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BASIC SCIENCE

Biomechanical similarities among subscapularis repairs after shoulder arthroplasty

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Hypothesis: Many authors suggest that subscapularis deficiency after shoulder arthroplasty has a negative effect on long-term outcomes. Thus, increasing emphasis has been placed on the technique for repair of the tendon. This study evaluated the biomechanical strength of 3 different repairs: osteotomy, tendon to bone, and a combined method.
Materials and methods: Twenty-four paired shoulders from deceased donors were prepared for shoulder arthroplasty. The subscapularis tendon was removed/repaired with the lesser tuberosity in the osteotomy group, was removed periosteally in the bone-to-tendon group, and was tenotomized in the combined group. The tendon-to-bone repair used bone tunnels, and the combined construct added tendon-to-tendon fixation. A materials testing system machine was used for cycling. A digital motion analysis system with spatial markers was used for analysis.
Results: There were no significant differences ($P > .05$) in age, bone mineral density, or construct thickness. No statistically significant differences ($P > .05$) in elongation amplitude ($P = .67$) or cyclic elongation ($P = .58$) were detected within the constructs or between repair techniques. Failure testing revealed no differences in maximum load, stiffness, or mode of failure.
Discussion: There remains no consensus about the optimal method of repairing the subscapularis tendon during shoulder arthroplasty. Furthermore, the results of the current study do not support one technique over another with regard to initial fixation properties. All constructs investigated exhibited comparably robust biomechanical performance. Durability may, therefore, be more a result of healing potential than the specific construct chosen.
Level of evidence: Basic Science Study, Biomechanical Study.

Keywords: Shoulder arthroplasty; subscapularis; repair; lesser tuberosity osteotomy; tendon to tendon repair

Shoulder arthroplasty is an effective treatment for patients with end-stage glenohumeral arthritis, and its prevalence has increased in contemporary orthopedics with the availability of new implants and an aging population. Patients are now younger and more active, thus magnifying the issue of prosthetic durability and functionality. Many factors influence the outcome of a shoulder replacement, including rotator cuff functionality, soft-tissue balancing, activity

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demands, bone quality, and component wear. However, recent research has focused on the contribution of the subscapularis muscle.[3,7,8,10]

The standard deltopectoral surgical approach to the shoulder mobilizes the subscapularis tendon with an osteotomy or tenotomy for exposure to the glenohumeral joint. The effect of a compromised subscapularis tendon postoperatively has been the focus of current clinical and biomechanical studies. Miller et al[15] showed by physical examination that approximately 66% of patients have persistent subscapularis dysfunction after shoulder arthroplasty. Gerber and Edwards et al[7,10] have further suggested that subscapularis deficiency has a negative effect on the long-term outcomes for shoulder arthroplasty. Thus, increasing emphasis has been placed on the technique for repair of the tendon.

The 3 predominant methods for releasing the tendon are a tenotomy leaving a cuff of tendon, periosteal release off the proximal humerus, and osteotomy of the lesser tuberosity in its entirety.[9] A variety of techniques have been proposed for reattachment of the subscapularis tendon.[1,6,9,10,20] These include bone-to-bone, tendon-to-tendon, tendon-to-bone, and combination procedures. Each method has its own innate technical complexities, and current biomechanical results do not consistently support one construct over another.

Krishnan et al,[13] using a biomechanical test protocol with progressively increasing cyclic load levels, found bone-to-bone to be stronger than tendon-to-tendon repair, yet Van den Berghe et al[20] demonstrated no difference under conditions of fatigue loading. Ahmad et al[1] have suggested that a combined construct is more resilient than a tendon-to-bone repair; however, this configuration has not been compared against a bone-to-bone technique.

Long-term clinical data are presently unavailable. The objective of the current study was to assess the biomechanical response to cyclic subfailure loading and to quantify the failure properties of a bone-to-bone lesser tuberosity osteotomy, tendon-to-bone, and combined tendon-to-bone subscapularis repair techniques used in shoulder arthroplasty.

Materials and methods

This study was exempt from Investigational Review Board approval.

Testing was done with 24 fresh frozen shoulders from deceased male donors (12 contralateral pairs) who were an average age of 57 $\pm$ 8 years. Bone mineral density (BMD) testing was performed on all specimens using a dual-energy x-ray absorptiometry (DEXA) scanner (General Electric Lunar Prodigy, Madison, WI). During the scan, each humerus was specifically positioned so that BMD was assessed near the fixation site. After BMD measurements, the shoulders were randomly divided into 3 groups while ensuring that the same repair technique was not used for both the left and right shoulders of a particular matched pair: a combined bone-to-tendon repair, a tendon-to-bone repair, and a lesser tuberosity osteotomy. Each shoulder was dissected down to the glenohumeral joint. No specimens had evidence of fractures or gross pathology of the rotator cuff, glenohumeral capsule, or surrounding soft-tissue envelope.

The subscapularis was reflected off the scapula, and the humerus was detached from the glenoid by releasing the capsule with the subscapularis tendon intact. The supraspinatus and infraspinatus musculotendinous complexes were completely detached from their insertions on the proximal humerus, and attention was turned to preparation for the arthroplasty. The subscapularis tendon was removed, as described subsequently, and a reciprocating saw was used to make a bone cut at the anatomic neck of the proximal humerus, ensuring anatomic retroversion.

The humeral canal was prepared with standard arthroplasty broaches (Univers, Arthrex, Naples, FL). Once the canal was broached to the appropriate size, a 2.0-mm drill was used to create bone tunnels for each suture repair, as described subsequently. Prostheses with varying stem sizes according to the anatomic humeral size were then inserted (Univers TSR) for all repair groups, and the subscapularis tendon repair was completed.

Method 1: Combined tendon-to-bone/tendon

In the combined tendon-to-bone/tendon group, a tenotomy of the subscapularis tendon was performed approximately 1 cm medial to the attachment of the lesser tuberosity. The humerus was prepared, and 3 bone tunnels were created just lateral to the subscapularis insertion on the lesser tuberosity that exited in the humeral canal. Three sutures of No. 5 Fiberwire (Arthrex, Naples, FL) were placed through the bone tunnels, and the humeral prosthesis was inserted. The 3 sutures were then sutured to the tenotomized tendon in a modified Mason-Allen configuration. The tenotomy was reapproximated and 3 tendon-to-tendon simple sutures were placed to complete the repair (Fig. 1, A).

Method 2: Tendon-to-bone

In the tendon-to-bone group, the subscapularis was released periosteally off the lesser tuberosity. The humerus was cut and broached, and 4 holes were placed approximately 5 to 8 mm from the edge of the humeral cut. No. 5 Fiberwire suture (Arthrex, Naples, FL) was then placed through the bone tunnels. The prosthesis was inserted and the tendon was repaired with 4 No. sutures through the bone tunnels in a modified Mason-Allen construct (Fig. 1, B).

Method 3: Lesser tuberosity osteotomy

A thin osteotome was used to remove the lesser tuberosity with the subscapularis insertion intact, as described by Gerber et al.[9] The humerus was prepared in a standard fashion and 4 unicortical bone tunnels were created just lateral to the lesser tuberosity.[9] The humeral component was inserted, and the lesser tuberosity osteotomy was repaired by placing 2 No. 5 sutures over the osteotomized fragment. Each suture entered the superficial tendon at the tendon-bone interface and was then brought from deep to superficial in a mattress-type configuration. The needle was passed through the bone tunnel and tapped out of the cortex at the greater tuberosity. The sutures were tied over a small 7-hole titanium plate (Synthes, Paoli, PA), as described by Gerber et al[9] (Fig 1, C).