INTRODUCTION:
Though it is well established that mechanical stimulus is necessary for optimal soft tissue response to injury, there is limited knowledge regarding the effect of mechanical load (i.e. rehabilitation) on tendon-to-bone surface healing. Arthroscopic and mini-open rotator cuff repairs yield good initial results, however MRI and ultrasound have demonstrated high re-tear rates. Further understanding of the role of mechanical load on the healing of tendon to a bone surface could provide scientific rationale for improved rehabilitation protocols following rotator cuff repair. Ultimately this may lead to improved clinical results following rotator cuff repairs. Therefore, we aimed to develop and validate a feasible means of controlling the timing and magnitude of mechanical load applied to an in vivo rat model of a healing tendon-to-bone surface interface.

METHODS:
Animal Model
Our design requirements were: 1. Repair tendon to bone surface (as in rotator cuff repair), 2. Use external fixator (ex-fix) device to control loads on healing tendon post-operatively. Since anatomical constraints prevented application of controlled loads to the rodent rotator cuff tendon via an ex-fix, we instead developed a surgical technique in which the rat patellar tendon is detached and repaired to the surface of the tibia, analogously to rotator cuff repair.

Patellar Tendon-Tibial Surface Repair Technique
The patellar bone and tendon are exposed via a medial parapatellar incision and a 22 gauge needle is used drill through the patellar bone. Suture wire is passed through the patella and attached to a washer, forming a pull-ring that can be used to apply mechanical load to the patellar tendon-bone surface interface. The fibers of the quadriceps muscle are cut just proximal to the patellar bone to prevent load transmission to the patellar tendon. The patellar tendon is detached from the tibial tuberosity and then repaired back to the bone with sutures pulled through bone tunnels. A 4mm diameter disk of gore-tex is placed beneath the patella to prevent adhesion to the distal femur (Fig1).

RESULTS:
Time Zero Repair Strength:
The average load to failure of the intact and repaired patellar tendons at time 0 was found to be ~37N and ~19N, respectively, (Fig. 2). Half of the intact tendons failed by wire breakage proximal to the patella, while the remaining half failed by fracture at the tendon-tibia junction. The repaired tendons failed at the repair site by suture pull through the distal tendon repair site.

In Vivo Validation:
The surgical procedure was well-tolerated by all rats as they resumed ambulation and feeding within hours of the procedure. Daily in vivo mechanical loading was also well-tolerated by rats as only 1 rat was euthanized prematurely due to femoral fracture. Gross inspection of the patellar tendons showed no signs of failure, though some inflammation and degenerative changes were noted.

DISCUSSION:
We developed a novel animal model, ex-fix and force-controlled loading device to apply known loads across a healing tendon-bone surface interface. Our preliminary in vivo and in vitro evaluation supports the feasibility of this system.
Our surgical technique provides strong fixation of the patellar tendon to the tibial surface, yielding a 19N time-0 failure load; over 6 times greater than the 3N daily applied load. In vivo work has shown that the surgery and two weeks of daily loading are well-tolerated by the rats. Patellar tendons were grossly intact following 2 weeks of loading.

Our loading device allows control of the magnitude and frequency of the applied loads as well as dwell time between cycles. These mechanical factors may influence the course of healing and can be explored with our system in the future.
We are currently using our model to compare healing between a control group of rats receiving no load, and 3 experimental groups receiving daily load beginning on postoperative day 1, 4, or 10. Outcomes will be evaluated using biomechanical testing, histology, and microCT. Further investigation will likely provide insight into the effect of timing and magnitude of mechanical load on a healing tendon to bone surface interface.

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