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Lesser tuberosity osteotomy and subscapularis tenotomy repair techniques during total shoulder arthroplasty: A meta-analysis of cadaveric studies

John B. Schrock *, Matthew J. Kraeutler, Darby A. Houck, Gina G. Provenzano, Eric C. McCarty, Jonathan T. Bravman

University of Colorado School of Medicine, Aurora, CO 80045, USA

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ABSTRACT

Background: Numerous techniques have been used to mobilize and repair the subscapularis tendon during total shoulder arthroplasty. The purpose of this study is to perform a detailed comparison of subscapularis tenotomy and lesser tuberosity osteotomy repairs during total shoulder arthroplasty.

Methods: Two independent reviewers searched two databases (PubMed and the Cochrane Library) to find cadaveric studies comparing the biomechanical strength of various subscapularis repair techniques following total shoulder arthroplasty. Articles that compared at least two repair techniques with similar biomechanical methods were included.

Findings: An initial literature search resulted in 145 studies. A title and abstract review resulted in five studies which analyzed outcomes of subscapularis tenotomy (total $n = 29$) or lesser tuberosity osteotomy using a single- or dual-row suture technique (total $n = 46$). Load to failure was significantly higher in the lesser tuberosity osteotomy group (M 443, SD 231 N) than the tenotomy group (M 350, SD 113 N) ($p = 0.047$). Tenotomy ($n = 19$) and lesser tuberosity osteotomy ($n = 31$) had average cyclic displacements of 1.7 mm (SD 1.3) and 2.1 mm (SD 1.6), respectively ($p = 0.34$). Mode of failure was significantly different between the two groups ($p < 0.0001$), with soft tissue failure accounting for most tenotomy repairs (97%) and bone failure accounting for the majority of lesser tuberosity osteotomy repairs (72%).

Interpretation: Based on current biomechanical data, lesser tuberosity osteotomy is a stronger repair than a subscapularis tenotomy at "time-zero" in terms of load to failure. However, cyclic displacement did not differ statistically between the two techniques.

1. Introduction

Total shoulder arthroplasty (TSA) is commonly performed via the deltopectoral approach. This approach requires mobilization of the subscapularis tendon from the anterior humerus by either lesser tuberosity osteotomy (LTO) or subscapularis tenotomy or peel. Tenotomy with simple suture repair was the traditional technique (Caplan et al., 2009), though this technique may result in complications such as subscapularis dysfunction, attenuation, and complete rupture (Jackson et al., 2010). LTO has gained in popularity because of the belief that bone-to-bone healing could lead to a more durable subscapularis repair (Gerber et al., 2006; Ponce et al., 2005). Additionally, there is the subscapularis peel method, which involves a tendon-to-bone repair (Defranco et al., 2010). In regards to re-attachment techniques, several have been described, including bone-to-bone techniques, tendon-to-tendon, and tendon-to-bone options in addition to a combined approach. To date, there is no consensus in subscapularis management during TSA. The purpose of this meta-analysis is to compare available biomechanical outcomes of subscapularis tenotomy versus lesser tuberosity osteotomy in cadaveric studies simulating total shoulder arthroplasty.

2. Methods

2.1. Literature search

Two independent reviewers searched PubMed and the Cochrane Library from January 2000 to March 2016 to find cadaveric studies comparing the biomechanical strength of various repair techniques following total shoulder arthroplasty. The following subject headings and keywords were used to retrieve articles: *subscapularis, subscapularis repair, arthroplasty, total shoulder, biomechanics, lesser tuberosity*

* Corresponding author at: CU Sports Medicine and Performance Center, 2150 Stadium Drive 2nd Floor, Boulder, CO 80309, USA.
E-mail address: john.schrock@ucdenver.edu (J.B. Schrock).

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osteotomy, and *subscapularis tenotomy.* All potentially relevant articles were reviewed.

2.2. Inclusion and exclusion criteria

Studies included were required to be written in 2000 or later, to be written in English, and to compare biomechanical outcomes of at least two subscapularis repair techniques.

Two independent reviewers extracted the data from the studies which met the inclusion criteria. Articles meeting inclusion criteria were further analyzed for homogeneity in surgical technique and biomechanical testing protocols.

2.3. Surgical procedures

2.3.1. Tenotomy

The subscapularis tendon is incised 1 cm medial to its insertion on the lesser tuberosity. An anatomic soft tissue tendon-to-tendon repair is performed. Typically 4–8 sutures are used and can be secured through a figure-of-eight fashion or a Mason-Allen technique.

2.3.2. Lesser tuberosity osteotomy

Krishnan et al. (2009) described the dual-row suture repair technique for LTO. The goal of this technique is to reconstruct both the tendinous footprint of the subscapularis on the lesser tuberosity and the tendinocapsular confluence on the anatomical neck of the humerus. In the dual-row repair, the four lateral sutures provide circumferential, transosseous fixation of the bony fleck while the 4 medial sutures neutralize the load on the lateral row.

