# Biomechanical Evaluation of Rotator Cuff Repairs and Measuring Gaps within the Repair Site

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**Introduction:** The goal of rotator cuff tear repair is to restore normal biomechanics to the glenohumeral joint by obtaining secure fixation of the ruptured rotator cuff tendon at its anatomic footprint on the humeral tuberosities to allow healing of the tendon to bone interface. A repair must have a high level of fixation strength and provide minimal tensile stress to the rotator cuff tendon to create mechanical stability under cyclic loading without gap formation during the entire rehabilitation period. Burkhart et al have conjectured that if a 5 mm or greater gap forms between the tendon and the bone at any time during the critical healing process of a rotator cuff tear, that the repair will fail.[1] Gap formation results from low level muscle contraction during the rehabilitation process and possibly even during sling immobilization. It is a goal of the surgeon to minimize the gap formation at the tendon to bone interface during the healing phase of the repair in an effort to ensure a healthy tendon to bone construct. Several biomechanical studies have attempted to measure the gap in the repair site using DVRT's. The purpose of this study was to evaluate the measurement methods reported in the literature for biomechanics of rotator cuff repairs.

**Methods**: All shoulders were kept frozen until the day of dissection. Sixteen cadaver shoulders were identically prepared by removing the extrinsic shoulder muscles. The rotator cuff and underlying capsule were left intact. The supraspinatus tendon was sharply dissected from the footprint at the greater tuberosity to simulate the lesion. Two repair techniques were used to compare the measures of gap and elongation of the repairs to serve for this study for the comparison of measurement methods. In each specimen, linear differential variable reluctance transducers (DVRT) (Microstrain, Burlington, VT, USA) with a range of displacement of 9 mm were mounted anterior and posterior on the tendon across the repair gap and secured to the humeral head lateral to the anchor insertions, as described by Shea.[2] Displacement of these gauges served as one measure of gap formation as a function of load on the construct. Using a biopsy needle, a 1 mm diameter stainless steel bead was embedded in the proximal humerus where it would be visible by fluoroscopy and would not interfere with the anchors. A suture clip was fastened to the underside of the supraspinatus tendon near its insertion to the humerus, see Fig. 1. These metal markers were used to identify the relative change in position of the tissues close to the gap in the repair site in the fluoroscopic video images (FVI) during loading cycles. A mini-fluoroscope (FluoroScan Premiere, Hologic Corp., Bedford, MA) was placed around the specimen so as to track the relative motion of the embedded stainless steel ball and staples. One pixel in the FVI is about 1/8 of a mm so the accuracy of the measure is about 0.13 mm. The humeral shaft was held securely in an angle vice and the angle of the shaft was set to 30° from vertical. The supraspinatus muscle was gripped proximal to the repair site with a soft tissue grip and attached to the Instron E3000 (Instron, Canton, MA) for loading in tension.

**Methods** … continued …
Each video clip recorded from the fluoroscope was synchronized with a video clip of the lateral side of the repair from a Nikon camera as well as with the Instron and DVRT recordings so that all recordings for each step of the testing could be identified and synchronized during data analysis.

The mechanical test consisted of a sinusoidal vertical cyclic load from 10 N to 100 N tension in load control at 0.5 Hz for 200 cycles.

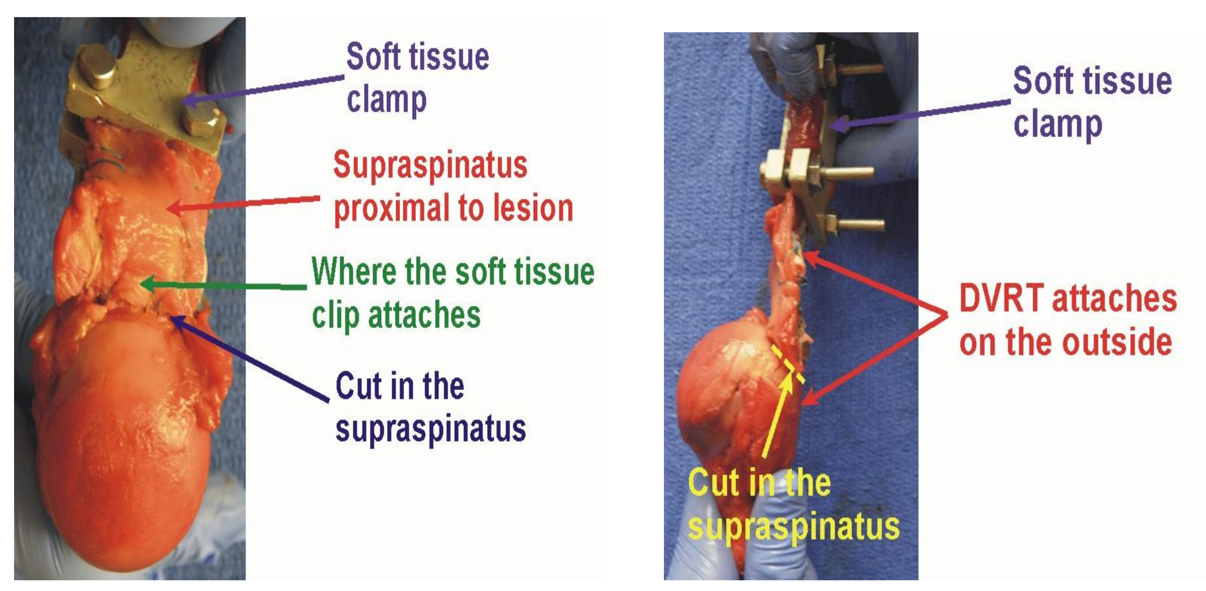


Figure 1 – Note the positioning of the lesion and the markers for measuring any increase in the gap at the repair site, deep on the underside of the supraspinatus muscle and tendon.

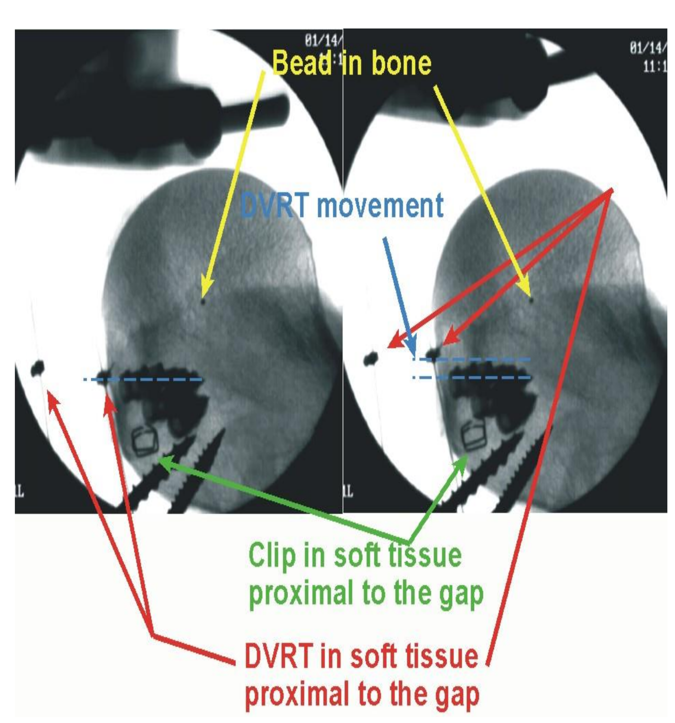


Figure 2 – the image captured of a repaired cuff with load relaxed, left, and then at the peak of the load cycle, right, shows visible movement of the DVRT anchor on the outside of the supraspinatus, but not for the clip on the inside of the supraspinatus just proximal to the gap.

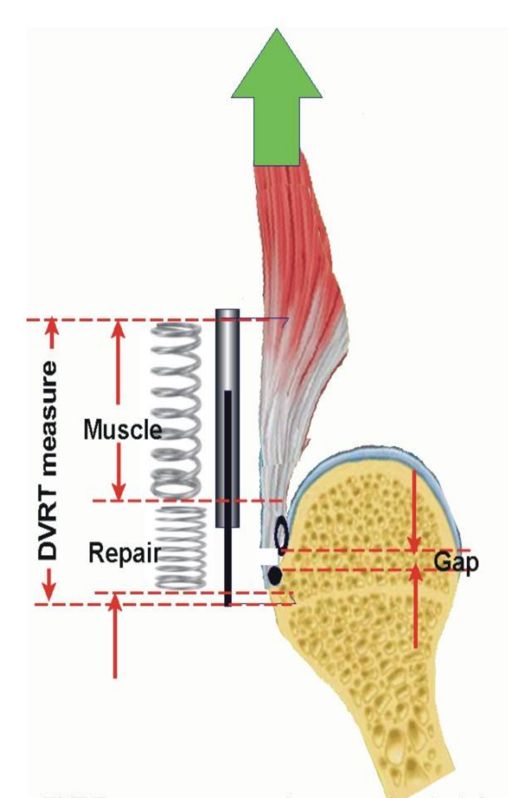


Figure 3 – The tissues are like springs. Each system measures the stretch across all it spans.

**Results:** There were significant differences between the measures of the DVRT's and the changes in position of the beads and clips from the FVI's during cyclic loading. In general, the DVRT measures were 134.6% ± 112.5 for comparison of 24 DVRT measures to 12 FVI's in 12 shoulders. Some DVRT measures were smaller than those from the fluoroscopic measures, but most were larger. The major difference between the DVRT and fluoroscopy measures is their location and the tissues they anchor in. The DVRT's anchor in the outer surface of the muscle tissue with a span of 20-30 mm. The bead is fixed to the bone and the clip is in the soft tissue a few mm proximal to the lesion.

**Discussion**: There are several factors that may contribute to the difference in measures seen by the DVRT's and the fluoroscopic videos. The first major difference is the span of the tissue in which the measurement is made. The DVRT's in our study were placed so that their initial span of tissue was about 30 mm, similar to the spans seen in other studies.[2] The measure then represents all the stretch and movements between the anchors of the DVRT, see Fig. 3. If a gap opens, that would contribute to the DVRT measure, but also any stretch in the muscle, tendon and graft within that span also would contribute to the measurement of the DVRT. If no gap opened and the tissue only stretched uniformly by 10% strain, the DVRT would measure 3 mm of stretch over its 30 mm span. The markers placed in the soft tissue at the lesion were about 3 mm from the bone interface at the cut in the tendon. So with the same uniform 10% stretch, the soft tissue clip would only move 0.3 mm from the bone. If a gap of 5 mm did open, both the DVRT and the FVI would measure the size of the gap in addition to the stretch in the tissue within its span. The DVRT would measure 35 mm and the FVI would measure 5.3 mm.

However, some DVRT measures were less than those of the FVI for the same test. Did the barb for the DVRT slip through the tissue? We do not yet have an answer for that question

**Conclusions:** FVI measures of gap opening are more accurate than DVRT measures of the stretch of the muscle and repair of the supraspinatus. The DVRT measures still provide useful information about the mechanical behavior of the repair, but do not accurately reflect the gap at the lesion.

**References:** 1) Burkhart SS, Johnson TC, Wirth MA, Athanasiou KA: "Cyclic loading of transosseous rotator cuff repairs: tension overload as a possible cause of failure." Arthroscopy. 1997; 13: 172–176. 2). Shea KP, Obopilwe E, Sperling JW, Iannotti JP: "A biomechanical analysis of gap formation and failure mechanics of a xenograft-reinforced rotator cuff repair in a cadaveric model", J Shoulder Elbow Surg (2012) 21, 1072-1079.

**Acknowledgements:** This project was supported by Artelon, Inc. and MBI for Biomechanics, at Mount Sinai Medical Center, Miami Beach, FL