Does Mechanical Load Affect Tendon to Bone Healing: A Novel System to Apply Controlled Cyclic Strain In Vivo to a Healing Anterior Cruciate Ligament Reconstruction

Mark E. Stasiak, Scott A. Rodeo
Research, Hospital for Special Surgery, New York, NY
stasiakm@hss.edu

Introduction: The effect of mechanical load on tendon to bone healing is not well understood. An improved understanding of this effect has important implications for rehabilitation protocols that follow ligament and tendon reconstruction surgery. Although it is well established that strain has a positive effect on tendon and ligament physiology, its effect on the tendon-bone or ligament bone junction is poorly understood. [1, 2]

To investigate the effect of mechanical load on tendon to bone healing, a novel, in vivo joint fixation/distraction system was developed, using a rat model of anterior cruciate ligament reconstruction. The device is intended to aid in testing the hypothesis that loading in the form of a cyclic tensile strain aids the ingrowth of a tendon graft into bone tunnels. To our knowledge this is the first description of a device that allows repetitive, controlled loading of a tendon graft in-vivo.

Materials and Methods: The system includes an external fixator (Fig. 1) to secure the orientation of the femur relative to the tibia prior to ACL reconstruction. Postoperatively, the animal is secured through the fixator to a cyclic distraction mechanism (Fig. 2) that repeatedly distracts its femur and tibia along a path constrained parallel to the axis of the bone tunnels, placing an axial tensile strain on the healing tendon graft. The force generated within the tendon is measured as displacement is applied. The force-displacement relation reflects the mechanical properties of the bone-tendon-bone construct and can be used to indicate temporal changes related to healing.

Results: In a pilot study, 14 rats had the fixator placed and underwent ACL reconstructions using a flexor digitorum longus tendon autograft. Four were sacrificed to determine the average slack length immediately following reconstruction. Sequential sectioning of other soft tissues, followed by loading served to demonstrate that the grafts received strain. The remaining 10 received 50 cycles of daily loading to 10% of their initial graft length under anesthesia for 28 consecutive days. Between loading sessions, the fixator was locked to immobilize the knee. Nine of the 10 showed a steady significant increase in maximum load at maximum displacement over the 28 days. (Fig. 3)

Discussion: Ligament reconstruction using a tendon graft (such as ACL reconstruction) requires secure tendon-to-bone healing, since the tendon grafts are subject to mechanical loading due to joint motion. The overall aim of our work is to develop a device capable of applying repetitive controlled strain to a healing tendon graft in-vivo. There is currently very little information available on the effect of mechanical load on tendon-to-bone healing. Better understanding of how applied strain influences tendon-to-bone healing may allow for optimized rehabilitation in patients following ACL reconstruction and rotator cuff repair.

Our preliminary results presented here verify the feasibility of our mechanical loading device. We were able to successfully perform ACL reconstruction in the rat knee and apply an external fixator device to maintain the position of the joint. The fixator permitted reproducible application of cyclic tensile strain to the healing tendon graft. The animals tolerated the daily anesthetic protocol well with no discernible adverse effects and no deaths during the anesthesia protocol. Our cyclic distraction mechanism allowed us to obtain reproducible load-displacement curves that will provide unique information on the mechanical properties of the tibia-ACL graft-femur complex.

The animals tolerated the indwelling fixator and daily anesthesia. Based on these results, the system was judged effective for the further study of mechanical load on tendon to bone healing.

Acknowledgements: The authors wish to thank Louis Hernandez of the Mechanical Engineering Department of the City College, CUNY for his generous assistance related to this study.

References: