Clinical Biomechanics 60 (2018) 45–50

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Biomechanical effects of position and angle of insertion for all-suture anchors in arthroscopic Bankart repair

Jae-Hoo Lee[a], Yasuo Itami[b,d], Bobak Hedayati[b], Benjamin Bitner[b], Michelle H. McGarry[b], Thay Q. Lee[b,c], Sang-Jin Shin[e,*]

[a] *Department of Orthopaedic Surgery, Inje University Ilsan Paik Hospital, Goyang, Republic of Korea*
[b] *Orthopaedic Biomechanics Laboratory, Tibor Rubin VA Medical Center, Long Beach, CA, USA*
[c] *Department of Orthopaedic Surgery, University of California, Irvine, CA, USA*
[d] *Department of Orthopedic Surgery, Osaka Medical College, Takatsuki, Osaka, Japan*
[e] *Department of Orthopaedic Surgery, Ewha Womans University Mokdong Hospital, College of Medicine, Seoul, Republic of Korea*

A B S T R A C T

Background: The biomechanical properties of all-suture anchor for labral repair depending on the insertion angle and location are lacking. The purpose of this study was to quantify the biomechanical fixation characteristics of the anchor position and insertion angle of all-suture anchors for arthroscopic Bankart repair.
Methods: Twenty-four fresh frozen cadaveric glenoid were used. All-suture anchors with 1.5-mm diameter were randomly inserted at 2:30, 4:00, and 5:30 o'clock positions on the glenoid edge, with either 30°, 45° or 60° insertion angles to the mediolateral axis of the glenoid. Anchors were preloaded to 5 N and cyclically loaded from 5 N to 20 N for 10 cycles, followed by a load to failure test at 60 mm/min. Permanent, non-recoverable displacement was quantified at the end of the cyclic loading test to yield load.
Findings: All-suture anchors implanted at the 2:30 o'clock position of the glenoid provided greater stiffness, yield load, and ultimate load than those inserted at the 4:00 and 5:30 o'clock positions, regardless of the insertion angle. Displacement at yield and ultimate load were similar among the positions and insertion angles (yield load, vs. 4:00, $p = 0.01$; vs. 5:30, $p = 0.045$; ultimate load, vs. 4:00, $p < 0.01$; vs. 5:30, $p < 0.01$). The insertion angles of 30°, 45° and 60° did not influence mechanical stability between the 4:00 and 5:30 o'clock positions.
Interpretation: The insertion angle of all-suture anchors does not significantly affect the stability at antero-inferior quadrant of the glenoid.

1. Introduction

Arthroscopic Bankart repair using suture anchors is considered a standard treatment option for traumatic anteroinferior labral tear with recurrent shoulder instability (Aboalata et al., 2016; Ahmed et al., 2012; DeLong et al., 2015). Successful repair requires a sufficient number of suture anchors, especially on the anteroinferior surface of the glenoid (Ahmed et al., 2012). The number of inferiorly placed anchors, however, is often restricted to one or two due to limited space for suture anchor placement. Furthermore, the placement of an anchor for anteroinferior labral lesion in anterior shoulder instability demands technical attention to avoid anchor insertion with an excessively acute angle, especially when solid anchors are used with a straight anchor guide through the standard anterior portal (Frank et al., 2014; Seroyer et al., 2010). Recently, all-suture anchors have been introduced with advantages compared to conventional solid anchors, including flexible suture anchor positioning on the glenoid with the desired angle and a smaller diameter anchor (Mazzocca et al., 2012; Nho et al., 2013).

Despite the advantages of all-suture anchors for positioning on the glenoid and their comparable ultimate load to failure as conventional solid suture anchors, however the lower load to early displacement of all-suture anchors could potentially lead to clinical failure (Barber and Herbert, 2013; Chiang et al., 2016; Dwyer et al., 2016; Mazzocca et al., 2012). Failure may result from the softness and flexibility of the all-suture anchors and micromotion after deployment (Dwyer et al., 2016; Pfeiffer et al., 2014). Anatomical variance along the rim of the anterior-inferior glenoid rim also has a significant influence on the suture anchor insertion angle for labral repair (Levy et al., 2014; Roth et al., 1998). Therefore, the inherent biomechanical characteristics of all-suture anchors and the anatomical characteristics of the anteroinferior glenoid rim make it difficult to predict the biomechanical stability of the anchor fixation associated with the position and insertion angle. Despite these concerns, no studies have quantified the biomechanical characteristics of all-suture anchor fixation on the anteroinferior glenoid rim.

The purpose of this study was to quantify the biomechanical characteristics of all-suture anchor fixation on the glenoid with respect to

* Corresponding author at: Department of Orthopaedic Surgery, Ewha Womans University Mokdong Hospital, 1071 Anyangcheon-ro, Yangcheon-gu, Seoul 07985, Republic of Korea.
E-mail address: sjshin622@ewha.ac.kr (S.-J. Shin).

https://doi.org/10.1016/j.clinbiomech.2018.10.002
Received 19 June 2018; Accepted 1 October 2018

the position and angle of insertion in arthroscopic Bankart repair. We hypothesized that the all-suture anchors would have greater fixation strength when inserted in the upper than the lower part of the glenoid and that the angle of insertion would vary depending on the shape of the glenoid rim at the insertion site.

2. Materials & methods

2.1. Specimen preparation

Twenty-four fresh-frozen cadaveric shoulders (14 male, and 10 female) with an average age of mean 58 (SD 9) years were used. All specimens were macroscopically intact with no pre-existing shoulder pathology. Specimens were dissected to remove all soft tissues, and the glenoid was isolated to preserve the glenoid labrum and articular cartilage. The scapula was then mounted on a custom clamp with the glenoid face parallel to the ground. A clock face of the glenoid was used to describe anchor insertion position, with the center point of the long head of the biceps footprint of the glenoid defined as the 12:00 o'clock position (described for right shoulder, anterior; 3 o'clock, posterior; 9 o'clock).

Single-loaded, 1.5-mm all-suture type anchors (Omegaknot Plus, ARC, Seoul, Korea) were randomly inserted at 2:30, 4:00, and 5:30 o'clock on the glenoid edge, with either 30°, 45°, or 60° insertion angles (Fig. 1.). As a result, each insertion angle was tested at each of the clock-face positions in 8 individual shoulders. The suture anchor was composed of a single strand of No.2 ultra-high-molecular-weight polyethylene (UHMWPE) and polyester woven with a 2-mm-length polyester anchor sleeve. The deployed ‘omega’ shape of the anchor portion was created by pulling the main suture. This experiment simulated arthroscopic Bankart repairs, where all-suture anchors were inserted in the anteroinferior quadrant of the glenoid at 2:30, 4:00, and 5:30 o'clock positions. The insertion angles were chosen to simulate clinical situations and defined as follows. First, a target plane was set to simulate an arthroscopic anterior portal at an angle of 45° to the glenoid surface in the superior-inferior axis of the glenoid (Fig. 2A.). The insertion angle was then determined as the angle relative to the glenoid surface in the sagittal plane (Fig. 2B.). For anchor insertion, a 1.5-mm hole was predrilled to a depth of 22 mm, and the anchor was inserted. The anchor was pulled back until it was completely deployed. Throughout the testing, specimens were kept moist with a 0.9% saline solution.

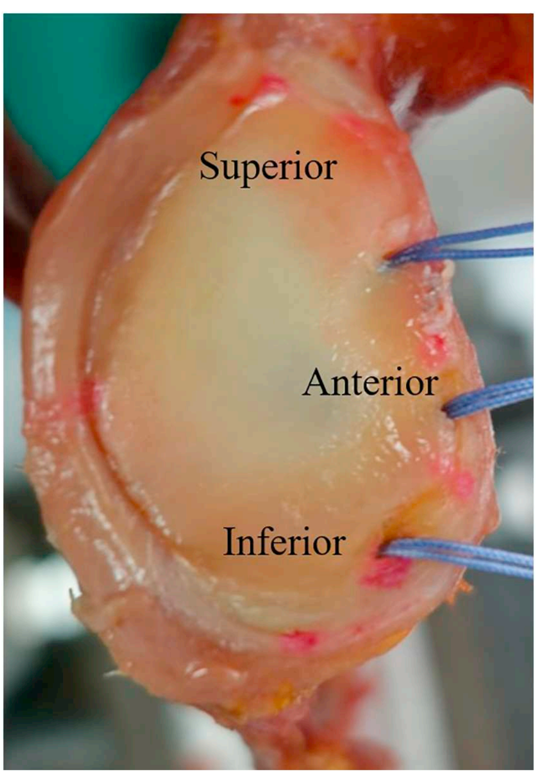

Fig. 1. Photograph showing soft anchors inserted at the 2:30, 4:00, and 5:30 o'clock positions on the glenoid edge.

2.2. Biomechanical test

A custom scapula clamp and an Instron machine (Instron 3365, Instron, Norwood, MA) were used for the anchor pull-out test. Specifically, the custom scapula clamp permitted positioning of the glenoid articular surface so that the direction of loading was perpendicular to each insertion site. The suture length between the anchor on the glenoid and the Instron crosshead attachment was set at 30 mm.

Permanent dots were marked on the sutures just above the bone-anchor interface and on the bone just below the bone-anchor interface (Fig. 3). A video digitizing system and WINanalyze motion software (Mikromak Service, Berlin, Germany) were used to analyze the region specific suture displacement (Lee and Danto, 1992). The video digitizing system and WINAnalyze software were previously determined to by 0.15 mm accurate, 0.075 mm precise and 0.071 mm repeatable (Park et al., 2008). Anchors were preloaded to 5 N for 5 s and then cycled from 5 N to 20 N for 10 cycles, followed by a load to failure test at 60 mm/min. Failure was defined as anchor pullout or suture break. Displacement of the all-suture type anchor was measured in reference to a stationary marker on the bone. Stiffness, yield load, ultimate load, and failure mode were calculated. Permanent non-recoverable displacement was quantified at the end of the cyclic loading test. Deformation at yield and ultimate load were also calculated. Yield load was determined as the load where the load-displacement curve deviated from the highest linear stiffness of the curve.

2.3. Statistical analysis

The sample size was calculated based on preliminary experiments. The yield load was considered as the primary result because displacement at yield was measured at about 2 mm, which is accepted as clinical failure. Primary yield load at 2:30, 4:00 and 5:30 o'clock were 85, 55, and 65 N, respectively, and pooled standard deviation was 17, 9, and 11 N, respectively, with an α value of 0.05 and power of 95% with Type I error. A minimum of 6 specimens per group were derived from the factors including effect size of 0.65, the number of subgroups and items to measure. The randomized sequence to select the insertion angle was determined by using the method of permuted blocks of four, provided by a web service. A two-way analysis of variance was used to compare the effect of the insertion angle and glenoid clock position with $p < 0.05$. If a significant difference was determined, pair-wise comparison was performed with Holm-Sidek post hoc analysis. All statistical analyses were performed with SPSS statistical software version 20 (IBM Co., Armonk, NY, USA).

3. Results

3.1. Stiffness

The stiffness of the suture anchor fixation was influenced by the clock position and insertion angle of the glenoid (Fig. 4). Total stiffness was significantly greater at the 2:30 o'clock position than the 4:00 o'clock ($p = 0.01$) and 5:30 o'clock position ($p = 0.04$). Stiffness was also significantly greater at an insertion angle of 30° than 45° ($p = 0.03$) and 60° ($p = 0.03$) at the 2:30 o'clock position. Comparison of insertion angle between the 4:00 and 5:30 o'clock positions showed no significant