Augmentation of Tendon-to-Bone Healing with a Magnesium-Based Bone Adhesive
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Introduction: ACL reconstructions with tendon grafts rely on tendon-bone healing which results in fibrous tissue formation that is weaker than the normal fibrocartilagenous insertion. Calcium phosphate cements have been used to augment soft tissue-bone healing in animal models with encouraging results (1,2). Osteocrete® (Bone Solutions, Inc) is a magnesium-based cement with adhesive properties. Preliminary studies have shown that it can achieve loads to failure three times that of calcium based cements in tendon-bone cadaver models (3).

The objective of this study was to determine if the addition of this bone adhesive can improve tendon-bone healing in a rabbit ACL reconstruction model. We hypothesized that the adhesive would limit fibrous tissue formation and increase bone and fibrocartilage formation at the healing interface when compared to untreated controls.

Materials and Methods: Study Design:
32 New Zealand rabbits underwent bilateral ACL reconstructions with semitendinosus autografts. One limb received 12.5g of the bone-adhesive, the other limb received no adhesive. 16 animals were sacrificed at 3 weeks and 16 at 6 weeks (4 for microCT and histology, 12 for biomechanical testing).

Microcomputed Tomography:
At the time of necropsy, limbs were dissected, fixed in 10% formalin, and axial sections were obtained at the midportion of the tibial and femoral tunnels. MicroCT analysis was subsequently performed using a MS-8 In Vitro Specimen Scanner (GE Medical System, Ontario, CA). A 4.5mm D x 6.0mm H cylindrical volume of interest (VOI) aligned with the bone tunnel was analyzed. Total bone volume (TBV, mm3) was calculated based on the number of bone voxels compared to the total number of voxels in the VOI.

Histology:
The specimens were decalcified, embedded in paraffin, sectioned and stained with H&E and Safranin-O. Image J was used to measure the width of the tendon-bone interface and the area of new cartilage formation. Interface width was determined by measuring the distance from the tendon graft to the bone tunnel at 16 different points on the axial sections. The area of new cartilage formation was determined by outlining the area of metachromasia on the Safranin-O slides and determining the total area for each specimen. Three observers performed the measurements together and arrived at a consensus.

Biomechanical Testing:
The femur-ACL graft-tibia complexes were fixed in a custom-made MTS machine. A pre-load of 1N was applied. After cyclic preconditioning between 0 and 0.75mm, a load-to-failure test was performed at an elongation rate of 10mm/min.

Statistical Analysis:
Means and standard deviations were determined for all outcomes and statistics were performed with a paired Student’s T-test with significance at p=0.05.

Results: There was significantly more cartilage formation as evidenced by the area of metachromasia and less fibrous tissue formation as evidenced by the tendon-bone interface width in the tibiae and femurs of the 6 week limbs that received the bone adhesive compared to controls (p=0.05 for all variables) (Image 1). There was significantly more bone formation in the tibiae of the bone adhesive limbs at 6 weeks on microCT (p=0.01) (Image 2). The load-to-failure was significantly higher in the bone adhesive group at 6 weeks (71.8±31.8 vs 43.4±14.8, p=0.04) (Image 3). There were no differences at 3 weeks in any outcome variable.

Discussion: The results of this study indicate that a magnesium-based bone adhesive can improve tendon-bone healing in a rabbit model. We found that this material can induce fibrocartilage formation, limit fibrous tissue formation, and increase osteointegration at 6 weeks. Furthermore, these finding correlated with improved tensile loads-to-failure. The positive effects from the adhesive are likely related to its osteoconductive properties.

It may eventually be possible to use this bone adhesive clinically to augment tendon-bone healing, potentially leading to increased attachment strength and a diminished risk of graft failure or slippage. Further evaluation in a large animal model is required to evaluate the clinical potential of this bone adhesive.


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