FUNCTIONAL AND HISTOLOGICAL ASSESSMENT OF TENDON RECONSTRUCTION TO A PROSTHESIS IN AN IN VIVO MODEL

INTRODUCTION: Functional outcome following proximal tibial replacement with massive endoprosthesis can be impaired by extensor mechanism inefficiency. Contemporary methods to re-attach the patellar tendon are inconsistent in the level of extensor function achieved. Successful attachment requires initial mechanical stability to allow biological fixation. We have employed an implant to model tendon attachment to a massive prosthesis, in order to test the hypothesis that a tendon-implant interface can be engineered, whose morphology and function are similar to that of the normal osseointegrating tendon.

MATERIALS AND METHODS: A titanium alloy (Ti₆Al₄V) implant base plate (BP) with a 70 micronm thick coating of dense hydroxyapatite (HA) was attached to the site of a tibial tubercle osteotomy with cortical bone screws, to simulate the surface of a proximal tibial replacement, in 12 skeletally mature Friesland ewes. An autologous cancellous bone and marrow graft harvested from the ipsilateral iliac crest was packed onto the HA coated base plate. The right patellar tendon was elevated from the proximal tibia by sharp dissection and the free end was clamped onto the base plate with a lid, with mechanical fixation being provided by nine interlocking spikes (1mm diameter; 4mm length) (Figure 1). The study was performed in accordance with the Home Office Animals (Scientific Procedures) Act 1986 (UK). The animals were divided into two equal groups to be examined functionally at t = 6 weeks (Group One), and t = 12 weeks (Group Two). All animals underwent pre-operative 2-dimensional optical kinematic gait assessment of their right hind limb using Qualisys motion analysis equipment. Kistler force plate analysis of both hind limbs was carried out 6 weeks post-operatively. Group One also underwent motion analysis assessment at t = 6 weeks, prior to euthanasia. Group Two undertook further force plate assessment and motion analysis at 12 weeks, and then underwent euthanasia. Operated and non-operated proximal tibiae specimens were harvested and processed for routine resin sectioning and histology. The vertical component of the peak Ground Reaction Force (GRF) obtained from the force plate was expressed as a percentage of the operated limb to the non-operated limb, and as a change in functional weight bearing with time for both operated and non-operated limbs. Kinematic data from the motion analysis software was exported into a custom written program to calculate the range of movement at the stifle joint at extremes of the gait cycle. An angle was defined from the mean pre-operative minus mean post-operative stifle joint position at extension, and was defined as a Lag (if negative) or a Hyper-extension (if positive).

RESULTS: The engineered patellar tendon - implant construct produced a mean stifle joint range equal to that observed pre-operatively for Group One (42.73 degrees +/- 1.92 Pre- and 50.01 degrees +/- 1.90 post-operatively) (p = 0.05), and Group Two (46.17 degrees +/- 2.63 Pre- and 52.78 degrees +/- 2.46 post-operatively) (p > 0.05). All Group One animals showed a significant lag at 6 weeks (mean lag = -18.34 degrees +/- 4.75) (p values < 0.01). However after 12 weeks, animals showed a mean hyper-extension of 0.97 degrees +/- 4.71 (Figure 2). Between t = 6 and t = 12 weeks, a significant increase in GRF through the operated versus non-operated limb was observed for all animals (p = 0.05) (Figure 3). By 12 weeks, animals had reached functional weight bearing through the operated limb up to 94% of the non-operated side. Histologically (t = 6 weeks), there were areas of remodeling bone graft intimately associated with the dense HA coated base plate. The clamped tendon tissue (T) contained regions of dense collagenous fibers in a parallel orientation, interspersed with a high density of elongated fibroblast nuclei. An early soft tissue – bone graft (B) interface had developed with collagenous Sharpey’s-like fibers penetrating remodeling bone, in a perpendicular manner (Figure 4).

DISCUSSION: We have demonstrated that initial mechanical stability in a tendon – prosthesis model can be achieved, which allows early mobilization. Objective measures of gait used in this study have eliminated subjective errors, which may limit clinical assessment of function. At 12 weeks, the interface created in this model enabled a normal range of joint motion, whilst weight bearing increased up to 94% of the contralateral limb over this period. Extensor reconstruction by the method described in this animal model, resulted in a lag, which is lower, that that observed with many clinical techniques. Early examination of the morphology shows a developing soft tissue – bone – HA interface.