcium Phosphate to create a Biphasic Hyperelastic bone™. All animals had surgery on the left tibia. A mini−rail linear external fixator was applied to the left tibia and distracted at a rate of 0.75 mm per day, divided into three increments of 0.25 mm. Each tibia was lengthened by 20% of its original length. Plain X−rays were carried out weekly during the distraction phase and fortnightly during the consolidation phase. Necropsy was carried out after 8 weeks of consolidation, during which the tibia was harvested. Harvested specimens underwent micro−CT imaging of the regenerate bone area for quantitative analysis.

Results: There was regenerate bone visible in the distraction gap on plain x−rays by the 2^{nd}−3^{rd} week in all groups. All groups achieved satisfactory corticalization of the regenerate by the end of the consolidation period. Micro−CT analysis revealed that both experimental study groups had higher bone volume (BV) and total volume (TV) compared to the control group. The biphasic Hyperelastic bone™ group had higher bone volume and total volume compared to the traditional Hyperelastic bone, although this was not statistically significant. The biphasic group also had higher bone mineral density values compared to the control and traditional Hyperelastic bone™ groups.

Conclusions: This pilot study is the first to evaluate the qualitative and quantitative properties of regenerate bone formed during distraction osteogenesis in a rabbit tibial model that was supplemented with a 3D printed scaffold. Although not statistically significant, the Biphasic Hyperelastic bone™ produced better results compared to the traditional Hyperelastic bone™ and the control group during distraction osteogenesis.
The promising results of this study indicate that there may be a role for bone scaffolds in distraction osteogenesis. Additional research to refine the optimal scaffold shape and design should be performed in an attempt to further accelerate the regenerate bone maturation process.

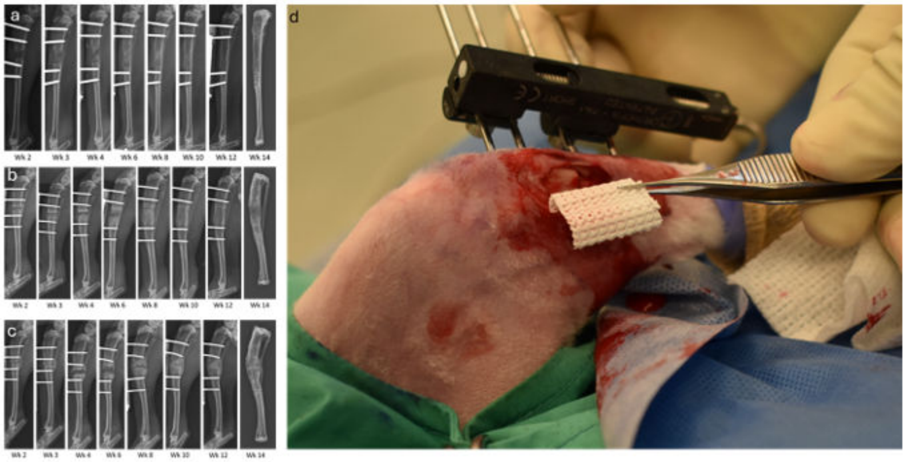

Figure 1. Serial radiographs during the distraction and consolidation phases. **A**) Control group (no Hyperelastic Bone). **B**) Study group 1 (Hyperelastic Bone – Hydroxyapatite with 0.8mm interfiber spacing, 6 x stacking morphology, containing 10% PLGA, 90% Calcium Phosphate, and 100% Hydroxyapatite). **C**) Study group 2 (Hyperelastic Bone – Biphasic with 0.8mm interfiber spacing 6 x stacking morphology, containing 10% PLGA, 90% Calcium Phosphate and 80% Hydroxyapatite +20% Beta-Tricalcium Phosphate). **D**) Picture showing intraoperative use of Hyperelastic bone.

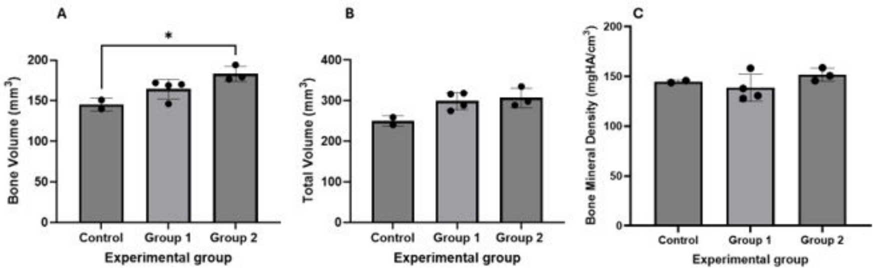

Figure 2. Quantitative micro-CT assessment of the regenerate bone following 20% lengthening of the left tibia in a rabbit external fixator lengthening model in a Control group (no Hyperelastic Bone), Study group 1 (Hyperelastic Bone – Hydroxyapatite with 0.8mm interfiber spacing, 6 x stacking morphology, containing 10% PLGA, 90% Calcium Phosphate, and 100% Hydroxyapatite) and Study group 2 (Hyperelastic Bone – Biphasic with 0.8mm interfiber spacing 6 x stacking morphology, containing 10% PLGA, 90% Calcium Phosphate and 80% Hydroxyapatite +20% Beta-Tricalcium Phosphate). **A**) Bone volume comparison. **B**) Total volume comparison. **C**) Bone mineral density comparison.