Ponce et al. (2005) described an LTO technique where a 4–5 mm wafer osteotomy is performed using a curved osteotome. The size of the fragment was picked to match the average surface area of the subscapularis insertion. Repair of the tendon is performed via number-5 FiberWire through two parallel rows of 3–4 drill holes medial and lateral to the osteotomy site, through the subscapularis at the tendon-bone junction and finally tied over the top of the fragment.

Single-row LTO differs from dual-row in that it uses a single column of drill-holes just lateral to the osteotomy site (Ponce et al., 2005). Instead of suture passing from within the humeral canal through the medial drill holes, as in a dual-row technique, the suture passes out of the top of the humeral cut beneath the head of the prosthesis.

Both single-row and dual-row repairs were grouped together as lesser tuberosity osteotomy techniques. In addition, LTO repairs using a thick or thin bony wafer were included.

2.4. Data extraction

Data extracted for this review included gap formation during cyclic loading, failure strength, and modes of failure of the different repair techniques.

2.5. Statistical analysis

For continuous variables, a weighted average and composite standard deviation was calculated for each group, as previously described (Kraeutler et al., 2013). Data was then analyzed using a two-sample independent *t*-test, based on unequal variance (www.openepi.com). A chi-square test was used to compare mode of failure data.

3. Results

An initial literature search resulted in 145 studies. A title and abstract review resulted in twelve studies (Ahmad et al., 2007; Fishman et al., 2014; Giuseffi et al., 2012; Heckman et al., 2011; Krishnan et al., 2009; Kummer et al., 2014; Ponce et al., 2005; Schmidt et al., 2014; Van den Berghe et al., 2008; Van Thiel et al., 2010; Wheeler et al., 2010) which analyzed biomechanical outcomes of various subscapularis repair techniques. Further analysis resulted in five studies (Fishman et al., 2014; Giuseffi et al., 2012; Krishnan et al., 2009; Ponce et al., 2005; Schmidt et al., 2014) specifically analyzing tenotomy or lesser tuberosity osteotomy using a single-row or dual-row suture technique and similar biomechanical testing protocols. Twenty-nine shoulders underwent subscapularis tenotomy repair and 46 underwent LTO repair (Table 1). Load to failure was significantly higher for the LTO technique (M 443, SD 231 N) compared to subscapularis tenotomy (M 350, SD 113 N) ($p = 0.047$). Three studies (Giuseffi et al., 2012; Ponce et al., 2005; Schmidt et al., 2014) tested cyclic displacement at a force of 100 N for 3000 cycles at 1 Hz. There was no significant difference in gap formation between the two groups (tenotomy M 1.7, SD 1.3 mm, LTO M 2.1, SD 1.6 mm, $p = 0.34$).

Mode of failure was categorized as soft tissue, suture, or bone failure and was significantly different between the two groups ($p < 0.0001$), with soft tissue failure accounting for most tenotomy repairs (97%) and bone failure accounting for the majority of LTO repairs (72%) (Table 2). All soft tissue failures in the tenotomy group were due to suture tear out through the tendon/muscle. Among bone failures in the LTO group, 64% failed by suture cutting through the bony wafer, 15% failed by suture cutting through the humerus, and 15% were categorized as either fracture of the bony wafer and/or humerus fracture. In the last 6% of failures, the osteotomy was displaced.

Table 1
Load to failure and cyclic displacement outcomes. Data are given as a mean (SD). LTO = lesser tuberosity osteotomy. Two studies used different cyclic displacement protocols and were not included in that analysis (Krishnan et al., 2009; Kraeutler et al., 2013).

Study	n	Load to failure (N)		Displacement (mm)	
		Tenotomy ($n = 29$)	LTO ($n = 46$)	Tenotomy ($n = 19$)	LTO ($n = 31$)
Fishman et al. (2014)[a]	10	300 (92)	375 (125)	–	–
Giuseffi et al. (2012)	20	439 (96)	447 (89)	0.8 (0.2)	1.8 (0.6)
Krishnan et al. (2009)[b]	15	252 (99)	466 (158)	–	–
Krishnan et al. (2009)[c]		–	430 (202)	–	–
Ponce et al. (2005)	18	334 (88)	738 (261)	2.7 (1.2)	0.9 (0.5)
Schmidt et al. (2014)[d]	12	–	249 (150)	–	2.4 (1.1)
Schmidt et al. (2014)[e]		–	234 (97)	–	4.2 (2.3)
Total	75	350 (113)	443 (231)	1.7 (1.3)	2.1 (1.6)
p-Value		*0.047*		0.34	

[a] Dual row fleck LTO.
[b] Double-row LTO.
[c] Single-row LTO.
[d] Thick osteotomy bony wafer.
[e] Thin osteotomy bony wafer.