INTRODUCTION: Physiologic shoulder motion is dependent on a complex balance of forces. In particular, the anterior-posterior (AP) force balance in the shoulder is primarily comprised of the subscapularis and infraspinatus-teres minor complex of the rotator cuff [1]. Massive chronic rotator cuff tears, a common clinical problem, can disrupt this balance and present a management challenge. Moreover, chronic tears can lead to joint damage, presumably from altered joint mechanics leading to changes in cartilage loading [2]. A patient with only a supraspinatus tear can have good function, suggesting that an intact AP force balance can play a pivotal role in maintaining joint function.

Previous rat model studies have shown that partial repair of a two-tendon tear can restore joint kinetics similar to a two-tendon repair [3]. However, the effect of a partial repair on glenoid cartilage health remains unknown. Therefore, the objective of this study was to evaluate the effect of partial repair of a massive chronic tear of the rotator cuff on glenoid cartilage thickness and mechanical properties. We hypothesized that, compared to no-repair, partial repair of the rotator cuff tear would lead to H1) changes in thickness, H2) improved mechanical properties, and H3) no significant differences in cartilage between animals with a partial repair and those with a two-tendon repair in either comparison.

METHODS: Surgical Model and Sample Preparation: Thirty adult male Sprague-Dawley rats (400-450 grams) underwent unilateral detachment of the supraspinatus and infraspinatus tendons in the left shoulder (IACUC approved), then returned to cage activity. Four weeks post-injury, animals were randomized to one of three repair types (n=10 each): partial-repair (infraspinatus only), no-repair (negative control), or two-tendon repair (positive control) (Fig 1). All rats were sacrificed 4 weeks after repair surgery. The scapula was dissected, secured in a custom-fixture, and immerced in PBS containing a protease inhibitor cocktail (5 mM Benz-HCl, 1mM PMSF, 1 M NEM) at room temperature.

Glenoid Cartilage Thickness Measurement: Specimens were scanned at 0.25 mm increments using a 25 MHz ultrasound probe (VisualSonics, Inc) in plane with the scapula. Captured B-mode images of each scan were segmented by selecting the glenoid articular and bony surfaces. The 3D positions of these surfaces were reconstructed and used to determine cartilage thickness maps. Each thickness map was divided into five regions (center (C), antero-superior (AS), antero-inferior (AI), postero-superior (PS), postero-inferior (PI)), and an average thickness was computed for each region for all three experimental groups.

Glenoid Cartilage Mechanical Property Testing: Utilizing a 0.5 mm diameter, non-porous spherical indenter tip, glenoid cartilage indentation testing was performed: preload (0.005 N), 8 step-wise stress relaxation tests (8 um ramp at 2 um/s followed by a 300 s hold). The scapula was repositioned for each localized region using rotational and linear stages such that the indenter tip remained perpendicular to the cartilage surface at each location. Equilibrium elastic modulus was calculated, as described previously [4], at 20% indentation and assuming Poisson’s ratio (v=0.3).

Statistics: To compare the effect of partial-repair to no-repair (negative control) and partial-repair to two-tendon repair (positive control), a one-way ANOVA was performed for each comparison, followed by a Fisher’s post-hoc test. To account for the two tests, a Bonferroni correction was performed, and significance set to p<0.025.

RESULTS: Glenoid cartilage thickness was significantly greater in the antero-inferior region of the partial repair group compared to the no-repair group, while there were no thickness differences between the partial and two-tendon repair groups (Fig 2).

Equilibrium modulus of the glenoid cartilage was significantly less in the antero-inferior region of the partial repair group than in the no-repair group. The two-tendon repair group also differed from the partial repair group, but only in the postero-inferior region (Fig 3).

DISCUSSION: Due to the complex clinical problem, recent attention has turned to developing an animal model to study the effect of surgical management of massive, chronic tears. Previous clinical studies have suggested that partial repair of these tears may provide improvement in function and pain relief [5]. In the current tendon repair study in the rat model, we demonstrated higher thickness and lower modulus in glenoid cartilage in the setting of partial repair compared to no-repair, suggestive of altered joint loading.

In arthritis, mechanical properties of articular cartilage are typically inferior and cartilage can become thinned, while in the setting of increased physiologic loading, cartilage stiffness can be increased [6]. Although there is an effect of repair strategy on the antero-inferior region in this study, the interpretation of that effect is unclear. The animal may compensate at this relatively early time point, giving an effect similar to exercise, leading to the unexpectedly increased equilibrium modulus with thinner cartilage seen in the no-repair group.

Further studies will compare cartilage thickness and mechanics to uninjured animals, as well as attempt to determine kinematic effects on shoulder motion in the setting of a chronic rotator cuff tendon repair.

CLINICAL SIGNIFICANCE: This study suggests that partial repair of a massive rotator cuff tear leads to different cartilage properties than either no repair or full repair, and provides impetus for further clinical study.

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