INTRODUCTION:
Healing after rotator cuff repair has emerged as an important clinical problem. The role of the mechanical environment on the healing insertion site is unclear. We previously showed that cast immobilization is beneficial to healing compared to exercise [1]. Removal of load by paralyzing the supraspinatus muscle has been suggested as a way to reduce “tendon pull-off”. The purpose of this study was to evaluate the effect of the mechanical environment on the healing rotator cuff by paralyzing the supraspinatus muscle and casting the operative shoulder in a rat model of rotator cuff injury and repair. We hypothesized that removal of load would be detrimental to rotator cuff healing.

MATERIALS AND METHODS:
All animal studies were approved by the Institutional Animal Care and Use Committee. The supraspinatus tendons in unilateral shoulders of 108 rats were sharply detached at the humeral insertion and repaired using a transosseous suture. Following the repair, a single intramuscular injection of Botulinum A toxin (9 unit/Kg body weight) was applied to the ipsilateral supraspinatus muscle in 36 rats (Botox/Casted group). In a second group of 36 rats, an equal volume of saline was injected into the operative-side supraspinatus muscle (Saline/Casted group). The contralateral shoulders were left untreated. The operated shoulders of these 2 groups were immobilized in a cast postoperatively to protect the repair. In a third group of 36 rats, the same dose of Botulinum A toxin was injected into the operative-side supraspinatus muscle, but no cast was applied (Botox group). 60 rats were sacrificed 21 and 56 days after repair for biomechanical testing (N=10 per group). The remainder were sacrificed 7, 14, 21, and 56 days after surgery for histological analysis (N=10 per group). Biomechanical testing consisted of a stress relaxation test followed by a uniaxial tensile test to failure, as previously described [1,2]. Ultimate stress, tangent modulus, ultimate force, stiffness, and viscoelastic parameters were determined. Scar volume of the healing insertion site was determined by microCT. Groups were compared using an ANOVA followed by a Fisher’s LSD post-hoc test. Histological specimens were stained with Toluidine blue, Picrosirus red, Masson’s trichrome, and Hematoxylin and Eosin. Slides were examined by 3 investigators for differences in cellularity, fibrocartilage formation, and collagen organization.

RESULTS:
Gross observations of the botulinum-toxin-injected shoulders demonstrated atrophy of the rotator cuff musculature. The scar volume of the repaired tendon insertion in the Botox/Casted and Botox groups was significantly smaller than that in the Saline/Casted group at all time points (Fig.1). Biomechanical testing demonstrated that most structural properties of the repaired tendons were significantly greater in the Saline/Casted group than in the Botox/Casted and Botox groups (Fig.2) (Table 1). Ultimate load at 8 weeks was significantly higher in the Botox group compared to the Botox/Casted group (Fig. 2) (Table 1). There were no other differences between Botox and Botox/Casted groups. Material properties, specifically ultimate stress and tangent modulus, showed no statistically significant difference when comparing the Botox/Casted and Botox groups to the Saline/Casted group (Table 1). Viscoelastic properties were improved in the Botox/Casted group compared to the Botox group at 21 days, but this difference was not seen at 56 days. Histological analysis revealed no apparent differences in cellularity, fibrocartilage formation, or collagen organization.

DISCUSSION:
Completely removing mechanical load from a healing rotator cuff insertion is detrimental to tendon healing. We previously showed that cast immobilization without paralysis of the supraspinatus muscle was beneficial to healing [1]. In the present study, we demonstrated that when all load is removed from the healing tendon by paralyzing the supraspinatus muscle, the scar volume and the structural properties are decreased compared to control specimens. Allowing free motion of the shoulder did not obviate the negative effect of muscle load removal. The viscoelastic material property results suggest that there may be some improvement in the early quality of the healing tissue with paralysis. However, in the longer term both saline and paralyzed groups produced similar poor quality scar tissue. Thus, the improvement in the structural properties in the saline-injected side was the direct result of an increased quantity of scar material. Optimizing the repair environment both biologically and mechanically is important to improve tendon healing. Providing the proper load environment has clinical implications in terms of immobilization and rehabilitation protocols after surgery. Paralyzing the supraspinatus to minimize the risk of tendon pull-off may be detrimental to rotator cuff repair.

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REFERENCES: