The Use of Demineralised Cortical Bone for Tendon and Ligament Repair

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Introduction: Treatment of tendon and ligament injuries remains challenging; secondary healing and prolonged post operative immobilisation result in suboptimal outcome. A biocompatible graft with mechanical and structural properties that replicate those of normal tendon and ligament has so far not been identified. The use of demineralised bone for reattachment of tendon back onto bone has been shown to be effective in promoting the regeneration of a normal enthesis structure and function (Sundar et al 2009). Because of its structural and mechanical properties, we proposed that Demineralised Cortical Bone (DCB) can be used in repair of tendon and ligament as well as regeneration of the enthesis. DCB contains a scaffold of type 1 collagen with a mix of osteogenic and chondrogenic proteins. It is porous and has the potential to be remodelled by the host tissues. We examined the mechanical properties of DCB after gamma irradiation (GI) and freeze drying (FD) using different techniques for repairing bone-tendon-bone with DCB.

Methods: Tibias were harvested from skeletally mature ewes and cut into bony strips. Demineralisation was a modified Urist technique (Urist 1965) using 0.6M HCL and mineral removal confirmed by X-ray. Specimens were washed in Phosphate Buffer Solution (PBS) until a pH of 7.0 +/- 0.2 was achieved. Specimens were allocated into 4 groups and were either freeze dried and/or gamma irradiation. The groups were: 1)Group (A) non freeze dried, non gamma irradiated. 2)Group (B) freeze dried, non gamma irradiated. 3)Group (C) non freeze dried, gamma irradiated. 4)Group (D) freeze dried and gamma irradiated. Specimens were rehydrated in phosphate buffered saline for 1 hour and then trimmed into dog bone shapes. The maximum tensile force, stress and modulus were measured (figure 1). In the second part of the study, Patella-tendon-tibia construct of skeletally mature ewes were harvested and the distal 1 cm of the patellar tendon was excised, 4 models of repair were designed; Model-1, DCB was used to bridge the gap between the tendon and the tibial tuberosity. The DCB strip was stitched to the tendon using one bone anchor. Model-2, similar to model 1 with the use of 2 bone anchors. Model-3, similar to model 2, construct was off loaded by Fiberwire (Arthrex) continuous thread looped twice through bony tunnels sited in the patella and in the tibial tuberosity. Model-4, similar to model 3 with 3 hand braided fiberwire threads as off loading loop (figure 2). In model-3 and model-4 failure of the off loading loop was used as end point, 6 samples were tested in each model. All 4 models were tested until failure and force displacement curves used to investigate the structural properties of the reconstruction.

Results: The Median of maximum tensile force (figure 3) for group (A) was 218 N [95% CI: 147.9 - 284.7 N], group (B) was 306 N [95% CI: 154.1 - 488.6 N], group (C) was 263 N [95% CI: 227.8 - 315.6 N], group (D) was 676 N [95% CI: 127 - 1094.9 N]. The median ultimate stress for group (A) was 15N/mm2 [95% CI: 8.8 - 21.5 N/mm2], group (B) was 41N/mm2 [95% CI: 31.4 - 50.8 N/mm2], group (C) was 18.7N/mm2 [95% CI: 12.8 - 22.4 N/mm2], group (D) was 54.6 N/mm2 [95% CI: 7.9 - 90.6 N/mm2]. Group (D) results were statistically higher (p=<0.05) compared to group (A) and (C), while there was no statistical significance compared to group (B). The median failure force for model-1 (N=5) was 250 N, (95% C.I. = 235-287), 2 samples failed due to suture pullout of the anchor and the other failed due to patellar tendon pull out. While the median failure force in model-2 (N=5) was 290 N (95% C.I. = 197-396), 4 samples failed due to tendon pull out and the last sample failed by suture cut out of the anchor. Median failure force of model-3 was 767 N (95% C.I. = 730-812) and for model-4 was 934 N (95% C.I. = 867-975) (figure 4). There was no statistical significance between model-1 and model-2 (p=0.249), however statistical significance was found between other models.

Discussion: We examined the effect of gamma irradiation and freeze drying as a possible technique for long term storage on the tensile strength of the DCB. We found that both of these techniques had no effect on DCBs material properties. Demineralised Bone is widely used in orthopaedics and dentistry as a bone graft substitute.. In this study we focus on the potential use of demineralised bone in ligament and tendon repair. A previous animal study by our group found that the use of demineralised bone can enhance healing of the enthesis. Other published studies suggested the possibility of using DCB as ligament substitute (Jackson et al 1996, Summit et al 2003).

Significance: Our study shows that a tendon repair following rupture can be successfully augmented with DCB giving initial appropriate mechanical strength suitable for use in vivo.

Acknowledgments:

Jackson DW et al. Biologic Remodeling after ACL Reconstruction Using a Collagen Matrix Derived from Demineralized Bone; An
Summitt MC, Reisinger KD. Characterization of the mechanical properties of demineralised bone. Journal of Biomedical Materials research Part A, 2003. 67A (3); 742-
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