INTRODUCTION:
Current rotator cuff repairs have a high incidence of asymptomatic defects [1]. Researchers have quantified that current repairs only restore a maximum of 67% of the original footprint of the rotator cuff [2]. Recently, double row suture anchors repair techniques have been reported that could re-establish the footprint of the rotator cuff [3,4]. Reports have shown that the biomechanical properties increase with the addition of another row of anchors [5]; but have only evaluated isolated portions of the tendon and not evaluated the overall rotator cuff complex. Therefore, the objective of our study was to investigate the response of the rotator cuff complex after single and double row repair to both cyclic loading and failure along with quantifying the restoration of the original rotator cuff footprint.

MATERIALS AND METHODS
Twenty-two fresh frozen human cadaveric shoulders (mean age=49±7 years) were dissected to reveal the rotator cuff interval. 3 centimeters of the rotator cuff interval was then isolated starting at the most anterior point of the supraspinatus footprint and proceeding posterior toward the infraspinatus tendon. The tendon was then clamped in a custom sinusoidal clamp and attached to the crosshead of a materials testing machine (Adelaide Testing Machines, Model TTS-25 Series, Toronto, Canada). The humerus was potted in a cylindrical mold of epoxy putty and mounted to the base of the testing machine. Superior displacement of the tendon was moved parallel to the long axis of the humeral shaft.

After mounting, an initial preload of 5N was achieved to pretension the isolated tendon (Figure 1). A digitizing system (Microscribe3D, San Jose, CA) was then used to record the footprint of the isolated tendon’s attachment site and custom software was then used to calculate area of the footprint. The intact tendon was subjected to 100 cycles of cyclic loading from 20N to 100N at a constant speed of .25 mm/sec. After one half hour of recovery, a 3 cm tear was created starting along the greater tuberosity and including all the attachment area to simulate a massive cuff tear. After a preload of 5N, the torn tendon was subjected to the same cyclic loading protocol performed on the intact tendon.

After another recovery period, the full thickness rotator cuff tear was then repaired using one of four repair techniques: Single Row A (Simple Lateral), Single Row B (Simple Mattress), Double Row A Medial Mattress/Lateral Simple) and Double Row B (Transosseous Simple) (AnchorSew, USS Sports Medicine, North Haven, CT). After each pair of anchors was secured, the new footprint of the repaired rotator cuff was digitized as previously described and the area was calculated (Figure 2). Another round of cyclic loading was then performed. After another recovery period a load-to-failure protocol was then performed at a speed of 1.25 mm/sec. During failure of the repaired tendon, no significant differences could be detected between all of the repairs for ultimate load and stiffness (Figure 3, p>0.05). All specimens failed at the tendon-suture interface.

RESULTS
The average footprint restoration of the single row repairs was 40% and significantly increased to 90% for the double row repairs (p<0.05). The structural properties of the repaired tendon including ultimate load (N) and stiffness (N/mm) were derived from the load-elongation curve and the mode of failure was recorded. A Student’s paired T-test was used to statistically compare the structural properties and footprint restoration of the repaired rotator cuff tendon complexes with a significance set at p<0.05.

DISCUSSION
The footprint restoration and the structural properties of the repaired rotator cuff complex were characterized and compared in this study. The experimental testing setup and protocol allow for a more clinically realistic injury setting before repair and testing of the rotator cuff complex. The single and double row repair complex has comparable structural properties to current RC repairs; however does not improve upon these properties. The discrepancies to recent reports can be attributed to the incorporation of the surrounding tissue. An acute injury setting (low cycles) simulated in this study could be increased in the future to possibly mimic a chronic injury state. The increase in footprint restoration could increase the tendon-to-bone interface after healing and must be evaluated to determine clinical and biomechanical effect. Future optimization of the double row repair techniques should decrease the number of anchors to prevent against toxic overload to the greater tuberosity.

ACKNOWLEDGEMENTS
Support for this study provided by US Surgical Sports Medicine

REFERENCES