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Effect of shoulder abduction on the fixation of humeral greater tuberosity fractures: a biomechanical study for three types of fixation constructs

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Background: An abduction brace and abduction exercises are commonly employed after humeral greater tuberosity fracture repair. However, the effects of glenohumeral abduction on the biomechanical strength have seldom been elucidated.
Method: We studied 24 pairs of female fresh frozen porcine shoulders randomly divided into 3 groups. After creation of a greater tuberosity fracture on each shoulder, 3 fixation techniques were used for the 3 groups: double-row suture anchor fixation (DR), suture bridge technique (SB), and 2-screw fixation (TS). This biomechanical study was conducted to compare the forces that create 3- and 5-mm displacements and the ultimate failure load at the simulated shoulder abduction angles of 0° and 45° among the 3 groups.
Results: In the DR group, the mean forces to create 3- and 5-mm displacements and the failure load at 0° were higher than those at 45° ($P = .036$, $P = .012$, $P = .027$). By contrast, in the SB group, the mean forces to create 3- and 5-mm displacements at 45° were greater than those at 0° ($P = .012$, $P = .012$). There were no significant differences in the forces to create 3- and 5-mm displacements and construct failure between 0° and 45° in the TS group ($P = .575$, .327, .478).
Conclusion: The DR group had greatest initial fixation strength at a low abduction angle, whereas the SB group had the highest initial fixation strength at a high abduction angle. The TS group appeared unaffected by the abduction angle.
Level of evidence: Basic Science, Biomechanics.

Keywords: Humeral greater tuberosity fracture; surgery; abduction; biomechanics; suture anchor; screw

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Despite the common occurrence of the proximal humeral fracture, the subgroup of isolated greater tuberosity (GT) fracture remains less well understood. Serving as the insertion site of the rotator cuff tendons, the GT fragment

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usually displaces posterosuperiorly after fracture because of the deforming forces. Because untreated malunited GT fracture results in persistent pain and limited motion of the shoulder, surgical treatment of displaced GT fracture is sometimes required.[14]

Firm fixation of the GT fragment to the humerus is an important factor in initial fracture healing and allows subsequent rehabilitation. A magnetic resonance imaging study showed that the strain of the supraspinatus tendon increased with increasing glenohumeral abduction angle.[4] Also, shoulder abduction affects tension and activity of the rotator cuff muscles.[13,27] Thus, different shoulder abduction positions can place different loads on a repaired GT fragment. As an abduction brace and abduction exercises are commonly used after humeral GT fracture repair,[17,24] it is a clinically relevant issue to investigate the effects of shoulder abduction on GT fixation constructs to optimize the biomechanical properties after surgery.

Suture anchors and screws are well accepted as fixation materials in open, percutaneous, or arthroscopic surgeries for the GT fractures.[5,12,16,19] A previous study compared the biomechanical strength of 3 common fixation constructs of these 2 materials and showed that constructs using suture anchors had better biomechanical strength.[22] However, no biomechanical studies have been conducted to investigate the influence of shoulder abduction position on the biomechanical properties of these 3 fixation constructs.

The aim of this study was to analyze the effects of shoulder abduction on the fixation of a humeral GT fracture among 3 common configurations with use of suture anchors or screws in a porcine model. The hypotheses for the current study are (1) that shoulder abduction position will affect the biomechanical strength of the GT fixation constructs and (2) that shoulder abduction position will have different effects on different fixation configurations.

Materials and methods

Specimen preparation

This study used 24 pairs (48 in total) of fresh frozen 6-month-old female porcine shoulders. Before testing, specimens were stored at −20°C, and the bone mineral density of each specimen was determined. Specimens were thawed at room temperature overnight before dissection and testing; other than preservation of 5 cm of the supraspinatus tendon, all remaining soft tissues were excised, leaving only the humerus and supraspinatus tendon for testing. Then, by a standard osteotomy method, a GT fracture was produced at the base of the GT, after which shoulder pairs were randomly assigned to 1 of the 3 fixation methods under study, with each method allotted 8 pairs. To maintain consistency, 1 orthopedic surgeon performed all fixation constructs.

Fixation configurations

Double-row suture anchor fixation (DR group)

Two single-loaded medial-row suture anchors (Corkscrew, 5.0 mm; Arthrex, Naples, FL, USA) were inserted 2 cm apart at the dead man's angle of 45° on the articular edge of the humeral head. We then passed the medial anchor sutures (No. 2 FiberWire; Arthrex) through the intact cuff attached to the GT fragments. The 2 double-loaded lateral-row suture anchors were embedded 5 mm distal to the GT fragment in the humeral cortex. Suture limbs from both sutures of each lateral-row anchor were passed through the intact cuff between the medial row of sutures and the medial aspect of the fracture fragments. The medial-row sutures were tied as mattress sutures, and the 2 lateral-row anchors' 4 strands were tied as simple sutures (Fig. 1, *A*).

Suture bridge technique (SB group)

For this fixation, medial anchors were embedded according to the aforementioned technique. After the medial mattress sutures were tied, pilot holes aligned with the medial anchors and 5 mm distal to the lateral margin of the fracture site were drilled for knotless suture anchors (PushLock, 3.5 mm; Arthrex). One suture limb from each medial suture anchor was threaded through the eyelet of each knotless anchor. In completing the fixation, 2 PushLock anchors were inserted into the pilot holes by way of the suture bridge technique (Fig. 1, *B*).

Two-screw fixation (TS group)

Two threaded parallel cancellous screws (diameter, 6.5 mm), the length of which was selected on the basis of the distance to the opposite subcortical bone without capturing the opposite cortex, were fitted with washers and implanted in the GT fragment's central area (Fig. 1, *C*).

Biomechanical testing

The humeral shaft was positioned in the custom-made fixture, which was mounted vertically on the table of the universal materials testing machine (AG-X; Shimadzu Corp., Tokyo, Japan). Using the Krackow technique and spanning the myotendinous junction, the supraspinatus tendons were fixed to a stainless steel cable connected to the materials testing system by a pulley mounted onto the table. The setup was built to enable adjustments to the pulley, thereby allowing the traction force direction to be adjusted for simulation of the different abduction positions (Fig. 2). Each shoulder pair was tested at 2 distinct abduction angles: one shoulder at 0° and the other at 45°, defined relative to the horizontal plane (Fig. 3). Each fixation configuration was measured in 8 specimens for each angle. The loading pattern followed previous protocol,[22] for which a 20 N preload was set. All fixations initially began with cyclic loading of 40 N for 50 cycles and were subsequently subjected to a stepwise load increase of 40 N for 50 cycles with a cyclic load speed of 1 mm/s until construct failure. Ultimate failure was defined as a sudden decrease or discontinuity in the load-displacement curve.

Two separate but aligned markers were made on and below the GT fracture site to ascertain displacement (Fig. 1). A digital video camera (DCR-DVD 803; Sony Corp., Japan) recorded marker displacements until construct failure, after which an independent researcher determined displacements with image analysis software (SigmaScan Pro 5.0; SPSS, Inc., Chicago, IL, USA). The cyclic