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Biomechanical testing of small versus large lesser tuberosity osteotomies: effect on gap formation and ultimate failure load

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Background: Subscapularis muscle dysfunction after total shoulder arthroplasty (TSA) can be a devastating complication. Recent biomechanical and clinical results suggest the superiority of lesser tuberosity osteotomy (LTO) over subscapularis tenotomy; however, disagreement over the best repair technique remains. This study aimed to characterize the strength of 2 novel repair techniques for LTO fixation compared with standard tenotomy and dual-row tuberosity osteotomies during TSA.
Methods: Twenty fresh frozen cadaveric shoulders were dissected of all soft tissues except the humeri and attached subscapularis myotendinous unit. Humeri and subscapularis muscle belly were secured to a materials testing frame and subjected to cyclic loading, followed by load to failure for characterization of gap formation, ultimate failure load, and mechanism of failure. Repair techniques investigated were traditional subscapularis tenotomy and dual-row fleck LTO compared with novel techniques of single-cable and 2-suture large LTO repairs.
Results: No significant difference in ultimate failure load was noted among the repair techniques ($P = .565$). The tenotomy repair (6.0 ± 3.9 mm) displayed significantly greater gapping in response to increasing load than LTO repair techniques ($P < .05$). No significant difference was noted between any LTO repairs at specific loads during cyclic testing ($P > .05$).
Conclusion: Our study displayed superior repair integrity of LTO vs tenotomy repairs. The advantages of the 2-suture large LTO technique over other LTO techniques include its simple technique, with a minimum amount of suture, avoidance of metallic hardware, and greater access to the glenoid, while providing comparable repair stability. Further research is warranted to fully evaluate these new techniques.
Level of evidence: Basic Science Study, Biomechanics, Cadaver Model.

Keywords: Total shoulder arthroplasty; lesser tuberosity osteotomy; biomechanical evaluation; subscapularis tenotomy

Total shoulder arthroplasty (TSA) is most commonly performed using the deltopectoral approach, which mobilizes the subscapularis tendon from the lesser tuberosity. Traditional management of the subscapularis tendon consists of a tenotomy with simple suture repair,[5] but complications,

Investigational Review Board approval was not required for this basic science biomechanics study.

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including dysfunction, attenuation, or complete rupture of the tendon have been reported.[12] However, the postoperative physical examination of the subscapularis tendon does not correlate with ultrasound findings, making it difficult to accurately diagnose the integrity of the tendon repair postoperatively.[2] Subscapularis dysfunction can have significant clinical implications, including decreased internal rotation strength, subtle or gross glenohumeral joint instability, and overall poorer functional outcomes,[6,8,17,18,20] which may lead to technically challenging revision surgery.

Newer techniques, such as lesser tuberosity osteotomy (LTO), avoid violation of the subscapularis tendon and have been developed to rely on the high reliability of bone-to-bone healing. Proponents of LTO cite increased strength and stability of the repair complex and the ability to assess the repair radiographically as distinct advantages over the tenotomy techniques.[9,10,19,21] Another common repair technique, the subscapularis peel, involves a tendon-to-bone repair after a sharp subscapularis (and anterior capsule) release off the lesser tuberosity.[7] However, a randomized controlled trial by Lapner et al[15] established no significant difference between groups. Lapner et al[14] also established no statistical differences in healing rates or subscapularis fatty infiltration grades between the peel and LTO.

To date, no definitive consensus exists regarding the optimal subscapularis management technique after TSA. Most of the studied techniques have used a LTO consisting of a small bony fragment strictly limited to the anatomic footprint of the subscapularis, termed a "wafer" or "fleck" LTO. Potential disadvantages of a small LTO include bony resorption of the fragment, difficulty obtaining rigid fixation of the fragment, biomechanical properties similar to tenotomy, and minimal enhancement of glenoid exposure. Recently, Budge et al[4] hypothesized that a larger LTO fragment, at least 100% larger (8 cm^2 × 7- to 10-mm thickness vs 2.5 cm^2 × 4- to 5-mm thickness[19]) than previously reported LTO sizes, might have better biomechanical properties than a small LTO. Potential advantages of a large LTO include more reliable bone-to-bone healing with less chance of bony resorption, rigid internal fixation of the larger fragment, enhanced biomechanical properties compared with tenotomy and small LTO, and significantly enhanced glenoid exposure.

To our knowledge, no study has evaluated the biomechanical properties of a larger LTO fragment. The purpose of this study was to evaluate the biomechanical strength of 2 novel repair techniques that both use a larger LTO instead of the fleck LTO. We hypothesized that both large LTO repair techniques would be biomechanically superior to tenotomy and small LTO.

Materials and methods

This biomechanics testing study used 20 fresh frozen cadaveric shoulders (average age, 54.2 ± 3.3 years; minimum, 50 years; maximum, 59 years). The selected cadavers did not have previously diagnosed shoulder pathology and were randomly assigned to each repair group. Cadaveric age (P = .828) and body mass index (P = .571) were not significantly different between repair groups as determined by a one-way analysis of variance (ANOVA) performed after assignment of specimens to each repair group.

All soft tissue was dissected from the proximal humerus, except for the subscapularis muscle and tendon unit, which remained attached to the lesser tuberosity. All surgical techniques involved implantation of a press-fit Zimmer Bigliani-Flatow (Zimmer Inc, Warsaw, IN, USA) humeral prosthesis in a standard fashion after subscapularis tenotomy or LTO. Because these were trial prostheses, no proximal coating was present on the stems used for implantation.

Tenotomy repair technique

The subscapularis tendon was tenotomized perpendicular to its fibers, 1-cm medial to its insertion. After insertion of the implant, the tenotomy was repaired using 4 evenly spaced, #2 FiberWire sutures (Arthrex, Naples, FL, USA) in a modified Mason-Allen configuration. This repair is shown in Figure 1, *A* and *B*.

Dual-row fleck LTO technique

The fleck LTO was performed with use of a 2-cm curved osteotome starting in the bicipital groove. The insertional footprint of the subscapularis was then osteotomized as described by Krishnan et al.[13] After insertion of the implant, the osteotomy was repaired with 2 rows of sutures. The lateral row was created using 4 #2 FiberWire sutures. Each suture was passed through the subscapularis tendon just medial to the bony footprint. The sutures were then passed transosseously through the osteotomy bed to exit through the lateral aspect of the osteotomy bed. The sutures were tied in a simple fashion on the superficial aspect of the reduced LTO fragment.

The medial row of sutures consisted of 4 #2 FiberWire sutures. Four drill holes were created medial to the LTO bed along the anatomic neck cut. The sutures were then passed through the subscapularis tendon along the location of the anatomic neck to pass through the bone tunnels and exit through the medullary canal along the anatomic neck. The sutures were tied in a horizontal fashion. The dual-row fleck LTO repair is shown in Figure 1, *C* and *D*.

Single-cable large LTO technique

The single-cable large LTO was described by Budge et al.[4] The large fragment LTO was performed using an oscillating saw to create a horizontal cut inferior to the lesser tuberosity at the level of the surgical neck and a vertical cut lateral to the lesser tuberosity in the base of the bicipital groove. A 2-cm curved osteotome was used to complete the LTO medially at the humeral head articular margin. This resulted in a large fragment of the entire lesser tuberosity. The fragment was approximately 2- to 3-cm wide medial-to-lateral, 3- to 4-cm long superior-to-inferior, and 1- to 2-cm thick. Five bone tunnels were drilled lateral to the bicipital groove. Both ends of 4 #2 FiberWire sutures were passed through the consecutive lateral bone tunnels and into the tuberosity bed. One end of each suture was passed deep and around the incompletely inserted tip of the stem of the prosthesis before