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Transosseous braided-tape and double-row fixations are better than tension band for avulsion-type greater tuberosity fractures

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ABSTRACT

Introduction: The optimal treatment for avulsion-type greater tuberosity fractures is yet to be determined. Three fixation methods are tested: tension band with #2 wire suture (TB), double-row suture bridge with anchors (DR), and simple transosseous fixation with braided tape (BT).
Materials and methods: Twenty-four porcine proximal humeri were randomised into three groups: TB, DR and BT. A standardised greater tuberosity (GT) osteotomy was performed at 90° to the humeral diaphysis axis. A mechanical testing machine was used to simulate supraspinatus contraction. The force required to produce 3 mm and 5 mm displacement, as well as complete failure was measured with an axial load cell. Also, three cycles of shoulder flexion/extension with 25 N of supraspinatus contraction were performed. Maximum GT fragment translation and rotation amplitude during one cycle were measured.
Results: During supraspinatus contraction, DR and BT groups ($p < 0.05$) were superior to TB group for both displacements. The BT technique had the strongest maximal load to failure (BT = 466 N; DR = 386 N; TB = 320 N). For the flexion/extension, DR and BT groups had less displacement and rotation than TB group (anterio-posterior displacement: BT = 2.0 mm, DR = 1.9 mm, TB = 5.8 mm; anterio-posterior angular displacement: BT = 1.4°, DR = 1.0°, TB = 4.8°). No significant difference was observed between DR and BT groups, except for the medio-lateral rotation favouring the DR group.
Conclusion: In conclusion, BT and DR are good fixation methods to treat displaced avulsion-type greater tuberosity fractures. They have similar mechanical properties, and are stronger and more stable that the TB construct. Potential advantages of the BT over the DR may be a lower cost and easier surgery.
Level of evidence: Basic science study (LEVEL II).

Introduction

Greater tuberosity fractures are relatively common and can occur either in isolation or as part of a more complex fracture or dislocation of the proximal humerus [1]. The majority of these fractures can be managed non-operatively but the literature suggests that surgical treatment results in better functional outcome when there is displacement greater than 3–5 mm in individuals involved in overhead activities [2,3].

Greater tuberosity fractures are usually classified according to the Neer or the AO/OTA shoulder fracture classifications [4–6]. A classification specific to GT fractures was recently described in which fractures are differentiated according to their morphology (avulsion, split and depression) [7]. The avulsion-type fracture, a rotator cuff equivalent, comprised 41% of cases. Despite the fact that some authors recognise this fracture pattern might necessitate another fixation method, no biomechanical or clinical study has specifically addressed the avulsion-type fracture [8].

The goal of this study was to determine the best fixation method for the greater tuberosity avulsion-type fracture. Three methods were selected: transosseous tension-band fixation with a #2 wire suture (TB); suture-bridge double row with anchors fixation (DR); and two simple transosseous sutures with braided

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tape fixation method (BT). These three methods of fixation were chosen based on the morphology of the fracture, current practices and the experience of the senior investigator [3,9–11]. In contrast to the split-type fracture which allows for the placement of screws with or without a plate, the avulsion-type fragment is too small to permit screw fixation.

Materials and methods

Twenty-four shoulders were harvested from 12 pigs aged between 5 and 6 months. Porcine shoulders were chosen because this surrogate for the human humerus has been used in many previous studies with consistent results [12–14]. Additionally, the bone density of immature pigs is similar to young humans [15]. The trials were carried out within 1 week of the animal's death. All shoulders were prepared as follows: All muscles except the supraspinatus were removed. The humerus was osteotomised at the level of the distal metaphysis and potted into a 50.8 mm ABS (acrylonitrile butadiene styrene) tube using polyester resin. A 3 mm slot approximately 30 mm deep oriented in the sagittal plane was created in the distal ABS tube and articulated with the testing machine to prevent humerus mechanical axis rotation of the specimen during flexion and extension movements. An GT osteotomy was practiced distal to the supraspinatus insertion and perpendicular to the diaphysis. The proximal fragment had a height of approximately 8–10 mm depending on the morphology of the specimen. Each specimen was randomly assigned to a group (TB, DR or BT, Fig. 1) with a total of eight shoulders per group.

For the TB technique, a hole was made in the antero-posterior direction at the level of the metaphyso-diaphyseal junction (approximately 15 mm distal to the osteotomy line) (Fig. 1). A #2 wire suture (#2 FiberWire, Arthrex, Naples, FL, USA) was passed through the hole and then trough the tendon closest to the bone and attached with six square knots. For the DR technique, two single loaded suture anchors (5.5 mm Corkscrew, Arthrex, Naples, FL, USA) were inserted in the proximal humerus just lateral to the articular surface edge at an angle 45° to the osteotomy plane. The sutures were passed through the tendon and tied with six square knots. One suture from each anchor was then passed through two knotless suture anchors (3.5 mm PushLock, Arthrex, Naples, FL, USA), which was then inserted 15 mm distal to the osteotomy line. For the BT technique, two holes were drilled in the latero-medial direction from a point 15 mm distal to the osteotomy line to a point just lateral to the edge of the articular surface. A braided tape (2 mm FiberTape, Arthrex, Napales, FL, USA) was passed through each hole and then trough the tendon and fixed with 6 square knots.

To pull on the supraspinatus tendon/muscle, a thermoelectrically cooled clamp was used (Fig. 2) [16]. The clamp was attached to the actuator of a biomechanical testing machine (858 Bionix II, MTS Corp., Eden Prairie, MN, USA) and the potted specimen was fixed to the ABS tube holder. The experimental set-up was designed to mimic a supraspinatus contraction at 0° of abduction. With some minor set-up changes, a simulation of approximately ±15° arm flexion/extension in 0° of abduction was also possible. For the flexion/extension set-up, the humerus head was placed in a hemispherical cavity support fixed in the ABS tube holder to mimic the glenohumeral articulation. The potted section of the specimen was placed in the flexion/extension support fixed on the vertical actuator (vertical actuator not shown in the figure).

The first part of this study was to evaluate the relative 3D displacement and rotation of the GT fragment during flexion and extension movements with 0° of abduction. Three flexion/extension cycles were applied to each specimen. An arm angular displacement of ±15° was applied with a 25 N load on the supraspinatus tendon/muscle (Fig. 2). The speed of the vertical actuator of the traction machine was set at 1 mm/s. Displacement and rotation were measured in the three anatomic axes and the maximum amplitude of displacement and rotation within a cycle was noted.

The second part of the study was to evaluate the load to failure for the three fixation methods. A 25 N pre-load was applied to the supraspinatus tendon/muscle to achieve a steady state. Actuator displacement was then applied at a rate of 1 mm/s up-to failure. An axial load cell was used at a sample rate of 15 Hz to measure the maximum load up to 3 mm and 5 mm of the 3D GT relative displacement and up to failure (load capacity 2500 N, calibrated by the manufacturer; MTS Corp., Eden Prairie, MN, USA). Stiffness was also calculated with the force/displacement (N/mm) curve up to 5 mm displacement of the GT fragment. This stiffness was calculated as the slope of the force/displacement curve.

To measure the relative 3D displacement between the two contact surfaces at the osteotomy site, one marker array was rigidly fixed to the osteotomised GT fragment and one on the lateral humerus at the surgical neck line (Fig. 2). The 3D

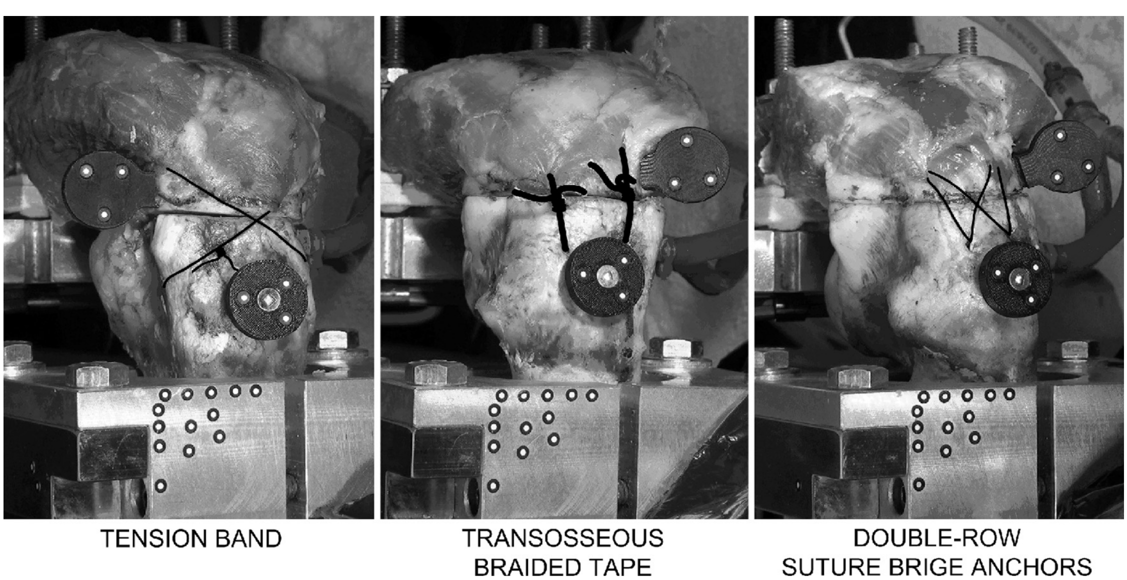

Fig. 1. Pictures of the three different constructs: tension band with #2 suture (left); two simple transosseous braided tape sutures (centre); double row suture bridge with anchors (right).