The Effect of Mechanical Load on Tendon to Bone Healing
Hettrich, CM; Gasinu, S; Beamer BS; Stasiak M; Birmingham, P; Fox, A; Deng, XH; Ying O; +Rodeo SA
+ Hospital for Special Surgery, New York, NY
Senior author rodeos@hss.edu

Introduction: There are more than 75,000 rotator cuff repairs in the United States annually. Unfortunately, 11-95% of these repairs demonstrate structural failure at 2 years, with failed repairs having decreased strength and function. These failures may be the result of intrinsic (biologic) or extrinsic (mechanical load) factors. Long-term outcomes are predicated upon secure tendon-to-bone healing.

Joint motion is commonly prescribed following tendon repair surgeries such as rotator cuff repairs; however, the ideal rehabilitation program to optimize tendon-to-bone healing is unknown. Prior studies have demonstrated the detrimental effects of immediate load, as well as both detrimental and positive effects of immobilization; however, there is no literature to date describing the in-vivo effect of immobilization versus immediate and delayed load in tendon-to-bone healing where the loads are rigidly controlled. We hypothesized that delayed loading would result in a mechanically stronger and better organized tendon to bone interface compared to prolonged immobilization or immediate loading.

Methods: 278 Sprague Dawley rats underwent unilateral patellar tendon detachment and repair followed by placement of a custom designed external fixator. Rats were assigned to: 1. immobilization, 2. immediate postoperative loading, or 3. delayed onset loading (4- or 10-day delay). Tendon loading was controlled using a specially designed motorized device to apply 3 Newtons (low load) or 6 Newtons (high load) of axial tensile load to the healing bone-tendon complex at 0.17 Hz for 50 cycles per day with the animal under anesthesia (Figure 1). Rats were sacrificed at 4, 10, 21, or 28 days post-operatively for histomorphometric, immunohistochemical, radiographic, molecular, and biomechanical analyses.

Biomechanical testing was performed in a Materials Testing System to allow uni-axial tensile testing in line with the repaired tendon. The specimen was loaded to failure and the failure site was recorded. The load-to-failure data was recorded and stiffness was calculated from the load-deformation curves.

Results: The load-to-failure was significantly higher in the immobilized group compared to the immediate and delayed loading groups (p<.05), (Figure 2). Micro CT analyses showed no difference between groups in trabecular bone, but significantly less bone volume, total volume, and bone mineral density in the immediate load group.

The immobilized specimens had significantly less fibrocartilage compared to the loaded specimens at 4, 10, and 28 days. The immobilized animals also had significantly better collagen fiber organization at 4, 10, and 21 days and decreased expression of MMP-13 at 4, 10, 21, and 28 days (Figure 3).

Discussion: Immobilized animals had significantly better mechanical results than the immediate loading and delayed loading groups. The immobilized animals also had less fibrocartilage, better collagen fiber organization at 4, 10, and 21 days, and decreased expression of MMP-13 at 10, 21, and 28 days. Other studies have also shown that immobilization results in superior biomechanical properties and improved collagen fiber organization (1). In vitro studies have also shown that MMP-13 is increased after stress deprivation as compared to cyclically loaded controls (2,3), and with increasing periods of immobilization there are increases in MMP-13 and a decrease in the TIMP/MMP-13 ratio (4). Although immobilization of native tendons decreases tendon mechanical properties, immobilization has a positive effect in the immediate post-operative healing environment.

Literature Cited